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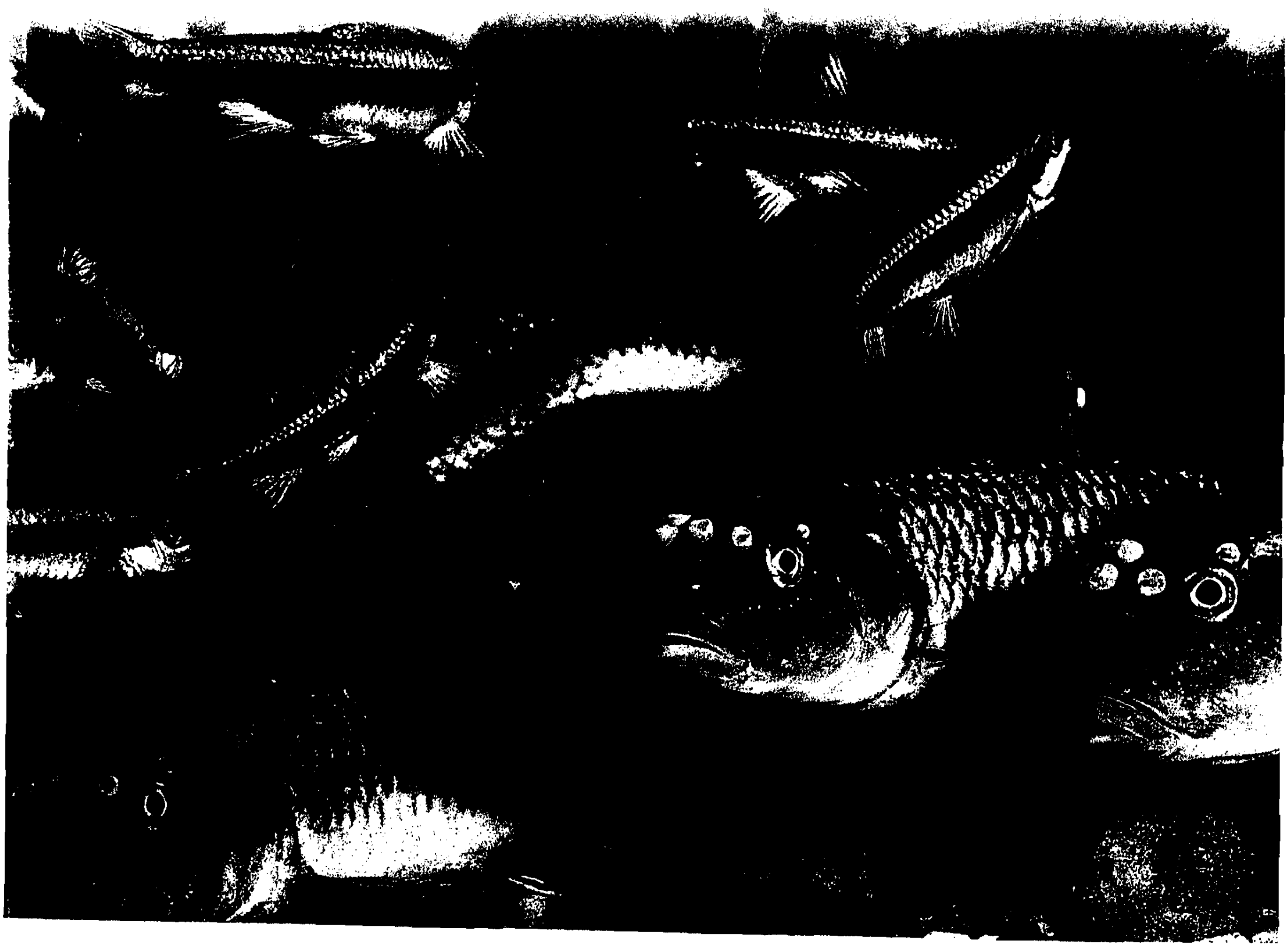
FISHES *of the* Middle Savannah River Basin

WITH EMPHASIS ON THE SAVANNAH RIVER SITE



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Introduction

Our book is based primarily on fisheries studies from 1879 to 2002 in the middle Savannah River basin (MSRB) and studies since 1950 on the U.S. Department of Energy's Savannah River Site (SRS). This book significantly expands *The Fishes of the Savannah River Plant: National Environmental Research Park* (Bennett and McFarlane 1983), which reported on 79 fish species collected on the SRS. Our book enlarges the geographical focus to include the portion of the Savannah River basin that is hydrologically and physiographically similar to the SRS and is the subject of more studies and the source of more data.

Our book comprises habitat characterizations, family descriptions, species accounts, habitat and species photographs, and a taxonomic identification key. We address 24 fish families that include 98 native or introduced fish species historically collected in the MSRB, and list 86 fish species collected specifically on the SRS since the 1950s. Of the 98 species covered in this book, 84 are native (Warren et al. 2000). Thus, this book covers approximately 70% of the native species found in the entire Savannah River drainage. A brief account of each family is followed by accounts of all species of that family found in the MSRB.

The study area comprises the stream reaches corresponding to the U.S. Geological Survey's hydrological unit codes (HUC) 03060106 (the Middle Savannah River) and 03060108 (Brier Creek). This area includes the Savannah River and its tributaries from the Fall Line just above Kiokee Creek in Columbia County (about 6 km below Clarks Hill Dam), Georgia, to the mouth of Brier Creek (river kilometers [rkms] 156–355) and all of the Brier Creek drainage. This represents all of the Savannah River drainage area on the Upper Coastal Plain plus small areas at the edge of the Lower Coastal Plain. Stevens Creek, in Edgefield and McCormick counties, South Carolina, while part of HUC 03060106, is not included because it is a Piedmont stream with a fish species assemblage more similar to that of the upper Savannah River basin.

Geographical and Historical Perspectives

The Savannah River lies in an area of the United States with high fish species diversity. The Savannah River basin is home to at least 118 native fish species (Warren et al. 2000), equal to the number of native freshwater fish species found in all of Kansas and more than the number found in 14 western states and 8 northeastern states (Warren and Burr 1994). The Edisto River basin, which adjoins the Savannah River basin to the east, has a reported (collected and identified) fish fauna of 87 species (25 families) in its freshwater portion and 120 species (52 families) in its saltwater portion (Marcy and O'Brien-White 1995).

Fifteen of the 98 species that are found in the MSRB and covered here were introduced into the area, mostly for fisheries purposes. The effects of these fish on the 84 native species are largely unknown. Several species should have no effect because they have little chance of becoming established in the MSRB. Examples are the grass carp, which is being introduced as triploid sterile indi-

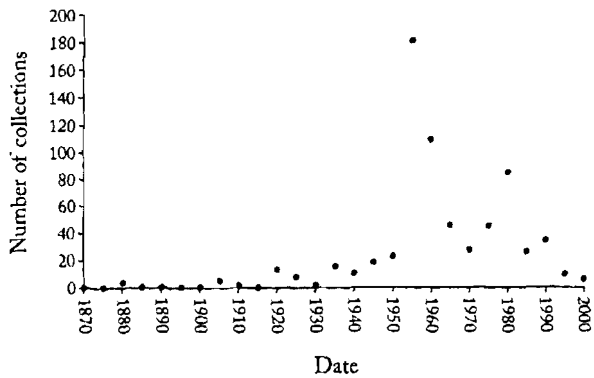


FIGURE 2. Number of individual collections of MSRB fishes held in museums. *Note*: A collection is considered here to be all species of fish taken from one location on one date. Collection numbers are grouped by 5-year intervals.

use of fertilizer and other agricultural chemicals as well as some shifting to silviculture and development of smaller "bedroom communities." Major industries that might influence water quality in the Savannah River in addition to SRS activities are textile mills, polystyrene foam and paper product plants, chemical processing plants, and a commercial nuclear power plant, Plant Vogtle.

The first surveys of the fish fauna in the middle Savannah River began in the late 1800s. Map 4 shows the locations where the historical fish samples (1879–2002) that were used in preparing fish species distribution maps for our book were collected. Our sources of data were museum collections, reports in peer-reviewed journals, and unpublished reports from SRS monitoring programs and South Carolina, Georgia, and Plant Vogtle environmental monitoring reports and databases. The appendix lists museum and agency sources of collection data supporting the species distribution data and maps.

Few of the museum specimens from this geographical area were collected prior to the 1920s, and most, as indicated by museum holdings, were collected post-1945 (see Figure 2). The greatest sampling efforts seem to have been in conjunction with various projects to characterize the fauna of the SRS and the environmental impacts of its operation. These projects began just prior to the start of SRS construction (1950).

In addition to specimens placed in museums, the Savannah River Ecology Laboratory, the Savannah River National Laboratory, and various environmental subcontractors have created published and unpublished reports (about 500). Those that give exact locations for species sampled and were judged to be probably correct in species identifications were used in our analysis of local distributions. In addition, South Carolina and Georgia state agencies have sampled this area, and they made reports and data files available to us for these analyses. The appendix lists the reports, data files, and publications used.

Native Fish Species

The native species of the MSRB can be divided into four categories: (1) resident species that are present for all life stages, (2) diadromous (catadromous or anadromous) species that are present only for certain life stages, (3) marine species that penetrate rivers up to the Fall Line either regularly or as strays, and (4) upland species that sometimes stray below the Fall Line. Table 3 summarizes the native species falling into each category. Of the marine species included in our book, the mountain mullet and the tarpon are rare or infrequently collected and the others are part of the regular summer and fall fauna of the MSRB.

Introduced Fish Species

The introduced species can likewise be divided into categories (Table 4): (1) persistently abundant and established, (2) rare and possibly not established or established only in restricted areas, (3) definitely not established, and (4) too little information to determine status.

General Distribution within the Region

Each of the species considered in this book has its own distribution pattern within the MSRB, but most fit into one of four categories. For the benefit of this discussion we use the following definitions taken from Conner and Suttkus 1986:

- "river"—flowing body of water with an average width of 70 m or more at mean low stage;
- "stream"—flowing body of water with an average width of 10–70 m at mean low stage;
- "creek"—flowing body of water with an average width less than 10 m at mean low stage; and
- "swamp"—sluggishly flowing or lentic features asso-

TABLE 3. Native resident, diadromous, marine, and upland fish species of the MSRB (listed in phylogenetic order).

	Scientific name	Common name
Resident species		
Lepisosteidae	*Lepisosteus osseus*	longnose gar
	Lepisosteus platyrhincus	Florida gar
Amiidae	*Amia calva*	bowfin
Clupeidae	*Dorosoma cepedianum*	gizzard shad
Cyprinidae	*Cyprinella leedsi*	bannerfin shiner
	Cyprinella nivea	whitefin shiner
	Hybognathus regius	eastern silvery minnow
	Hybopsis rubrifrons	rosyface chub
	Nocomis leptocephalus	bluehead chub
	Notemigonus crysoleucas	golden shiner
	Notropis chalybaeus	ironcolor shiner
	Notropis cummingsae	dusky shiner
	Notropis hudsonius	spottail shiner
	Notropis lutipinnis	yellowfin shiner
	Notropis maculatus	taillight shiner
	Notropis petersoni	coastal shiner
	Opsopoeodus emiliae	pugnose shiner
	Pteronotropis stonei	lowland shiner
	Semotilus atromaculatus	creek chub
Catostomidae	*Carpiodes cyprinus*	quillback
	Carpiodes velifer	highfin carpsucker
	Erimyzon oblongus	creek chubsucker
	Erimyzon sucetta	lake chubsucker
	Hypentelium nigricans	northern hogsucker
	Minytrema melanops	spotted sucker
	Moxostoma collapsum	notchlip redhorse
	Moxostoma robustum	robust redhorse
	Scartomyzon sp. cf. *lachneri*	brassy jumprock
Ictaluridae	*Ameiurus brunneus*	snail bullhead
	Ameiurus catus	white catfish
	Ameiurus natalis	yellow bullhead
	Ameiurus nebulosus	brown bullhead
	Ameiurus platycephalus	flat bullhead
	Noturus gyrinus	tadpole madtom
	Noturus insignis	margined madtom
	Noturus leptacanthus	speckled madtom
Esocidae	*Esox americanus*	redfin pickerel
	Esox niger	chain pickerel
Umbridae	*Umbra pygmaea*	eastern mudminnow
Aphredoderidae	*Aphredoderus sayanus*	pirate perch
Amblyopsidae	*Chologaster cornuta*	swampfish
Fundulidae	*Fundulus chrysotus*	golden topminnow
	Fundulus lineolatus	lined topminnow
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish
Atherinopsidae	*Labidesthes sicculus*	brook silverside
Centrarchidae	*Acantharchus pomotis*	mud sunfish
	Centrarchus macropterus	flier
	Enneacanthus chaetodon	blackbanded sunfish

TABLE 3. (continued)

	Scientific name	Common name
Resident species		
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish
	Enneacanthus obesus	banded sunfish
	Lepomis auritus	redbreast sunfish
	Lepomis gibbosus	pumpkinseed
	Lepomis gulosus	warmouth
	Lepomis macrochirus	bluegill
	Lepomis marginatus	dollar sunfish
	Lepomis microlophus	redear sunfish
	Lepomis punctatus	spotted sunfish
	Micropterus salmoides	largemouth bass
	Pomoxis nigromaculatus	black crappie
Elassomatidae	*Elassoma evergladei*	Everglades pygmy sunfish
	Elassoma okatie	bluebarred pygmy sunfish
	Elassoma zonatum	banded pigmy sunfish
Percidae	*Etheostoma fricksium*	Savannah darter
	Etheostoma fusiforme	swamp darter
	Etheostoma hopkinsi	Christmas darter
	Etheostoma inscriptum	turquoise darter
	Etheostoma olmstedi	tessellated darter
	Etheostoma serrifer	sawcheek darter
	Percina nigrofasciata	blackbanded darter
Diadromous species		
Acipenseridae	*Acipenser brevirostrum*	shortnose sturgeon
	Acipenser oxyrinchus	Atlantic sturgeon
Anguillidae	*Anguilla rostrata*	American eel
Clupeidae	*Alosa aestivalis*	blueback herring
	Alosa mediocris	hickory shad
	Alosa sapidissima	American shad
Moronidae	*Morone saxatilis*	striped bass
Marine species		
Megalopidae	*Megalops atlanticus*	tarpon
Belonidae	*Strongylura marina*	Atlantic needlefish
Mugilidae	*Agonostomus monticola*	mountain mullet
	Mugil cephalus	striped mullet
Achiridae	*Trinectes maculatus*	hogchoker
Upland species		
	Micropterus coosae	redeye bass[1]

[1] The Savannah River is the only area of the redeye bass's range where it occurs below the Fall Line.

TABLE 4. Introduced fish species in the MSRB and their status.

	Scientific name	Common name
Clearly established		
Clupeidae	*Dorosoma petenense*	threadfin shad
Cyprinidae	*Cyprinus carpio*	common carp
Ictaluridae	*Ictalurus punctatus*	channel catfish
Percidae	*Perca flavescens*	yellow perch
Rare and possibly not established		
Cyprinidae	*Carassius auratus*	goldfish
Moronidae	*Morone americana*	white perch
	Morone chrysops	white bass
Centrarchidae	*Lepomis cyanellus*	green sunfish
	Pomoxis annularis	white crappie
Clearly not established		
Cyprinidae	*Ctenopharyngodon idella*	grass carp
Salmonidae	*Oncorhynchus mykiss*	rainbow trout
Too little information		
Ictaluridae	*Ictalurus furcatus*	blue catfish
	Pylodictis olivaris	flathead catfish

ciated with floodplains of lowland streams, includes marshes and sloughs.

The distribution patterns that we have noted are: (1) species living primarily in river mainstream including impoundments and side channels; (2) swamp, marsh, oxbow lake, or slough inhabitants; (3) primarily stream or creek inhabitants; and (4) generalists. There are no large permanent natural lakes in the MSRB, so it is not surprising that there are few species that are primarily lake and pond dwellers. The distribution pattern is noted in the account for each species.

Summary

At this time it appears that the fish fauna of the middle Savannah River basin region is still in relatively good condition. The major concerns for the future are continued urbanization with increased runoff, channelization, siltation, and chemical and nutrient input. Also, if Harding et al. (1998) are correct, the full effects on the fauna of recent conditions may not yet be apparent. Unfortunately, the data set we have had to use in our analyses lacks the information necessary to assess sampling effort and relative species abundance. Anderson et al. (1995), using a data set with consistent sampling effort and species relative abundance estimates, were able to show significant changes in species assemblages for freshwater fishes of Texas and the effects of dams and other local impactors.

The effects of introduced species in the MSRB are not well known at the present time either, but to date they seem to have been subtle, or at least minor. On a more positive note, seriously depleted species such as the American shad, the shortnose sturgeon, and the robust redhorse (Figure 3) are spawning in this subdrainage. Their reproductive success is still under evaluation.

FIGURE 3. The robust redhorse, *Moxostoma robustum*. This endangered species found in the MSRB appears to be making a comeback with help from the Robust Redhorse Recovery Plan.

Savannah River and Swamps

The MSRB is in many ways typical of southeastern river basins. It is home to a diverse fish fauna, and its associated tributaries and wetlands are important spawning and nursery areas. And like other southeastern rivers, the Savannah River watershed is increasingly affected by the region's growing human population.

Fish Habitats of the Middle Savannah River Basin and Associated Swamps

The Savannah River itself has several habitat types that are utilized by the fish populations of the MSRB. The most obvious of these habitats is the main river channel (Figure 4). The main river channel within the MSRB generally has a sandy substrate, but a variety of bottom substrate types may be found: cobbles and rock shelves at and near the Savannah River Rapids, sand or gravel where there is moderate flow, and mud and plant detritus in backwaters.

In addition to the main channel there are a number of "cutoff bends" and "dead rivers" (former river channels that are still connected to the main channel). Many cutoff bends and dead rivers were created when the Augusta Navigational Project modified the original river channel for barge traffic. Dead rivers and cutoff bends have characteristics intermediate between those of flowing lotic systems and still-water lentic systems, and they form oxbow lakes when both ends become disconnected from the main river channel. In this discussion, dead rivers are considered part of the lotic environment, and oxbows are treated as lentic environments. Historically there has been little sampling in dead rivers of the MSRB. Side channels are segments of former river channels that are still connected to the main channel at each end but have reduced flow compared with the main channel. Side channel habitat, which is limited, has likewise been sampled little but is similar to that of cutoff bends.

The major swamp habitats in the MSRB are in two locations: Phinezy Swamp, adjacent to Augusta and the Savannah River, and the Savannah River Swamp, located mostly within the SRS adjacent to the Savannah River (Figures 5 and 6). The Savannah River Swamp receives water from Upper Three Runs (rkm 251), Fourmile Branch (rkm 241), Beaverdam Creek (rkm 243), Pen Branch (which does not directly drain into the Savannah River), Steel Creek (rkm 227), and Lower Three Runs (rkm 206). Across the river from the SRS there is swamp habitat, essentially a continuation of the Savannah River Swamp, associated with Sweetwater Creek (rkm 214). While there has been sporadic sampling of the fish fauna in the Savannah River Swamp, there are virtually no fisheries data for Phinezy Swamp or for the Sweetwater Creek area. There are some data from a swampy area on McBean Creek in Georgia, and some samples from the lower part of Brier Creek and Beaverdam Creek in Screven County, Georgia. These latter samples should probably be considered swamp samples, but the site description information was limited.

There are other swamp or swamplike habitats in the MSRB in addition to those identified above. Each of the streams and creeks has associated floodplains with bottomland hardwood forest. Major rain events normally

FIGURE 4. Savannah River main channel at about the middle of the Savannah River Site boundary.

cause flooding of these bottomland forests with a slow return of the stream to its main channel. Several fish species enter such flooded areas to feed or to spawn. Floodplain ponds and pools are common on these floodplains. These wetlands are connected with the mainstream during flooding events but are isolated during normal flows. Several fish species colonize these ponds during flood events and remain until either the next floodwater incursion or the area dries up. Very little information is available on the fishes of the floodplain ponds.

In the lower reaches of Steel Creek, Pen Branch, and Fourmile Branch on the SRS, heated reactor effluent eliminated the natural vegetation, and sediments from parts of the upper stream basin and upper floodplain were deposited onto the lower floodplain where the stream entered the Savannah River Swamp, forming deltas. After reactor shutdown in 1986, these bottomland forests were partially replaced with grassy marshes through natural regeneration. The marshes have been sampled; the limited fish data for these specific marsh habitats are discussed more fully elsewhere.

The term "slough" has several meanings, but in the MSRB context it denotes linear wetlands that may represent sediment-filled oxbow lakes or other former river or stream channels. This habitat is quite limited, and the fish fauna data for it are proportionally smaller.

Human Influences on the Fish Fauna of the Savannah River and Associated Swamps

There are many sources of indirect influences on local fish fauna. Those whose effects are best documented are discussed here.

URBANIZATION Three urbanized counties—Richmond and Columbia counties in Georgia and Aiken County in South Carolina—are the center of population for the MSRB. Increased urban population brings with it an in-

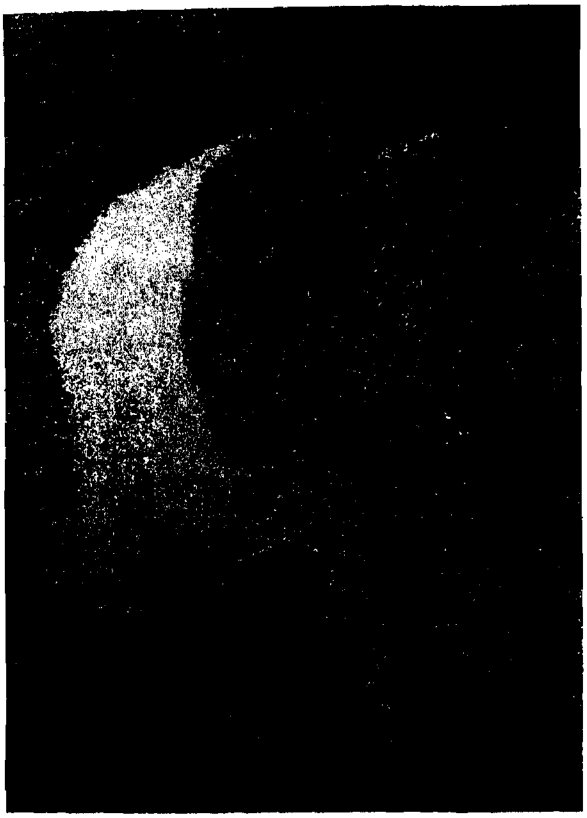


FIGURE 5. Savannah River main channel and the Savannah River Swamp near the mouth of Steel Creek.

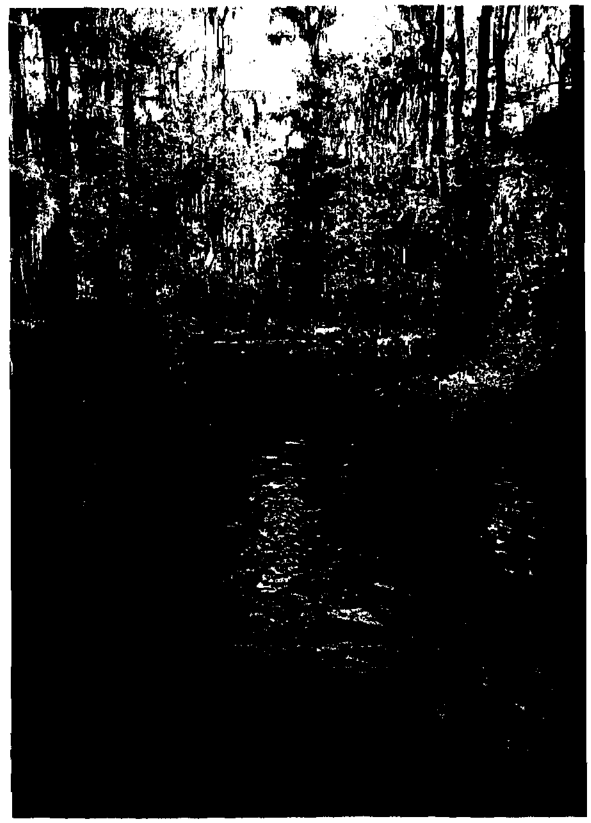


FIGURE 6. Savannah River Swamp.

crease in water-impervious surfaces such as roofs, roads, and paved driveways, and a decrease in natural vegetation. Water cannot infiltrate such surfaces and instead flows directly into streams. This runoff increases the frequency of flash floods and decreases the predictability of flooding. In doing so it interferes with the reproduction of the species that breed in the floodplains, which require predictability in the timing and intensity of flooding for successful reproduction.

FISHERIES The sport, subsistence, and commercial fisheries have a direct influence on fish populations and species assemblages. Sportfishing in the MSRB largely targets largemouth bass, black crappie, sunfishes, American shad, chain pickerel, larger catfishes such as the white catfish or channel catfish, and striped bass and its hybrids. Local newspaper fishing reports indicate that the area just below the New Savannah Bluff Lock and Dam is one of the most popular sportfishing areas within the MSRB.

Significant commercial fisheries are those on American shad, channel catfish, and white catfish. Commercial fisheries for blueback herring formerly existed in South Carolina (Ulrich et al. 1978), but no herring are taken in Georgia because of netting restrictions. Music (1981) reported that the Savannah River American shad catches represented 51% of Georgia landings in 1980, although only 13% of Georgia's commercial shad fishermen operated in the Savannah River. Striped bass are considered sport fish, and no commercial bass fishery is allowed in the Savannah River. Because they are highly regarded as a recreational species, considerable effort has been expended by government agencies to improve striped bass population levels. While Gilbert et al. (1986) suggested that striped bass spawn outside the MSRB, primarily in the tidal portions of the Savannah River, Paller et al. (1984, 1985, 1986b) have documented spawning well up into the river basin.

INDUSTRIAL ACTIVITIES Use of river water for industrial purposes, such as cooling water, has affected MSRB fish populations through entrainment (in which fish eggs and larvae are caught up in the current of a water intake device) and impingement (the removal of juvenile and adult fish from the intake stream by means of a small-mesh [0.95 cm] screen). Entrainment occurs wherever large volumes of water are removed, such as at domestic water treatment plants, or used in industrial processes. Mortality due to entrainment varies according to the species of fish, its life stage, and physical parameters of water flow such as current speed and turbulence. Changes in temperature or other water quality parameters and amelioration devices such as traveling screens that return the entrained animal to the water away from the intake device also play a role in survival. See Schubel and Marcy 1978 for biological assessment of entrainment impacts. Historically, the largest sources of entrainment in the MSRB have been the reactor cooling water intakes for the SRS (9.8% of Savannah River flow) and the Plant Vogtle nuclear power station (4.2% of river flow; Wiltz 1981; DOE 1990).

SAVANNAH RIVER SITE Historically, the SRS has affected populations of commercially and recreationally important fish species in the river primarily through impingement and entrainment losses of fish eggs, larvae, and adults during intake of cooling water (McFarlane et al. 1978). The overall rates of impingement at the SRS intakes were low relative to those of other cooling-water intake facilities in the Southeast (DOE 1988). Cessation of reactor operations and the concomitant lack of need for cooling water withdrawals from the Savannah River reduced entrainment impacts substantially.

FLOOD/WATER CONTROL Dams, levees, and locks all influence fish species assemblages. Dams and their associated locks convert lotic environments into lentic ones. Levees restrict overbank flooding, preventing the filling of riparian wetlands that are important to the life cycles of numerous riverine fish species and altering the frequency of floodplain inundation, which has profound effects on species assemblages utilizing floodplain ponds and sloughs. Overbank flooding also affects the biological community structure of rivers through introducing nutrients in the form of plant-derived materials into the main channel. The Clarks Hill/J. Strom Thurmond Dam, the most downriver of the U.S. Army Corps of Engineers dams, probably has the strongest effect due to its regulation of flooding events. Additionally, the water released below the Clarks Hill/J. Strom Thurmond Dam is from below the thermocline and thus has a profound effect on temperature and dissolved oxygen levels for considerable distances downstream.

The New Savannah River Lock and Dam, the first dam on the Savannah River fish migrating upstream encounter, is a major obstruction for commercial and recreational species such as American shad, blueback herring, striped bass, and Atlantic sturgeon. It also affects the movements of such threatened and endangered species as the robust redhorse and shortnose sturgeon. In the early 1900s, some of these species migrated annually to the headwaters of the Savannah River—all the way to Tallulah Falls, 614 km from the Atlantic Ocean. Construction of reservoirs, dams, and hydropower facilities eliminated essential riverine habitat for these species. Access to historic spawning habitats has been reduced so that migrating fish can go only half as far upriver as formerly, and this is a major cause of the decline in the Savannah River's migratory fish populations (U.S. Fish and Wildlife Service 2001).

CHANNELIZATION Portions of the Savannah River, including 31 meander cutoffs, were channelized by the Corps of Engineers to enhance navigation between Augusta and Savannah, reducing the river length between these cities by 24.1 km (Wike et al. 1994). In addition to eliminating the meander cutoffs, the channelization increased the water velocity, likely decreased habitat heterogeneity in the straightened main channel, and increased backwater habitat in the form of dead rivers and man-made oxbows. These cutoffs are prominent in the lower portion of the MSRB. The work was completed by 1965, but some dredging continued through 1985 (Wike et al. 1994). Additionally, pile dikes increase the water velocity of the main channel by restricting flows. Eddies behind and around these dikes provide refuges from the high water velocities where fish frequently congregate. These areas are frequently favorite spots for anglers.

SEDIMENTATION AND POLLUTION The introduction of commercial agriculture in the eighteenth century increased the potential for erosion and thus increased sedimentation. The recent shift toward silviculture and pastureland is working to ameliorate this process. Countering this trend is the increased urbanization of the MSRB, which tends to increase sedimentation from construction activities and stormwater runoff. Sedimentation eliminates breeding habitat for fishes requiring clean substrates, extirpates invertebrates that may serve as food sources, and leads to wholesale changes in flora and fauna in affected areas (Berkman and Rabeni 1987; Waters 1995; Jones et al. 1999). In southern Appalachian streams, sedimentation resulting from deforestation shifts fish species assemblages away from species that spawn in rock crevices and clean gravel or cobbles to mound-building minnows, their nest associates, and fish that excavate nests in soft sediments (sunfishes and basses) (Sutherland et al. 2002).

Along with the aforementioned changes in runoff and erosion there is the problem of eutrophication. The Public Interest Research Group lists the Savannah River as the eighth most polluted river in the United States (National Science Center's Fort Discovery 2002). The expanding human population in the area has increased the amount of organic waste concentrated in a relatively small area. Even with sewage treatment, nutrients such as nitrogen compounds and phosphates are entering waterways at high enough levels to cause increased plant growth in some bodies of water. Additionally, even though less land area is under cultivation now than in the nineteenth century, agricultural fields are receiving higher levels of fertilizers and other chemicals. Water percolating through the soils of these fields picks up fertilizer, and the soil particles, often accompanied by absorbed inorganic fertilizer, enter waterways through erosion. This effect is most obvious in certain smaller bodies of water because of lack of dilution.

The deteriorating water quality (especially reduced levels of dissolved oxygen) appears to be degrading the southern river nurseries and summer habitats of the shortnose sturgeon and the Atlantic sturgeon; protection of these essential habitats is critical (Collins et al. 2000b). Influences of the deterioration on other species are not as well documented.

The factors that cause increased nutrient loading in the local waterways also introduce toxic substances. Currently, the Environmental Protection Agency (EPA) advises against eating fish from most streams and other water bodies in the MSRB due to mercury concentrations. Although there are many possible sources of this mercury, about 99% of it appears to be entering the river through atmospheric deposition (EPA 2000). Other contaminants include pesticides from agricultural practices, radiocesium (^{137}Cs) and tritium from previous SRS operations, toxic chemicals from lawns, fecal coliform bacteria from domestic animals, and other urban pollutants.

Fish Habitat in Savannah River and Associated Wetlands

Natural flooding regimes are important in organizing "natural" fish communities. For instance, in Missouri, both the stream fish assemblages and the assemblages occurring in the bottomland hardwood wetlands were very different in areas with natural flood regimes and those with flood regimes regulated by dam release (Finger and Stewart 1987). Several of the species that were abundant in the naturally flooded areas were absent from the regulated areas. Unfortunately, we can say little about this with regard to the MSRB as we found no reliable data for the Savannah River collected before completion of the Clarks Hill/J. Strom Thurmond Dam around 1951; probably none exist predating the Stevens Creek Dam (rkm 333) completed in 1914.

Floodplain ponds are important habitats for MSRB fish species such as the pickerels and pirate perch. While these are not, strictly speaking, lotic environments, they are integral parts of swamp and marsh habitats, and when inundated they are part of the river itself. Adult fishes utilize the available habitats to varying degrees. A number of species are either largely confined to the main river channel habitat or use river channels most of the time but use swamp habitat or lower reaches of tributaries as available (Figures 7 and 8; Table 5).

While some of the numbers in Table 5 may be biased by the number of available collections for particular habitats (e.g., *Lepomis marginatus* and *Notropis chalybaeus* are not typical of large river habitat), some species clearly are most prevalent in the river. A smaller number of species are primarily swamp or marsh dwellers that may use the river channel or stream channels periodically. One complicating factor is that neither time of day of capture nor life stage is known for most of the specimens contained in our derived historical database. Ross and Baker (1983) showed that during spring inundations of floodplains in

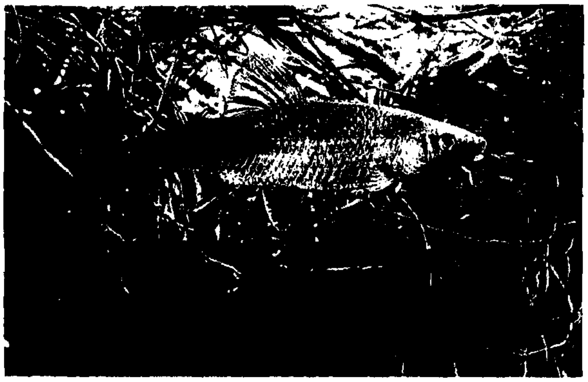


FIGURE 7. The whitefin shiner, *Cyprinella nivea*, is largely confined to the Savannah River and the lower reaches of tributary streams.

FIGURE 8. The snail bullhead, *Ameiurus brunneus*, is common in the Savannah River.

Mississippi, a number of "flood-exploitative" species were taken frequently on the floodplain in daylight hours but were more common near the channel at night, while "flood-quiescent" species were largely restricted to the channel and were almost never taken on the floodplain.

River and Swamp Spawning Habitat

In general, there are specific guilds of fish that preferentially spawn in channels rather than in backwater habitats such as oxbows, sloughs, "dead rivers," and floodplain pools (Copp 1989). Light trap data from the Tallahatchie River of Mississippi indicated that larval *Lepomis* spp., *Pomoxis* spp., and *Dorosoma* spp., and juvenile *Gambusia affinis* were much more abundant in sloughs and low-current floodplain tributaries, while minnow larvae were more abundant in the higher-current (channel) areas (Turner et al. 1994). The bowfin, *Amia calva*, is one of the most common species caught by subsistence fishermen. In the SRS, larval fish appear to use submerged macrophytes for cover in floodplain braided streams of the Steel Creek Swamp more during daylight hours than during nighttime (Paller 1987).

Seasonal movement into and out of floodplain pools has been documented for a number of species. Flooding of backwater habitats during spawning periods increases year class production of fish that spawn in these habitats, especially largemouth bass (Lambou 1959). In the Kankakee River of Illinois, the following species found in the MSRB moved into and out of backwater habitats during the spring and early summer (the period of most spawning): redfin pickerel, common carp, golden shiner, pugnose minnow, yellow bullhead, tadpole madtom, pirate perch, largemouth bass, green sunfish, bluegill, white crappie, and black crappie (Kwak 1988). Similar seasonal movements have been noted for largemouth bass in the Savannah River (Jones 2001). In the early winter, when water temperatures in the Savannah River Swamp drop below temperatures in the main river channel, largemouth bass and apparently many other species leave portions of the swamp and the entire Steel Creek Inlet and move out into the river. The fish return to the inlet in the spring when this temperature differential disappears; however, extreme drought conditions may reduce water quality in the swamp and inlet, preventing their use.

There are a number of species that either spawn on the inundated floodplain or whose larvae are more frequently captured there when these habitats are sampled. In the bottomlands along the Cache River of Arkansas, the larvae of the following MSRB species were found more frequently in the flooded bottomland forest than in the main channel: gizzard shad, pugnose minnow, tadpole madtom, pirate perch, flier, and black crappie. In addition, spotted sucker and channel catfish larvae were found about as frequently in the flooded bottomland forest as in the main channel (Killgore and Baker 1996).

Seasonal inundations, in addition to furnishing access to feeding areas and spawning sites, also provide highways for fish (Whitehurst 1981), and even species that spend long periods sedentary in swamps may move long

TABLE 5. Fish represented in collections from river and swamp habitats significantly more than would be represented by chance (more than 30% of records from river habitat or more than 15% of records from swamp habitat; species are listed in phylogenetic order).

Scientific name	Common name	Number[1]	River[2]	Swamp[2]	Lake[2]	Stream[2]
Acipenser brevirostrum	shortnose sturgeon	7	100			
Acipenser oxyrinchus	Atlantic sturgeon	7	100			
Lepisosteus osseus	longnose gar	96	68	21		11
Lepisosteus platyrhincus	Florida gar	17	24	76		
Amia calva	bowfin	77	45	27	5	22
Anguilla rostrata	American eel	142	42	10	2	45
Alosa aestivalis	blueback herring	37	92		8	
Alosa mediocris	hickory shad	7	57	43		
Alosa sapidissima	American shad	38	92	8		
Dorosoma cepedianum	gizzard shad	90	74	14	7	4
Dorosoma petenense	threadfin shad	19	68		32	
Cyprinella leedsi	bannerfin shiner	60	88	2	5	5
Cyprinella nivea	whitefin shiner	88	88		2	10
Cyprinus carpio	common carp	10	70	20	10	
Hybognathus regius	eastern silvery minnow	124	94	1	3	2
Hybopsis rubrifrons	rosyface chub	39	87			13
Notemigonus crysoleucas	golden shiner	197	46	10	19	25
Notropis chalybaeus	ironcolor shiner	135	50	13	5	31
Notropis hudsonius	spottail shiner	165	91	1	2	6
Notropis maculatus	taillight shiner	151	77	6	6	11
Notropis petersoni	coastal shiner	210	53	9	3	35
Opsopoeodus emiliae	pugnose minnow	78	82	12	1	5
Carpiodes cyprinus	quillback	11	100			
Carpiodes velifer	highfin carpsucker	3	100			
Erimyzon oblongus	creek chubsucker	111	36	9	3	52
Minytrema melanops	spotted sucker	178	57	11	2	30
Moxostoma collapsum	notchlip redhorse	39	167	9		24
Moxostoma robustum	robust redhorse	2	100			
Scartomyzon sp. cf. *lachneri*	brassy jumprock	2	100			
Ameiurus brunneus	snail bullhead	49	65			35
Ameiurus catus	white catfish	24	67	4	8	21
Ameiurus natalis	yellow bullhead	122	33	13	12	42
Ameiurus nebulosus	brown bullhead	78	54	6	8	32
Ameiurus platycephalus	flat bullhead	120	48	7	18	28
Ictalurus punctatus	channel catfish	40	58	15	2	25
Noturus gyrinus	tadpole madtom	106	40	8	8	44
Pylodictis olivaris	flathead catfish	1	100			
Esox americanus	redfin pickerel	231	38	7	10	44
Esox niger	chain pickerel	209	42	10	12	35
Umbra pygmaea	eastern mudminnow	38	26	21	18	34
Aphredoderus sayanus	pirate perch	227	38	10	4	48
Chologaster cornuta	swampfish	31	22	35		42
Strongylura marina	Atlantic needlefish	9	100			
Fundulus chrysotus	golden topminnow	18	89	11		
Fundulus lineolatus	lined topminnow	108	56	6	10	29
Gambusia holbrooki	eastern mosquitofish	236	45	8	8	38
Labidesthes sicculus	brook silverside	205	58	10	10	21

TABLE 5. (continued)

Scientific name	Common name	Number[1]	River[2]	Swamp[2]	Lake[2]	Stream[2]
Morone americana	white perch	2	50		50	
Morone chrysops	white bass	3	100			
Morone saxatilis	striped bass	5	100			
Elassoma evergladei	Everglades pygmy sunfish	1	100			
Elassoma okatie	bluebarred pygmy sunfish	5	60		40	
Elassoma zonatum	banded pygmy sunfish	100	62	16	1	21
Centrarchus macropterus	flier	85	58	10	8	24
Enneacanthus gloriosus	bluespotted sunfish	98	67	12	5	15
Lepomis auritus	redbreast sunfish	293	44	5	13	37
Lepomis cyanellus	green sunfish	9	78		11	11
Lepomis gibbosus	pumpkinseed	79	86		4	10
Lepomis gulosus	warmouth	203	48	7	18	27
Lepomis macrochirus	bluegill	271	47	7	15	31
Lepomis marginatus	dollar sunfish	185	42	7	22	30
Lepomis microlophus	redear sunfish	113	64	14	4	18
Lepomis punctatus	spotted sunfish	250	38	10	11	42
Micropterus coosae	redeye bass	4	100			
Micropterus salmoides	largemouth bass	250	42	11	15	32
Pomoxis annularis	white crappie	39	79	5	8	8
Pomoxis nigromaculatus	black crappie	135	70	4	16	9
Etheostoma fusiforme	swamp darter	139	66	6	10	17
Etheostoma olmstedi	tesselated darter	205	51	2	2	44
Perca flavescens	yellow perch	116	66	7	15	12
Agonostomus monticola	mountain mullet	2	100			
Mugil cephalus	striped mullet	21	52	43		5
Trinectes maculatus	hogchoker	44	100			

[1] The number of collections in our historical data set in which a given species occurred.
[2] The number is the percentage of records from the given habitat type, rounded to the nearest whole number.

distances (measured in kilometers) during spring floods. For example, tagged white catfish moved 23 km downstream and 61 km upstream during spring and early summer in the Connecticut River (Marcy 1976).

Because sloughs, oxbow lakes, and floodplain ponds are populated with subsets of the adjacent river's fauna, these habitats may serve an important function as refuges in the event of catastrophic stream mortality (Halyk and Balon 1983). On the other hand, floodplain sloughs and ponds may serve as population sinks during droughts, drying up much as large areas of the Everglades do each year, with concomitant heavy mortality of fishes (Carlson and Duever 1977).

highly dependent on river discharge, with optimum discharge correlating directly to river drainage area (Bilkovic 2000). The relationship of drainage area to discharge may be modified in the MSRB by upstream dams. Apparently this species is unable to complete all life stages in fresh water, as all introductions into landlocked situations have failed, though some adult fish survived for several years after introduction (Hildebrand 1963). A recent 40-year summary of early life history and adult population dynamics studies can be found in Leggett et al. 2004 and Savoy et al. 2004, respectively.

CONSERVATION STATUS Fisheries stocks have shown a coastwide decline with some recovery of stock size in the Savannah River (Atlantic States Marine Fisheries Commission 1999).

BIOLOGY Spawning runs may begin in November in Florida and may occur as late as July farther north (Leggett and Whitney 1972; Stier and Crance 1985). Males dominate the earliest runs of the season (Smith 1907). Populations in the Carolinas spawn in March to early May at water temperatures ranging from 10.5 to 21.6 °C (Jones et al. 1978). Southern populations (i.e., south of Cape Hatteras, North Carolina) tend to spawn once and die; northern populations usually are repeat spawners (Leggett and Carscadden 1978). Adults eat little during the 2 months they spend in fresh water on the spawning run, and weight loss and mortality are significant (Leggett 1972; Chittenden 1976; S. M. Davis 1980). Individuals that significantly delay the downstream postspawning migration may lose enough weight to cause mortality (Nichols 1959). Meristic data indicate that northern populations return to their natal streams for spawning (Carscadden and Leggett 1975; Melvin et al. 1986; Bentzen et al. 1989). Tagging experiments support such homing (Hollis 1948), and olfaction and vision appear to aid in homing to natal rivers (Dodson and Leggett 1974). Spawning is usually at night and may occur anywhere in a river, but the most frequented sites have flats or shallow water (Marcy 1972; Stier and Crance 1985). Eggs hatch in 71–86 hours, are demersal or pelagic, and are scattered randomly in the spawning act. Eggs travel 1.6–6.4 km from the point where they were broadcast (Marcy 1972). Larvae have similar survival and growth rates in salinities ranging from 0 to 20 ppt (Limburg and Ross 1995). Lippson and Moran (1974) summarized descriptions of American shad larvae and their distinguishing features.

Larvae and juveniles remain in their tidal freshwater nursery until water temperatures drop in the late fall, when they migrate out to sea or at least migrate downstream to overwinter near the mouth of the river or bay (Milstein 1981). In northern populations, the juveniles may remain in brackish water or inshore for the first year (Hildebrand 1963). In Virginia, stocked juvenile American shad migrated 28 km upstream from the site of release, and the smallest juveniles, both native and stocked, were found farthest upstream (Dixon et al. 1998). This migration cannot be accounted for by swimming alone; they must have made use of selective tidal transport. Juveniles remain in the ocean until they are at least 2 years of age. While at sea they form large schools. Most males mature at 2–3 years; females mature at 3–4 years of age.

Marine adults eat zooplankton, plant material, molluscs, and small fishes. The mysid zooplankters available in freshwater streams are much smaller than marine mysids and are therefore unavailable to adult American shad (Atkinson 1951), which thus feed little in fresh water while on the spawning run. Larvae and juveniles eat crustaceans, insect larvae, and, sometimes, smaller fish (Hildebrand 1963).

SCIENTIFIC NAME *Alosa*, from Saxon *allis* = old name for the European shad, *Alosa alosa*; *sapidissima* = "most delicious" (Latin).

Morone saxatilis (Walbaum, 1792)
Striped bass

DESCRIPTION Body elongate, compressed. Head with acute snout; mouth large, with lower jaw projecting ahead of upper jaw. Maximum body depth three or more times into standard length. Margin of operculum with two sharp spines; margin of preopercle serrate. Lateral line complete and almost straight. Two elongate tooth patches on back of tongue. First and second dorsal fins completely separate. Caudal fin forked.

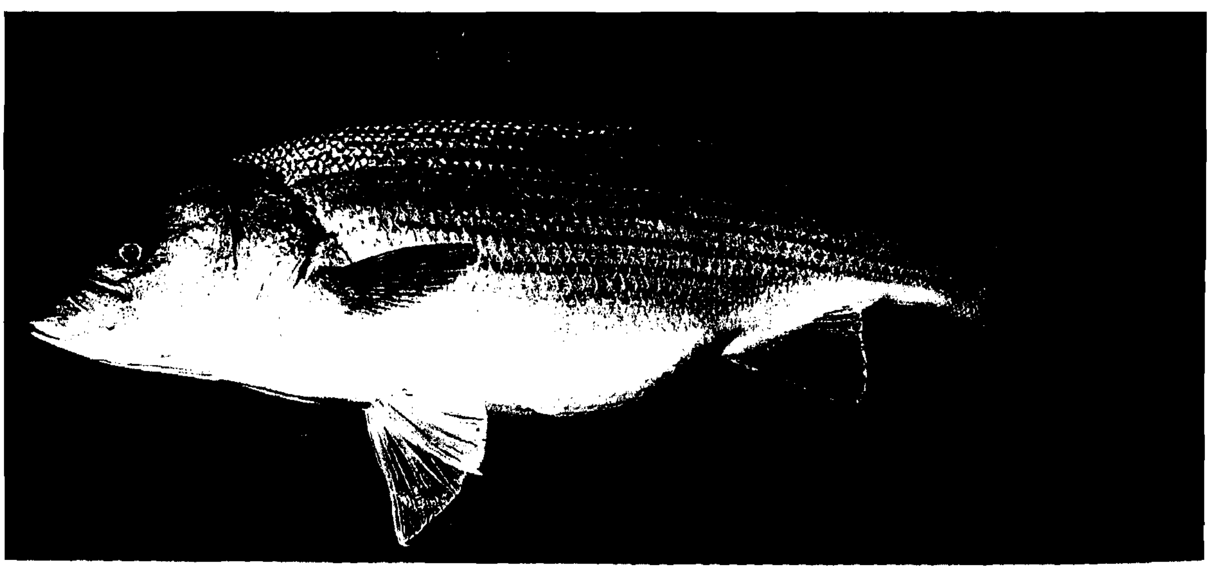
Back dark gray to green. Sides green to silver, shading to white or cream on the belly. Seven or eight continuous black stripes on side: three or four stripes above the lateral line, one containing the lateral line, and three below. Juveniles smaller than 12.7 cm may have vertical bars on the sides.

SIZE Males to 116 cm FL, females possibly to 183 cm. Landlocked striped bass reach 27.5 kg; marine fish may exceed 45 kg. Maximum size in SRS is about 10 kg (Bennett and McFarlane 1983).

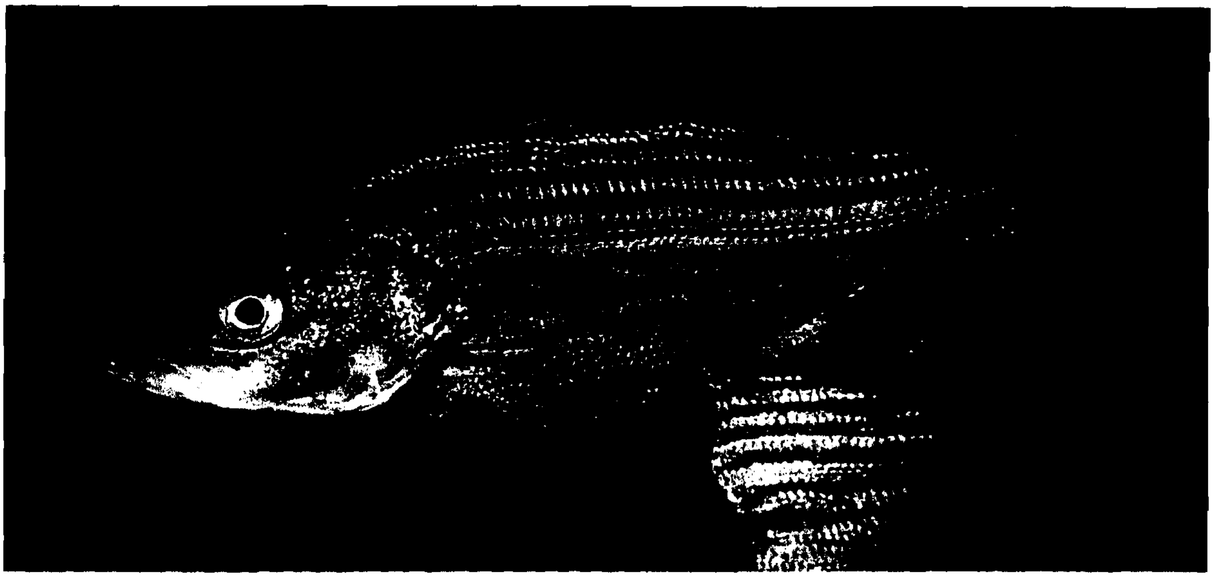
MERISTICS First dorsal spines 8–9, second dorsal spine 1, dorsal rays (9)12(14), anal spines 3, anal rays (7)9–12(13); lateral line scales 50–72, Gulf Coast populations 63–72, Atlantic Coast populations 50–67 (Hardy 1978); gill rakers on lower arch 12–15, on upper arch 6–12.

DISTRIBUTION On the Atlantic Coast, from the St. Lawrence River of Canada and Nova Scotia to the St. Johns River of Florida; in the Gulf of Mexico, from western Florida through the Mobile Bay drainage of Alabama west to Lake Ponchartrain, Louisiana (Burgess *in* Lee et al. 1980). Striped bass (uncertain whether native or introduced) have been taken in marine water in Texas (Hoese and Moore 1977), and may be native in east Texas (Pam Fuller pers. comm.). They were introduced in California and now occur from Ensenada, Mexico, to the Columbia River of Washington (Bain and Bain 1982). Also introduced into the former Soviet Union and South Africa. In the MSRB, most frequently found in the Savannah River, but relatively large numbers ascend larger tributaries such as Upper Three Runs in the summer to avoid warmer river water.

HABITAT Free-flowing rivers, reservoirs, and coastal marine waters with at least some current, over bottoms with gravel, rocks, and vegetation. In marine waters, they are seldom more than 6–8 km from shore (Bigelow and Schroeder 1953). Spawning habitat appears to be fresh water well above the salt wedge in the estuary. Enough current to keep the semipelagic eggs in the water column



Morone saxatilis, striped bass; adult



Morone saxatilis, striped bass; juvenile

is required as well as enough distance above the salt wedge or still water to allow the eggs to hatch before sinking to the bottom. Striped bass seem to avoid temperatures above 21 °C, and larger adults are generally found in deeper water.

BIOLOGY There is an enormous body of literature on the biology of this species, not least because of its economic importance as a sport fish (e.g., see *Transactions of the American Fisheries Society*, especially volumes 110[1], 1981, and 114, 1985; and *Fisheries Management and Ecology*, volume 10[5], 2003). Although the striped bass is generally considered anadromous, some reproducing landlocked and largely riverine populations exist. Striped bass migrate upriver and into tributaries for spring spawning in March, April, and May; larger fish migrate longer distances than smaller fish. Spawning occurs in strong currents of large rivers when the water temperature is above 14.4 °C. Hardy 1978 provides a detailed summary of larval development. Adults usually return to estuaries or coastal marine waters after spawning, but in some populations they may move farther upriver (Dudley et al. 1977); this tendency is more pronounced in the southern part of the range (Crance 1984). The young of nonlandlocked populations spend the first year in coastal estuaries. Where not prevented by dams, they overwinter in estuaries and in coastal marine waters. Populations from New England northward and from Cape Hatteras southward do not move great distances from the mouth of the natal stream; those in the Mid-Atlantic Bight migrate long distances and mingle breeding stocks (Hardy 1978). There is evidence of stream fidelity (Mulligan et al. 1987). Young-of-the-year grow significantly larger in low-salinity estuarine environments than in fresh water (Secor et al. 2000). Males reach sexual maturity at age 2 or 3, females at age 4 or 5. Males may be sexually mature at 18 cm; females can be mature at 36 cm.

Striped bass occur in large, continuously moving schools and feed on schooling fishes such as shads (Stevens 1958; Etnier and Starnes 1993). The larvae feed primarily on crustacean nauplii, switching to larger zooplankton and macroinvertebrates as they grow (Humphries and Cumming 1973). High concentrations of small zooplankton appear necessary for the survival of larvae during the first few days after hatching (Setzler et al. 1980; Cooper and Polgar 1981; Eldridge et al. 1981; Martin et al. 1985; Martin and Wright 1987; and Setzler-Hamilton et al. 1987). There is high mortality during the first winter, and the nutritional condition of the fish determines success in overwintering (Hurst et al. 2000).

SCIENTIFIC NAME *Morone*, meaning unknown; *saxatilis* = "rock dwelling" (Latin).

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