A SUMMARY BRIEF FROM THE ALOSINE SPECIES TEAM

ECOSYSTEM-BASED FISHERIES MANAGEMENT
IN CHESAPEAKE BAY

Alosines

What Are Alosines and Why Are They Important?

Shads and herrings arguably rank among the most iconic and culturally significant fish species in the Chesapeake Bay region and beyond. Several of the anadromous shads and herring were chosen as focal species for the Ecosystem-Based Fisheries Management (EBFM) Program for Chesapeake Bay because of the integral part they play in the structure and function of the Bay ecosystem and surrounding tributaries, as well as their historical and cultural importance to the region. Alosines are fishes of the subfamily Alosinae, commonly called "shads" of the herring family (Clupeidae). Anadromous alosines found in the Chesapeake include American shad (*Alosa sapidissima*), hickory shad (*Alosa mediocris*), blueback herring (*Alosa aestivalis*), and alewife (*Alosa pseudoharengus*) (Figure 1).

If the value of a fish species can be measured by what is gained by its presence and lost by its absence, alosines are a valued species given their recreational, commercial, and artisanal significance. Historically, alosines were among the most abundant and economically valuable fishes of Chesapeake Bay. In pre-Colonial times, Native Americans used hooks, harpoons, weirs, seines, gill nets, scoop nets, gigs, and hand nets to catch alosines. During the 18th century, to supplement income, subsistence and trade anglers fished for shad and herring using small haul seines or dip nets in the upper tributaries of Chesapeake Bay. With population increases in Maryland and Virginia, commercial fishing in the Chesapeake region increased for all four species, but especially for American shad. Consequently, for more than a century, abundance has steadily declined, leaving the fisheries in dismal shape. Today they are largely regulated by a moratorium on directed fishing. This summary brief will outline the value lost because of declining alosine abundances within the Chesapeake Bay ecosystem, and touch on the sociological and cultural value to be gained through successful restoration.

The Alosine Species Team members approached their work by focusing on ecosystem issues related to socioeconomics, habitat, stock dynamics, and foodwebs. They recognized that alosines serve a supporting role as prey for associated species, as bait in several commercially important fisheries, as forage for birds, mammals and other predatory fish, and as vehicles for nutrient cycling. American shad were considered one of the most valuable food fish of the U.S. Atlantic coast before World War II, and the river herring fishery is considered one of the oldest documented fisheries in North America. Further, alosines assist in fostering social relations, increase awareness of a common cultural heritage, provide a sense of place to community members, increase environmental awareness, and stimulate local economies. Alosine species provide for recreational fisheries, ecotourism, seasonal festivals, and volunteer monitoring programs.

Figure 1. American shad, alewife, hickory shad, and blueback herring. Credit: Duane Raver, U.S. Fish & Wildlife Service.

Life History and Evolving Management

Generally, adult American shad, blueback herring, and alewife migrate from overwintering grounds on the continental shelf to spawn in rivers, streams, and creeks in late winter and early spring. Hickory shad spawn during the same period but little is known about the distribution of this species in general. Larval and early juvenile development occurs in non-tidal and tidal freshwater areas, although residency within rivers during the first year of life varies by species. Juvenile hickory shad are likely the first to move downstream into estuarine waters. Given these unique life histories and varied use of habitats, accounting for direct and indirect ecosystem stressors is challenging.

Several fisheries management theories for guiding management of shad have come in and out of vogue. The "brood-stock" theory (1850-1953) dictated that shad be conserved by preserving the breeding individuals and propagating them in hatcheries. The "optimum catch" theory (about 1925-1940) focused on operating shad fisheries to produce the best catches, while the "controlled-catch" theory (1930-1953) sought to stabilize fishing rates by limiting the number of fishermen and gear through a licensing system. On a practical level, because of the jurisdictional boundaries within alosine home ranges, there is not a one-size-fits-all management strategy. Effective management will need to include restrictions on the number of fishermen, gear types, seasonal fishing periods, as well as implement enhancement programs to supplement wild stocks with fry and fingerlings — all options presently in use.

The Atlantic States Marine Fisheries Commission (ASMFC) is currently responsible for oversight and management of American shad, hickory shad, alewife, and blueback herring in state waters (0–3 miles offshore) ranging from Maine to Florida, and the Shad and River Herring Management Board within ASMFC directs management of these species. Within Chesapeake Bay, fishery-independent monitoring is required by the ASMFC for American shad and river herring through Amendments 2 and 3 to the Interstate Fishery Management Plan. The amendments call for a juvenile abundance index (JAI) survey in Maryland's Upper Chesapeake Bay, the Potomac, James, York, and Rappahannock rivers, and a spawning stock biomass survey in the Upper Chesapeake Bay, the Rappahannock River, and the James River. Fishery-dependent monitoring is also required of MDNR, DC F&W, and VMRC, with each responsible for monitoring and annually reporting commercial and recreational catch, effort, and catch composition. In addition to these public agencies, numerous non-governmental organizations (NGOs) within the Chesapeake watershed have instituted programs that foster active engagement in education, outreach, and advocacy aimed at protecting and restoring habitats and water quality critical to alosine population health.

Socioeconomics Issues and Drivers

Services and Valuation

An in-depth evaluation of the ecosystem services provided by alosines has not been conducted. The river herring fishery is considered one of the oldest documented fisheries in North America. Some of the easiest fish to catch, alosines have historically been harvested in great numbers for food or sold smoked, salted, or pickled. Currently river herring are used primarily for bait, fertilizer, fish meal, and oil but are also valued as a source of Omega-3 fatty acids. Alosines are considered important in sustaining East Coast striped bass populations, one of the most economically valuable fish species in Chesapeake Bay. They are also of seasonal

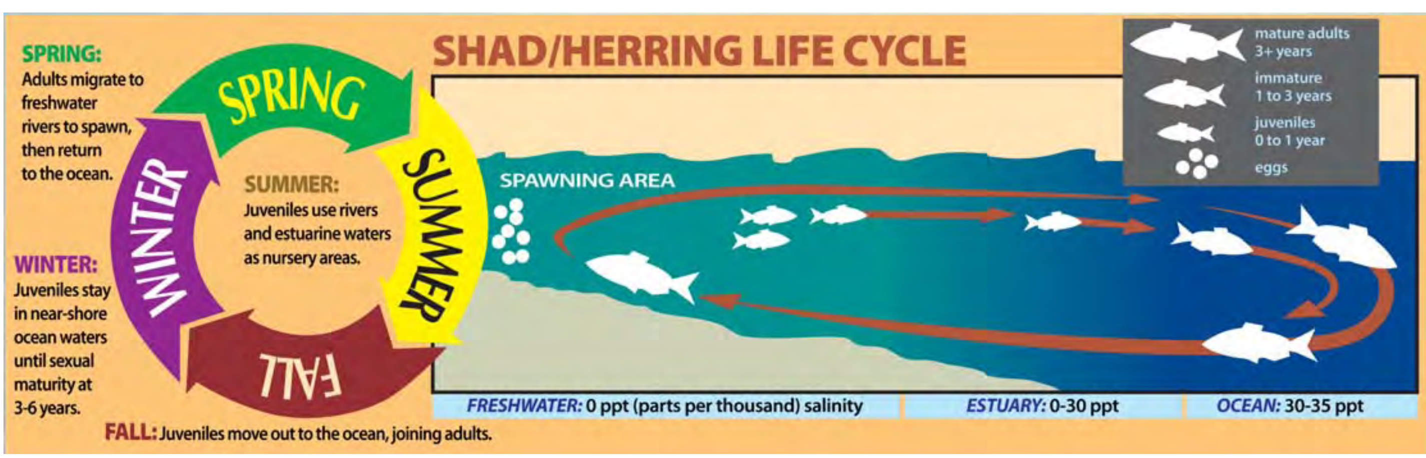

Figure 2. Shad and herring life cycle, courtesy of the Pennsylvania Fish and Boat Commission. Graphics and illustration, Ted Walke.

importance as bait for lobster fisheries and they support overall ecosystem health through natural nutrient cycling (egg deposition, excretion, and mortality). There are few fish species with greater cultural historical significance than shads and river herrings. They are valued by recreational fishermen and support ecotourism through the myriad community festivals celebrating shads and herrings. Multiple fishways within the Chesapeake include integrated platforms to allow for public viewing of annual alosines migrations from the coastal waters to freshwater spawning grounds upstream (shad runs). State and local agencies also use such facilities to engage volunteers in fish monitoring programs which inevitably encourage conservation and restoration of essential habitat for these valuable fish.

Restoration Techniques and Management Considerations

Managers currently employ two methods to increase alosine production — restoration and stock enhancement. Restoration aims to re-establish a run in a stream that historically supported shad populations. Typically, existing runs are reconnected to inaccessible habitat by removing dams or building fishways. Stock enhancement attempts to increase the size of a diminished run by replacing reproductive output of natural habitat with hatchery production. To develop effective programs for targeted watersheds, management schemes must assess the opportunities and limitations of these approaches. Although some restoration projects have been successful, there is no consensus on what constitutes an effective restoration or enhancement strategy.

Restoration efforts are guided by a desired target stock size, often developed from historical data measured either as population size, as passage numbers where barriers occur, or through areal estimates of spawning habitat. Mortality rates are difficult to measure in alosines and mortality-based benchmarks have not been determined for all alosine species of the Chesapeake Bay. These are factors which must be considered when management efforts aim for restoration or enhancement or both.

Habitat Issues and Drivers

Migratory Barriers

Dams and other artificial structures in streams create migratory barriers that represent one of the most significant factors causing the decline of anadromous alosine runs. The types of dams and obstacles commonly found in the Chesapeake Bay region are for hydroelectric power, flood control, water supply, agriculture, aesthetic/residential, former hydro-mechanical (mill), and former canal feeders.

Figure 3. Migration routes along the East Coast of the U.S. for shad and river herring. Source: Pennsylvania Fish and Boat Commission.

Culverts, improperly designed road crossings, tide gates, perched utility services, and armored "aprons" designed to combat headcutting in artificially re-graded streams also block alosine runs. Physical riverine and stream alterations increase turbidity, degrade habitat and water quality, and change flow patterns. Other "barriers" such as plumes of elevated water temperature and reduced water quantity can also inhibit upstream migration. Decreased accessibility to historical spawning grounds leads to crowding near obstacles during spawning migrations, makes fish vulnerable to exploitation, forces spawning activities to occur in less than ideal habitats, and truncates migrations. In an ecosystem context, these barriers do more than just impact the species; they result in the loss of potentially valuable nutrient input further upstream.

Habitat Alteration and Degradation

In addition to barriers, there are many physical alterations that affect alosines in rivers. For example, bulkheads or

Figure 4. As part of Maryland DNR's Fish Passage Program, the removal of Octoraro Creek Dam restored access to 20 miles of suitable habitat for shad and herring. The photos above show the creek — a tributary of the Susquehanna River — before and after dam removal. Credit: Photographs, Maryland Department of Natural Resources; watershed map, NASA.

landfills can result in the loss of natural shoreline; wing dams often change flow patterns; and piers, platforms, and jetties potentially provide cover for predators and degrade habitat quality. Channelization for shipping or flood control can also have multiple detrimental effects. Dredging to deepen channels can cause short term increases in turbidity and impede fish movements and decrease primary productivity. Dredging deeper channels often requires concomitant widening of channels, which may eliminate shallows or bottom structures which are vital to various life stages of alosines species. Sedimentation from dredging or construction projects may cover preferred spawning sites. These activities may also alter river current patterns, velocities, and the position of estuarine salt fronts.

Flow and Water Quality

Variability in water flow, timing of delivery, frequency of disturbances, and the amount of dissolved and particulate constituents are all part of the ecosystem. Under natural flow regimes there are a range of conditions (e.g., current velocity, dissolved oxygen, water temperature, pH) that facilitate hatching of eggs and promote growth and survival of larval and juvenile alosines. Rapid development in Chesapeake Bay has lead to increased runoff and changes to the natural flow regime, and has impacted ground water storage and recharge. Climate change will also likely further affect flow regimes, sediment and nutrient loading, dissolved oxygen, water temperature, and salinity in the Bay. Increases in water temperature during winter and spring will likely shift the timing of spawning migrations, hatching and feeding success rates, as well as growth and mortality rates. Restoration efforts aimed at improving aspects of ecosystem function important to alosines should focus on the spatial and temporal dynamics of flow, nutrient cycling, and biodiversity. Process oriented management targets that consider a distribution of conditions would provide greater benefit than threshold values, which do not have associated time, frequency, or spatial benchmarks.

Land Use

Radical transformations in land use results in significant variations in material fluxes to drainage basins, which can dramatically alter ecosystems and their suitability for alosines. Recent studies have used percent impervious surface coverage as a metric to quantify and assess land use changes. Research has shown a substantial increase (61%) in developed land between 1990 and 2000, of which more than half was derived from agricultural and grasslands and a third from forest. Empirical analyses of Chesapeake Bay subwatersheds showed high sensitivity of water quality to land-use type. Research also suggests that rating stream health as "excellent" requires watershed-wide impervious surface cover be less than 6% and for at least 65% vegetated riparian zones. A rating of "good" requires thresholds of

10% and 60%, respectively. The sustainability of alosine runs depends on responsible riparian corridor management, including delineating buffer zones to protect against impacts from development and minimizing erosion and nutrient runoff from disturbed lands.

Stock Dynamics Issues and Drivers

Assessment Summary

Initial attempts to characterize stock status of Chesapeake Bay alosines from the late 1800s and early 1900s focused on summaries and evaluation of landings data. Assessments have become increasingly sophisticated with the use of complex computer-generated population models and have been conducted by biologists working for Federal and state fisheries agencies, universities, and most recently the ASMFC. Most status assessments have been made on American shad stocks but a few have been made on river herring and hickory shad. Assessments vary for each of the four alosine species but most have been made at the species and stock (river specific) level. Currently alewife and blueback herring are managed as a single stock, which hinders evaluation of individual fishing impacts.

Population Structure and Connectivity

Alosine populations are defined by groups of inter-breeding spawners using the same freshwater habitat. Depending upon species and location, spawning habitats may be large mainstem rivers, their tributaries, lower order coastal streams, headwater ponds or lakes, dammed impoundments along the course of a river, or brackish tidal waters below impassable barriers. Because fish can and do stray, spawning populations are sub-populations within larger metapopulations defined by riverine or estuarine watersheds. Less frequent exchange among major watershed metapopulations occurs, which contributes to the maintenance of minimal genetic homogeneity, preventing speciation. Therefore, multiple ecologically and demographically relevant metapopulations likely exist along the coast, nested within a larger evolutionarily significant coast-wide metapopulation. The extent of interconnectedness varies between these scales, with important implications for conservation and management. Genetic and tagging evidence, in addition to observations of fluctuating abundance, indicate that American shad form discrete populations that display high homing fidelity typical of nearly all anadromous fishes. This high spawning site fidelity necessitates careful consideration with regard to development projects and their potentially adverse impacts to migrating alosine populations (i.e., block migration to natal streams, decrease amount of accessible habitat).

Foodweb Issues and Drivers

Community and Forage

Alosines are an important component of the foodweb because of their ability to shape zooplankton communities and because they serve as prey for numerous species. Alosines are important vectors of nutrients within and between watershed and coastal marine ecosystems. Feeding patterns vary by species, life stage, diel time period, and habitat type. Feeding intensity and growth also vary with environmental conditions, habitat, and life stage. Community impacts from alosines' feeding shift as a result of differing species assemblages found within the different habitats.

Predation

Recently, predation of alosines by striped bass has been the focus of increased attention as striped bass populations have increased in abundance in recent decades. There is also a suite of introduced finfish piscivores that could potentially affect alosine populations as could many other fish, avian, reptilian, and mammal piscivores that prey on them.

Vectors

Anadromous alosines serve an important ecological function through the transportation of energy, carbon, and nutrients between freshwater and saltwater ecosystems. Considerable research has focused on the importation of marine-derived nutrients into freshwater systems by Pacific salmon. Relatively little research has focused on such a mechanism for Atlantic anadromous alosines, but some have suggested that the input of nitrogen and phosphorus by alewife into coastal ponds could be comparable to that of Pacific salmon runs.

Table 1. Critical Ecosystem Considerations for Alosines (American shad, Hickory shad, Blueback herring, and Alewife) in Chesapeake Bay.

Ecosystem Stressor		Issues
1. Habitat	a. Climate Change	• Increasing water temperatures will likely shift the timing of spawning migrations, hatching, and feeding success rates, as well as growth and mortality rates of Chesapeake Bay alosines. • Climate change will impact flow regimes, natural water temperatures, sediment and nutrient loading, dissolved oxygen levels, and salinity in the Bay.
	b. Habitat Degradation and/or Modification	• Dams and other obstructions create migratory barriers, interrupting life history by blocking access to historical upstream spawning grounds and altering natural riverine conditions. • Alterations in the amount of water, timing of delivery, frequency of disturbances, and amount of dissolved and particulate constituents will impact species' health and survival.
	c. Fishing Pressure	• Despite historically supporting one of the most abundant and economically valuable fisheries in the Chesapeake, abundances have steadily declined and are now largely regulated by moratorium on direct fishing.
2. Foodwebs	a. Predation	• Due to increased abundances, much attention has focused on the potential impact of striped bass predation on alosines populations. • Predation by many other fish, avian, reptilian, mammals, and potentially introduced finfish piscivores also impacts alosines.
	b. Community and Forage	• Alosines are an important component of the Bay foodweb because of their role in shaping zooplankton communities and because they serve as prey for numerous species. • Because feeding patterns, feeding intensity, and growth for alosines vary by species, life stage, diel time period, environmental conditions, and habitat type, additional research is needed.
	c. Nutrient Cycling	• Because of their unique life cycle, an important ecological function served by anadromous alosines is the transportation of energy, carbon, and nutrients between freshwater and saltwater ecosystems. While little research has focused on this it has been suggested that the nutrient input could be comparable to that of Pacific salmon.
3. Stock Dynamics	a. Population Dynamics	• Because alosine populations are defined by groups of inter-breeding spawners using the same freshwater habitat, these sub-populations are defined by riverine or estuarine watersheds. Management efforts should account for these distinct sub-population needs. • Research indicates that American shad form discrete populations that display high homing fidelity typical of nearly all anadromous fishes, lending additional support for the need to carefully consider any potential adverse impacts of development projects on migrating alosine populations.
	b. Anthropogenic Drivers of Juvenile and Adult Mortality	• Decreased accessibility to historical spawning grounds due to manmade barriers within tributaries results in decreased species health and increased mortality. • Degraded habitat caused by physical alterations (including dams), development projects, channelization, dredging, and sedimentation negatively impact all stages of alosine life cycle. • Significant sources of mortality come from non-directed or ancillary mortality from dams with inadequate passage, turbine mortality, and bycatch mortality.
4. Socioeconomics	a. Ecosystem Services	• Alosine populations contribute primarily through their roles in food provision, supporting other fisheries, and cultural heritage within the Bay. • Alosines foster social relations through community festivals which focus on them, increasing awareness of a common cultural heritage, providing a sense of place to community members, increasing environmental stewardship, and stimulating local economies.
	b. Cultural Importance	• Despite depleted populations, communities continue to celebrate the historical cultural heritage of shads and herrings. This helps increase awareness of the depressed status of stocks, provide education and outreach opportunities which encourage stewardship, and fundraising for conservation and monitoring efforts. • Several fishways within the Chesapeake have been built with public viewing platforms to allow for observation opportunities of shad runs as alosines migrate from coastal waters to freshwater spawning grounds upstream. Such facilities are also utilized by state and local agencies to engage volunteers in fish monitoring programs.
	c. Restoration	• Over the last century, human population growth and development have steadily increased in the Chesapeake region. Resulting increases in commercial fishing pressure have led to declining alosine stock abundances. • Restoration efforts require focus on restoring access to historical spawning grounds, removing obstacles to migrations, improving riverine habitat quality, and bolstering wild populations with hatchery reared fry and fingerlings.

The Ecosystem-Based Fisheries Management (EBFM) Project for Chesapeake Bay *has been developed and coordinated by Maryland Sea Grant, working in partnership with the scientific community and the region's state and federal agencies (the Virginia Marine Resources Commission, Maryland Department of Natural Resources, Potomac River Fisheries Commission, Atlantic States Marine Fisheries Commission, District of Columbia Department of the Environment, NOAA, and EPA). The EBFM Project targets five key species identified in the Ecosystem Planning for Chesapeake Bay document, including striped bass, menhaden, blue crab, alosines, and oysters. The goals of the EBFM project are to build a sustainable mechanism for addressing ecosystem issues for fisheries within Chesapeake Bay and to develop ecosystem tools for use in ecosystem-based fishery management plans for the five key species (or group of species in the case of alosines). Currently the project involves 85 scientists, managers, and stakeholders from within and beyond the Chesapeake Bay region. For more information on Maryland Sea Grant's Ecosystem-Based Fishery Management Project please visit: www.mdsg.umd.edu/ebfm.*

Authors and Editors

The information in this summary brief was adapted from the EBFM for Chesapeake Bay Alosine Background and Issue Briefs authored by the Alosine Species Team members: Troy Tuckey (VIMS, Chair); Steve Gephard (CT DEP), Julie Harris, (NCSU), Andy Kahnle (NY DEC), Jake Kritzer (EDF), Wilson Laney (USFWS), Richard McBride (NEFSC), Bob Sadzinski (MD DNR), Kate Taylor (ASMFC), John Waldman (CUNY), Marek Topolski (MD DNR), Bill Duffy (WHOI), and Mike Hendricks (PFBC). Alesia Read, Jonathan Kramer, Shannon Green, and Jessica Smits served as editors.

For More Information and References

Please visit our website for more information on the Alosine Species Team and all other information related to the Ecosystem-Based Fisheries Management Program at Maryland Sea Grant: www.mdsg.umd.edu/programs/policy/ebfm/

Further information and all references for primary literature can be found within the species briefs here: www.mdsg.umd.edu/programs/policy/ebfm/bioteam/alosines/

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