ISSN 1092-194X

FLORIDA MARINE RESEARCH INSTITUTE
TECHNICAL REPORTS

Florida's Shad and River Herrings (*Alosa* species): A Review of Population and Fishery Characteristics

Richard S. McBride

Florida Fish and Wildlife Conservation Commission

FMRI Technical Report TR-5 2000

The Florida Marine Research Institute (FMRI) is a division of the Florida Fish and Wildlife Conservation Commission (FWC). The FWC is"managing fish and wildlife resources for their long-term well-being and the benefit of people." The FMRI conducts applied research pertinent to managing marine-fishery resources and marine species of special concern in Florida.

Programs at the FMRI focus on resource-management topics such as managing gamefish and shellfish populations, restoring depleted fish stocks and the habitats that support them, protecting coral reefs, preventing and mitigating oil-spill damage, protecting endangered and threatened species, and managing coastal-resource information.

The FMRI publishes three series: *Memoirs of the Hourglass Cruises, Florida Marine Research Publications,* and *FMRI Technical Reports. FMRI Technical Reports* contain information relevant to immediate resource-management needs.

Florida's Shad and River Herrings (*Alosa* species): A Review of Population and Fishery Characteristics

Richard S. McBride

Florida Fish and Wildlife Conservation Commission
Florida Marine Research Institute
100 Eighth Avenue Southeast
St. Petersburg, Florida 33701

Florida Fish and Wildlife Conservation Commission
FMRI Technical Report TR-5

2000

Cover Photograph

A lone angler catches an American shad on the St. Johns River near Sanford, Florida. Photograph by Richard S. McBride.

Copies of this document may be obtained from

Florida Marine Research Institute
100 Eighth Avenue SE
St. Petersburg, FL 33701-5095
Attn: Librarian

Document Citation

McBride, R. S. 2000. Florida's shad and river herrings (*Alosa* species): A review of population and fishery characteristics. Florida Marine Research Institute Technical Report TR-5. 18 pp.

Document Production

This document was composed in Microsoft® Word and produced using QuarkXPress® on Apple Power Macintosh® computers. The headline font is Adobe® Avant Garde, the text font is Adobe® Palatino, and the cover headline is Adobe® Gill Sans. The cover and text papers are Consolidated Fortune Matte Recycled.

The cover and text papers used in this publication meet the minimum requirements of the American National Standard for Permanence of Paper for Printed Library Materials Z39.48—1992.

Table of Contents

Acknowledgments

S. Brown, R. Davis, and J. Holder provided unpublished data. B. Brock assisted with literature searches. R. Crabtree, F. Cross, B. Mahmoudi, R. Matheson, J. Quinn, R. Williams, and D. Winkelman made helpful suggestions for improving the manuscript. J. Leiby copyedited the final manuscript. L. French produced the document for printing. L. Palmer (National Museum of Natural History, Division of Fishes) furnished digital images for Figure 1. I thank all of the above.

Florida's Shad and River Herrings (*Alosa* species): A Review of Population and Fishery Characteristics

Executive Summary

Five species of shad and river herrings occur in Florida. American shad *(Alosa sapidissima),* hickory shad *(A. mediocris),* and blueback herring *(A. aestivalis)* occur in northeast Florida. Alabama shad *(A. alabamae)* and skipjack herring *(A. chrysochloris)* are present in northwest Florida. With the possible exception of skipjack herring, these species are anadromous, spawning in rivers and spending most of their adult lives at sea. The sea migration of *Alosa* species can extend into international waters. For example, locally spawned American shad migrate to Canada before returning to Florida to spawn.

All of these *Alosa* species occur in other states, where their biology may differ from the biology of Florida's populations. The life cycle of American shad in populations from Florida to Canada is well documented and serves as a good example. In populations north of the Carolinas, American shad live longer and grow larger but they produce fewer eggs per unit body weight than southern populations of American shad. South of the Carolinas, water temperatures are too high and migration distances in the ocean are too long for American shad to spawn more than once in a lifetime. Fish in southern populations compensate for this inability to spawn repeatedly by reducing the size and age at spawning and increasing their egg production per unit of body weight. Consequently, adult shad migrating in Florida's St. Johns River are smaller and younger but have higher egg counts than adult shad migrating into other North American rivers. Florida's American shad spawn once and then die, whereas American shad from rivers north of the Carolinas can spawn more than once in a lifetime.

Netting for shad began in Florida during the mid-1800s, and this fishery expanded rapidly once railroads began transporting shad to northern markets a few decades later. Most Florida shad were harvested from the St. Johns River during the December–April spawning run. Florida's populations spawned earlier than populations of the other Atlantic states did, so they entered the northern markets earlier and sold at higher prices than shad harvested from other Atlantic states did. At the turn of the nineteenth century, American shad was among the top five fishery species in the U.S. Landings (*i.e.,* pounds) and value peaked at this time but have declined steadily during the twentieth century. Hickory shad and blueback herring were also landed and sold during the late 1800s and early 1990s, and although they no longer constitute significant fisheries in Florida, they are still economically important to a few east coast states. Fisheries for Alabama shad and skipjack herring never developed.

Shad fishing methods have changed considerably since the 1950s in Florida. Haul seines were used until the 1970s, and gill nets were gradually phased out by various regulations during the 1990s. Hook and line fishing for shad first became popular in the 1940s; during the 1950s and 1960s, the largest shad sport fishery among the Atlantic states was in Florida's St. Johns River. Today, the only allowable gear for shad fishing is hook and line. In addition, a saltwater fishing license is now required for most anglers who land shad or river herrings in Florida, and it is illegal to possess more than an aggregate of 10 American shad, Alabama shad, and hickory shad. Because of the virtual elimination of Florida's commercial fishing effort, it is predicted that there will be increases in shad abundance, length of the spawning run, average fish size, and numbers of female shad (up to a 1:1 sex ratio). Commercial ocean-intercept fisheries that exist offshore of nearly all other Atlantic coastal states can still affect Florida's populations, but these fisheries are scheduled to be phased out by the year 2005. Adequate water flow and water quality at shad spawning grounds are now probably the major factors limiting Florida's shad abundance and recovery.

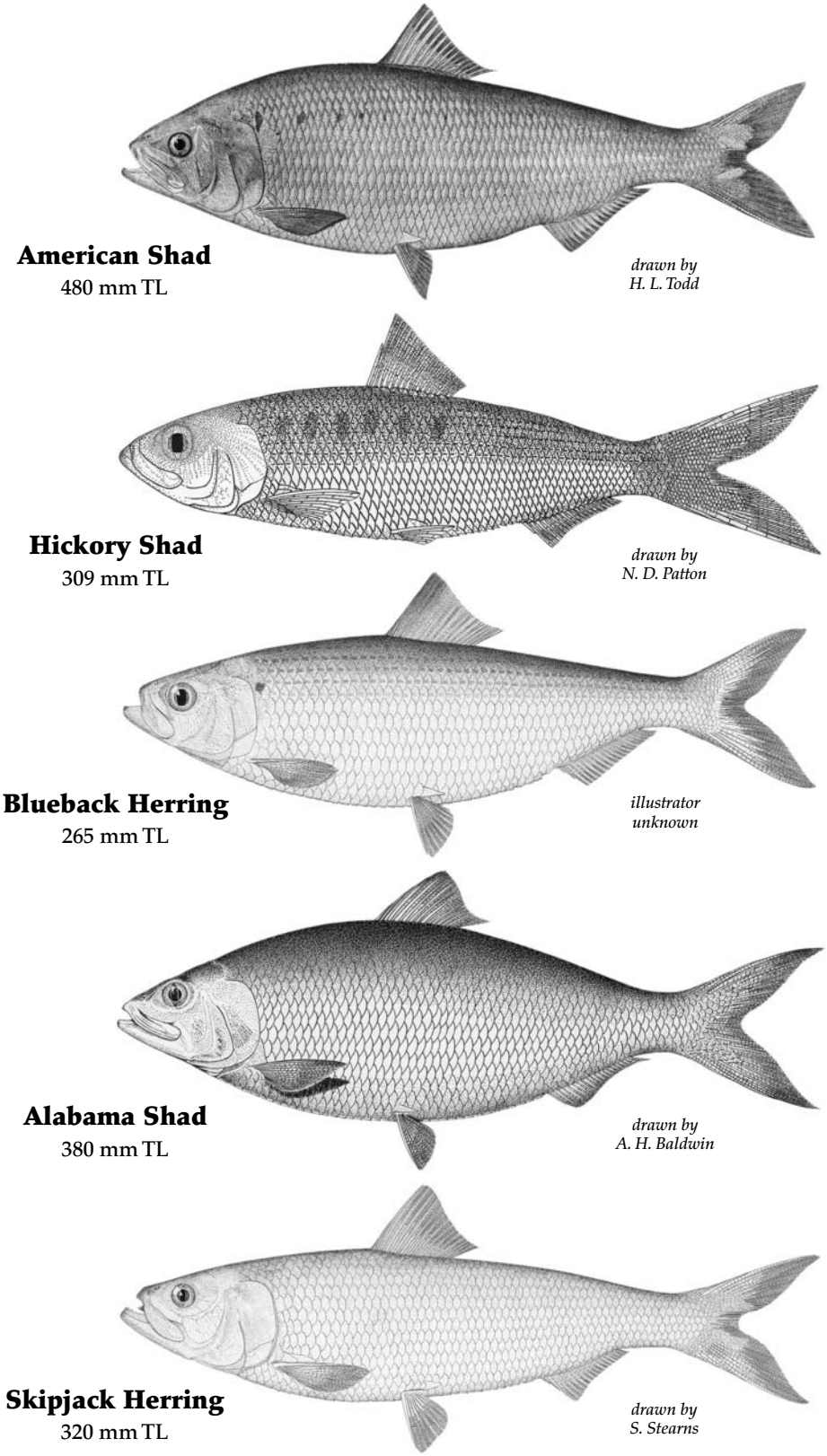

Figure 1. *Florida's shad and river herrings (digital images courtesy of the Smithsonian Institution, National Museum of Natural History, Division of Fishes).*

Florida's Shad and River Herrings (Alosa species): A Review of Population and Fishery Characteristics

Introduction

Of the six shad and river herring species (Clupeidae: *Alosa* species) found in North America, five occur in Florida (Figure 1), more than in any other state in the U.S. These species, with one possible exception, are anadromous (*i.e.,* they move from salt water to fresh water to spawn). On Florida's Atlantic coast, there are three species: American shad *(Alosa sapidissima),* hickory shad *(A. mediocris),* and blueback herring *(A. aestivalis)*. Two species are present on Florida's gulf coast: Alabama shad *(A. alabamae*) and skipjack herring *(A. chrysochloris*). The Atlantic species range northward from Florida to as far as Canada, and the gulf species range westward to Louisiana.

At the turn of the nineteenth century, American shad was one of the most economically important U.S. fishes, but shad populations have declined dramatically in abundance and value since then. Florida's shad spawned earlier than those in populations in other east coast states did, so Florida's shad sold for higher prices than were available later in the year. The early spawning season in Florida also meant that tourists could fish for shad weeks or months earlier than they could in their home states. Recreational shad fishing in Florida grew in popularity during the mid-1900s, and the largest shad sport fishery along the Atlantic coast was in Florida's St. Johns River. More recently, Florida's commercial fishery for shad and river herrings has been virtually eliminated by a series of regulations that restrict the use of fishing nets, but an economically valuable recreational fishery persists for American shad in the St. Johns River.

In this document, I assemble and summarize information about Florida's populations of *Alosa* species and discuss the status and trends of those populations. Much of the information assembled here is from the published literature, but I also review and synthesize unpublished reports and data available from the archives and databases of the Florida Marine Research Institute. After a general account of species distributions, I review the biology, ecology, and fishery of American shad. Comparative information, whenever available, is presented for other alosid species in subsequent subsections. A review of markets, regulations, and factors that adversely affect alosid populations is followed by a brief summary.

Species Diversity and Distribution in Florida

Shad and river herrings, collectively referred to as alosids, occur in several river systems on the east and west coasts of Florida (Lee *et al.,* 1980; Rulifson *et al.,* 1982; Warren *et al.,* 2000; Williams and Grey, undated). American shad, hickory shad, and blueback herring are present in the St. Johns and St. Marys rivers in northeastern Florida (Figure 2). Some individuals may range south to the Tomoka River, just north of Cape Canaveral, but there are no reports of these species south of St. Lucie Inlet. On the gulf coast, Alabama shad ranges through Florida's panhandle and south to the Suwannee River, whereas skipjack herring does not occur south or east of the Apalachicola River. The southern distributional limit for all these alosids is limited by temperature (Hildebrand, 1963; Leggett, 1969; Leggett and Whitney, 1972).

American Shad

Research Review

The American shad was described by Wilson (1811), and it was included in classic references on American fishes by Mitchill and DeKay (Hildebrand, 1963). The fishery and husbandry of American shad was well detailed in the literature of the nineteenth century (*e.g.,* Baird, 1874a–g; Milner, 1874; McDonald, 1884a–d, 1887; Stevenson, 1898, 1899). Early references that specifically mentioned shad in Florida are Baird (1874g), Goode and Shepard (1874), Osborn (1882, 1883), Hamlen (1884), McDonald (1884a, b, c, d, 1887), Smiley (1884), Cary (1885), Stearns (1885, 1887), Dempsey (1887), Collins (1892), Smith (1893, 1894, 1898), Brice (1898b), Evermann and Bean (1898), Henshall (1898), Stevenson (1898, 1899), and Townsend (1899, 1900). Hildebrand (1963; see also Berry, 1964) provided an excellent sum-

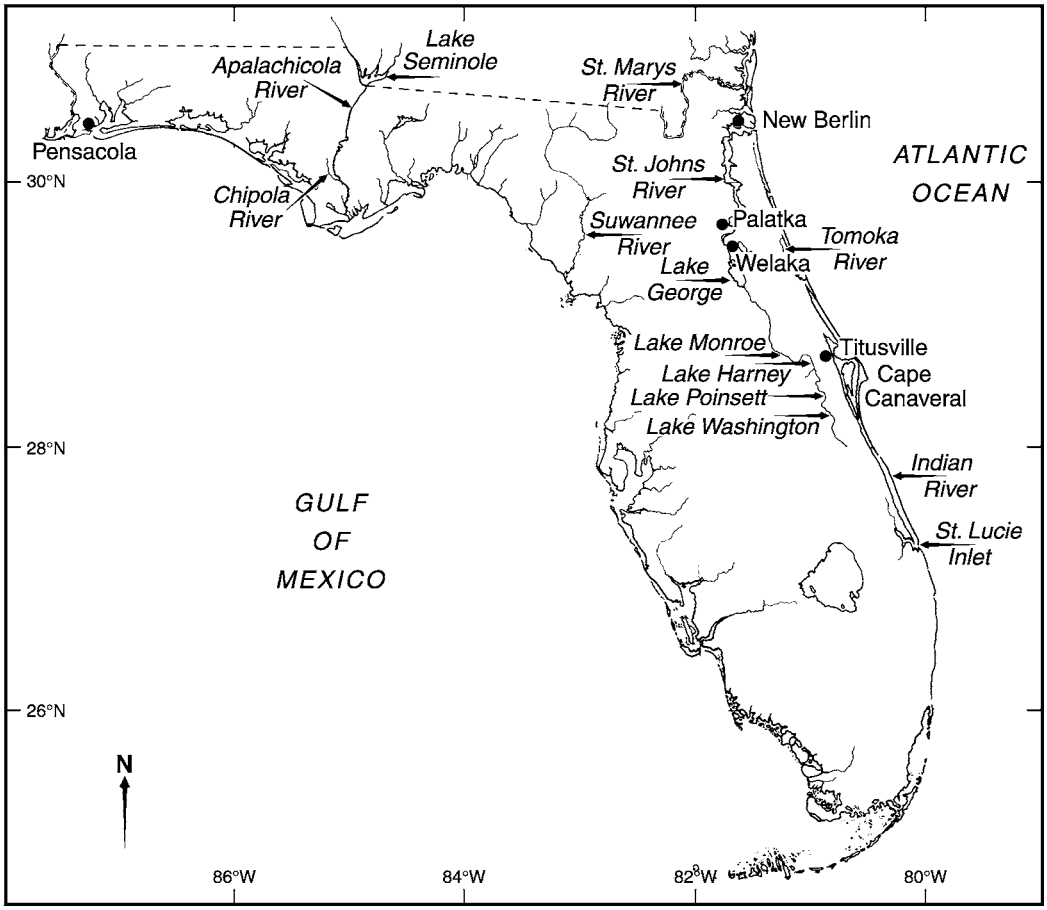

Figure 2. *Map of Florida's rivers, indicating water bodies and other landmarks mentioned in the text.*

mary of ecological and systematic research on shad and river herrings; Walburg and Nichols (1967) assessed the economics of the shad fishery and culture; fishery landings, values, and trends were complied by various authors (see Fishery sections); McLean (1955), Moody (1961), Williams and Bruger (1972), and Williams *et al.* (1975) investigated shad and river herring life histories and the ecology of the St. Johns River (Table 1).

American shad are anadromous, and in the St. Johns River they spawn in the freshwater part of the river between Lake Monroe and Lake Poinsett (Williams and Bruger, 1972). Their progeny move downstream to the sea and eventually migrate to Canada. After four years, on average, they return to the St. Johns River to spawn. Each river from Florida to Canada presumably hosts a reproductively isolated population of American shad. Researchers often use specimens from the St. Johns River when examining intraspecific genetic, morphological, or life-history variations, because this Florida population is at the limit of the southern range of the species. Population studies that have examined the Florida population of American shad exclusively or in part include those of Walburg (1956, 1960a, b), Davis (1957), La Pointe (1957), Nichols (1959, 1964, 1965, 1966a, b), Leggett (1969), Leggett and Whitney (1972), Williams and Bruger (1972), Carscadden and Leggett (1975), Leggett and Carscadden (1978), Glebe and Leggett (1981a, b), Dadswell *et al.* (1987), Conover (1990), Nolan *et al.* (1991), Melvin *et al.* (1992), Bentzen *et al.* (1993), Hogans *et al.* (1993), Epifanio *et al.* (1995), and Brown *et al.* (1996, 1999).

Because American shad are anadromous, the population size in any specific river can vary independently from the sizes of populations in other rivers. A recent stock assessment of shad populations (ASMFC, 1998) documented declining abundance in 2 of 12 selected populations from Maine to Georgia (no Florida rivers were included in this assessment because of insufficient data). The American shad is frequently used in studies of fish recruitment dynamics (*e.g.,* Leggett, 1969; Crecco *et al.,* 1983; Crecco and Savoy, 1984; Savoy and Crecco, 1988; Limburg, 1995). Nonetheless, the causes of population declines remain debatable (see Adverse Factors section).

Table 1. *Life history data for* Alosa *species in Florida. Data for American shad come from Walburg (1960a), Williams and Bruger (1972), and Williams* et al. *(1975); data for hickory shad and blueback herring are from Williams* et al. *(1975); data for Alabama shad are from Laurence (1967) and Laurence and Yerger (1967); data for skipjack herring are from Wolfe (1969).*

	St. Johns River			Apalachicola River	
	American shad	Hickory shad	Blueback herring	Alabama shad	Skipjack herring
Adults					
Fecundity (1,000s)	277–659	168–591	151–349	46–149	76–962[a]
Fish size[b] (mm)	353–460	323–414	213–278	368–427	352–451
Riverine diet	Not feeding	Fish	Invertebrates	Not feeding	Fish
Spawning					
Months	Dec–Apr	Nov?–Feb	Dec–Apr	Feb–Apr	Dec–Apr
(Peak)	(Feb–Mar)	(?)	(Feb–Mar)	(Apr)	(Mar–Apr)
Areas (km)[c]	240–330	<300?	200–380	Below Woodruff Dam	Extensive
Length range[b]	317–480	303–416	204–262	330–431	240–482
Modal age	IV	III	V–VI	III	III
(Age range)	(III–VI)[d]	(II–IV)	(III–VIII)	(II–IV)[e]	(II–IV)[e]
Frequency	1	1?	5?	2?	1?
Juveniles					
Growth rate	0.23–0.32 mm d^{-1}	—[f]	—[f]	—[f]	—[f]
Diet	Invertebrates	—	—	Fish/ Invertebrates	Fish/ Invertebrates

[a] Length–fecundity relationship was not statistically significant.
[b] Studies in the St. Johns River measured fork length (FL), and studies in the Apalachicola River measured total length (TL).
[c] There is a 14% difference in river miles/kilometers reported in Williams and Bruger (1972) and Williams *et al*. (1975).
[d] Less than 1% of the fish in the spawning run were either ages II or ages VI+.
[e] 1%–2% of the fish in the spawning run were age I.
[f] Data in original report/thesis could probably be used to calculate growth rates.

American shad research has led to important insights regarding the evolutionary ecology of fishes. The seminal work of Leggett (1969; see also Leggett and Carscadden, 1978) established the adaptive significance of geographic variation in shad life history. Leggett noted that American shad arrive at each Atlantic coast river at different dates but at similar water temperatures (*i.e.*, southern populations arrive at rivers to spawn during winter months and northern populations arrive at spawning rivers during late spring months). These temperatures are optimal for the survival of eggs and larvae, but they occur at the various rivers during different times of the year because of latitudinal variation in seasonality. He also demonstrated the adverse effects of high temperatures on spawning adults and how fecundity (*i.e.*, egg number) and spawning frequency vary with latitude; in fact, American shad is a repeat spawner (iteroparous) in the north but a one-time spawner (semelparous) in the south. He concluded that because southern populations of American shad die after spawning once, these populations appear to be at a biological disadvantage when compared with the multiple-spawning northern populations of American shad. This total mortality in the south results from the shad's physiological limits being exceeded during the very long oceanic migrations and from the rapidly rising temperatures in southern rivers. The biology of southern shad populations, however, has evolved to compensate for this inability to spawn repeatedly. Despite being smaller and younger than individual shad in northern rivers, Florida's shad produce more eggs per unit of body weight. Consequently, the lifetime reproductive potential of individuals in both the northern and southern populations of American shad is roughly equal. This adaptive variation in size, age, egg number, spawning frequency, and migration energet-

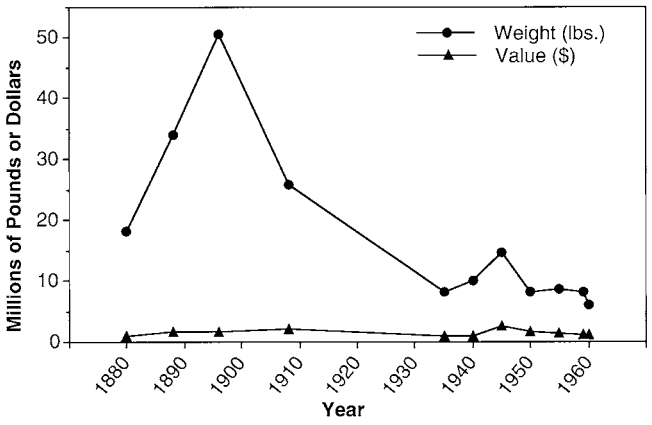

Figure 3. *Weight (circle) and value (triangle) of American shad landings, 1880–1960, for the United States Atlantic coast. Values are unadjusted for inflation (from Walburg and Nichols, 1967,Table 55).*

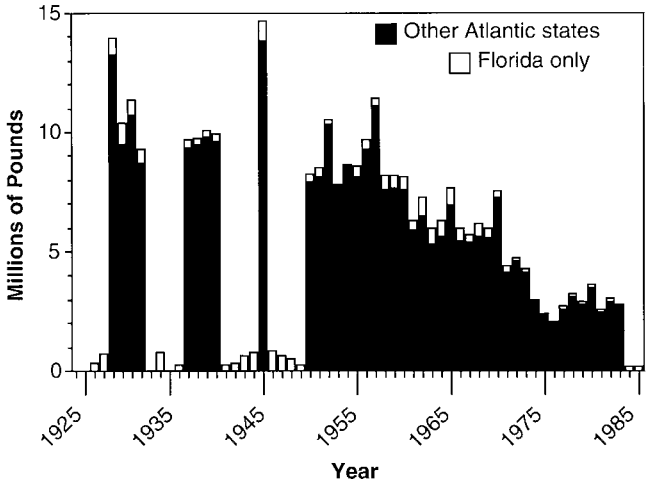

Figure 4. *Annual landings, 1926–1985, of American shad in Florida (open portion of bar) and all other Atlantic states (filled portion of bar). Complete data do not exist for all years before 1950. Data source: ASMFC (1985: Table II-2).*

ics across latitudes is strong evidence of life history evolution in a marine fish. Such fine tuning between reproductive strategies and the environment may be the ultimate cause for the evolution of homing behavior (Leggett and Carscadden, 1978).

Commercial Fishery

Today, American shad landings are of minor importance when compared to the U.S. landings of all other fishes (*e.g.,* U.S. Department of Commerce, 1993). Historically, however, the American shad fishery was one of the most important fisheries along the Atlantic seaboard (Smith, 1894; Walburg and Nichols, 1967), and shad were a very popular foodfish (Nichols, 1918). Native Americans fished for anadromous fishes, and fishing rights along alosid spawning runs were leased during the Colonial period (Loesch and Atran, 1994). At the turn of the nineteenth century, millions of pounds of shad—worth millions of dollars then—were landed (Figure 3; Leim, 1924; Lyles, 1967a–c; Walburg, 1960a, b; ASMFC, 1985). In 1896, approximately 25,000 fishers were engaged in shad fishing (Stevenson, 1898, 1899). In 1908, American shad ranked second by volume and third by value for all fisheries nationwide (Walburg and Nichols, 1967).

A gill-net fishery for American shad began in Florida's St. Johns River in the 1850s (Walburg, 1960a), but this was the last shad fishery to develop along the U.S. east coast (Goode and Shepard, 1874; McDonald, 1887; Stevenson, 1899; Walburg and Nichols, 1967). It was also relatively small compared to shad fisheries in other states (Figure 4; Collins, 1892; Smith, 1893, 1894, 1898; Stevenson, 1899; Leim, 1924). Still, in 1889 and 1890, Florida's shad landings (> 2 million lbs) and their value ($100,000) were higher than those of any other marine product harvested within the state (Smith, 1893). Brice (1898a) discussed the rapid expansion of Florida's fisheries as the railroad expanded along the east coast and reached Titusville, Florida, in 1885. Railroads provided the infrastructure for transporting American shad to northern markets and made Florida's fishery much more valuable. Florida's shad landings peaked at the turn of the century at about 1–3 million lbs and fluctuated between 200,000 and 900,000 lbs from the 1920s to the 1960s. Landings have declined further, from <200,000 lbs in the early 1970s to nearly zero by the late 1990s (Tables 2, 3; Walburg, 1960a, b; Lyles, 1967a; Walburg and Nichols, 1967; ASMFC, 1985).

Both Walburg (1960a, b) and Nichols (1964, 1965, 1966a) estimated the population biomass of Florida's American shad to range from 1 to 3 million pounds during the 1950s and 1960s, which is roughly equal to the peak yields of the fishery at the turn of the nineteenth century. During the 1950s, about 2%–8% of the American shad stock in the St. Johns River was harvested annually with commercial gill nets, another 7%–20% taken with commercial haul seines, and 3%–8% taken with hook and line by sport anglers (Walburg, 1960a, b; see also Walburg and Nichols [1967] and ASMFC [1985]); total fishing mortality then was about 15%–37%. Based on these values, either the virgin (or predevelopment) stocks were much larger than those during the 1950s were, or the mortality rates were astonishingly high at the turn of the nineteenth century, or both of these conditions existed.

Fishers at the turn of the nineteenth century in Florida caught shad primarily in drifting gill nets, sec-

Table 2. *Pounds of American shad landed in Florida, by gear type. Data from Walburg and Nichols (1967) and ASMFC (1985).*

	Gill Net			
Year	Drift	Anchor	Seine	Rod & Reel
1896	940,000	5,000	353,000	no data reported
1960	50,000	163,000	299,000	198,000
1965	239,000	202,000	316,000	no data reported
1970	27,000	65,000	127,000	no data reported
1976	5,000	23,000	0	no data reported

ondarily in haul seines, and thirdly in anchored or staked gill nets (Smith, 1898; Stevenson, 1899). These gears were common in nearly all other states, although pound nets, weirs, fyke nets, and bow nets were also used outside of Florida. In many areas of the St. Johns River gill nets were not used because the waters were too sluggish or the aquatic vegetation was too dense (Walburg and Nichols, 1967). Haul-seining was discontinued during the early 1970s in Florida's St. Johns River, but gill netting effort remained relatively constant from the 1950s to the 1970s (Williams and Bruger, 1972). Therefore, the decline in gill-net landings during the 1970s (Table 2) probably represents a real decline in population size. The declining trend in Florida's landings during the 1990s (Table 3), however, should be credited to the increase in fishing gear restrictions (see Markets and Regulations).

As has happened in many other states, Florida's shad fishing grounds shifted geographically in the last few decades, so that by the 1990s most of the shad harvested came from gill nets fished in coastal waters. Because American shad migrate between their natal river and Canada they are vulnerable to fishing in coastal waters beyond the state of origin. Ocean-intercept fishing offshore of other Atlantic states probably adds to the fishing pressure on Florida's populations. Ocean-intercept landings have more than doubled in the past two decades (ASMFC, 1999), which could indicate that this source of fishing mortality has increased recently. Unfortunately, the impacts of this developing

Table 3. *Annual commercial landings of* Alosa *in Florida. Landings are presumably all American shad, but reporting criteria did not require distinguishing between American and hickory shad. Data are restricted to reports from Nassau, Duval, and St. Johns counties (all coastal) and Putnam County (inland). A fishing year (July–June) is used because the spawning run begins as early as November and continues for several months. Data source: Florida Marine Fisheries Information System (Steve Brown, Florida Marine Research Institute, personal communication). Data for 1997–98 are preliminary.*

	Coastal County Landings			All Florida Landings		
Year	Pounds	Trips	Value ($)	Pounds	Trips	Value ($)
1986–87	142,026	248	12,454	155,430	313	13,620
1987–88	266,251	220	22,900	266,374	224	22,911
1988–89	164,839	254	16,484	165,112	263	16,511
1989–90	169,881	278	18,501	289,293	544	31,419
1990–91	58,810	278	8,527	71,592	322	10,084
1991–92	49,633	267	6,170	49,798	270	6,191
1992–93	24,503	133	5,574	24,503	133	5,574
1993–94	24,930	174	7,346	24,968	175	7,357
1994–95	26,791	150	5,853	26,886	152	5,881
1995–96	3,650	2	818	3,650	2	818
1996–97	54	2	12	54	2	12
1997–98	18	2	4	18	2	4

Table 4. *Catch and effort in the St. Johns River recreational shad fishery for six fishing seasons. Catch per unit effort (CPUE) is a stratified mean number of fish per angler hour. The same stratified, roving sampling design was used in all years of this survey. Sampling times were chosen randomly within predetermined periods (weekdays/weekends, morning/mid-day/afternoon). The survey was conducted in an area where shad fishing is concentrated, a 9.6-km stretch of river from the Lake Jessup boat ramp to Iron Bend.*

Year	Catch (n)	Effort (Angler-hours)	CPUE
1992–93	9,432	12,623	0.77
1993–94	4,907	9,143	0.55*
1994–95	5,270	8,357	0.65
1995–96	8,423	7,190	1.18
1996–97	No data	No data	No data
1997–98	2,367	5,610	0.46*
1998–99	5,434	4,764	1.19

*The winters of 1993–94 and 1997–98 were exceptionally rainy, with very high water levels in rivers, and may be anomalous. Data for 1998–99 are preliminary. Data sources: Holder and Cross (1996), Holder (1998), and Davis (1999).

fishery for various shad populations cannot be assessed because attempts to delineate the stock composition in these mixed-stock ocean fisheries have been inconclusive (Epifanio *et al.,* 1995; ASMFC, 1998; ASMFC, 1999; Brown *et al.,* 1999). Because of concerns that fishing mixed stocks of shad in the ocean could be adversely affecting small populations, whereas larger (and generally better monitored) populations could appear unaffected (ASMFC, 1985, 1998), ocean-intercept fishing will be phased out by 2005 (ASMFC, 1999). Although the exact effect of this fishery on Florida's shad population size is not known, a phase-out of ocean fishing by other states will improve Florida's ability to control fishing pressure on local anadromous populations.

Recreational Fishery

Seining for shad was considered sport at the turn of the nineteenth century, and anglers were fishing for shad in the St. Johns River as early as the 1880s (Pfeiffer, 1975). Nonetheless, Florida's shad sport fishery is generally recognized as originating in 1942 (Snyder, 1949; Nichols, 1959; Walburg, 1960a, b). The introduction of spinning tackle in the 1940s helped popularize shad sport fishing, principally because it was an effective way to fish with the light lures used to catch shad. Fly-fishing for shad has also become popular in recent years (Lindsay, 1999). Anglers fish for shad from public boat ramps and at a small number of fish camps on the St. Johns River between Lake Monroe and Lake Poinsett (Branyon, 1999). Traditional shad fishing spots in this area are found at Marina Isle, Mullet Lake Park, Lemon Bluff, Puzzle Lake, and Hatbill Park. The certified state record fish (a tie) for American shad (5.19 lbs.) were caught in Seminole and Volusia counties.

During the 1950s and 1960s, the shad sport fishery in the St. Johns River was estimated to be larger than the shad sport fisheries in any of the other Atlantic states (Nichols, 1959, 1966a; Walburg and Nichols, 1967). Other estimates of recreational landings have been reported by Nichols (1964, 1965), Walburg (1960a, b), Williams and Bruger (1972), Williams (1996), Holder and Cross (1996), Holder (1998), Davis (1999), and Cheek (undated). Estimates from the above reports are not easily compared to each other, however, except as noted below. During the 1990s, catch per unit effort (CPUE) for shad caught by recreational fishers in the St. Johns River ranged between 0.5 and 1.2 American shad per fishing hour (Table 4). Release rates of boated fish varied from 20 to 89% in any given year. In years of exceptional rainfall (*i.e.,* 1993–94 and 1997–98) the CPUEs were lower, most likely because when river water levels are extremely high, the fish scatter. One overall trend in the data is that the average CPUE for 1995–96 and 1998–99 was higher than that for 1992–93 and 1994–95 (1.2 versus 0.71 fish per angler hour). This increase in CPUE may be due to the implementation of Florida's 1995 constitutional amendment banning certain nets in state waters (see Markets and Regulations), which would be expected to improve the chances that adult fish reach the spawning grounds. Tentative plans are to continue to gather CPUE data during 1999–2004 and to add an electrofishing survey so that we can independently evaluate whether the recent increase in shad recreational CPUE is significant and sustained (McBride, 1999).

Stock Enhancement

Artificial fertilization of American shad eggs succeeded as early as 1848, and the federal government stocked U.S. streams with nearly 100 million shad fry during the 1870s alone (Baird, 1874a–e; Milner, 1874; Walburg and Nichols, 1967). There were several letters advocating the stocking of American shad in Florida's St. Johns and St. Marys rivers (Goode and Shepard, 1874; Osborn, 1882, 1883; Hamlen, 1884; Smiley, 1884; Cary, 1885; Dempsey, 1887; McDonald, 1887; Smith, 1893; Evermann and Bean, 1898; Henshall, 1898; Stevenson, 1899; Townsend, 1900), but there is no clear evidence that this was done (nor any evidence that it was necessary). American shad were stocked in Florida's Indian River (Evermann and Bean, 1898), but this system is probably too warm for shad, and stocking was not successful. Stearns (1885) and letters in Baird (1874g) advocated stocking gulf coast rivers, and stocking occurred in the Suwannee (Brice, 1898b), the Alabama (Baird, 1874f; McDonald, 1884c), and in the Mississippi (Baird, 1874c; Pfieffer, 1975) rivers. Efforts to stock fish in Gulf of Mexico rivers were considered to be unsuccessful by Hildebrand (1963) and Walburg and Nichols (1967). Elsewhere, unsuccessful stocking occurred in Colorado streams, the Great Lakes, and the Great Salt Lake, but a successful introduction of shad occurred in the Pacific along the U.S. west coast (Welander, 1941; Walburg and Nichols, 1967). The federal shad hatchery program declined in production after the turn of the nineteenth century and ended in 1950, although many states (but not Florida) have their own programs.

Other Alosids

Research Review

Hickory shad and blueback herring were first described by Mitchill (1814) and re-classified by Svetovidov (1964). Blueback herring and alewife, *A. pseudoharengus,* are collectively referred to as 'river herrings' because they occur together abundantly in northern rivers and are difficult to distinguish from each other. This is not a problem in Florida, because alewife does not occur here (Hildebrand, 1963). The prior research emphasis on American shad and the passage of the Anadromous Fish Act of 1965 (Public Law 89-304) led Williams *et al.* (1975) to focus their attention on hickory shad and blueback herring during their investigation of the ecology of American shad in the St. Johns River (Table 1). Detailed information on hickory shad and blueback herring in Florida appears to be limited to Williams *et al.*'s (1975) unpublished report and to McLean (1955) and Moody (1961).

The presence of 'white shad' along the gulf coast was first noted by Baird (1874f, g). Twenty years later, Evermann (1896) described the Alabama shad from specimens of white shad from an Alabama river and from Pensacola, Florida. Evermann stated:

"In view of the importance of this discovery, it is thought desirable to publish this preliminary description in advance of a more complete report upon the species."

The more "complete" report of this species was not done, however, for another 70 years. Laurence (1967) and Laurence and Yerger (1967) examined the ecology of Alabama shad in the Apalachicola River (Table 1), and Mills (1972) continued this research using funds made available under the Anadromous Fish Act (P.L. 89-304). Evermann (1898), Bailey *et al.* (1954), Hildebrand (1963), and Boschung (1992) also made noteworthy contributions to the knowledge of this species in several Florida rivers, and the consensus is that the largest population occurs in the Apalachicola River. Huntsman (1994) regards Alabama shad as being notably reduced in abundance and vulnerable to extinction.

Rafinesque's 1820 description of skipjack herring was so confounding that this species' taxonomic status was in doubt until the review of alosids by Hildebrand (1963) confirmed its validity. This species is distributed extensively in freshwater river systems of the midwestern U.S. (Lee *et al.,* 1980), and the type specimen (*i.e.,* the fish used to describe the species) was from the Ohio River. Distributional records reported by Hildebrand (1963), Wolfe (1969), Lee *et al.* (1980), and Boschung (1992) included several records in the Gulf of Mexico and in Florida estuaries. Still, the lone population study of this species (Wolfe, 1969; Table 1) presented only equivocal evidence that it is anadromous.

Fisheries

There has been no directed commercial fishery for hickory shad, but landings of this species have been included as unidentified bycatch in American shad landings. The amount of such bycatch is unknown and is difficult to estimate because it varies depending on both river location and season. For example, Williams *et al.* (1975) reported catching roughly 1 hickory shad for every 7 American shad during the 1971–72 sampling season (combined n = 880) but only about 1 hickory shad for every 99 American shad during the 1972–73 season (combined n = 1216). These very different between-year results may be partially explained by the fact that hickory shad enter rivers earlier than American shad (Moody, 1961), and Williams *et al.* started sampling three calendar weeks earlier in their first year than they did in their second year, when they found fewer hickory shad (Figure 5). Hickory shad also

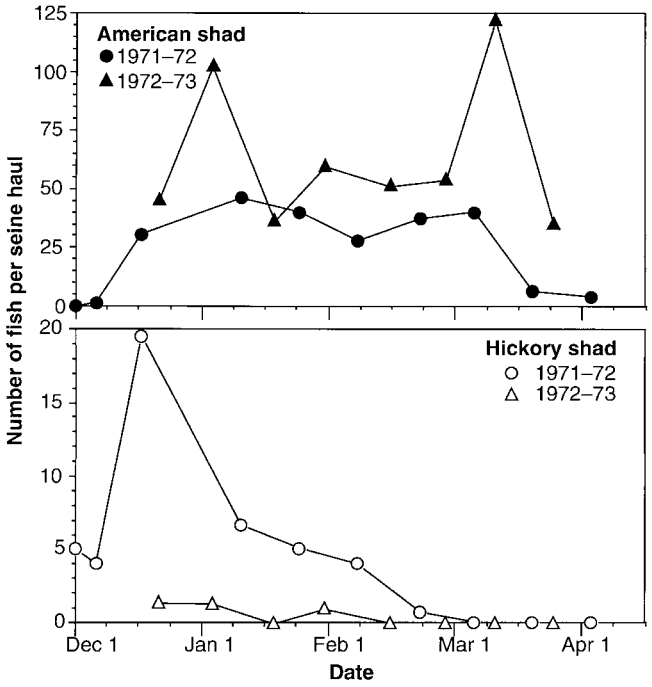

Figure 5. *Catch per unit effort of American shad (filled symbols) and hickory shad (open symbols) in a tidal portion of the St. Johns River, between Palatka and Welaka. Two sampling periods were covered: December 1971–April 1972 (circles) and December 1972 and March 1973 (triangles). Data are from Williams* et al. *(1975).*

do not migrate as far upstream as American shad do, and they appear to be more abundant (by frequency of occurrence and by weight) in deeper water than American shad are (Moody, 1961).

Historic reports of 'alewife' landings in Florida are a combination of blueback herring and hickory shad on Florida's east coast (McDonald, 1887) and menhaden (*Brevoortia* spp.) on Florida's west coast. These landings peaked at just over 1 million pounds in the first quarter of the twentieth century (Lyles, 1967a). Landings reported by the Atlantic States Marine Fisheries Commission (ASMFC, 1985) depict Florida's landings of river herrings as high and steady in the 1930s and 1940s, variable and lower in the 1950s, and declining to zero by the 1960s (remaining so during the 1970s and 1980s).

Hildebrand (1963) reported nominal landings of Alabama shad, but a commercial fishery for either this species or skipjack herring has never developed (Baird, 1874f, g; Evermann and Kendall, 1898; Mills, 1972). 'Shad' are often reported as landed in west coast counties, according to the State of Florida's Marine Fisheries Information System, but these fish, locally called shad, are actually menhaden (*Brevoortia* spp.).

Recreational fishing for *Alosa* species other than American shad is minor. There is no directed sport fishery for hickory shad, although some anglers may land them preferentially because they consider their roe to be better to eat than American shad's (Nichols, 1959). Still, hickory shad are relatively rare; a 1958 angler creel survey (Walburg, 1960a) reported that 1,553 (2.4%) hickory shad were present among the 65,246 shad caught in the St. Johns River. Our perception of hickory shad as a rare species is influenced at least partly by angler behavior, particularly to fish in late winter and in upstream portions of the St. Johns River. These conditions exaggerate the abundance of American shad compared to hickory shad, because hickory shad has an earlier spawning run and does not migrate as far up the river. Many anglers simply cannot distinguish between American and hickory shad (Walburg, 1960a), so detailed records of species composition of the catch are not available. Sport fishing for Alabama shad began around 1950 but has not developed significantly (Smith, 1968; Mills, 1972), and there is no sport fishery for blueback herring. Sport fishing for skipjack herring occurs during spring, and Yerger (1977) reported that this species is popular among fly-rod enthusiasts.

Markets and Regulations—All Alosids

Fillet quality varies from "delicious" for American shad, Alabama shad, and blueback herring, to "inferior in flavor" for hickory shad, to "not especially well flavored" for skipjack herring (Hildebrand, 1963). The roe of American shad, hickory shad, and Alabama shad is also eaten (Nichols, 1959; Smith, 1968). Walburg and Nichols (1967) concluded that American shad had declined in popularity relative to other fishes and recommended that improved methods of handling, particularly deboning, could increase the demand for shad.

Florida has a particular marketing advantage over other states because of the early spawning season for American shad there. Historically, this allowed Florida to be a main supplier during February and March, when prices were high (Figure 6; Henshall, 1898; Stevenson, 1899). Walburg and Nichols (1967) noted that American shad caught in the St. Johns River were usually shipped to New York City and other distant markets, whereas those caught in the St. Marys River were mainly sold at local or regional markets. Although, landings of hickory shad are not recorded separately from those of American shad, they probably do not contribute substantially to shad landings in Florida. In Florida, as in most other Atlantic states, landings of blueback herring are generally far less than those of shad. Blueback herring were a historically valuable

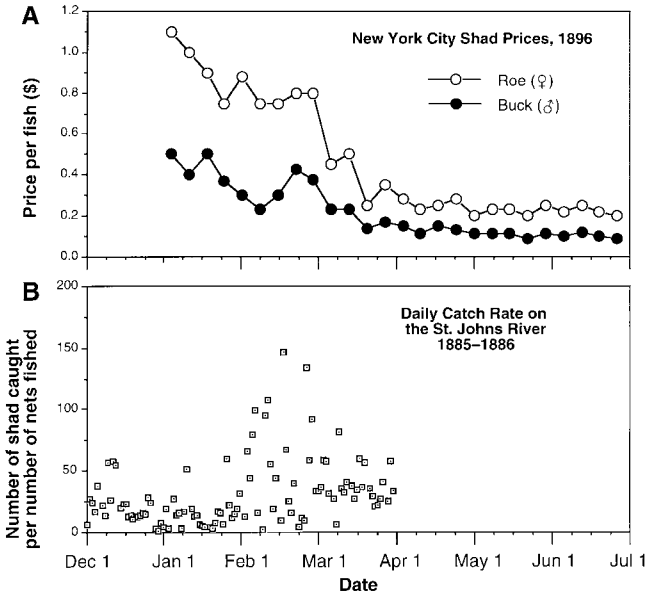

Figure 6. *(A) Prices of shad in New York City, by week and sex, during 1896 (from Stevenson, 1899), (B) Daily number of shad per net fished from 1 December 1885 to 31 March 1886 at New Berlin, Florida (from Dempsey, 1887).*

commercial fishery in Florida, when these fish were a salted and shipped to distant markets, but blueback herring declined in importance after the development of refrigeration (McDonald, 1884a; Hildebrand, 1963). In the 1970s, both blueback herring and hickory shad were used primarily as bait for the crab and catfish fisheries (McLean, 1955; Williams *et al.,* 1975). Markets for Alabama shad and skipjack herring never developed.

Commercial fishing regulations for Florida's American shad populations have existed since at least 1896, when (1) fishing was allowed only from sunrise on Monday to sundown on Saturday and from December 1 to March 31, (2) mesh sizes were restricted to > 5 inches for gill nets and to >3 inches for seines, and (3) using seines in the lake portions of the rivers was prohibited (Stevenson, 1899; Walburg and Nichols, 1967). Moreover, an act approved in 1893 prohibited netfishers (except those using cast nets) from taking commercial food-fish within one mile of any pass, inlet, or river mouth connecting with the Atlantic Ocean (Brice, 1898a).

Regulations for the St. Johns River in 1960 included (1) a restricted commercial season from November 15 to March 15 and (2) an area closed to commercial nets south of Lake George. The legal fishing season for the St. Marys River (which runs along the Florida-Georgia border) in 1960 was from December 15 to April 15, but there were no other restrictions for Florida's part of this river (Walburg, 1960a; Walburg and Nichols, 1967).

A series of regulations in the 1990s caused sharp reductions in Florida's commercial landings of shad. Landings for upstream gill-net fishing were severely reduced after January 1, 1992, by a regulation to increase mesh size (≥ 6 inches stretched mesh) to assist in the management of striped bass *(Morone saxatilis)* populations (Williams, 1996). The ocean shad fishery was restricted by net-tending and net soak-time regulations that gradually took effect from March 1992 to May 1994 (Williams, 1996). Furthermore, fishing with nets in coastal waters is now severely restricted by a 'net ban' amendment to Florida's Constitution (Art. X, Sec. 16) that took effect in July 1995. This amendment prohibits the use of entangling nets >500 ft^2, which were commonly used for shad fishing, within three miles of the Atlantic coast. Consequently, although sale of alosids is not prohibited, the commercial net fishery for shad and blueback herring has been effectively eliminated within state waters.

Sport fishing for American shad has been regulated by bag limits since 1955, and the initial bag limit of 15 fish per day was lowered to 10 fish in 1973 (Williams, 1996). Since January 1, 1990, a saltwater fishing license has been required of most anglers who fish for marine species, and this also applies to anglers who fish for anadromous species such as shad and river herrings. Since January 1, 1997 (Chapter 68B-52.001 of the Florida Administrative Code), hook and line has been the only allowable fishing gear for alosids and it has been unlawful to possess more than 10 fish (as an aggregate of American shad, Alabama shad, and hickory shad).

Management of all U.S. east-coast shad and river herring populations is overseen by the Atlantic States Marine Fisheries Commission (ASMFC) through a Fishery Management Plan (FMP) subscribed to by the individual Atlantic-coast states. Maximum exploitation rates for Florida's Atlantic populations of alosids was set at 25% in 1985 by the ASMFC (ASMFC, 1985). Amendment 1 to the ASMFC's 'Shad and River Herring FMP' calls for (1) a 5-year phase out of the ocean-intercept fishery, (2) regulating the in-river fishery at target exploitation rates (*e.g.,* F_{30}), and (3) implementing bag limits of 10 fish per day in the recreational fishery (ASMFC, 1999). American shad abundance had been closely monitored in some states but not in others, such as Florida (ASMFC, 1998), so Amendment 1 also establishes monitoring programs for all states; it requires Florida to monitor commercial and recreational shad fisheries and to complete fishery-independent surveys of American shad (McBride, 1999).

Adverse Factors—All Alosids

Declines in shad and river herring populations were evident in many Atlantic rivers as early as the nine-

teenth century (Baird, 1874e; Walburg and Nichols, 1967; Loesch and Atran, 1994). Many different factors have been cited as causing population declines of alosids during the past two centuries. Rulifson *et al.* (1982) listed a number of anthropogenic factors that could adversely affect anadromous fish populations in Florida rivers, none of which are unique to Florida, and Williams and Bruger (1972) discussed several of these factors—fishing pressure increases, river-flow alterations, water quality declines, and human population growth in the St. Johns watershed—in more detail. Not all variations in shad production are the result of anthropogenic causes, however. Leggett (1969) related year-class strength and post-spawning mortality to variations in temperature in a Connecticut river, and Summers and Rose (1987) found that spawning stock size, river flow rate, and temperature were important predictors of future American shad population sizes. The major factors affecting or that have the potential of affecting Florida's populations of shad and river herring are discussed below.

Dam building, which precluded fish movement between freshwater spawning grounds and marine feeding grounds, was one of the earliest known causes of alosid population declines. This was a particular problem in the northeastern states, where industrial power was developed with water resources as early as Colonial times, and there are numerous cases in which entire runs of shad were eliminated by damming (Stilwell *et al.,* 1874; Stevenson, 1898; Loesch and Atran, 1994). Fishways built prior to 1930 were largely unsuccessful in allowing fish to pass around dams, but fishway designs have improved since for both allowing adult fish to move upstream (Walburg and Nichols, 1967; Quinn, 1994) and for reducing the mortality rates of young-of-the-year fish moving downstream (Martin *et al.,* 1994). In Florida, there are a few structures that adversely affect shad populations. A dam built on the Ocklawaha River, a branch of the St. Johns River, has been under consideration for removal for several years (Joseph, 1998; Klinkenberg and Hauserman, 1998). Removing this dam would be a first step towards restoring a shad run to this area, but it will have little effect unless shad spawning habitat is restored. The Lake Washington Weir cuts off areas of the upper St. Johns River that were historic spawning grounds for shad, but it is not considered a significant impediment to shad spawning success because it occurs upstream of what is now the major spawning area for shad. To protect farming communities from floods, alterations along the St. Johns River were made beginning at the turn of the nineteenth century and continued to be made during the 1940s and 1950s. These flood-control activities had severe effects on sedimentation dynamics, water quality, and habitat availability (Bass and Cox, 1985; Walther, 1989; Cox, 1997). Two proposed water-control structures, at Lakes Harney and Poinsett along the St. Johns River, were proposed as recently as the 1970s, but they were not built because of environmental concerns (Williams and Bruger, 1972). The spawning migration of Alabama shad is limited in the Apalachicola River by the Woodruff Dam and in the Chipola River by the Dead Lakes Dam. Suitable spawning habitat occurs below these dams, and there is no historical evidence that the fish migrated farther upstream (although they probably did; Laurence, 1967). Obstructions within Florida rivers probably reduce total shad production to some degree, and improved designs to existing structures may improve shad population size.

Pollution is also cited frequently as being detrimental to shad production. As was true for damming, the effects from declining water quality were evident even before the turn of the nineteenth century, again mainly in the industrialized northern states (Walburg and Nichols, 1967). In the Delaware River during summer, for example, extremely low levels of dissolved oxygen caused by municipal and industrial pollutions may kill both adult and juvenile shad during migrations in some years (Sykes and Lehman, 1957). Ironically, sewage loads have existed for so long (*i.e.,* since prior to 1929) in the Delaware River, as well as in the Hudson River, that they were not identified as significantly affecting shad populations in time-series analyses of shad populations and habitat quality during the years 1929–1976 (Summers and Rose 1987). Significant factors for predicting shad population sizes in the Summers and Rose study were spawning stock size, water flow, and water temperature, the last two of which are related indirectly to water quality. More recently, Weisberg *et al.* (1996) documented the increasing distribution and abundance of American shad in the Delaware River concurrent with improvements in water quality during the period 1980–1993.

In Florida's St. Johns River, approximately 35 million gallons of treated sewage enter the river daily between Lake Harney and Lake Monroe (Bass and Cox, 1985), an area that overlaps American shad spawning grounds. Here, the combination of severely altered river flow and the increased nutrient loadings from sewage has degraded water quality and sometimes caused fish kills. However, since the 1970s, this situation has been mitigated somewhat by restoration of the floodplain marsh habitats and by installation of more advanced sewage treatment systems (Bass and Cox, 1985; Miller, 1997). Dredging can also affect water quality, and there is increasing concern about the effects of dredging on fish and wildlife communities in the Apalachicola River (Bass and Cox, 1985; Hauserman,

1999). Williams *et al.* (1975: 109) identified the following in their discussion of water quality in the St. Johns River and alosid populations:

"The large elevation gradient between Lake Harney and Lake Poinsett is an important geological characteristic that ensures a current in the upper river and ensures that American shad have a suitable spawning area, even during low water conditions. The importance of this area as a spawning ground for American shad should be given high consideration by agencies, organizations, or individuals that seek to build flood control or water conservation structures that would in any way impair or prevent shad migration into this area, or that would lower the quality of water in this area, or that would alter its physical characteristics such as adequate current and clean sand bottom."

Power plants that require cooling water may adversely affect alosids. *Alosa* larvae or juveniles may become trapped on the intake screens and die (Fletcher, 1985; Horwitz, 1987) or they may be killed by the elevated temperatures associated with power plant cooling systems (Schubel *et al.,* 1977). At present, power plant cooling systems do not appear to be located in areas that affect Florida alosids (*e.g.,* Grimes, 1975).

The adverse effects of fishing pressure on shad populations have been demonstrated by increases in population sizes that occurred after fishing effort was reduced in some northern rivers (Walburg and Nichols, 1967). Relatively high levels of fishing mortality of American shad occurred in the St. Johns River during the 1950s (Walburg, 1960a, b), but Nichols (1959: 39) concluded that"sport and commercial fisheries [in the St. Johns River] are not of a great enough magnitude, at least at the present time, to adversely affect the [shad] population." Later, Nichols (1964: 13) even postulated that the 1962 shad"production increase of 30 percent over the previous season, probably resulted from the large spawning escapement of more than 2 million pounds in 1957–58."Nonetheless, in a summary of these studies by the U.S. Fish and Wildlife Service, Walburg (1960a: p. 499) concluded that"factors that affect size of the run are unknown."The size of the St. Johns River population appeared to decline shortly after the early 1960s, and Williams and Bruger (1972) raised concerns about the effects fishing pressure was having on American shad in the St. Johns River. They noted that American shad sex ratios deviated from 1:1, which they associated with high levels of gillnetting effort and concurrent declines in haul-seining effort. They reasoned that because female shad are larger than male shad, and because shad egg production is related to body size, then this shift in fishing gears disproportionally reduces the numbers of the largest females reaching the spawning grounds and subsequently it could substantially reduce shad egg production.

Analyses of fishing effects on shad have repeatedly focused on the overlap of shad fishing grounds versus shad spawning grounds. Early on, Stevenson (1898, 1899) noted geographic shifts in shad fishing effort so that by 1896 approximately 45% of U.S. shad landings were harvested from estuarine waters, whereas 50 years earlier all fishing was near river headwaters. Stevenson concluded that because nearly half the fish caught were landed before they reached the spawning grounds, this change in fishing areas had an adverse effect on the population sizes of American shad. Over the past two decades, the expansion of shad fishing in coastal waters has renewed concern about the adverse effects of fishing away from the spawning grounds (ASMFC, 1999), and now it is not just because the fish are harvested before they reach the spawning grounds. Coastal fishing is referred to as ocean-intercept, because such fishing (north of Florida) harvests a mixture of alosid stocks. The actual composition of this mixed-stock, ocean-intercept fishery varies with location and season, but it is largely undocumented and it appears to be impractical to monitor routinely (see Melvin *et al.,* 1992; Epifanio *et al.,* 1995; Thorrold *et al.,* 1998; Brown *et al.,* 1999). Complicating this matter, intensive fishing of river herring stocks by foreign fleets occurred in the Fisheries Conservation Zone (3–200 miles offshore) during the 1970s (Richkus, 1988), and alosids may still be significant but undocumented bycatch in ocean fisheries such as that for Atlantic herring (Field *et al.,* 1996). Until these fisheries outside Florida's waters are managed, Florida has only a limited ability to control the total fishing mortality experienced by its populations.

Summary

American shad were historically valuable to Florida and other Atlantic states, but population sizes have declined dramatically during the twentieth century. Information about other alosids in Florida is scant, and nothing is known about *Alosa* populations in Florida rivers other than the St. Johns and Apalachicola except for presence or absence. No current information about Florida's St. Johns River population of American shad was included in the ASMFC's recent stock assessment (ASMFC, 1998) because insufficient information was available, but new monitoring requirements should lead to a better determination of the status and trends of this population (ASMFC, 1999). American shad in the St. Johns River are familiar to both resident and tourist anglers, and the fishing pressure on Florida's alosid populations is probably lower today than it has been

for the past several decades. This could lead to a stable or a rebuilding population in the future.

Literature Cited

ASMFC (ATLANTIC STATES MARINE FISHERIES COMMISSION). 1985. Fishery Management Plan for American Shad and River Herring. Fisheries Management Report No. 6. Atlantic States Marine Fisheries Commission, Washington, D.C.

ASMFC (ATLANTIC STATES MARINE FISHERIES COMMISSION). 1998. American Shad Stock Assessment Peer Review Report. March 1998. Atlantic States Marine Fisheries Commission, Washington, D.C. 217 pp.

ASMFC (ATLANTIC STATES MARINE FISHERIES COMMISSION). 1999. Amendment 1 to the Interstate Fishery Management Plan for Shad and River Herring. Fishery Management Report No. 35 of the Atlantic States Marine Fisheries Commission, Washington, D.C. 76 pp.

BAILEY, R. M., H. E. WINN, and C. L. SMITH. 1954. Fishes from the Escambia River, Alabama and Florida, with ecologic and taxonomic notes. Proceedings of the Academy of Natural Sciences at Philadelphia 106: 109–164.

BAIRD, S. F. 1874a. Propagation of shad in 1873. Report of the Commissioner for 1872 and 1873, U.S. Commission of Fish and Fisheries, Part 2: xxvi–xxx.

BAIRD, S. F. 1874b. Fishes especially worthy of multiplication. I. The shad. Report of the Commissioner for 1872 and 1873, U.S. Commission of Fish and Fisheries, Part 2: xlviii–lix.

BAIRD, S. F. 1874c. Statistical tables of propagation. Distribution of young shad to the waters of the United States. Report of the Commissioner for 1872 and 1873, U.S. Commission of Fish and Fisheries, Part 2: lxxxviii–xci.

BAIRD, S. F. 1874d. Statistical tables of propagation. Shad-hatching operation in the United States. Report of the Commissioner for 1872 and 1873, U.S. Commission of Fish and Fisheries, Part 2: xcii.

BAIRD, S. F. 1874e. The shad and alewife (species of Clupeidae). Report of the Commissioner for 1872 and 1873, U.S. Commission of Fish and Fisheries, Part 2 (Appendix C): 387–462.

BAIRD, S. F. 1874f. Letters referring to experiments of W. C. Daniell, M.D., in introducing shad to the Alabama River. Report of the Commissioner for 1872 and 1873, U.S. Commission of Fish and Fisheries, Part 2 (Appendix C): 387–390.

BAIRD, S. F. 1874g. Letters referring to the presence of shad in rivers tributary to the Gulf of Mexico. Report of the Commissioner for 1872 and 1873, U.S. Commission of Fish and Fisheries, Part 2 (Appendix C): 391–395.

BASS, D. G., and D. T. COX. 1985. River habitat and fishery resources of Florida. Pp. 121–187 *in* W. Seaman, Jr., ed. Florida Aquatic Habitat and Fishery Resources. American Fisheries Society, Florida Chapter, Kissimmee, Florida.

BENTZEN, P., W. C. LEGGETT, and G. G. BROWN. 1993. Genetic relationships among the shads *(Alosa)* revealed by mitochondrial DNA analysis. Journal of Fish Biology 43: 909–917.

BERRY, F. 1964. Review and emendation of: Family Clupeidae. Copeia 1964(4): 720–730.

BOSCHUNG, H. T. 1992. Catalogue of freshwater and marine fishes of Alabama. Bulletin of the Alabama Museum of Natural History No. 14.

BRANYON, M. 1999. A cruise down shad alley. Florida Sportsman 31(1): 186–193.

BRICE, J. J. 1898a. The fisheries of Indian River, Florida. Report of the Commissioner for the year ending June 30, 1896, U.S. Commission of Fish and Fisheries, Part 22: 223–227.

BRICE, J. J. 1898b. The fish and fisheries of the coastal waters of Florida. Report of the Commissioner for the year ending June 30, 1896, U.S. Commission of Fish and Fisheries, Part 22: 263–342.

BROWN, B. L., J. M. EPIFANIO, P. E. SMOUSE, and C. J. KOBAK. 1996. Temporal stability of mtDNA haplotype frequencies in American shad stocks: to pool or not to pool across years? Canadian Journal of Fisheries and Aquatic Sciences 53: 2274–2283.

BROWN, B. L., P. E. SMOUSE, J. M. EPIFANIO, and C. J. KOBAK. 1999. Mitochondrial DNA mixed-stock analysis of American shad: coastal harvests are dynamic and variable. Transactions of the American Fisheries Society 128: 977–994.

CARSCADDEN, J. E., AND W. C. LEGGETT. 1975. Meristic difference in spawning populations of American shad *Alosa sapidissima:* evidence for homing to tributaries in the St. John River, New Brunswick. Journal of the Fisheries Research Board of Canada 32: 653–660.

CARY, H. H. 1885. The Saint John's River as a shad stream. Bulletin of the U.S. Fish Commission 5 (for 1885): 422.

CHEEK, R. P. Undated. Biological studies to determine the possible effect of the proposed upper St. Johns River flood control project on the American shad fishery, 1963. Progress Report of the Bureau of Commercial Fisheries Biological Laboratory, Beaufort, North Carolina.

COLLINS, J. W. 1892. Statistical review of the coast fisheries of the United States. Report of the Commissioner, U.S. Commission of Fish and Fisheries, Part 16 (for 1888): 271–378.

CONOVER, D. O. 1990. The relation between capacity for growth and length of growing season: evidence for the implications of counter gradient variation. Transactions of the American Fisheries Society 119 (3): 416–430.

COX, D. T. 1997. Pressures leading to restoration of the upper St. Johns River. P. 20 *in* Florida Aquatic Ecosystem Restoration: Is It Possible? Symposium. Program Abstracts for the 17th Annual Meeting Florida Chapters of the American Fisheries Society. Withlacoochee Training Center. Brooksville, Florida. February 25–27, 1997.

CRECCO, V. A., and T. F. SAVOY. 1984. Effects of fluctuations in hydrographic conditions on year-class strength of American shad *(Alosa sapidissima)* in the Connecticut River. Canadian Journal of Fisheries and Aquatic Sciences 41: 1216–1223.

CRECCO, V., T. SAVOY, and L. GUNN. 1983. Daily mortality rates of larval and juvenile American shad *(Alosa sapidissima)* in the Connecticut River with changes in year-class strength. Canadian Journal of Fisheries and Aquatic Sciences 40: 1719–1728.

DADSWELL, M. J., G. D. MELVIN, P. J. WILLIAMS, and D. D. THEMELIS. 1987. Influence of origin, life history and chance on the Atlantic coast migration of American shad. American Fisheries Society Special Symposium Series 1: 313–330.

DAVIS, R. 1999. American Shad *(Alosa sapidissima)* Angler Creel Survey St. Johns River. Report of the Florida Department of Environmental Protection, Florida Marine Research Institute. St. Petersburg, Florida.

DAVIS, W. S. 1957. Ova production of American shad in Atlantic coast rivers. U.S. Fish and Wildlife Research Report 49: 1–5.

DEMPSEY, W. 1887. Shad in the Saint John's River, Florida. Bulletin of the U.S. Fish Commission 6 (for 1886): 96.

EPIFANIO, J. M., P. E. SMOUSE, C. J. KOBAK, and B. L. BROWN. 1995. Mitochondrial DNA divergence among populations of American shad *(Alosa sapidissima)*: how much variation is enough for mixed-stock analysis? Canadian Journal of Fisheries and Aquatic Sciences 52: 1688–1702.

EVERMANN, B. W. 1896. Description of a new species of shad, *Alosa alabamae,* from Alabama. Report of the Commissioner for the year ending June 30, 1895, U.S. Commission of Fish and Fisheries, Part 21: 203–205.

EVERMANN, B. W. 1898. The fish fauna of Florida. Bulletin of the U.S. Fish Commission 17 (for 1897): 201–208

EVERMANN, B. W., and B. A. BEAN. 1898. Indian River and its fishes. Report of the Commissioner for the year ending June 30, 1896, U.S. Commission of Fish and Fisheries, Part 22: 227–248.

EVERMANN, B. W., and W. C. KENDALL. 1898. Descriptions of new or little-known genera and species of fishes from the United States. Bulletin of the U.S. Fish Commission 17 (for 1897): 125-133.

FIELD, J., L. FLAGG, V. CRECCO, H. JOHNSON, D. ST. PIERRE, and H. MEARS. 1996. 1995 Review of the Atlantic States Marine Fisheries Commission Fishery Management Plan for American Shad and River Herring (*Alosa* sp.). Pp. 7–16 *in* 1995 Annual Review of Interstate Fishery Management Plans. Special Report No. 60 of the Atlantic States Marine Fisheries Commission.

FLETCHER, R. I. 1985. Risk analysis for fish diversion experiments: Pumped intake systems. Transactions of the American Fisheries Society 114: 652–694.

GLEBE, B. D., and W. C. LEGGETT. 1981a. Temporal, intra-population differences in energy allocation and use by American shad *(Alosa sapidissima)* during the

spawning migration. Canadian Journal of Fisheries and Aquatic Sciences 38: 795–805.

GLEBE, B. D., and W. C. LEGGETT. 1981b. Latitudinal differences in energy allocation and use during the freshwater migrations of American shad *(Alosa sapidissima)* and their life history consequences. Canadian Journal of Fisheries and Aquatic Sciences 38: 806–820.

GOODE, G. B. and J. SHEPARD. 1874. Letters to S. F. Baird. Report of the Commissioner for 1872 and 1873, U.S. Commission of Fish and Fisheries, Part 2: xlviii–l.

GRIMES, C. B. 1975. Entrapment of fishes on intake water screens at a steam electric generating station. Chesapeake Science. 16(3): 172–177.

HAMLEN, W. 1884. Reconnaissance of Florida rivers with a view to shad hatching. Bulletin of the U.S. Fish Commission 4 (for 1884): 206–208

HAUSERMAN, J. 1999. Officials question river's dredging during visit. St. Petersburg Times, September 8, 1999: 5B.

HENSHALL, J. A. 1898. A plea for the development and protection of Florida fish and fisheries. Bulletin of the U.S. Fish Commission 17 (for 1897): 253–255.

HILDEBRAND, S. F. 1963. Family Clupeidae. Pp. 257–454 *in* Fishes of the Western North Atlantic. Sears Foundation for Marine Research, New Haven, Connecticut. Memoir I, Part 3.

HOGANS, W. E., M. J. DADSWELL, L. S. UHAZY, and R. G. APPY. 1993. Parasites of American shad, *Alosa sapidissima* (Osteichthyes: Clupeidae), from rivers of the North American Atlantic coast and the Bay of Fundy, Canada. Canadian Journal of Zoology 71: 941–946.

HOLDER, J. 1998. The 1997–1998 American Shad Angler Creel Survey of the Lower St. Johns River. Report to the Florida Department of Environmental Protection, Florida Marine Research Institute. St. Petersburg, Florida.

HOLDER, J., and F. CROSS. 1996. The 1995–1996 American Shad Angler Creel Survey of the Lower St. Johns River. Report to the Florida Department of Environmental Protection, Florida Marine Research Institute. St. Petersburg, Florida.

HORWITZ, R. J. 1987. Impingement studies. Pp. 254–269 in K. L. Heck, Jr., ed., Ecological Studies in the Middle Reach of Chesapeake Bay. Springer-Verlag, Berlin.

HUNTSMAN, G. R. 1994. Endangered marine finfish: neglected resources or beasts of fiction? Fisheries 19(7): 8–15.

JOSEPH, P. 1998. The battle of the dams. Smithsonian 29(8): 48–61.

KLINKENBERG, J., and J. HAUSERMAN. 1998. Letting a river run free. St. Petersburg Times, April 12, 1998: F1, F3.

La POINTE, D. F. 1957. Age and growth of the American shad, from three Atlantic coast rivers. Transactions of the American Fisheries Society 87: 139–150.

LAURENCE, G. C. 1967. Life history studies of the Alabama shad, *Alosa alabamae,* in the Apalachicola River, Florida. M.S. thesis. Florida State University, Tallahassee. 58 pp.

LAURENCE, G. C., and R. W. YERGER. 1967. Life history studies of the Alabama shad, *Alosa alabamae,* in the Apalachicola River, Florida. Pp. 260–273 *in* Proceedings of the 20th Annual Conference, Southeastern Association of Game and Fish Commissioners.

LEE, D. S., C. R. GILBERT, C. H. HOCUTT, R. E. JENKINS, D. E. McALLISTER, and J. R. STAUFFER, JR. 1980. Atlas of North American Freshwater Fishes. North Carolina Biological Survey, Publication No. 1980-12: 61–68.

LEGGETT, W. C. G. 1969. Studies on the reproductive biology of the American shad (*Alosa sapidissima*, Wilson). A comparison of populations from four rivers of the Atlantic seaboard. Ph.D. dissertation. McGill University, Montreal. 124 pp.

LEGGETT, W. C., and J. E. CARSCADDEN. 1978. Latitudinal variation in reproductive characteristics of American shad *(Alosa sapidissima)*: Evidence for population specific life history strategies in fish. Journal of the Fisheries Research Board of Canada 35: 1469–1478.

LEGGETT, W. C., and R. R. WHITNEY. 1972. Water temperature and the migrations of American shad. Fishery Bulletin, U.S. 70 (3): 659–670.

LEIM, A. H. 1924. The life history of the shad, *Alosa sapidissima* (Wilson), with special reference to factors limiting its abundance. Contributions in Canadian Biology 2(11): 163–284.

LIMBURG, K. E. 1995. Otolith strontium traces envi-

ronmental history of subyearling American shad *Alosa sapidissima*. Marine Ecology Progress Series 119: 25–35.

LINDSAY, B. 1999. Florida shad flies. Florida Sportsman 31(1): 100, 101.

LOESCH, J. G., and S. M. ATRAN. 1994. History of *Alosa* fisheries management: Virginia, a case study. Pp. 1–6 *in* J. E. Cooper, R. T. Eades, R. J. Klauda, and J. G. Loesch, eds. Anadromous *Alosa* Symposium. Tidewater Chapter, American Fisheries Society. Bethesda, Maryland.

LYLES, C. H. 1967a. Historical catch statistics (South Atlantic States). U.S. Department of the Interior, Washington, D.C. C.F.S. No. 4148.

LYLES, C. H. 1967b. Historical catch statistics (Chesapeake States). U.S. Department of the Interior, Washington, D.C. C.F.S. No. 4147.

LYLES, C. H. 1967c. Historical catch statistics (Middle Atlantic States). U.S. Department of the Interior, Washington, D.C. C.F.S. No. 4146.

MARTIN, P., N. TAFT, and C. SULLIVAN. 1994. Reducing entrainment of juvenile American shad using a strobe light diversion system. Pp. 57–63 *in* J. E. Cooper, R. T. Eades, R. J. Klauda, and J. G. Loesch, eds. Anadromous *Alosa* Symposium. Tidewater Chapter, American Fisheries Society, Bethesda, Maryland.

McBRIDE, R. 1999. Florida's plan for state fishing/recovery of American shad. Submitted to the Atlantic States Marine Fisheries Commission's Shad and River Herring Technical Committee.

McDONALD, M. 1884a. The shad and the alewives. The river herrings, or alewives—*Clupea aestivalis* and *C. vernalis*. Pp. 570–588 *in* G. B. Goode, ed. The Fisheries and Fishery Industries of the United States. Section I. Natural History of Useful Aquatic Animals. Government Printing Office, Washington, D.C.

McDONALD, M. 1884b. The inland alewife or skipjack (*Clupea chrysochloris*). P. 594 *in* G. B. Goode, ed. The Fisheries and Fishery Industries of the United States. Section I. Natural History of Useful Aquatic Animals. Government Printing Office, Washington, D.C.

McDONALD, M. 1884c. The shad and the alewives. The shad—*Clupea sapidissima*. Pp. 594–607 *in* G. B. Goode, ed. The Fisheries and Fishery Industries of the United States. Section I. Natural History of Useful Aquatic Animals. Government Printing Office, Washington, D.C.

McDONALD, M. 1884d. The hickory shad or Mattowacca *(Clupea mediocris)*. Pp. 607–609 *in* G. B. Goode, ed. The Fisheries and Fishery Industries of the United States. Section I. Natural History of Useful Aquatic Animals. Government Printing Office, Washington, D.C.

McDONALD, M. 1887. The rivers of eastern Florida, Georgia, and South Carolina. Pp. 613–625 *in* G. B. Goode, ed. The Fisheries and Fishing Industries of the United States. Vol. I, Section V, Part XII, No. 1. Government Printing Office, Washington, D.C.

McLEAN, W. M. 1955. The fishes of the St. Johns River system. Ph.D. dissertation. University of Florida, Gainesville. 362 pp.

MELVIN, G. D., M. J. DADSWELL, and J. A. McKENZIE. 1992. Usefulness of meristic and morphometric characters in discriminating populations of American shad *(Alosa sapidissima*) (Ostreichthyes: Clupeidae) inhabiting a marine environment. Canadian Journal of Fisheries and Aquatic Sciences 49(2): 266–280.

MILLER, S. J. 1997. The upper St. Johns River Basin Project: Merging flood control with aquatic ecosystem restoration and preservation. Pp. 20, 21 *in* Florida Aquatic Ecosystem Restoration: Is It Possible? Symposium. Program Abstracts for the 17th Annual Meeting Florida Chapters of the American Fisheries Society, February 25–27, 1997. Withlacoochee Training Center. Brooksville, Florida.

MILLS, J. G., Jr. 1972. Biology of the Alabama shad in northwest Florida. Florida State Board of Conservation, Marine Laboratory Technical Series 68: 1–24.

MILNER, J. W. 1874. The progress of fish-culture in the United States. Report of the Commissioner for 1872 and 1873, U.S. Commission of Fish and Fisheries, Part 2: 523–558.

MITCHILL, S. L. 1814. Fishes of New York. (Not seen, cited from Hildebrand, 1963.)

MOODY, H. L. 1961. Exploited fish populations of the St. Johns River, Florida. Quarterly Journal of the Florida Academy of Sciences 24(1): 1–18.

NICHOLS, J. T. 1918. Favorite food fishes. American Museum Journal 18(1): 66–69.

NICHOLS, P. R. 1959. St. Johns shad fever. Florida Wildlife 12(9): 22–39.

NICHOLS, P. R. 1964. Shad program. Pp. 12, 13 *in* Annual Report of the Bureau of Commercial Fisheries Biological Laboratory, Beaufort, N.C. for the Fiscal Year Ending June 30, 1963. U.S. Fish and Wildlife Service Circular 184.

NICHOLS, P. R. 1965. Shad program. P. 16 *in* Annual Report of the Bureau of Commercial Fisheries Biological Laboratory, Beaufort, N.C. for the Fiscal Year Ending June 30, 1964. U.S. Fish and Wildlife Service Circular 215.

NICHOLS, P. R. 1966a. Shad program. Pp. 27-38 *in* Annual Report of the Bureau of Commercial Fisheries Biological Laboratory, Beaufort, N.C. for the Fiscal Year Ending June 30, 1965. U.S. Fish and Wildlife Service Circular 240.

NICHOLS, P. R. 1966b. Comparative study of juvenile American shad populations by fin ray and scute counts. U.S. Fish and Wildlife Service Special Scientific Report—Fisheries No. 525. 10 pp.

NOLAN, K., J. GROSSFIELD, and I. WIRGIN. 1991. Discrimination among Atlantic coast populations of American shad *(Alosa sapidissima)* using mitochondrial DNA. Canadian Journal of Fisheries and Aquatic Sciences 48: 1724–1734.

OSBORN, J. H. 1882. Notes and suggestions concerning the Florida shad fishery. Bulletin of the U.S. Fish Commission 1 (for 1881): 351.

OSBORN, J. H. 1883. Shad fishing on the Saint John's River. Bulletin of the U.S. Fish Commission 2 (for 1882): 132.

PFEIFFER, C. B. 1975. Shad fishing. Crown Publishers, Inc., New York. 177 pp.

QUINN, R. F. 1994. Fish passage facilities for *Alosa*. Pp. 119–127 *in* J. E. Cooper, R. T. Eades, R. J. Klauda, and J. G. Loesch, eds. Anadromous *Alosa* Symposium. Tidewater Chapter, American Fisheries Society. Bethesda, Maryland.

RAFINESQUE, C. S. 1820. Ichthyologia Ohiensis. (Not seen, cited from Hildebrand, 1963.)

RICHKUS, W. 1988. Overview of anadromous fish biology and management. Pp. 23–34 *in* C. S. Manooch, and A. B. Manooch, eds. Impacts of dredging on anadromous fish: a transcript of presentations at a workshop, Raleigh, North Carolina, September 18–19, 1987. NOAA Technical Memorandum NMFS-SEFC-210.

RULIFSON, R. A., M. T. HUISH, and R. W. THOESEN. 1982. Status of anadromous fishes in southeastern U.S. estuaries. Pp. 413–426 *in* V. S. Kennedy, ed. Estuarine Comparisons. Academic Press, New York.

SAVOY, T. F., and V. A. CRECCO. 1988. The timing and significance of density-dependent and density-independent mortality of American shad, *Alosa sapidissima*. Fishery Bulletin, U.S. 86(3): 467–482.

SCHUBEL, J. R., C. F. SMITH, and T. S. Y. KOO. 1977. Thermal effects on power plant entrainment on survival of larval fishes: A laboratory assessment. Chesapeake Science 18 (3): 290–298.

SMILEY, C. W. 1884. Notes on the shad season of 1884, with references to other species. Bulletin of the U.S. Fish Commission 4 (for 1884): 337–341.

SMITH, G. 1968. Seeking secluded shad. Florida Wildlife 21(9): 12–17.

SMITH, H. M. 1893. Report on the fisheries of the south Atlantic states. Bulletin of the U.S. Fish Commission 11 (for 1891): 271–356.

SMITH, H. M. 1894. Statistics of the fisheries of the United States. Bulletin of the U.S. Fish Commission 13 (for 1893): 389–417.

SMITH, H. M. 1898. Report of the division of statistics and methods of the fisheries. Report of the Commissioner for the year ending June 30, 1897, U.S. Commission of Fish and Fisheries, Part 23: cxxv–cxlvi.

SNYDER, B. 1949. Silver lightning! Florida Wildlife. 2 (11): 36 pp.

STEARNS, S. 1885. Examination of the fisheries of the Gulf of Mexico. Bulletin of the U.S. Fish Commission 5 (for 1885): 285–287.

STEARNS, S. 1887. Some of the fisheries of western Florida. Bulletin of the U.S. Fish Commission 6 (for 1886): 465–467.

STEVENSON, C. H. 1898. The restricted inland range of shad due to artificial obstructions and its effect on natural reproduction. Bulletin of the U.S. Fish Commission 17 (for 1897): 265–71.

STEVENSON, C. H. 1899. The shad fisheries of the Atlantic coast of the United States. Report of the Commissioner for the year ending June 30, 1898, U.S. Commission of Fish and Fisheries, Part 24: 101–133.

STILWELL, E. M., M. C. EDMUNDS, M. McKENNIE, J. F. INGALLS, and J. M. MILNER. 1874. On obstructions to the ascent of fish in certain rivers. Report of the Commissioner for 1872 and 1873, U.S. Commission of Fish and Fisheries, Part 2: 617–634.

SUMMERS, J. K., and K. A. ROSE. 1987. The role of interactions among environmental conditions in controlling historical fisheries variability. Estuaries 10(3): 255–266.

SVETOVIDOV, A. N. 1964. Systematics of the North American anadromous clupeioid fishes of the genera *Alosa, Caspialosa,* and *Pomolobus*. Copeia 1964(1): 118–129.

SYKES, J. E., and B. A. LEHMAN. 1957. Past and present Delaware River shad fishery and considerations for its future. U.S. Fish and Wildlife Research Report 46: 1–25.

THORROLD, S. R., C. M. JONES, S. E. CAMPANA, J. W. McLAREN, and J. W. H. LAM. 1998. Trace element signatures in otoliths record natal river of juvenile American shad *(Alosa sapidissima)*. Limnology and Oceanography 43(8): 1826–1835.

TOWNSEND, C. H. 1899. Report of the division of statistics and methods of the fisheries. Report of the Commissioner for the year ending June 30, 1898, U.S. Commission of Fish and Fisheries, Part 24: cxlvii-clxxv.

TOWNSEND, C. H. 1900. Statistics of the fisheries of the south Atlantic states. Report of the Commissioner for the year ending June 30, 1899, U.S. Commission of Fish and Fisheries, Part 25: 171–227.

U.S. DEPARTMENT OF COMMERCE. 1993. Status of the fishery resources off the northeastern United States for 1993. NOAA Technical Memorandum NMFS-F/NEC-101. 140 pp.

WALBURG, C. H. 1956. Observations on the food and growth of juvenile American shad, *Alosa sapidissima*. Transactions of the American Fisheries Society 86: 302–306.

WALBURG, C. H. 1960a. Abundance and life history of shad, St. Johns River, Florida. Fishery Bulletin, U.S. 60: 486–501.

WALBURG, C. H. 1960b. Abundance of St. Johns River shad. Transactions of the 25th North American Wildlife Conference: 327–333.

WALBURG, C. H., and P. R. NICHOLS. 1967. Biology and management of the American shad and status of the fisheries, Atlantic coast of the United States, 1960. U.S. Fish and Wildlife Special Scientific Report—Fisheries 550: 1–105.

WALTHER, L. 1989. Enhancing the St. Johns. Florida Wildlife 43(3): 35.

WARREN, M. L., Jr., B. BURR, S. WALSH, H. BART, Jr., R. CASHNER, D. ETNIER, B. FREEMAN, B. KUHAJDA, R. MAYDEN, H. ROBISON, S. ROSS, and W. STARNES. 2000. Diversity, distribution, and conservation status of the native freshwater fishes of the southern United States. Fisheries 25(10): 7–31.

WEISBERG, S. B., P. HIMCHAK, T. BAUM, H. T. WILSON, and R. ALLEN. 1996. Temporal trends in abundance of fish in the tidal Delaware River. Estuaries 19(3): 723–29.

WELANDER, A. D. 1941. Notes on dissemination of shad, *Alosa sapidissima* (Wilson), along the Pacific coast of North America. Copeia 1941(4): 221–223.

WILLIAMS, R. O. 1996. Background document for workshop on American shad management. January 16–17, 1996. Sanford and Cocoa Beach, Florida. Florida Marine Fisheries Commission, Tallahassee.

WILLIAMS, R. O., and G. E. BRUGER. 1972. Investigations on American shad in the St. Johns River. Florida State Board Conservation Marine Laboratory Technical Series No. 66: 1–49.

WILLIAMS, R., and W. GREY. Undated. Stream Survey Section of Anadromous Fish Project. Florida Department of Natural Resources Marine Research Laboratory, St. Petersburg, Florida.

WILLIAMS, R. O., W. F. GREY, and J. A. HUFF. 1975. Study of anadromous fishes of Florida. Completion Report for the period 1 May 1971 to 30 June 1974 for research funded by the Anadromous Fish Act (PL 89-304). National Marine Fisheries Service, St. Petersburg, Florida.

WILSON, A. 1811. Ree's New Cyclopedia. Volume 9. Unpaginated. (Not seen, cited from Hildebrand, 1963.)

WOLFE, J. C. 1969. Biological studies of the skipjack herring, *Alosa chrysochloris,* in the Apalachicola River, Florida. M.S. thesis. Florida State University, Tallahassee. 68 pp.

YERGER, R. W. 1977. Fishes of the Apalachicola River. Pp. 22-33 *in* Proceedings of the Conference on the Apalachicola Drainage System, 23–24 April 1976. Gainesville, Florida. R. J. Livingston and E. A. Joyce, Jr., eds. Florida Marine Research Publications 26.