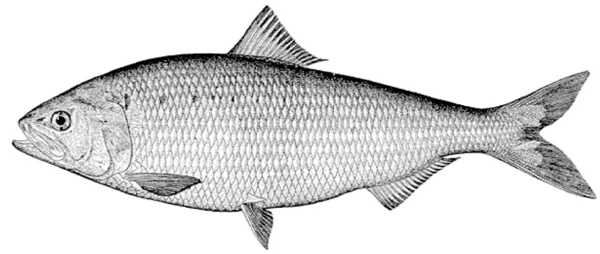
Alosines

American Shad *Alosa sapidissima*
Hickory Shad *Alosa mediocris*
Blueback Herring *Alosa aestivalis*

Contributor: John W. McCord



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DESCRIPTION

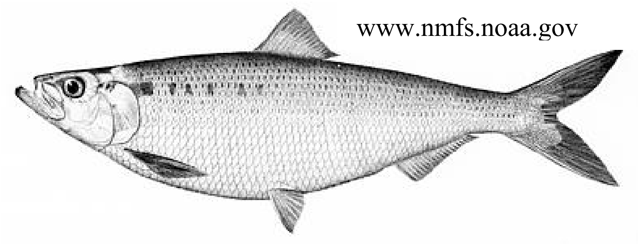
Taxonomy and Basic Description

The American shad, *Alosa sapidissima* (Wilson 1811), belongs to the herring family, Clupeidae. It is the largest Atlantic Coast member of the family, with females in South Carolina reaching about 66 cm (26 inches) total length (TL). Sexually mature female American shad, often called roe shad because of the large, highly prized ovaries, rarely attain more than 3 kg (7 pounds). Mature male shad, or bucks, are generally smaller than females, rarely exceeding 2 kg (4.5 pounds). American shad, like other alosines and most members of the Clupeidae, are laterally compressed, with relatively large scales. Scales on the midline of the underside form sharp scutes that produce a saw-toothed ridge. Coloration is dark bluish, greenish or bronze on the back, silvery on the sides and white below, and varies depending on color and turbidity of water. The mouth is near the midline of the snout, and a series of several dark spots usually extends backward to below the dorsal fin from near the operculum and pectoral fin. The fins are dark and without spines and the tail is deeply forked.

Most shad spawning in South Carolina are between three and six years old, with males averaging about a year less than females. Shad migrate several hundred miles or kilometers inland in large river basins and arrive in South Carolina from mid-January through mid-May. Peak spawning activity is water temperature dependent, but generally occurs during March and April. Shad are sequential or batch spawners, with groups of eggs released as the fish move upriver. Eggs are semi-buoyant and drift in the water column when flows and depth are appropriate. Eggs usually hatch within a few days into tiny larvae that soon transform into juveniles. Juveniles closely resemble adults, but are generally more silvery, typically reaching only 10 to 12 cm (4 to 5 inches) TL before they move toward the ocean to complete growth and maturation, usually after about one year of development in the rivers, sounds and bays. However, some juveniles remain within the Santee-Cooper Lakes at least until the summer of their second year, presumably because of difficulties in using out-migration options, some of which are not functional when outflows are limited due to low lake levels (D. Cooke, SCDNR, pers. comm., 2005).

Juvenile American shad feed primarily on small invertebrates, including insect larvae and zooplankton. Adult shad prefer larger zooplankton and rarely feed while in freshwater as they are thought to die after their initial spawning run. Both outmigrating juveniles and adults that survive spawning generally move into the Atlantic and migrate into coastal areas of Maine and southern Canada, where they mingle with shad from all Atlantic populations and prey primarily on abundant zooplankton. By fall, the vast conglomerate population migrates south and overwinters off the Mid-Atlantic States. Sexually mature fish then disperse up or down the coast to their respective rivers as late winter and spring water temperatures moderate and become ideal for spawning (Neves and Depres 1979; McCord et al. 1987).

The hickory shad, *Alosa mediocris* (Mitchill 1814), also belongs to the herring family, Clupeidae. It is smaller than the American shad, with females in South Carolina reaching about 55 cm (22 inches) TL. Sexually mature female hickory shad, often called roe jacks, also carry highly prized ovaries, but rarely attain more than 2 kg (4.5 pounds). Adult male hickory shad are usually smaller than females, rarely exceeding 1 kg (2.2 pounds). Hickory shad are shaped much like American shad and also have large scales. General coloration is greenish or bronze on the back, silvery on the sides and white below. A small, indistinct spot can usually be seen beneath each lateral scale. The mouth is nearer the top of the snout than in American shad. Several dark spots usually extend backward to below the dorsal fin from near the operculum and pectoral fins. The fins are dark and spineless and the tail is deeply forked. Juvenile hickory shad resemble adults, but are less distinctively marked. Juveniles usually emigrate from inland habitats by early winter at approximately 15 cm (6 inches) TL. Larval and smaller juvenile fishes are primary dietary items for juvenile hickory shad.



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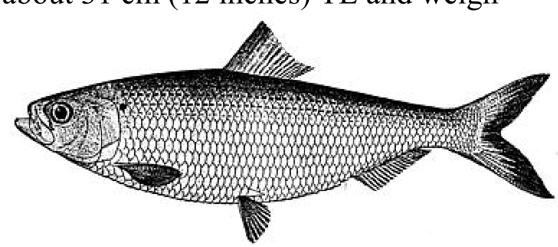
Adult hickory shad migrate and spawn earlier than American shad and blueback herring; hickory shad move inland from December through mid-April. Peak spawning for hickory shad in South Carolina is during February and early March. Hickory shad typically spawn along channel edges of tidally influenced freshwater river reaches, usually within 80 km (50 miles) of the ocean. Otherwise, the general life cycle is similar to the American shad. However, most hickory shad are believed to survive after spawning, presumably because they feed primarily on small fishes that are generally available in inland habitats. Hickory shad apparently concentrate farther south, principally from Delaware Bay to New England coastal inlets, where they feed primarily on small fishes (ASMFC 1999).

The blueback herring, *Alosa aestivalis* (Mitchill 1814), is the smallest alosine in the Southeast. Adult female blueback herring in South Carolina reach about 31 cm (12 inches) TL and weigh 0.3 kg (0.7 pounds); while the slightly smaller mature males approach 28 cm (11 inches) TL and weighs 0.27 kg (0.6 pounds). Adult blueback herring are shaped and marked much like American shad. Juveniles, which usually emigrate to the ocean by mid-winter, resemble tiny adults and are about 10 cm (4 inches) TL.



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Timing of inland migration, spawning and development of blueback herring closely follows patterns for American shad. However, blueback herring typically spawn in freshwater marshlands or small tributaries. Small zooplankton constitute much of the juvenile diet. Post-spawning survival rates are not well known for blueback herring, but probably exceed those for American shad. Migratory routes and timing of blueback herring are similar to those for American shad. During the spawning migration, herring move inland at distances intermediate to characteristics described for hickory and American shad. The distance that herring move upriver may be partly dependent upon the availability of habitats with suitable substrates for egg adhesion nearer the coast (Loesch and Lund 1977; J.W. McCord, SCDNR, pers. obs.).

During all life stages, alosines contribute greatly to the dynamics of food chains in freshwater, estuarine or marine habitats (Facey et al. 1986; MacKenzie et al. 1985; Weiss-Glanz et al. 1986). While at sea, alosines are prey for many species including sharks, tunas, mackerel and marine mammals, including porpoises and dolphin (ASMFC 1999; Weiss-Glanz et al. 1986). In fresh and brackish waters, both adult and juvenile alosines are consumed by American eel and striped bass (Facey et al. 1896; Mansueti and Kolb 1953; Savoy and Crecco 1995; Walburg and Nichols 1967). Juvenile herring are high quality prey for largemouth bass (*Micropterus salmoides*); accelerated growth of young bass occurs when herring consumption is high (Yako et al. 2000). Tissues taken from predatory fish in tidal freshwaters following the residency of migrating alosines had between 35 and 84 percent of their carbon-biomass derived from marine sources (Garman and Macko 1998; MacAvoy et al. 2000). East Coast alosines, particularly populations in the southeast where post-spawning mortality is highest, likely provide nutrients and carbon into riverine systems, similar to nutrient dynamics provided by salmon in the Pacific Northwest (Freeman et al. 2003). For example, the James River, Virginia may have received annual biomass input from alosines of 155 kg/ha (138 pounds/acre) before dams blocked migrations above the fall line (Garman 1992).

More than 40 species of birds and mammals congregate to feed on migrating anadromous fish in southeastern Alaska (Willson and Halupka 1995; Willson et al. 1998). Similar relationships likely occur between East Coast alosines and birds and mammals. Fish-eating birds like osprey (*Pandion haliaetus*) and bald eagle (*Haliaeetus leucocephalus*), prey upon alosines (pers. obs.) and may have evolved their late winter and spring nesting strategies in response to the availability of food resources supplied by pre and post-spawning alosines. In addition, nutrients released from carcasses of post-spawning alosines can substantially subsidize aquatic food webs by stimulating productivity of bacteria and aquatic vegetation (Kline et al. 1993; Richey et al. 1975), thereby stimulating the assimilation of marine-derived nutrients into aquatic invertebrates and fish (Bilby et al. 1996).

Status

American shad, hickory shad and blueback herring are experiencing coastwide reductions in all stocks compared to historical populations (ASMFC 1985; ASMFC 1999). Current spawning runs of east coast North American shad populations have been reduced to 10 percent of historical sizes and have been extirpated from over 4,000 km (2,500 miles) of riverine habitat (Limburg et al. 2003). Several alosine stocks (riverine populations) are of unknown status because no directed studies have been conducted. Hickory shad population status is very poorly known for South Carolina and historical data are virtually absent. The species is apparently not plentiful anywhere within South Carolina. Populations of blueback herring in the Waccamaw-Pee Dee and Santee-Cooper are presumably secure, though undoubtedly reduced from historical levels predating dams. Blueback herring populations for other drainages are perceived to be of poorer status, and perhaps absent.

POPULATION DISTRIBUTION AND SIZE

American shad occurs along the Atlantic coast from Bay of Fundy, Canada to St. Johns River, Florida. The historical range of hickory shad is very similar, from Bay of Fundy, Canada to Tacoma River, Florida, but current distribution is uncertain with known occurrence as far north as Connecticut (ASMFC 1999). Blueback herring are distributed from Nova Scotia to northern Florida, though they are most abundant from the Chesapeake Bay and south (Scott and Scott 1988). In South Carolina, all three species are presumed to occur as unique populations by coastal river system with a minimum of eight populations (presumably for all three species): Waccamaw-Pee Dee, Santee-Cooper, Ashley, Edisto, Ashepoo, Combahee, Coosawhatchie and Savannah drainage basins. Relatively unique populations likely occur in the major tributaries within the Waccamaw – Pee Dee basin, including Waccamaw, Little Pee Dee, Great Pee Dee, Lynches, Black and Sampit Rivers.

Historical population estimates are nonexistent, but historical distribution records (USFWS 2001) and anecdotal information on abundance strongly indicates that all populations of alosines in South Carolina are reduced compared to historical levels (early 20th century and earlier). American shad and, to a lesser extent, blueback herring historically ascended large river basins of the state (Waccamaw-Pee Dee, Santee and Savannah) well inland of the fall line and into North Carolina and Georgia (USFWS 2001).

Trends in American shad stocks have been primarily monitored by observations in commercial gill-net fishery catch rates since 1979. Based on these trends, American shad populations in Waccamaw-Pee Dee Basin and Savannah River have remained relatively stable and healthy over the past 25 years, though almost certainly below levels of a century past (McCord 2003). Fortunately, the lowermost dams on both Savannah and Waccamaw–Pee Dee Basins are approximately 320-river km (200 mi) from the ocean. However, historical alosine spawning migrations in these basins extended beyond the point of these dams (USFWS 2001). Anecdotal information indicates that both blueback herring and hickory shad occur in the Savannah in small populations. Dam-locked populations of blueback herring now occur in several reservoirs, including Lakes Jocassee and Hartwell. Hickory shad may have also become dam-locked in Savannah Basin reservoirs, but spawning has not been recorded (D. Cooke, SCDNR, pers. comm. 2005).

Among the ACE Basin rivers, Edisto River's shad populations apparently declined dramatically through the early 1990s, with overfishing indicated as a primary cause (McCord and Ulrich 1991). Directed management through restrictive commercial fishery regulations enacted in 1993 and a decline in the number commercial fishers has apparently promoted an increased population as indicated by improved catch rates for gill-net fishers (McCord 2003). However, this stock is considered to be in guarded condition until additional monitoring can better indicate stock status (McCord 2003). The Combahee River shad population was categorized as substantially declined in the late 1990s, presumably from an extended period of overfishing (McCord and Ulrich 1994; McCord 2003). Restrictive commercial fishery guidelines were established in 2000 and should allow for growth of this stock. The status of the American shad population in Ashepoo River, the smallest of the ACE Basin rivers, is unknown. Relatively few records exist for either hickory shad or blueback herring in the ACE Basin. Both species are presumed to occur in very small populations.

Both Ashley and Coosawhatchie Rivers are small, coastal plain drainages that historically supported limited commercial American shad fisheries. The current status of these populations is also unknown. Commercial fishing activity has been restricted substantially for the Ashley and banned for the Coosawhatchie since fishery laws were revised in 2000 in accordance with Act #245 of the 2000 South Carolina General Assembly. The status of alosine stocks in these small rivers, including whether any hickory shad and blueback herring are present, is unknown.

The Santee-Copper American shad population has grown substantially since 1985 and is among the largest on the Atlantic coast, with the population likely approaching one million adults annually (McCord 2003). The blueback herring population was estimated to average over six million in the five years following the rediversion of flows (Cooke and Leach 2003) and may be larger now following almost 20 years of increased flows and fish passage. Both American shad and blueback herring populations in the Santee-Cooper Basin have responded well to existing fish passage protocols and increased flows.

Hickory shad population status is poorly understood; however, based on anecdotal observations, the Santee-Cooper population is among the largest in the state, despite very low passage numbers recorded at St. Stephen Dam (Cooke and Leach 2001). All three alosines are thought to occur as secure stocks in the Waccamaw-Pee Dee Basin.

HABITAT AND NATURAL COMMUNITY REQUIREMENTS

Because of the highly migratory nature of alosines, these fishes require access to an expansive variety of high quality freshwater and marine habitats. Within state waters, adults migrate through nearshore Atlantic shelf waters and enter coastal sounds, bays and inlets to access the river basins in which they spawn. Eggs of American shad and hickory shad require adequate flows (generally 0.15 to 0.9 m/second or 0.5 to 3.0 feet/second) and sufficiently low sediment loads to keep eggs adrift until hatching (ASMFC 1985; Mansueti 1962; Williams and Bruger 1972). In river reaches where flows and/or water depth are not sufficient to keep eggs suspended, the semi-buoyant eggs sink to the bottom and roll or bounce on hard substrates but may be suffocated in areas with siltation (Massmann 1951; Williams and Bruger 1972). Successful spawning of blueback herring is partly dependent upon the availability of relatively clean vegetation and other substrates outside and at the periphery of river channels for egg adhesion and development with relatively low turbidity or suspended sediments (Christie et al. 1981). Christie et al. (1981) found high utilization of tidal, freshwater breached impoundments or relict rice-fields as blueback herring spawning habitat in the Cooper River basin.

American shad require high, but stable flows of high quality water for spawning and early nursery habitats (Crecco and Savoy 1987). Nursery habitats for American and hickory shad include all channel and adjacent out-of channel submerged habitats from a few kilometers or miles seaward to estuarine sounds and bays of river basin deltas. Larval and early juvenile blueback herring are associated more with the floodplain small tributaries and marshlands where spawning occurs, but older juveniles move into the same riverine and estuarine habitats used by

American and hickory shad. Where fish passage venues provide access into reservoirs, juveniles of all three species apparently successfully utilize artificial lake habitats as nursery areas (D. Cooke, SCDNR, pers. comm. 2005).

Abundant sloughs and flats with submerged vegetation are generally available in reservoirs, providing excellent spawning habitat for blueback herring During fall and winter, juvenile American shad and blueback herring tend to co-occur predominantly in deeper, channel habitats of estuarine systems, while hickory shad juveniles are more frequently encountered in shallow expanses of sounds and bays (pers. obs.). These variant distributions are likely reflective of differences in food preferences, as small crustaceans used by American shad and blueback herring are generally abundant near the bottom in estuarine channels and small fishes preferred by hickory shad are likely more numerous in shallower habitats adjacent to marshlands.

CHALLENGES

Obstructed access to a diversity of habitats may limit basin-specific alosine populations. Dams prevent upstream migration of alosines and other species (ASMFC 1985; ASMFC 1999; USFWS 2001). Atlantic streams from Maine to Florida have undergone a restriction or loss of access for migratory fishes to about 84 percent of stream habitat within historic ranges from dams alone (USFWS 2001, Busch et al. 1998). The Waccamaw-Pee Dee, Santee-Cooper and Savannah basins in South Carolina are impacted by dams that restrict migrations of alosines into historical habitats (USFWS 2001). Dams and other impediments to migration have eliminated alosines from many historical habitats in South Carolina (USFWS 2001); the result being a general reduction in alosine populations even in currently accessible river reaches. The ecosystem effects of this loss are difficult to identify (Power et al. 1996), but ecological roles for alosines may be greatly diminished (Garman and Macko 1998). For example, many freshwater mussels are dependent upon migratory fishes as hosts for their parasitic larvae and are presently among the most imperiled freshwater fauna (Neves et al. 1997; Vaughn and Taylor 1999), with 29 species of conservation concern in South Carolina.

The Santee Basin has the second largest drainage area and total discharge (only the Susquehanna is larger) of all river systems on the east coast of the U.S. (Hughes 1994). However, this large watershed has been adversely affected by damming to a greater extent than most basins on the Atlantic Coast of North America, with nearly 45 dams in the South Carolina portions of the basin alone (USFWS 2001). The original Santee-Cooper diversion project, completed in 1942, shifted approximately 88 percent of the historical Santee River flow into the Cooper River, changing the average Cooper River flow rate from 2 cms (cubic meters per second) or approximately 7 cfs (cubic feet per second) to 442 cms (1,560 cfs) (Kjerfve 1976). Prior to rediversion in 1985, water releases at Pinopolis Dam on the Cooper River were generally continuous. A weekly average flow of 122 cms (430 cfs) has been maintained in the Cooper River since rediversion to protect water supplies (Orlando et al. 1994), but generation time has been restricted to as little as 10 hours per day. Tidal freshwater marshes along the Cooper River (many of which are relic rice impoundments with breached or eroded dikes), which were used extensively as spawning habitat by blueback herring prior to rediversion of flows into the Santee River (Christie et al. 1981), are less extensive under reduced flows, and many are now partly dewatered or influenced by brackish water. Available fish passage and commercial fishery data indicate that the herring population has declined dramatically since flows were rediverted, presumably because of a reduction in the amount, and perhaps quality, of spawning and nursery habitat (Cooke and Eversole 1994). The original diversion of Santee River historical flows into the Cooper River caused average freshwater flow in the Santee River seaward of Wilson Dam to drop from 525 to 74 cms (1,850 to 260 cfs), and allowed saltwater intrusion (Kjerfve and Greer 1978). The Santee-Cooper Rediversion Project returned about 70 percent of the Cooper River flow to the Santee, increasing average flow to approximately 367 cms (1,290 cfs) and reducing salinity in the lower Santee (Orlando et al. 1994). However, there is no minimum flow requirement at St. Stephen Dam on the Rediversion Canal (D. Cooke, SCDNR, per. comm., 2005) and the average daily flow from Wilson Dam is only about 18 cms (63 cfs) (Orlando et al. 1994). During periods of low inflow into the Santee-Cooper Lakes, water releases can be discontinued at St. Stephen Dam (D. Cooke, SCDNR, per. comm., 2005). In contrast, the average daily discharge from Wilson Dam can approximate 500 cms (1760 cfs) during flood-control releases (Orlando et al. 1994). The resulting flow regimens in both the Cooper and Santee Rivers is typically in highs and lows (with more abrupt changes from peaked power generation and flood releases) than are characteristic of more gradual river flow changes that occur in open rivers where waters expand into, and withdraw from, floodplains.

With the construction of the Santee-Cooper lakes (Moultrie and Marion) in the 1940s, the vast majority of the Santee was closed to migratory fishes (USFWS 2001). Both the Pinopolis navigational lock and St. Stephen fish passage facility are currently used for alosine passage. Passageways at both facilities provide passage for blueback herring and American shad (Timko et al. 2003). The efficiency of passage at St. Stephen Dam for blueback herring is low (Cooke and Leach 2001) and has yet to be determined for American shad.

Fish passage designs and flow protocols currently used at dams on the lower Santee-Cooper Basin were initially designed for passing blueback herring into the lakes for forage and do not maximize passage efficiency for alosines in either direction (Cooke and Leach 2001; D. Cooke, SCDNR, pers. comm. 2005). Dams on the Santee-Cooper Basin that currently incorporate passage for alosines, do not employ methodologies that accommodate timely outmigration and maximized survival of post-spawning adults or emigrating juveniles. Delayed outmigration of juvenile alosines, as occurs in the Santee-Cooper Lakes, may result in increased mortality of juveniles from artificially high predation and from potential capture for bait since fish become concentrated near dams for an extended period of up to several months. In open rivers, juveniles gradually move seaward in groups that are likely spaced according to the spatial separation of spawning and nursery grounds (Limburg 1996; J.W. McCord, SCDNR, pers. obs.) Delayed outmigration not only concentrates juvenile alosines, but extends their stay in freshwater areas until moderating water temperatures of late spring and early summer induce more active feeding behavior for many freshwater piscivores. Delayed outmigration may also increase vulnerability of juveniles to marine predators that would otherwise be absent from coastal waters if juveniles were able to adhere to natural migration patterns. According to the ASMFC IFMP and Amendment 1 to the IFMP, a fish passage program for alosines is only legitimate if downstream passage is an integral part of such operations (ASMFC 1985, 1999).

Dams, and particularly hydropower dams, often produce flow regimens that are not reflective of natural seasonal flows. Pulse flows used for peaking hydropower production can disrupt natural productivity and availability of zooplankton needed for larval and early juvenile forage (Crecco and Savoy 1987; Limburg 1996), can displace eggs and/or larvae from otherwise highly productive habitats, and can disrupt both upstream and downsteam migration patterns for adult and juvenile alosines (ASMFC 1985; ASMFC 1999; Limburg 1996; USFWS 2001). Dams may also reduce minimum flows, potentially dewatering otherwise productive habitats, causing increased water temperature, or contributing to or exacerbating poor water quality such as reduced dissolved oxygen (ASMFC 1985; ASMFC 1999; NMFS 1998; USFWS 2001). Water releases from deep reservoirs may be poorly oxygenated and/or of below normal seasonal water temperature, thereby causing loss of suitable spawning or nursery habitat in otherwise suitable river reaches (ASMFC 1985; ASMFC 1999; NMFS 1998; USFWS 2001). Further, impounded marshlands in freshwater river reaches prevent access of blueback herring to potential spawning and early nursery habitat.

Large concentrations of double-crested cormorants (*Phalacrocorax auritus*) occur immediately below dams, particularly below those with fish passage and during the winter-spring season of alosine passage (J.W. McCord, SCDNR, pers. obs.). The cormorant population has increased dramatically over the past decade (Wires et al 2001) and these birds have been shown to feed heavily on alosines (Johnson et al. 1999). Small alosines can comprise up to 64.5 percent of the cormorant's diet (Johnson et al. 2000). Although the impact of cormorant predation on alosine populations has not been quantified, it appears that cormorants have to potential to negatively impact both upstream passage success for blueback herring and out-of-lake passage for all juvenile alosines.

Competition and predation from non-native species, in particular flathead catfish (*Pylodictis olivaris*) and blue catfish (*Ictalurus furcatus*), may be additive to 'more natural' sources of mortality and may be particularly problematic below dams where catfish density is often high (J.W. McCord, SCDNR, pers. obs). Even adult American shad have been observed in the diet of large flathead catfish (D. Allen, SCDNR, pers. comm.), and both non-native catfishes are presumed to be problematic to alosines as both competitors and predators (NMFS 1998).

Dredging can also negatively affect alosine populations by producing suspended sediments (Reine et al. 1998). Behaviorally, chronic turbidity from frequent or prolonged dredging can also affect fish migration, spawning, conspecific interactions, and foraging (Coen 1995). Migrating alosines are known to avoid waters of high sediment load (ASMFC 1985; Reine et al. 1998). Suspended sediments have been linked to a variety of lethal and sublethal responses in juvenile and adult fishes that are consistent with oxygen deprivation due to gill clogging (Sherk et al. 1975; Sherk et al. 1974). Filter-feeding fishes such as alosines are particularly susceptible to negative impacts of suspended sediments on gill tissues (Cronin et al.1970). Siltation from dredging and from agricultural, silvicultural and other land use practices can reduce spawning success by causing mortality of eggs or by coating substrates needed for attachment of adhesive eggs (NMFS 1998). Suspended sediments, whether caused by dredging or by erosion from land use practices, can also cause reduced feeding success in larval or juvenile fishes that rely on visual cues for plankton feeding (Kortschal et al. 1991). Larval striped bass (*Morone saxatilis*) consumed 40 percent less prey when suspended solids exceeded 200 mg/l (milligrams per liter) (Breitburg 1988). Survival of larval alosines decreases as turbidity or suspended sediments increases above 50 mg/l (Auld and Schubel 1978).

Dredging may negatively impact prey availability by removing benthic invertebrates within sediments, by increasing suspended sediments, or by producing changes in salinity or dissolved oxygen regimens (ASMFC 1990). Sediment resuspension from dredging can cause increased turbidity and localized depletion of dissolved oxygen, as well as increased bioavailability of any contaminants that may be bound to the sediments (Clarke and Wilber 2000). The eggs and larvae of estuarine and coastal fishes appear to be among the most sensitive to suspended sediment exposures of all the taxa and life history stages for which data are available (Clarke and Wilber 2000). High concentrations of suspended sediments, as well as relatively low concentrations sustained for several days, have been shown to cause direct mortality, impaired hatching success, reduced larval feeding, and diminished larval growth in several species of estuarine and anadromous fishes (Clarke and Wilber 2000). Waters with high suspended sediment are unproductive for primary and secondary portions of the food pyramid on which juvenile alosines feed, and changes in salinity regimens can dramatically impact prey distribution (ASMFC 1990).

Pollution from point and non-point sources is a primary cause of reduced habitat quality and aquatic species viability in tidal systems. Land use practices such as agriculture and logging, as well as residential, commercial and industrial development, greatly influence the input of chemicals and nutrients into waterways, and are the primary sources of increased siltation. All of these factors contribute to eutrophication and a general decline in water quality, including a reduction in dissolved oxygen as mentioned previously. Sediments and pesticides most commonly enter coastal waters in run-off from agricultural and silvicultural lands, and agricultural and silvicultural practices alone can significantly decrease the quality of water discharges into coastal habitats, thereby causing drastic adverse impacts on aquatic life (Butler 1968). In addition to sediments, run-off from uplands includes nitrates, phosphates, herbicides, pesticides, silt and other chemicals, any of which either acting alone or in combination with other pollutants can be lethal to aquatic life, and particularly to larval forms (Matthews et al. 1980). Chemicals and heavy metals from industrial and other sources that do not cause acute toxicity can be assimilated through the food-chain and can produce sub-lethal effects including behavioral and reproductive abnormalities (Matthews et al. 1980). Pollution can directly produce mortality from contaminants such as pesticides, can lower pH that may reduce egg and larval survival (Klauda 1994) and can contribute to reduced oxygen levels. All of the potential impacts of sediment resuspension and increased turbidity due to dredging (described in detail above) would also apply to sediments derived from upland sources.

Deforestation of swamp forest potentially leads initially to increased soil and water temperature (Aust and Lea 1991; Perison et al. 1993), siltation from increased erosion and runoff (Aust et al. 1997), decreased DO (Lockaby et al. 1997), disturbance of food-web relationships in adjacent and downstream waterways (Batzer et al. 2005). Forestry BMPs for bottomland forests are voluntary. When BMPs are not used, braided streams may be obstructed by plant material and disturbed soils, excessive ruts may channel eroded sediments into streams, and partially stagnated waters may become nutrient-rich and promote algal growth that can die under extended periods of cloud-cover (J.W. McCord, SCDNR, pers. obs.). Siltation from agricultural, silvicultural and other land use practices can reduce spawning success by causing entrapment and mortality of semi-buoyant eggs and adhesive eggs by coating substrates needed for attachment of adhesive eggs (Mansueti 1961). Siltation also causes increased water temperature and reduced DO, and can result in reduced productivity beginning at lower levels of food-chain relationships on which juvenile alosines are dependent (Mansueti 1961).

Siltation, from erosion due to land use practices or from dredging, physically covers and kills some aquatic life, including submerged aquatic vegetation (SAV) and thereby increases biological oxygen demand (BOD). SAV provides important ecological functions in freshwater habitats. SAV improves water quality (Rybicki and Hammerschlag) and provides habitat for predator avoidance, foraging and nursery development for many macro-invertebrates and resident and migratory fishes (Maldeis 1970; Killgore et al. 1989; Monk 1988). SAV can also provide important spawning habitat or substrate for blueback herring (Christie et al. 1981). SAV is adversely affected by suspended sediments less than 15 mg/l (Funderburk et al. 1991) and by deposition of excessive sediments (Valdes-Murtha and Price 1998).

Dewatering of freshwater streams from irrigation and other water removal projects decreases instream flows and decreases the quantity of both spawning and nursery habitat. Dewatering can result in reduced water quality from the impacts of more concentrated pollutants and/or increased water temperature (ASMFC 1985). Density dependent impacts such as predation and competition may also increase. Further, mortality of eggs, larvae and/or juvenile alosines can occur due to impingement and entrainment in water intakes at water removal projects and in turbines in dams (ASMFC 1985).

By-catch from 'non-game' gill-nets may exert excessive mortality on hickory shad. Participants in this late winter fishery have reported that numerous hickory shad are caught in these nets (J.W. McCord, SCDNR, pers. obs.). Further, hickory shad are not generally segregated from American shad in commercial catches nor are they easily differentiated in fish passage counts. These factors prevent the collection of reliable fishery-dependent and fishery-independent data collection as needed to properly manage hickory shad populations. Mortality from directed fisheries and/or from by-catch in other fisheries outside of state jurisdiction, including fisheries within the Exclusive Economic Zone (that portion of the Atlantic Ocean under federal jurisdiction from 3 to 200 miles offshore) and within Canadian waters, may negatively impact South Carolina stocks of alosines (ASMFC 1985; ASMFC 1999).

CONSERVATION ACCOMPLISHMENTS

The first river-specific restrictive commercial gill-net fishery regulations (Act # 343 of the 1992 South Carolina General Assembly) were enacted in 1993 for the Edisto River after SCDNR studies indicated overfishing as major contributor to a perceived trend of population decline (McCord and Ulrich 1991). In 2000, laws and regulations were revised to be more responsive to individual perceived population status by drainage basin or river system (Act #245 of the 2000 South Carolina General Assembly). The Coosawhatchie River shad population received the most protection, as the river was closed to commercial gill-nets (Act #245 of the 2000 South Carolina General Assembly). The amount of potential gill-net fishery effort was substantially reduced for other small, more imperiled stocks, including those in Combahee, Ashepoo and Ashley Rivers (Act #245 of the 2000 South Carolina General Assembly).

An interstate fisheries management plan (IFMP) has been developed for the alosines under the auspices of the Atlantic States Marine Fisheries Commission (ASMFC 1998). The original ASMFC IFMP for Shad and River Herring was completed in 1985 and was amended in 1999. The 1999 Amendment 1 to the ASMFC IFMP required all member states to close directed fisheries for American shad in coastal Atlantic Ocean waters by 2005 through a phase-out process initiated in 2000 (ASMFC 1999). Addenda to the IFMP were also approved in 2000 and 2002 (ASMFC 2000; ASMFC 2002). The Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA) of 1993 requires states to adopt management guidelines as mandated by approved ASMFC IFMPs, including the conduct of surveys in selected South Carolina rivers and the monitoring of catch and effort for commercial and recreational fisheries for alosines (ASMFC 1999).

The ASMFC IFMP also required states to limit recreational harvest through the establishment of possession limit not to exceed an aggregate of 10 American and hickory shad per angler per day by 2000. Through legislative action, South Carolina established a 10-fish limit in 2000 for all State waters, except for Santee River, where a 20-fish limit was allowed under a conservation equivalency adjustment.

Many dams in South Carolina are currently, or soon to be, undergoing FERC (Federal Energy Regulatory Commission) re-licensing processes; these processes will include considerations for improved access and migration of aquatic species. Passage at all types of dams and other barriers to migration is strongly recommended by the ASMFC IFMP. Existing passage systems and protocols have apparently contributed to observed increases in American shad and blueback herring populations in the Santee River.

The Santee-Cooper Rediversion Project enhanced year-around flows and average late winter and spring water levels in the Santee River, primarily seaward of the Rediversion Canal. These improved flow regimens have likely produced increases in the quantity and quality of alosine spawning and nursery habitat seaward of St. Stephen Dam and the Rediversion Canal.

CONSERVATION RECOMMENDATIONS

- Conduct statewide surveys of alosine distribution and population size, particularly for small rivers where stock status is unknown or perceived as poor, in order to make prioritized decisions for restoration and passage.
- Determine passage and outmigration efficiency for all alosines at existing facilities so potential changes in protocols or designs can be identified.
- Inventory sources of mortality, including existing outlets providing outmigration through dams and bycatch in commercial fisheries; formulate remedies where practical.
- Improve quality and scope of coverage for mandatory catch and effort records, for both recreational and commercial fisheries.
- Determine how often hickory shad is misidentified as American shad or blueback herring.
- Investigate impacts of logging in swamp forests on water quality and habitat, especially as related to blueback herring.
- Determine impacts of dewatering of freshwater streams to aquatic species.

- Conduct studies on the energetics and nutrient dynamics related to food-chain relationships and spawning migrations of alosines.
- Investigate potential success for fish passage at various dams by evaluating upstream habitats for value as spawning and nursery habitat
- Determine genetic relationships, or extent of homing, of alosines relative to tributary streams (particularly in Waccamaw-Pee Dee Basin).
- Determine impacts of competition and predation from non-native species, particularly below dams where alosines passing through existing outmigration routes may become stunned or disoriented, exacerbating predation impacts. To the extent possible, control and prevent further distribution of non-native blue and flathead catfish populations.
- Partner with federal authorities to create on-board observer programs to investigate by-catch of alosines by out-of-state jurisdictional fisheries.
- Partner with appropriate agencies to evaluate state water quality standards and Best Management Practices (BMP) that may impact wetlands to ensure that guidelines are stringent enough to protect alosine habitat.
- Determine impacts of pollution and siltation on life history stages of alosines.
- Determine biotic effects of alosine stocking in habitats where access was previously restricted or absent.
- Determine the relationships of alosines to freshwater mussels on the South Carolina Species of Concern list.
- Determine impacts of biotic and abiotic factors on egg, larval and juvenile survival and development and how such factors relate to spawning stock recruitment.
- Survey non-gamefish winter gill-net fisheries to determine potential impacts on alosines, particularly on hickory shad.
- Determine potential impacts of double-crested cormorant predation on passage of adult blueback herring and on all juvenile alosines, particularly at St. Stephen Dam.
- Participate in FERC-relicensing evaluations and partner with appropriate agencies to ensure that cost-effective and efficient designs for providing both upstream and downstream passage of alosines are installed in dams blocking access to suitable spawning and nursery habitats.
- Partner with appropriate entities to improve access to a full diversity of habitats by including fish passage designs, or improving existing designs, at facilities not under FERC jurisdiction.
- Impediments to migration, such as nonfunctional dams, dikes or causeways should be identified. Investigate the feasibility for these structures to ultimately be removed, breeched or bypassed through partnerships with the appropriate authorities.
- Build partnerships with NGOs, permitting authorities, and county and local governments to improve and/or implement the use of Best Management Practices (BMPs) in agriculture, silviculture and urban development activities to reduce siltation and contaminant input.
- Partner with the appropriate agencies to determine water removal guidelines for agricultural, civil or industrial purposes that include considerations for migratory fishes.
- Partner with appropriate entities to limit deforestation of river floodplains and swamp forests.

- Partner with appropriate permitting authorities to design dredging protocols that consider the timing of alosine migration.
- Partner with other coastal states to promote protection of the alosines in the EEZ and in Canadian coastal waters.
- Form an alliance with other state and federal agencies as well as NGOs to implement range wide conservation and management of alosines as described in the ASMFC IFMP.
- Build partnerships with natural resource agencies in Georgia and North Carolina to manage alosine populations that transcend individual state jurisdictions, specifically populations in the Savannah River and Waccamaw-Pee Dee Basin, respectively.
- Partner with NGOs and other state and/or federal agencies to promote changes in water release protocols for dams that will restore or approximate natural flow regimens and increase minimum flows.
- Partner with appropriate agencies and NGOs to develop or revise river basin plans to identify habitats areas of particular concern (HAPCs), to identify degraded or threatened habitats, and to identify preventative or mitigation actions.
- Partner with appropriate agencies to designate critical coastal areas.
- Develop Memoranda of Understanding (MOUS) with other state agencies for joint review of projects and planning activities to ensure that habitats, particularly HAPCs, are sufficiently protected.
- Develop education and outreach programs that distribute information to governments, civic groups, educational systems and NGOs about critical habitat needs, threats, and potential conservation actions related to alosines.

MEASURES OF SUCCESS

One measure of success would be to develop sound survey and monitoring programs and estimate trends in alosine populations. Once status has been determined, management plans can be developed to manage for stable to increasing alosine populations in South Carolina.

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