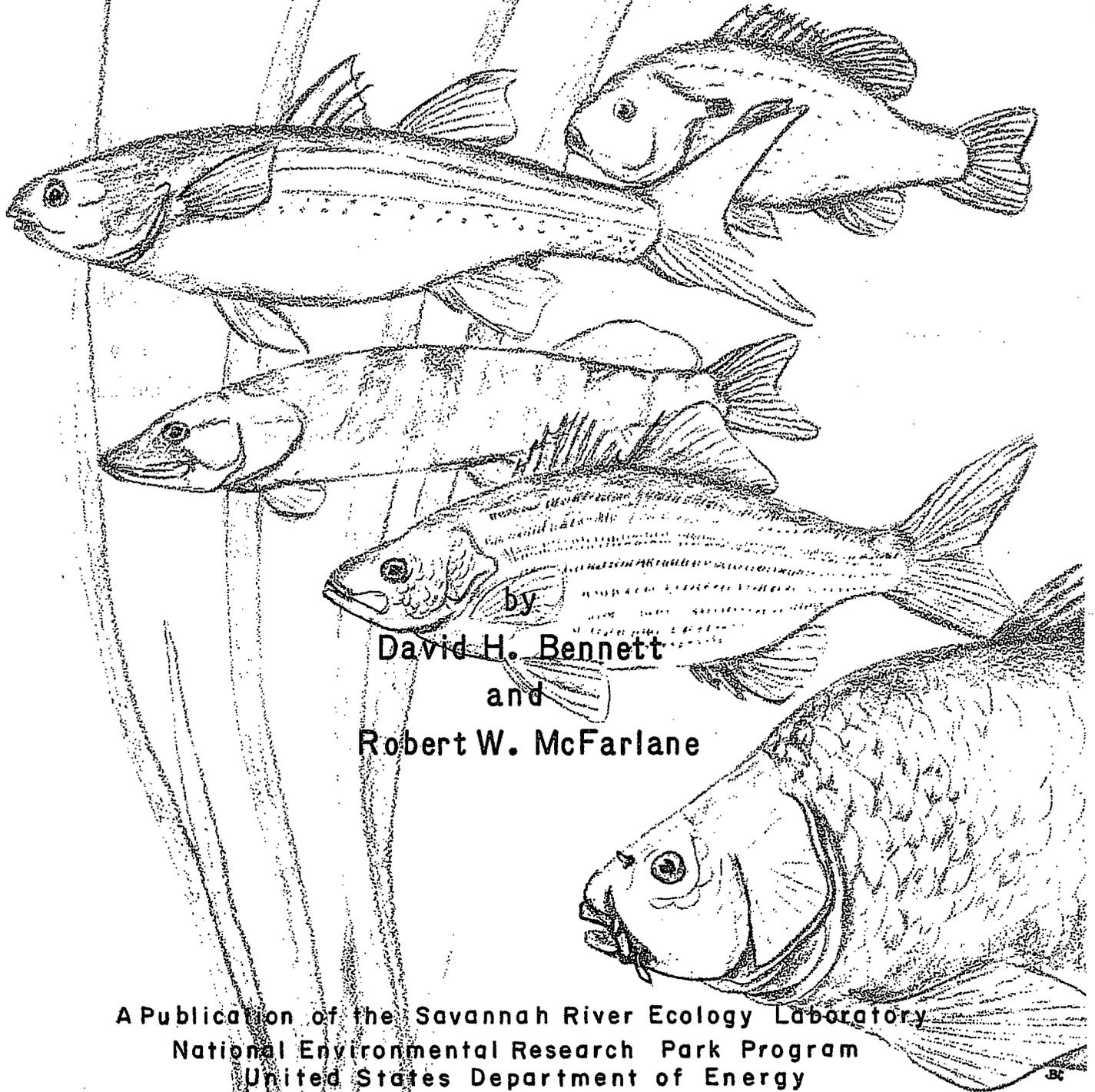


The Fishes of the Savannah River Plant: National Environmental Research Park



by
David H. Bennett
and
Robert W. McFarlane

A Publication of the Savannah River Ecology Laboratory
National Environmental Research Park Program
United States Department of Energy

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

A PUBLICATION OF DOE'S SAVANNAH RIVER PLANT NATIONAL ENVIRONMENTAL RESEARCH PARK

AUGUST, 1983

Copies may be obtained from
Savannah River Ecology
Laboratory

THE FISHES OF THE SAVANNAH RIVER PLANT: *James L. Oliver*

NATIONAL ENVIRONMENTAL RESEARCH PARK

by

David H. Bennett¹

Savannah River Ecology Laboratory

University of Georgia

and

Robert W. McFarlane²

Savannah River Ecology Laboratory

and

Savannah River Laboratory

E. I. duPont de Nemours and Co.

Aiken, South Carolina 29801

¹Associate Professor, Fishery Resources, College of Forestry,
Wildlife and Range Sciences, University of Idaho, Moscow, Idaho 83843

²Environmental Scientist, Brown & Root, Inc.,
P. O. Box 3, Houston, Texas 77001



TABLE OF CONTENTS

<u>Subject</u>	<u>Page</u>
Introduction	4
The Savannah River Plant	6
Groundwater and Surface Water	10
Aquatic Habitat Types	11
Historical Aspects	17
Collection of Samples	19
Measurements	20
Species Accounts	25
List of Fishes Collected on the Savannah River National Environmental Research Park	26
Relative Abundance of Fishes in Riverine Ecosystems	30
Relative Abundance of Fishes in Lentic Ecosystems	39
A Key to Fish Families	46
A Key to Species and Species Descriptions	55
Order Acipenseriformes	55
Acipenseridae - Sturgeon Family	55
Order Semionotiformes	55
Lepisosteidae - Gar Family	55
Key to Species of <u>Lepisosteus</u>	55
Order Amiiformes	57
Amiidae - Bowfin Family	57
Order Anguilliformes	57
Anguillidae - Eel Family	57

Table of Contents (continued)

<u>Subject</u>	<u>Page</u>
Order Clupeiformes	58
Clupeidae - Herring Family	58
Key to Species of Family Clupeidae	59
Order Salmoniformes	63
Umbridae - Mudminnow Family	63
Esocidae - Pike Family	63
Key to Species of <u>Esox</u>	64
Order Cypriniformes	65
Cyprinidae - Minnow Family	65
Key to Species of Family Cyprinidae	66
Catostomidae - Sucker Family	78
Key to Species of Family Catostomidae	79
Order Siluriformes	83
Ictaluridae - Catfish Family	83
Key to Species of Family Ictaluridae	83
Order Percopsiformes	90
Amblyopsidae - Cavefish Family	90
Aphredoderidae - Pirate Perch Family	91
Order Atheriniformes	92
Belonidae - Needlefish Family	92
Cyprinodontidae - Killifish Family	93
Poeciliidae - Topminnow Family	94
Atherinidae - Silverside Family	95

Table of Contents (continued)

<u>Subject</u>	<u>Page</u>
Order Perciformes	96
Percichthyidae - Temperate Bass Family	96
Key to Species of Family Percichthyidae	97
Centrarchidae - Sunfish Family	98
Key to Species of Family Centrarchidae	99
Percidae - Perch Family	113
Key to Species of Family Percidae	114
Mugilidae - Mullet Family	120
Order Pleuronectiformes	121
Soleidae - Sole Family	121
Problem Species: Possible Misidentifications	122
Glossary	124
Acknowledgments	127
Annotated Bibliography	128
Index	144
Appendix I	152

INTRODUCTION

The objective of this report is to update the taxonomic, distributional, and ecological information on fishes inhabiting waters on and adjacent to the Department of Energy's first National Environmental Research Park, known as the Savannah River Plant (SRP). Our intent is to provide background information for biologists initiating ichthyofaunal studies on the SRP. Because of the diversity of backgrounds of ecologists who may incorporate some segment of the ichthyofauna into their research on the SRP, we have purposely omitted use of unnecessary technical terminology. We feel that through this approach, the report will serve a broader audience of ecologists than those formally trained in the fisheries discipline. We also realize that much of the information contained in this document should be modified when additional information is available; consequently, we view this report more as a workbook than a "text."

Distributional reports of the ichthyofauna of various drainage systems or areas delimited by state boundaries are common for many parts of the United States. Accounts and keys of the freshwater fishes of the U. S. are given in major contributory works by Eddy (1957, 1969) and Blair et al. (1968). These keys are especially useful for the identification of various fish species when keys more regional in scope are not available.

Published checklists and/or keys to fishes in the southeastern U. S. have been completed for several states. Although a comprehensive report of the fishes of South Carolina has not been completed, information reported in proximal areas has been used heavily in this report. Loyacano (1975) published a checklist of fishes by drainages for South Carolina. Because most of the streams on the SRP drain into the Savannah River, Loyacano's report for the Savannah River drainage was helpful.

Another useful report on fishes from the Savannah River drainage is that by Dahlberg and Scott (1971a). Earlier reports by Fowler (1945) and especially the presentation of fishes of the SRP (Freeman 1954) have been used heavily in fortifying our distributional records.

Much energy has been expended in ecological research on fishes that occur on the SRP. Most of the published studies have examined some aspect of environmental perturbation associated with the operations of the SRP. The original bibliography of these studies (Murphy and Gibbons 1977) and an updated, more-inclusive version (Wiener and Smith 1981) have been invaluable sources of materials on aquatic studies. Further information regarding many SRP fishes may be found in Smith-Vaniz (1968), Carlander (1969, 1977), Douglas (1974), and Pflieger (1975).

THE SAVANNAH RIVER PLANT

The Savannah River Plant, located in west-central South Carolina, includes portions of Aiken, Barnwell, and Allendale counties (Fig. 1). The SRP lies approximately 20 km (12 mi) south of Aiken and 25 km (15 mi) east of Augusta, Georgia. The Savannah River, bordering the SRP on the southwest, is a large (100 m wide), low gradient (maximum 50 cm/km) river having an expansive flood plain and several oxbow lakes. The river provides cooling water for the SRP via pumping stations at two large canals.

The northwestern boundary of the SRP, which lies within the Atlantic Coastal Plain, is approximately 50 km (30 mi) south of the Fall Line (Fig. 2). Most of the streams on the SRP flow through or originate in the Sandhills or Upper Coastal Plain and are tributaries of the Savannah River which flows through the Lower Coastal Plain. The relief of this area is slight, including narrow, flat-bottomed, steep-sided valleys and rolling interfluvial areas (Siple 1967).

The climate on the SRP is typical of the southern Atlantic Coastal Plain. Precipitation, in the form of rainfall, averages 91-112 cm (36 to 44 in). Snow occurs rarely in the area. Months of highest rainfall are March, July and December. Mean annual temperature is 18° C (64° F). January and July are normally the coldest and warmest months of the year.

Land acquired by the U. S. Government for the SRP in 1951 was primarily in pine-hardwood forests or intensively farmed for corn and cotton. Since the time of land acquisition for the SRP, the U. S. Forest Service has converted most of the abandoned farm lands into managed, pine tree production sites. Lands not suited for pine planting have progressed toward a scrub oak-longleaf pine climax forest type. A very small proportion of the 780 km² (~ 300 mi²) area has been developed for the production of nuclear isotopes

and disposal of radioactive wastes. Most of the land area encompassed by the SRP is protected from the public by intensive security activities and regulations.

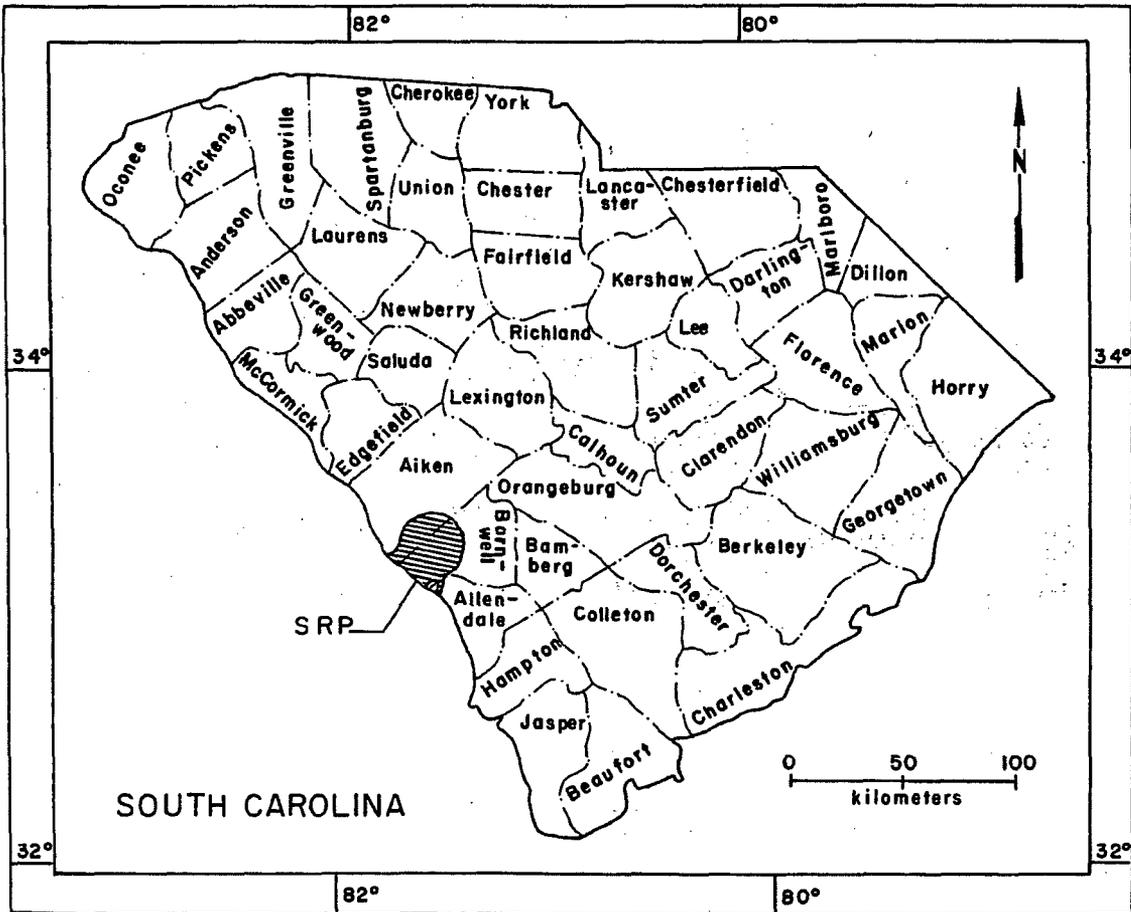


Figure 1. Location of the Savannah River Plant in South Carolina.

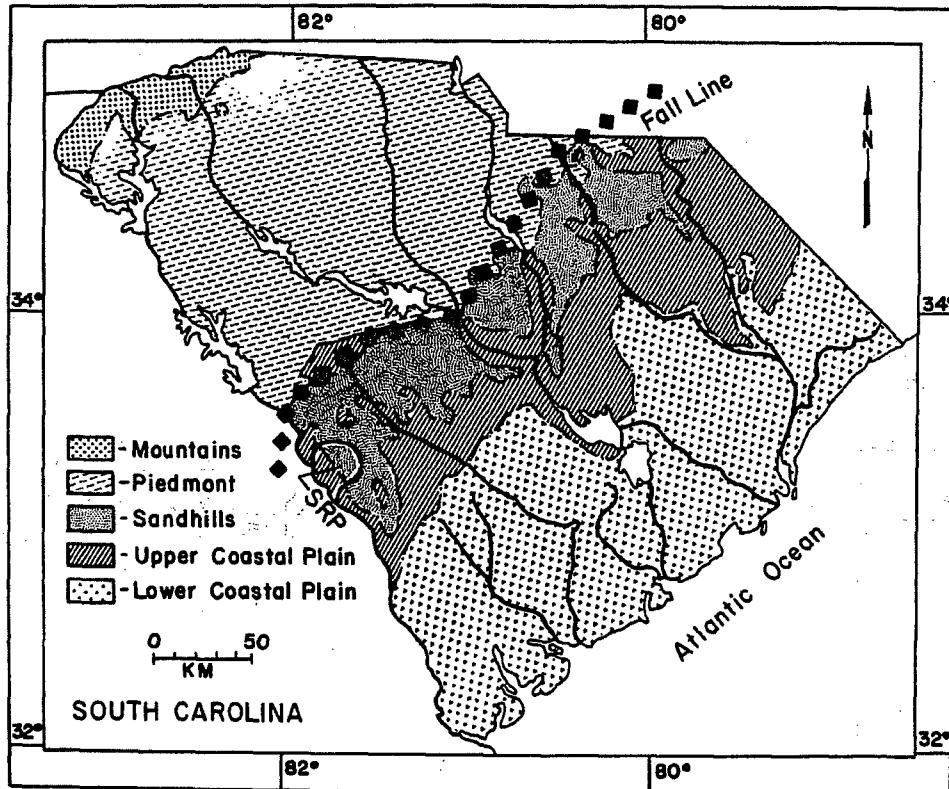


Figure 2. Location of the Savannah River Plant in relation to the physiographic regions in South Carolina.

GROUNDWATER AND SURFACE WATER

Quantity and quality of groundwater are affected by four basic geological formations on the SRP. These geological formations are unconsolidated sedimentary units: the Tuscaloosa Formation; the Ellenton Formation; the Tertiary (Eocene) Limestone; and, the Tertiary (Eocene) Sands (Siple 1967). Each of these formations contains water differing in water quality from that of the others.

Test wells in each of these formations have provided information on characteristics of groundwater emanating from these strata (Langley and Marter 1973). Water from the Tuscaloosa Formation is generally low in hardness (5 mg/l, CaCO_3), acidic, and low in dissolved solids. Water from the Ellenton Formation is low in dissolved solids (41 mg/l), low in hardness (median = 19 mg/l CaCO_3), high in iron (71 mg/l) and sulfate anions. Water from the limestone beds of the Eocene sediments has higher levels of dissolved solids and higher hardness (median = 72 mg/l CaCO_3). Water from the Tertiary Sands is similar in chemical composition to that of the Tuscaloosa Formation. The temperature of water from these formations ranges from 18° to 22° C (65° to 71° F). The quality of the ground water, in turn, reflects the surface water quality.

Surface water from the area is generally low in dissolved solids, iron, and total hardness. The pH of most streams on the SRP ranges from 6 to 7, while the Salkehatchie River is slightly more alkaline (pH ~ 7.3). The disposal of radioactive wastes in the area has had no measurable effect on the water quality (Siple 1967).

AQUATIC HABITAT TYPES

Six major aquatic habitat types occur on the SRP: small ponds, reservoirs, streams, the Savannah River, the river swamp, and Carolina bays. The standing waters vary in size from less than 0.1 to 1220 ha ($< \frac{1}{4}$ acre to about 2800 acres). Natural flows in the various streams range from less than 0.03 to $2.8 \text{ m}^3/\text{second}$ (1 to 100 cfs).

Small Ponds: A number of small, man-made ponds ranging in surface area from 0.1 to 1.2 ha ($< \frac{1}{4}$ to 3 acres) currently exist on the SRP. Some were farm ponds, constructed when the area was still under private ownership and were stocked with a variety of warmwater fish species. Others have resulted from cooling water canal or other construction projects.

Reservoirs: The need for water to cool nuclear production reactors on the SRP resulted in construction of two large impoundments, Par Pond and Pond B. Par Pond currently provides cooling water for a nuclear reactor and consequently receives artificially heated waters. Par Pond is about 1220 ha (2800 acres), including the 64 ha pre-cooling reservoir, Pond C. Par Pond has been the site of numerous studies primarily directed at evaluating the impact of thermal intrusions on lentic species (Gibbons and Sharitz 1974; Gibbons et al. 1975; Tilly 1975; Murphy and Gibbons 1977; Gibbons, Sharitz and Brisbin 1980; Gibbons and Sharitz 1981).

The other reservoir, Pond B (118 ha), is in a post-thermal recovery state. Thermal additions to Pond B ceased in 1964. The resulting responses by the biota in this reservoir have been lightly studied (Parker, Hirshfield, and Gibbons 1973; Gibbons and Sharitz 1974) and deserve more intensive research efforts.

Streams: Five major tributaries of the Savannah River are encompassed by the SRP in addition to several smaller streams (Fig. 3). The largest and

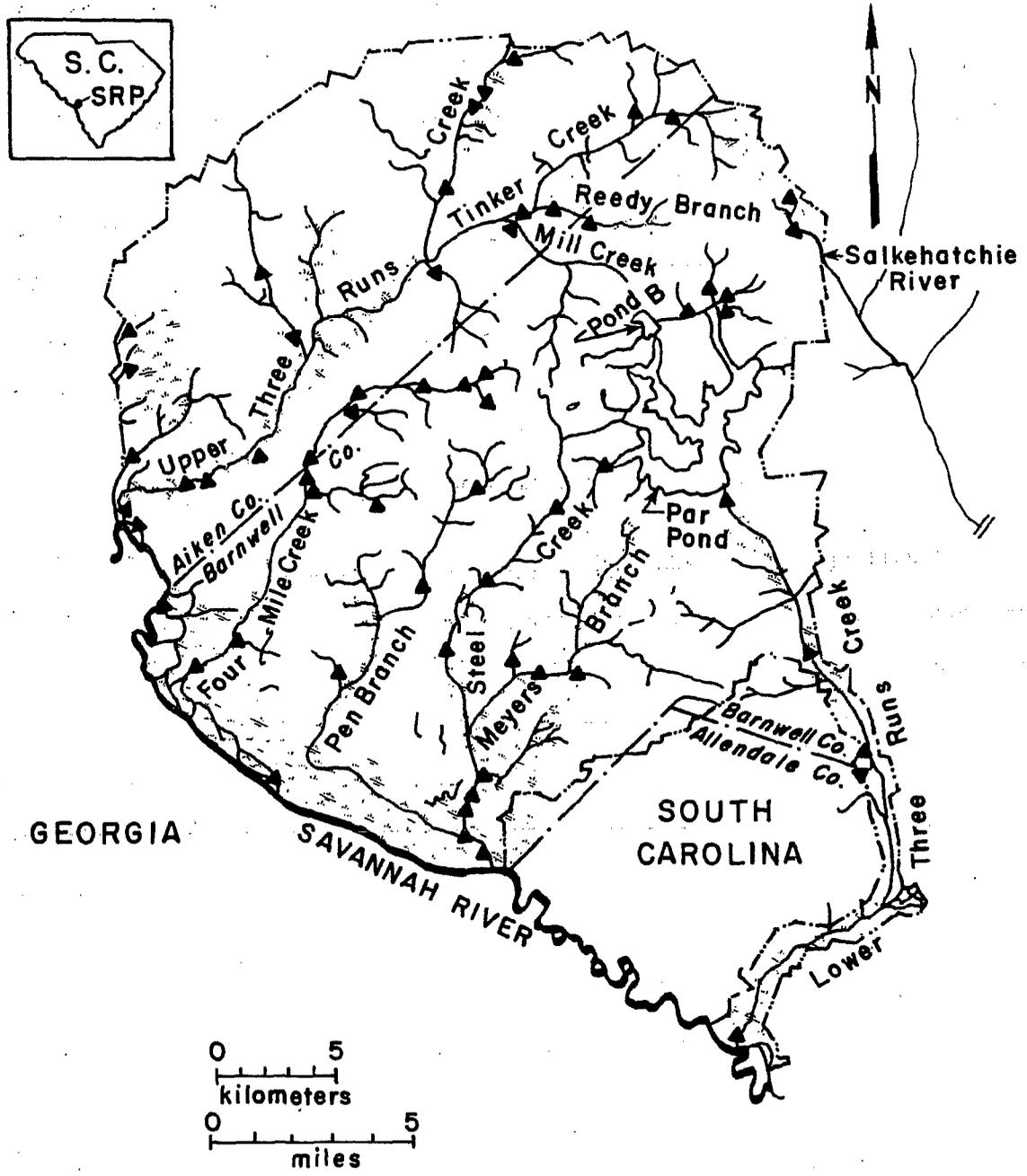


Figure 3. SRP collecting stations sampled by the authors from 1974 to 1978.

least disturbed of these is Upper Three Runs, a deep, swift blackwater stream 39 km long with a 490 km² drainage basin. This is the only stream which originates, and has a substantial portion of its watershed, beyond the SRP boundary. Upper Three Runs receives some industrial pollutants from Steed's Pond via Tim's Branch, which joins the stream just below the Savannah River Laboratory (SRL) Flowing Streams Lab. Because of this pollution, Tim's Branch has an impoverished ichthyofauna. In contrast, Upper Three Runs Creek possesses a very rich fauna and is minimally affected, if at all, by the entry of Tim's Branch. Upper Three Runs Creek has never been subjected to thermal perturbation, and most of its passage through the SRP is beneath an overhead canopy of bottomland hardwood trees.

Of similar size is Lower Three Runs, 38 km long with a 465 km² basin, which arises within the SRP and is encompassed by only a narrow corridor of SRP-owned lands for most of its length. This stream transported thermal effluent from 1953 to 1958. Since that time the impoundment of its upper extremity to create Par Pond has reduced stream flow considerably and altered water quality because of input into Par Pond from the Savannah River. Sixty different species of fishes have been collected from Upper and Lower Three Runs. Each stream has 55 species. These streams provide an adequate base for comparison with the smaller SRP streams which have been subjected to various environmental stresses.

Three adjacent streams drain the southern half of the SRP and flow into the floodplain swamp before reaching the river. Four Mile Creek (20 km long, 90 km² basin) has transported thermal effluent since 1955. Pen Branch (16 km long, 90 km² basin) has received thermal effluent since 1954. Steel Creek (15 km long, 90 km² basin) received thermal effluent from 1954 until 1968. During reactor operations the thermal streams experience temperatures from

a high near 80° C at the reactor outfall to approximately 40° C where they enter the swamp. These high temperatures exclude fishes from most of the thermally-stressed segments of the streams. Thermally non-stressed, upstream tributaries have also suffered a decline in species richness (McFarlane 1976). During reactor shutdown, waters with decreasing temperatures are rapidly invaded by numerous fish species. In addition to thermal stress, these streams have been modified by increased stream flow which produces erosion, siltation, aggradation, and the removal of aquatic vegetation and overhead canopy. Thus, the fishes of post-thermal Steel Creek are substantially different and more diverse than those of the undisturbed streams (McFarlane 1976).

One small stream that deserves mention because of the high stress conditions is Beaver Dam Creek, which receives thermal effluent from an electric power generating plant and chemical effluent from a heavy water production facility. Its upper reaches are subject to rapid fluctuations in pH, ranging from 1.5 to 13. The greater portion of the stream is inundated by Savannah River flood waters for lengthy periods.

The Salkehatchie River, originating on the SRP, is the only SRP stream that is outside of the Savannah River drainage. All of the species known from this segment of the Salkehatchie River are also found in other SRP streams. The limited fauna reported from this stream reflects its small size within the SRP.

Savannah River: The Savannah River basin is approximately 28,000 km², of which 20,800 km² lies upstream from the SRP. The river gradient in the vicinity of the SRP is 0.12 m/km. The mean annual discharge at this point is 316 m³/second (McFarlane et al. 1978, 1979). Peak flow and maximum variability in flow occur in March and April, while the lowest flow and least

variability are found during the summer and fall. The 7-day, 10-year minimum flow at the SRP site is estimated to be $160 \text{ m}^3/\text{second}$ ($\sim 5700 \text{ cfs}$). At flood stage the water mass breaches the channel to form a floodplain up to 3 km wide, and flow may approach $1200 \text{ m}^3/\text{second}$. Stream velocity is approximately $0.74 \text{ m}/\text{second}$ at mean annual discharge and $0.65 \text{ m}/\text{second}$ at 7-day, 10-year low flow (McFarlane et al. 1978, 1979).

The river characteristics are currently dominated by the release of hypolimnetic water from Clark Hill Reservoir. Its principal effects have been to decrease the incidence of both extreme high and low discharge, and to decrease the average river temperature by 3° C (McFarlane et al. 1978).

River Swamp: The floodplain swamp bordering the river is the least known aquatic habitat on the SRP from an ichthyofaunal standpoint. Its role as spawning and rearing grounds and as a nutrient sink are both unknown and generally unrecognized. This habitat is very diverse as definite water courses alternate with braided channels and broad flats of barely perceptible water movement. It is also one of the most variable habitats, experiencing depth fluctuations of 4 m or more and the input of thermal effluent from three SRP sources.

Fishes are, at times, very abundant in the river swamp and certain localities, such as the fabled "Honeyhole," attract large numbers of gar, bowfin and carp during winter. The logistic difficulties of systematic data collection within the swamp have limited investigations. Oxbow lakes and drying potholes teem with fishes, but little is known regarding their relative abundance.

Carolina Bays: Carolina bays, natural aquatic environments found across the coastal plain region of Georgia and the Carolinas, are scattered over the SRP. The most interesting aspect of Carolina bays, from a fishery stand-

point, is that they have widely fluctuating water levels, highly dependent on precipitation. Many of these natural aquatic systems periodically dry up and consequently, provide only temporary habitat for fishes.

HISTORICAL ASPECTS

The fishes of the study area received little attention from scientific workers until the decision of the United States Atomic Energy Commission to construct the SRP in the early 1950's. This action precipitated ichthyo-faunal collecting by three different groups.

The Academy of Natural Sciences of Philadelphia (ANSP) initiated biological surveys of the Savannah River in June, 1951 (Academy of Natural Sciences of Philadelphia 1953, 1955, 1957, 1961, 1962, 1963, 1967, 1969, 1970a, 1970b, 1973, 1974a, 1974b, 1976, 1977). cursory surveys have been conducted at upstream and downstream stations almost yearly since then. Complete faunal surveys at these and other stations have occurred at longer, less regular intervals. The numerous ANSP reports provide the longest documentation of fishes occurring at specific localities and collected by identical techniques for the SRP. These reports have emphasized the number of fish species present at each locality over time. They do not, however, provide quantitative information on the relative abundance of each species and were principally designed to examine effects upstream and downstream from the SRP. The upstream station (River Mile 160) was located at the former SRP boundary, property now managed by the U. S. Forest Service. The downstream station (River Mile 123) is a considerable distance below the SRP proper. The reader of these reports should be aware that channelization of the Savannah River has altered the designated river mile of the original stations by as much as 22 km (14 miles).

Simultaneously with the ANSP collections, the U. S. Public Health Service (USPHS) sampled fishes throughout a more extensive portion of the Savannah River. This baseline study resulted in a single interim report (Gold et al. 1954) which provides an interesting watershed perspective.

Beyond the efforts of the ANSP and USPHS, the fishes of the central Savannah River have received very little attention. Although the river has supported both commercial and sports fisheries for many years, its role as a state boundary appears to have diverted the interests of the state agencies toward waterways entirely within their jurisdiction or to the upstream impoundments. Similarly, most fish ecology studies at the SRP have focused upon onsite aquatic habitats, rather than the river, with emphases on demonstrating the effects of thermal alteration or patterns of radionuclide contamination or on gathering basic data on the presence and abundance of species.

The fishes of the streams and ponds of the SRP were studied by the University of South Carolina from July 1951 to February 1953 (Freeman 1952, 1954). The ANSP surveys collected additional information from a single station on Upper Three Runs during 1951, 1952, and 1956. The subsequent acquisition of the Lower Three Runs corridor directed attention to that stream in 1957-58 (Freeman 1958) and 1960-72 (Academy of Natural Sciences of Philadelphia 1961, 1962, 1963, 1969, 1973).

Construction of Par Pond in 1958 and Pond B in 1961 created major lentic habitats on the SRP. Most species of fishes found at these sites inhabited Joyce Branch of Lower Three Runs at the time of impoundment. However, the presence in Par Pond of a few fish species atypical of headwater tributaries attests to the efficacy of the pumping system in transporting fish as a result of the entrainment of fish eggs, larvae, and juveniles from the Savannah River. These reservoir habitats have attracted the attention of numerous workers of the University of Georgia's Savannah River Ecology Laboratory (SREL) and the Georgia Cooperative Fishery Research Unit.

COLLECTION OF SAMPLES

Collections of fishes from various aquatic habitats on the SRP have varied with the type of habitat, season, species, and personnel. In general, the collecting techniques used have been suited to the habitat. Most of the smaller streams have been sampled with seines, dip nets, electrofishing, and occasionally rotenone. The riverine habitats (e.g., Upper Three Runs Creek), especially in the lower sections, have been sampled with electrofishing gear from boats, and with seines, traps, and rotenone. The Savannah River has been sampled by boat-mounted electrofishing gear, traps, seines, and trammel nets. The sampling of lentic waters has been conducted with rotenone, boat-mounted electrofishing, seining, minnow traps, gill and trammel nets, trot lines, and rod and reel. Collections of smaller shoreline fishes (Gambusia, Fundulus, etc.) and collections in shallow bays and marshes have been made primarily with dip nets.

Most fish sampling on the SRP has been qualitative. Samples taken in the early 1950 surveys were more concerned with species composition than in obtaining quantitative estimates of density. The only quantitative sampling has been conducted in Par Pond with largemouth bass (Gibbons and Bennett 1973). Estimates of relative abundance have been developed for Par Pond from rotenone cove samples (Clugston 1973b); estimates of general fish abundance from other waters on the SRP developed in this report, are based on catch/effort data.

Specimens collected during the 1978 survey by the senior author are on deposit at SREL. Some specimens collected by various investigators associated with SREL are also on deposit at the same location. Collections made by McFarlane et al. (1978) are, unfortunately, no longer available. Freeman's collections (1954, 1958) are deposited in the National Museum of Natural History, Washington, D. C.

Distributional reports for SRP fishes are based on recent collections made by the authors during the period of 1974-1978 and surveys conducted prior to plant operations (Freeman 1954). Collections were made at numerous unnamed riverine sites by the authors (Fig. 3) and by other investigators (Fig. 4). Many of the lentic collecting sites are identified by local names (Fig. 5).

MEASUREMENTS

Standard methods of measuring and counting scales were employed, but the anatomical nomenclature used throughout this report has been kept as elementary as possible (Figs. 6 and 7). We have purposely avoided using scale counts when possible. If counts must be used, refer to Blair et al. (1968).

The spines and/or soft rays of the pectoral, pelvic, dorsal and anal fins (Fig. 6) are particularly useful in the identification of fishes in this region. Spines are never segmented or branched, whereas soft rays are always segmented and may be branched. Formulas are used to describe the number of spines and/or soft rays as follows: the number of fin spines is written first, in Roman numerals; and the number of fin rays is written second, in Arabic. If a space occurs between the spines and soft rays, the two numbers are separated by a dash, whereas if they are united, a comma separates the fin types. For example, a species with a spinous dorsal with six spines and ten soft rays would be written VI,10 (if the spines and rays were separate, the formula would be written as VI-10). An example of a fin ray count is shown in Fig. 7B.

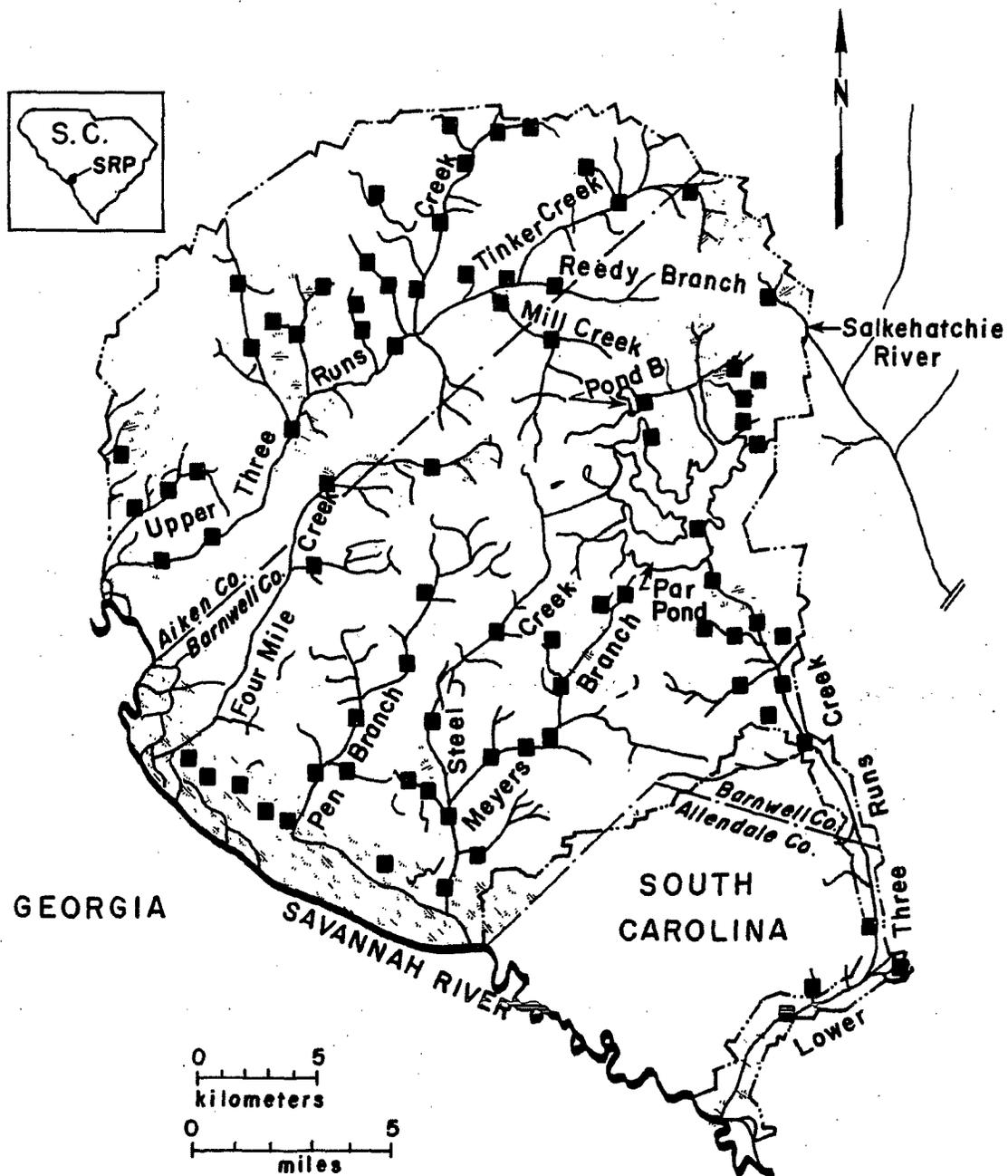


Figure 4. Approximate locations of fish collection sites known to have been sampled by previous investigators on the SRP.

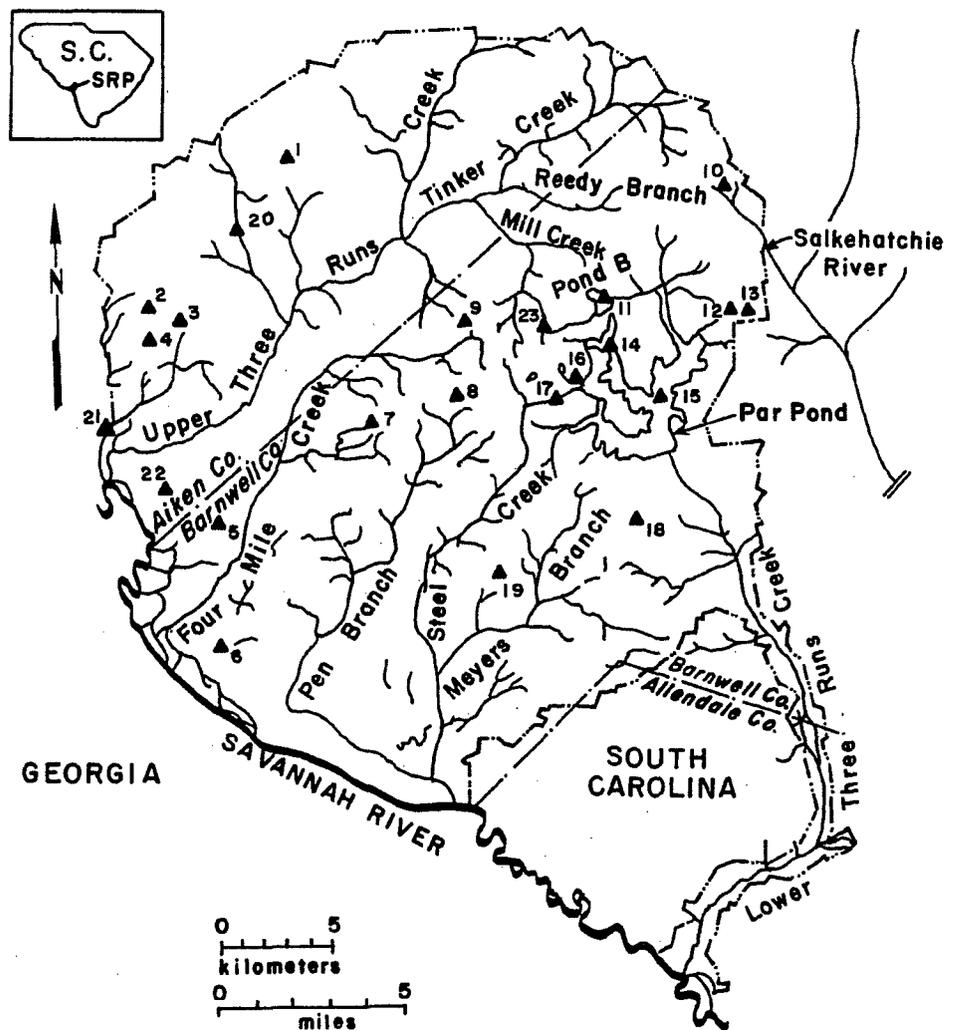


Figure 5. Identification and approximate locations of lentic aquatic ecosystems on the SRP.

- | | |
|--------------------|-------------------|
| 1. Karen's Pond | 13. Craig's Pond |
| 2. A-1 Pond | 14. Pond C |
| 3. Dry Bay | 15. Par Pond |
| 4. Morse Code Bay | 16. Pond 4 |
| 5. Asphalt Pond | 17. Pond 2 |
| 6. Risher Pond | 18. B Swamp |
| 7. Twin Lakes | 19. Pond 9 |
| 8. C-5 Bay | 20. Steed Pond |
| 9. Dick's Pond | 21. Skinface Pond |
| 10. Moon Lake | 22. Ellenton Bay |
| 11. Pond B | 23. R Canal |
| 12. Sarracenia Bay | |

Sites 6, 7, 9, 20 and 21 are farm ponds.

Sites 2, 3, 4, 8, 10, 12, 13, 18, and 22 are Carolina bays.

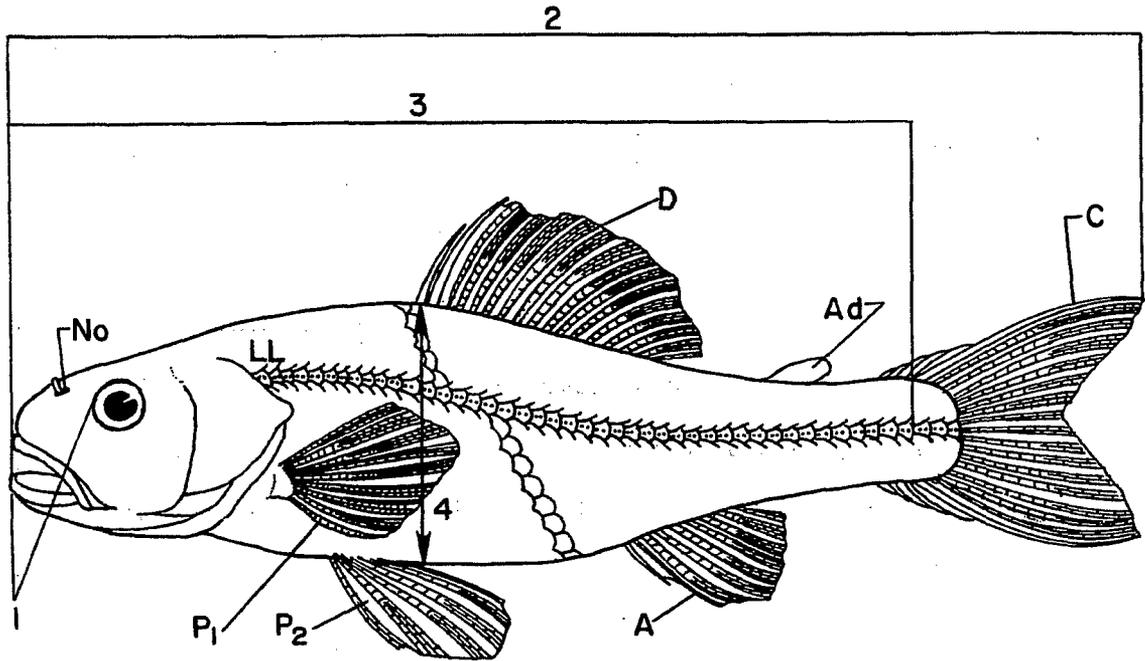


Figure 6. External features of a fish (after Eddy 1957; Blair et al. 1968). A = anal fin; Ad = adipose fin; C = caudal fin; D = dorsal fin; LL = lateral line; No = nostrils; P₁ = pectoral fin; P₂ = pelvic fin; 1 = snout length; 2 = total length; 3 = standard length; 4 = body depth (maximum). (See Appendix I).

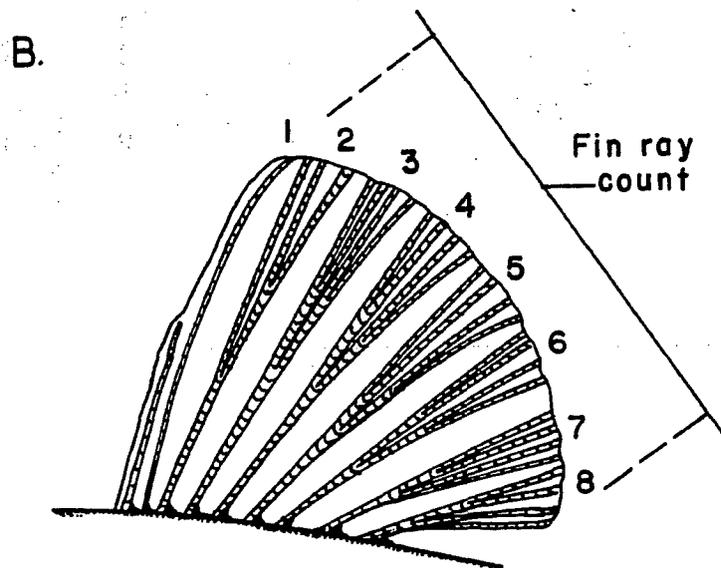
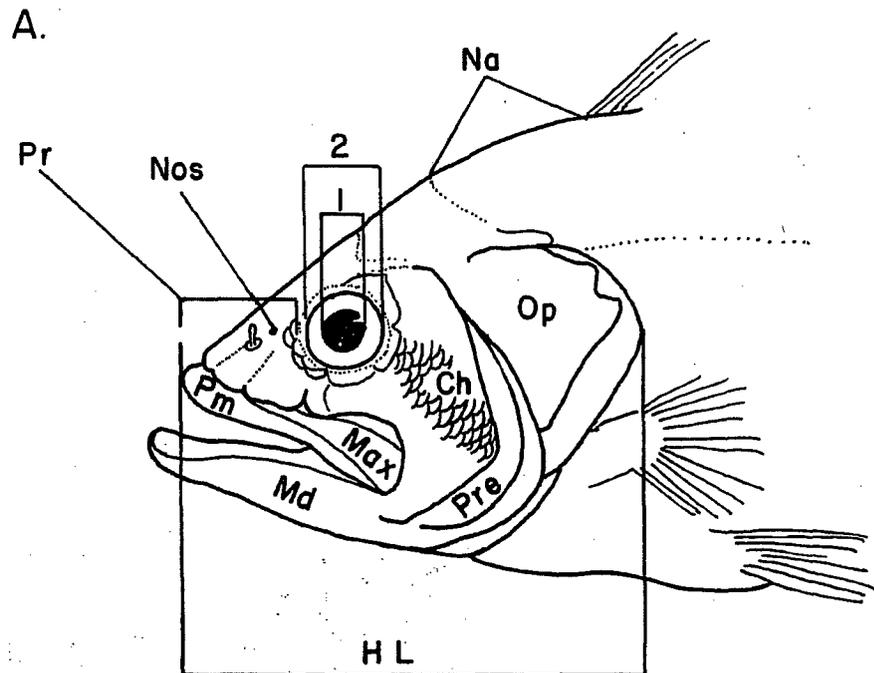


Figure 7A. Head of a fish showing external structures (after Bailey, 1951). Ch = cheek; HL = head length; Max = maxilla; Md = mandible; Na = nape; Nos = nostril; Pm = premaxilla; Pre = preopercle; Pr = preorbital length (snout length); Op = opercle; 1 = diameter of pupil; 2 = diameter of eye.

Figure 7B. Dorsal fin, showing how fin ray counts are made from Hubbs and Lagler 1947). (See Appendix I).

SPECIES ACCOUNTS

Seventy-nine species of resident and anadromous fishes have been collected on the Savannah River Plant's National Environmental Research Park (Table 1). These fishes represent 12 orders and 21 families. The following accounts are to assist investigators in rapid identification of the species and to document the distribution of these species in the various aquatic systems on the SRP. Basic ecological information is given to provide preliminary background knowledge to investigators not familiar with local species on the SRP or with freshwater fishes in general.

The following scheme of classifying relative abundance has been used in this report.

A - abundant: collected in large numbers in suitable habitats during the proper seasons.

C - common: collected in smaller numbers in suitable habitats during the proper season.

U - uncommon: collected occasionally in small numbers in the appropriate habitats and seasons.

R - rare: seldom encountered at any locality.

+ - present: collected but abundance is indefinite.

? - questionable presence: reported in literature.

The relative distributions of various species collected on the SRP from riverine habitats is shown in Table 2 and from lentic habitats in Table 3. Two lentic habitats (Craig's Pond, and C-5 Bay) have been sampled without success and fish are presumed absent. The diverse fauna of Skinface Pond probably reflects the intrusion of species from the Savannah River swamp following flooding. The Par Pond fauna is also affected by the river by means of entrainment, rather than direct migration.

Table 1. List of fishes (Class Osteichthyes) collected on the Savannah River National Environmental Research Park

<u>Order</u>	<u>Family</u>	<u>Species</u>	<u>Common Name</u>
Acipenseriformes	Acipenseridae	<u>Acipenser oxyrhynchus</u>	Atlantic sturgeon
Semionotiformes	Lepisosteidae	<u>Lepisosteus osseus</u>	longnose gar
		<u>Lepisosteus platyrhincus</u>	Florida gar
Amiiformes	Amiidae	<u>Amia calva</u>	bowfin
Anguilliformes	Anguillidae	<u>Anguilla rostrata</u>	American eel
Clupeiformes	Clupeidae	<u>Alosa aestivalis</u>	blueback herring
		<u>Alosa sapidissima</u>	American shad
		<u>Dorosoma cepedianum</u>	gizzard shad
		<u>Alosa mediocris</u>	hickory shad
		<u>Dorosoma petenense</u>	threadfin shad
Salmoniformes	Umbridae	<u>Umbrina pygmaea</u>	eastern mudminnow
	Esocidae	<u>Esox niger</u>	chain pickerel
		<u>Esox americanus</u>	redfin pickerel
Cypriniformes	Cyprinidae	<u>Cyprinus carpio</u>	carp
		<u>Hybognathus nuchalis</u>	silvery minnow
		<u>Hybopsis rubrifrons</u>	rosyface chub
		<u>Nocomis leptcephalus</u>	bluehead chub
		<u>Notemigonus crysoleucas</u>	golden shiner
		<u>Notropis chalybaeus</u>	ironcolor shiner
		<u>Notropis cummingsae</u>	dusky shiner

Table 1. Continued

<u>Order</u>	<u>Family</u>	<u>Species</u>	<u>Common Name</u>	
Cypriniformes	Cyprinidae (cont.)	<u>Notropis emiliae</u>	pugnose minnow	
		<u>Notropis hudsonius</u>	spottail shiner	
		<u>Notropis hypselopterus</u>	sailfin shiner	
		<u>Notropis leedsii</u>	bannerfin shiner	
		<u>Notropis lutipinnis</u>	yellowfin shiner	
		<u>Notropis maculatus</u>	taillight shiner	
		<u>Notropis niveus</u>	whitefin shiner	
		<u>Notropis petersoni</u>	coastal shiner	
		<u>Semotilus atromaculatus</u>	creek chub	
		Catostomidae	<u>Carpiodes cyprinus</u>	quillback
			<u>Erimyzon oblongus</u>	creek chubsucker
			<u>Erimyzon sucetta</u>	lake chubsucker
			<u>Hypentelium nigricans</u>	northern hogsucker
			<u>Minytrema melanops</u>	spotted sucker
			<u>Moxostoma anisurum</u>	silver redhorse
Siluriformes	Ictaluridae	<u>Ictalurus brunneus</u>	snail bullhead	
		<u>Ictalurus catus</u>	white catfish	
		<u>Ictalurus natalis</u>	yellow bullhead	
		<u>Ictalurus nebulosus</u>	brown bullhead	
		<u>Ictalurus platycephalus</u>	flat bullhead	
		<u>Ictalurus punctatus</u>	channel catfish	
		<u>Noturus gyrinus</u>	tadpole madtom	
		<u>Noturus insignis</u>	margined madtom	

Table 1. Continued

<u>Order</u>	<u>Family</u>	<u>Species</u>	<u>Common Name</u>
Siluriformes	Ictaluridae (cont.)	<u>Noturus leptacanthus</u>	speckled madtom
		<u>Pylodictis olivaris</u>	flathead catfish
Percopsiformes	Amblyopsidae	<u>Chologaster cornuta</u>	swampfish
	Aphredoderidae	<u>Aphredoderus sayanus</u>	pirate perch
Atheriniformes	Belonidae	<u>Strongylura marina</u>	Atlantic needlefish
	Cyprinodontidae	<u>Fundulus lineolatus</u>	lined topminnow
	Poeciliidae	<u>Gambusia affinis</u>	mosquitofish
	Atherinidae	<u>Labidesthes sicculus</u>	brook silverside
Perciformes	Percichthyidae	<u>Morone chrysops</u>	white bass
		<u>Morone saxatilis</u>	striped bass
	Centrarchidae	<u>Acantharchus pomotis</u>	mud sunfish
		<u>Centrarchus macropterus</u>	flier
		<u>Elassoma zonatum</u>	banded pygmy sunfish
		<u>Enneacanthus chaetodon</u>	blackbanded sunfish
		<u>Enneacanthus gloriosus</u>	bluespotted sunfish
		<u>Lepomis auritus</u>	redbreast sunfish
		<u>Lepomis cyanelus</u>	green sunfish
		<u>Lepomis gibbosus</u>	pumpkinseed
		<u>Lepomis gulosus</u>	warmouth
<u>Lepomis macrochirus</u>	bluegill		

Table 1. Continued

<u>Order</u>	<u>Family</u>	<u>Species</u>	<u>Common Name</u>
Perciformes	Centrarchidae (cont.)	<u>Lepomis marginatus</u>	dollar sunfish
		<u>Lepomis microlophus</u>	reëdar sunfish
		<u>Lepomis punctatus</u>	spotted sunfish
		<u>Micropterus salmoides</u>	largemouth bass
		<u>Pomoxis annularis</u>	white crappie
		<u>Pomoxis nigromaculatus</u>	black crappie
	Percidae	<u>Etheostoma fricksium</u>	Savannah darter
		<u>Etheostoma fusiforme</u>	swamp darter
		<u>Etheostoma hopkinsi</u>	Christmas darter
		<u>Etheostoma inscriptum</u>	turquoise darter
		<u>Etheostoma olmstedi</u>	tessellated darter
		<u>Etheostoma serriferum</u>	sawcheek darter
		<u>Perca flavescens</u>	yellow perch
		<u>Percina nigrofasciata</u>	blackbanded darter
	Mugilidae	<u>Mugil cephalus</u>	striped mullet
Pleuronectiformes	Soleidae	<u>Trinectes maculatus</u>	hogchoker

Table 2. Relative abundance of fishes in various riverine ecosystems on the Savannah River Plant. No entry means that no record currently exists of the species in the particular habitat although it has been reported from other areas on the SRP.

SPECIES	UPPER THREE RUNS CREEK	FOUR MILE CREEK	PEN BRANCH CREEK	STEEL CREEK	LOWER THREE RUNS CREEK	SALKEHATCHIE RIVER	SAVANNAH RIVER	SAVANNAH RIVER SWAMP	BEAVER DAM CREEK
Atlantic sturgeon (<u>Acipenser oxyrhynchus</u>)							R		
longnose gar (<u>Lepisosteus osseus</u>)	C	C			C		C	+	
Florida gar (<u>L. platyrhincus</u>)		R		R			R	+	
bowfin (<u>Amia calva</u>)	A	C		U	A		C	+	
American eel (<u>Anguilla rostrata</u>)	A	U	C	C	A		A	+	U
blueback herring (<u>Alosa aestivalis</u>)	+			+	+		A	+	
hickory shad (<u>A. mediocris</u>)							R		
American shad (<u>A. sapidissima</u>)				+			A		
gizzard shad (<u>Dorosoma cepedianum</u>)		U			+		C	C	C

Table 2. Continued.

SPECIES	UPPER THREE RUNS CREEK	FOUR MILE CREEK	PEN BRANCH CREEK	STEEL CREEK	LOWER THREE RUNS CREEK	SALKEHATCHIE RIVER	SAVANNAH RIVER	SAVANNAH RIVER SWAMP	BEAVER DAM CREEK
threadfin shad (<u>D. petenense</u>)							U		
eastern mudminnow (<u>Umbra pygmaea</u>)	+		+	U	+		R	+	
chain pickerel (<u>Esox niger</u>)	C	R	+	C	C	+	C	+	
redfin pickerel (<u>E. americanus</u>)	A	U	C	A	C	C	C		
carp (<u>Cyprinus carpio</u>)	+	+		R			U	+	
silvery minnow (<u>Hybognathus nuchalis</u>)	+	+			+		A		
rosyface chub (<u>Hybopsis rubrifrons</u>)	+	+					U		
bluehead chub (<u>Nocomis leptcephalus</u>)	A	C	A	A	+		R		
golden shiner (<u>Notemigonus crysoleucas</u>)	U	C	+	C	C		U		
ironcolor shiner (<u>Notropis chalybaeus</u>)	C	+	U		C		R		

Table 2. Continued.

SPECIES	UPPER THREE RUNS CREEK	FOUR MILE CREEK	PEN BRANCH CREEK	STEEL CREEK	LOWER THREE RUNS CREEK	SALKEHATCHIE RIVER	SAVANNAH RIVER	SAVANNAH RIVER SWAMP	BEAVER DAM CREEK
dusky shiner (<i>N. cummingsae</i>)	A	U	+	A	A		R		
pugnose minnow (<i>N. emiliae</i>)							R		
spottail shiner (<i>N. hudsonius</i>)	U			R			A		
sailfin shiner (<i>N. hypselopterus</i>)	U	U			U	U			
bannerfin shiner (<i>N. leedsi</i>)							U		
yellowfin shiner (<i>N. lutipinnis</i>)	A	U	A	A	A				
taillight shiner (<i>N. maculatus</i>)	+	+		U	+		R		
whitefin shiner (<i>N. niveus</i>)					+		U		
coastal shiner (<i>N. petersoni</i>)	A	C		C	C		U		
creek chub (<i>Semotilus atromaculatus</i>)	C	C	+	R	+				

Table 2. Continued.

SPECIES	UPPER THREE RUNS CREEK	FOUR MILE CREEK	PEN BRANCH CREEK	STEEL CREEK	LOWER THREE RUNS CREEK	SALKEHATCHIE RIVER	SAVANNAH RIVER	SAVANNAH RIVER SWAMP	BEAVER DAM CREEK
quillback (<u>Carpion</u> <u>cyprinus</u>)							R		
creek chubsucker (<u>Erimyzon</u> <u>oblongus</u>)	C	C	C	C	C	C	R		
lake chubsucker (<u>E. sucetta</u>)	+	C	+	C	C	+	R		
northern hogsucker (<u>Hypentelium</u> <u>nigricans</u>)	C		+	C			R		
spotted sucker (<u>Minytrema</u> <u>melanops</u>)	A	R			A		A		
silver redhorse (<u>Moxostoma</u> <u>anisurum</u>)	C				+		U		
snail bullhead (<u>Ictalurus</u> <u>brunneus</u>)				U			R		
white catfish (<u>I. catus</u>)	+			R	+		R		
yellow bullhead (<u>I. natalis</u>)	C	U	C	C	C	C	R		
brown bullhead (<u>I. nebulosus</u>)	+	+	+	+	C		R		

Table 2. Continued.

SPECIES	UPPER THREE RUNS CREEK	FOUR MILE CREEK	PEN BRANCH CREEK	STEEL CREEK	LOWER THREE RUNS CREEK	SALKEHATCHIE RIVER	SAVANNAH RIVER	SAVANNAH RIVER SWAMP	BEAVER DAM CREEK
flat bullhead (<u>I. platycephalus</u>)	A	+	C	C	+		C		
channel catfish (<u>I. punctatus</u>)	C	U			+		C	+	U
tadpole madtom (<u>Noturus gyrinus</u>)	A	U		C	+	+	R		
marginated madtom (<u>N. insignis</u>)	U		U	R	+				
speckled madtom (<u>N. leptacanthus</u>)	A	+	U	C	+		R		
flathead catfish (<u>Pylodictis olivaris</u>)							?		
swampfish (<u>Chologaster cornuta</u>)	R				R	R	R		
pirate perch (<u>Aphredoderus sayanus</u>)	A	C	A	A	A	+	R		
Atlantic needlefish (<u>Strongylura marina</u>)							R		
lined topminnow (<u>Fundulus lineolatus</u>)	U	U	+	C	C	U	R	+	

Table 2. Continued.

SPECIES	UPPER THREE RUNS CREEK	FOUR MILE CREEK	PEN BRANCH CREEK	STEEL CREEK	LOWER THREE RUNS CREEK	SALKEHATCHIE RIVER	SAVANNAH RIVER	SAVANNAH RIVER SWAMP	BEAVER DAM CREEK
mosquitofish (<u>Gambusia affinis</u>)	A	A	A	A	A	A	C	+	A
brook silversides (<u>Labidesthes sicculus</u>)	+	C		A	A		C	+	
white bass (<u>Morone chrysops</u>)							R		
striped bass (<u>M. saxatilis</u>)	+						R		
mud sunfish (<u>Acantharchus pomotis</u>)	+	+	+	R	+	+	R		
flier (<u>Centrarchus macropterus</u>)	+	+	+	C	+	+	R	+	U
banded pygmy sunfish (<u>Elassoma zonatum</u>)	U	+	+	R	U	+	R	+	
blackbanded sunfish (<u>Enneacanthus chaetodon</u>)	U								
bluespotted sunfish (<u>E. gloriosus</u>)	U		+	C	+	+	R		
redbreast sunfish (<u>Lepomis auritus</u>)	A	A	A	A	A		A	+	A

Table 2. Continued.

SPECIES	UPPER THREE RUNS CREEK	FOUR MILE CREEK	PEN BRANCH CREEK	STEEL CREEK	LOWER THREE RUNS CREEK	SALKEHATCHIE RIVER	SAVANNAH RIVER	SAVANNAH RIVER SWAMP	BEAVER DAM CREEK
green sunfish (<u>L. cyanellus</u>)	+				+		R		
pumpkinseed (<u>L. gibbosus</u>)		+					R		
warmouth (<u>L. gulosus</u>)	A	+	+	A	C	+	C	+	C
bluegill (<u>L. macrochirus</u>)	+	+	+	U	C	+	A	+	U
dollar sunfish (<u>L. marginatus</u>)	+	U	+	C	C	C	R	+	U
redeer sunfish (<u>L. microlophus</u>)	+	+	+	C	+		C	+	C
spotted sunfish (<u>L. punctatus</u>)	A	A	C	A	+		U	+	A
largemouth bass (<u>Micropterus salmoides</u>)	C	C	+	C	C	+	C	+	
black crappie (<u>Pomoxis nigromaculatus</u>)	+	+			+		C	+	U
white crappie (<u>P. annularis</u>)					+		R		

Table 2. Continued.

SPECIES	UPPER THREE RUNS CREEK	FOUR MILE CREEK	PEN BRANCH CREEK	STEEL CREEK	LOWER THREE RUNS CREEK	SALKEHATCHIE RIVER	SAVANNAH RIVER	SAVANNAH RIVER SWAMP	BEAVER DAM CREEK
Savannah darter (<u>Etheostoma fricksium</u>)	+			+	+				
swamp darter (<u>E. fusiforme</u>)	+		+	+	+	+	R		
Christmas darter (<u>E. hopkinsi</u>)	C	U	+	C			R		
turquoise darter (<u>E. inscriptum</u>)									
tesselated darter (<u>E. olmstedii</u>)	C	R	+	C	+		R		
sawcheek darter (<u>E. serriferum</u>)	+			U					
yellow perch (<u>Perca flavescens</u>)	+	R	+	+	+		C	+	
blackbanded darter (<u>Percina nigrofasciata</u>)	A	+	+	C	A		R		
striped mullet (<u>Mugil cephalus</u>)			U	U	U		U	+	
hogchoker (<u>Trinectes maculatus</u>)			U	U	U		U		

-
- * A - Abundant: collected in large numbers in suitable habitat during the proper season.
 - C - Common: collected most of the time or in smaller numbers in suitable habitat during the proper season.
 - U - Uncommon: collected occasionally in small numbers in the appropriate habitat and season.
 - R - Rare: seldom encountered at any locality.
 - + - Present: collected but abundance is indefinite.
 - ? - Questionable presence: reported in literature.
-

Table 3. Relative abundance* of fishes from lentic environments on the SRP. See Figure 5 for map of location of the various lentic environments. No entry means that no record currently exists of the species in the particular habitat although it has been reported from other areas on the SRP.

	KAREN'S POND	A-1 POND	DRY BAY	ASPHALT POND	RISHER POND	TWIN LAKES	DICKS POND	MOON LAKE	POND B	SARRACENIA BAY	POND C	PAR POND	POND 2	B SWAMP	STEED POND	SKINFACE POND	ELLENTON	R CANAL	
Florida gar (<u>Lepisosteus platyrhincus</u>)																			+
bowfin (<u>Amia calva</u>)												+							+
American eel (<u>Anguilla rostrata</u>)												+							+
blueback herring (<u>Alosa aestivalis</u>)											+	+							
gizzard shad (<u>Dorosoma cepedianum</u>)									+		+	+							
eastern mudminnow (<u>Umbra pygmaea</u>)										+									+

Table 3. continued

	KAREN'S POND	A-1 POND	DRY BAY	ASPHALT POND	RISHER POND	TWIN LAKES	DICKS POND	MOON LAKE	POND B	SARRACENIA BAY	POND C	PAR POND	POND 2	B SWAMP	STEED POND	SKINFACE POND	ELLENTON BAY	R CANAL
redfin pickerel (<u>Esox americanus</u>)									+		+	+				+		
chain pickerel (<u>E. niger</u>)												0				0		
golden shiner (<u>Notemigonus crysoleucas</u>)						0					+	+	+			+		
coastal shiner (<u>Notropis petersoni</u>)												+				+		
lake chubsucker (<u>Erimyzon sucetta</u>)		C					+				+	+				+		
spotted sucker (<u>Minytrema melanops</u>)												+						
yellow bullhead (<u>Ictalurus natalis</u>)					+	0	0		+		+	+				+		

Table 3. continued

	KAREN'S POND	A-1 POND	DRY BAY	ASPHALT POND	RISHER POND	TWIN LAKES	DICKS POND	MOON LAKE	POND B	SARRACENIA BAY	POND C	PAR POND	POND 2	B SWAMP	STEED POND	SKINFACE POND	ELLE'YTON BAY	R CANAL	
brown bullhead (<u>I. nebulosus</u>)					+	C						+							
flat bullhead (<u>I. platycephalus</u>)												+							
channel catfish (<u>I. punctatus</u>)												+				I			
tadpole madtom (<u>Noturus gyrinus</u>)												+							
flathead catfish (<u>Pylodictis olivaris</u>)												+							
pirate perch (<u>Aphredoderus sayanus</u>)											+	+				+			
lined topminnow (<u>Fundulus lineolatus</u>)																+			
mosquitofish (<u>Gambusia affinis</u>)	A	A		A	A	A		+	A			C	+	+	+	+		A	

Table 3. continued

	KAREN'S POND	A-1 POND	DRY BAY	ASPHALT POND	RISHER POND	TWIN LAKES	DICKS POND	MOON LAKE	POND B	SARRACENIA BAY	POND C	PAR POND	POND 2	B SWAMP	STEED POND	SKINFACE POND	ELLENTON BAY	R CANAL
brook silversides (<u>Labidesthes sicculus</u>)									+			+	+			+		
mud sunfish (<u>Acantharchus pomotis</u>)										+								
flier (<u>Centrarchus macropterus</u>)						C				+							+	
banded pygmy sunfish (<u>Elassoma zonatum</u>)								+		+	+	+				+		
bluespotted sunfish (<u>Enneacanthus gloriosus</u>)																	+	
redbreast sunfish (<u>Lepomis auritus</u>)									+		+	+	+		+	+		
warmouth (<u>L. gulosus</u>)				+	+	+			+		+	+				+		

Table 3. continued

	KAREN'S POND	A-1 POND	DRY BAY	ASPHALT POND	RISHER POND	TWIN LAKES	DICKS POND	MOON LAKE	FOND B	SARRACENIA BAY	FOND C	PAR POND	POND 2	B SWAMP	STEED POND	SKINFACE POND	ELENTON BAY	R CANAL
bluegill (<u>L. macrochirus</u>)		+		+	+	+			A		A	A	+			+		
dollar sunfish (<u>L. marginatus</u>)							+		+		+	+					+	
redeer sunfish (<u>L. microlophus</u>)						C					+	+					I	
spotted sunfish (<u>L. punctatus</u>)									+			+	+				+	
largemouth bass (<u>Micropterus salmoides</u>)							+		A		C	A		+		+		
black crappie (<u>Pomoxis nigromaculatus</u>)									+		+	C						
swamp darter (<u>Etheostoma fusiforme</u>)									+		+	+						

Table 3. continued

	KAREN'S POND	A-1 POND	DRY BAY	ASPHALT POND	RISHER POND	TWIN LAKES	DICKS POND	MOON LAKE	POND B	SARRACENIA BAY	POND C	PAR POND	POND 2	B SWAMP	STEED POND	SKINFACE POND	ELLENTON BAY	R CANAL	
yellow perch (<u>Perca flavescens</u>)									+			+							
Total Species Present	1	1	1	2	5	8	6	1	14	4	17	30	6	2	2	25	1	0	

*

A - Abundant: collected in large numbers in suitable habitat during the proper season

C - Common: collected most of the time or in smaller numbers in suitable habitat during the proper season

U - Uncommon: collected occasionally in small numbers in suitable habitat and the proper season

+ - Present: collected but abundance indefinite

I - Recently introduced

Size relationships of a species are often valuable to a researcher. Through the use of regression techniques, a weight estimate for a known length of a species can be determined (Ricker 1973; Carlander 1977). For most SRP species we have provided the expression $\ln W = \ln a + b(\ln TL)$, where: \ln = natural logarithm, W = estimated weight (grams) for a fish for a given total length (TL , millimeters), b is the slope of the regression line, and a is the Y-intercept. Also given are the sample size (N) and the correlation coefficient (r) of the regression. To provide further perspective, we have included the maximum size which a species may be expected to attain and the maximum size reported for SRP specimens (length and weight of a single fish are separated by a comma; when the maximum length and weight were obtained from different fish, these are separated by a semicolon).

Specific references of interest for a given species are also provided to guide the reader to relevant literature.

A KEY TO THE FISH FAMILIES OF THE SAVANNAH RIVER PLANT'S
NATIONAL ENVIRONMENTAL RESEARCH PARK

1. Caudal fin heterocercal (Fig. 8A) or appears to be homocercal with bony upper lobe (Fig. 8B)..... 2
 Caudal fin typically homocercal (Fig. 8C); both lobes lack bone..... 4
2. Jaws elongate, forming a pointed mouth; (Fig. 9K) body covered with hard, diamond-shaped (ganoid) scales 5
 Gar Family - Lepisosteidae page 5
 Jaws not elongate; and body may or may not be covered with ganoid scales :
3. Dorsal fin long, nearly continuous with caudal fin (Fig. 10A); mouth terminal (Fig. 9J).....Bowfin Family - Amiidae page 5
 Dorsal fin not long; mouth inferior with long barbels (Fig. 9C).
 Sturgeon Family - Acipenseridae page 5
4. Jaws elongate; pointed mouth resembling a long beak (Fig. 9L).
 Needlefish Family - Belonidae page 9
 Jaws not elongate.....
5. Body eel-like; dorsal, caudal, and anal fin continuous (Figs. 9A, 10B).
 Freshwater Eel Family - Anguillidae page 5
 Body not eel-like; dorsal, caudal, and anal fin not continuous.....
6. Pectoral fins absent; body flattened; eyes on one side of body (Figs. 11, 9D).....Sole Family - Soleidae page 1:
 Pectoral fins present; body not flattened; eyes on opposite sides f body
7. Head without scales.....
 Head with scales.....
8. Body without scales, conspicuous barbels present above and below mouth (Fig. 9B).....Catfish Family - Ictaluridae page
 Body with scales; barbels absent or inconspicuous.....
9. Lateral line absent; belly with sawtooth scales (Fig. 9O, 12); single dorsal fin without spinesHerring Family - Clupeidae page
 Lateral line present; belly without sawtooth scales; dorsal.....
 fin with or without spines.....

10. Dorsal fin with more than 10 rays; lips sucker-like (Fig. 13); pharyngeal teeth more than 10, always in a single row and "comblike" (Figs. 14B, 9U).....Sucker Family - Catostomidae page 78
- Dorsal fin with fewer than 10 rays; lips not sucker-like; pharyngeal teeth confined to 2 rows or, if on 1 row, fewer than 6 teeth present (Figs. 14A, 9T).....Minnow Family - Cyprinidae page 65
11. Pelvic fins absent; eyes functional but small and covered by skin; anus jugular (Figs. 15A, 9E)...Cavefish Family.....Amblyopsidae page 90
- Pelvic fins present; eyes not small and not covered by skin 12
12. Dorsal fin with completely separate spiny and soft-rayed sections..... 13
- Dorsal fin with continuous spiny and soft-rayed sections..... 16
13. Anterior dorsal fin with 3-5 spines..... 14
- Anterior dorsal fin with 6 or more spines..... 15
14. Lower jaw extending beyond upper jaw; snout dorsoventrally flattened; broad silver lateral stripe; body very thin, pencil-shaped; 1 anal spine (Fig. 9F).....Siversides Family - Atherinidae page 95
- Lower jaw not extending beyond upper jaw; snout blunt; mouth like an inverted "V"; 2 or 3 anal spines (Fig. 9G)..... Mullet Family - Mugilidae page 120
15. Anal spines 3 or more; opercles with well-developed spine; pseudobranch well-developed (Fig. 9H).....Temperate Bass Family - Percichthyidae page 96
- Anal spines fewer than 3; opercles with well or poorly developed spine; pseudobranch not well developed (Fig. 9I).....Perch Family - Percidae page 113
16. Mouth large and elongated; jaws duck-bill shaped (Fig. 9N)..... Pike Family - Esocidae page 63
- Mouth small and not elongated; jaws not shaped like duck-bill..... 17
17. Dorsal fin with spines..... 18
- Dorsal fin without spines..... 19
18. Anus anterior to usual position, usually under throat (Fig. 15B); anal spines 2; anal fin origin under posterior base of dorsal fin (Fig. 9M).....Pirate Perch Family - Aphredoderidae page 91
- Anus located in normal position (immediately anterior to anal fins); anal spines 3; anal fin origin anterior to posterior base of dorsal fin (Fig. 9S).....Sunfish Family - Centrarchidae page 98

19. Mouth large and terminal; maxillary extends to anterior edge of eye; premaxillaries not protractile (Fig. 9P)..... Mudminnow Family - Umbridae page 63
- Mouth small and superior; maxillary does not extend to anterior edge of eye; premaxillaries protractile..... 20
20. Dorsal fin base almost directly above anal fin base (Fig. 9Q); lateral scales more than 30; third anal ray branched; anal fin of male not modified into elongated intromittent organ..... Killifish Family - Cyprinodontidae page 93
- Dorsal fin base entirely or almost entirely posterior to anal fin base; lateral scales 30 or fewer; third anal ray not branched (Fig. 9R); anal fin of male modified into elongated intromittent organ..... Topminnow Family - Poeciliidae page 94

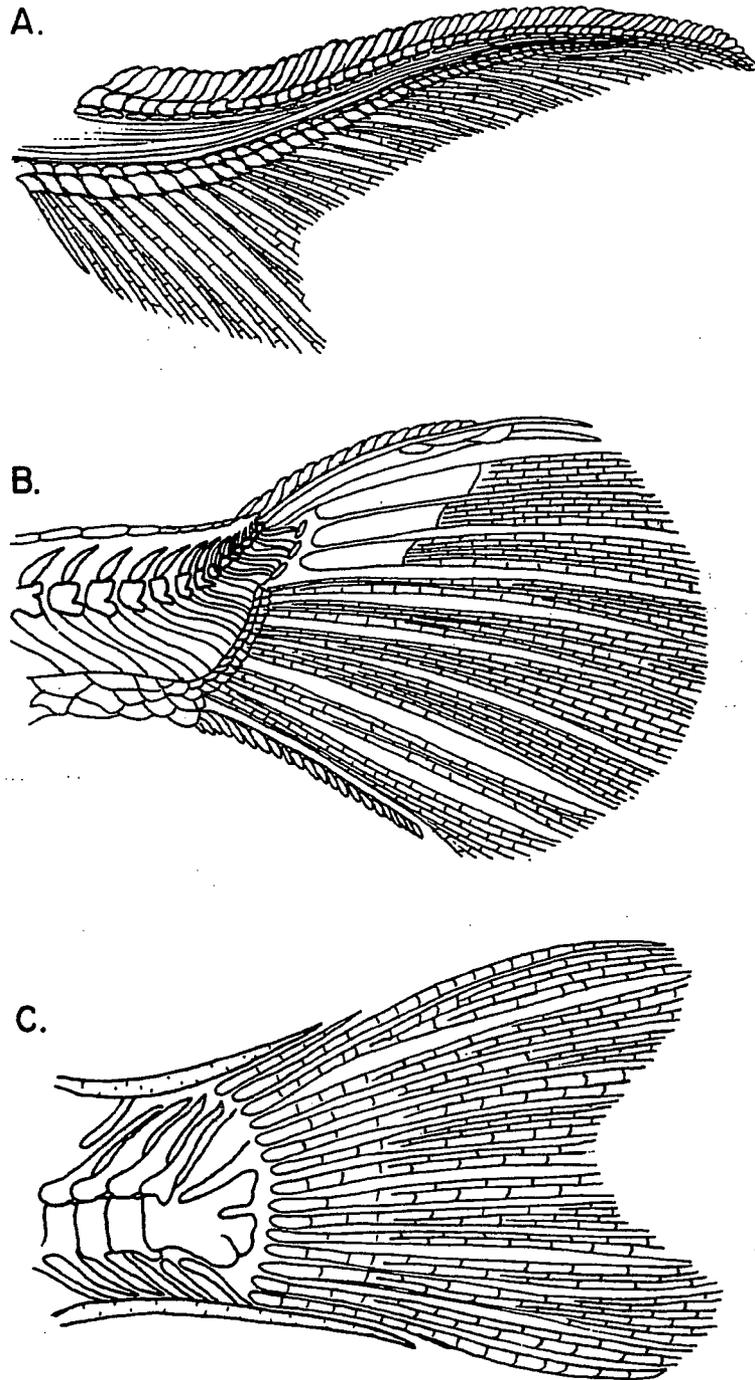
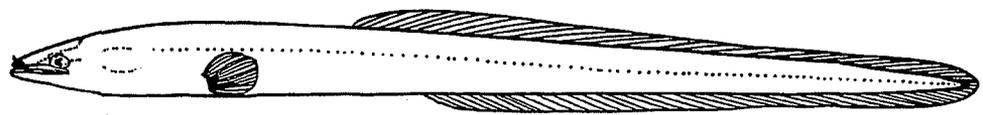


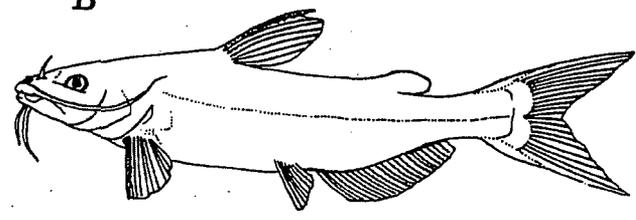
Figure 8. Heterocercal (A - sturgeon only; B - Gars and Bowfin) and homocercal (C - all other fishes in report) caudal fins (after Blair et al. 1968). (See Appendix I).

A



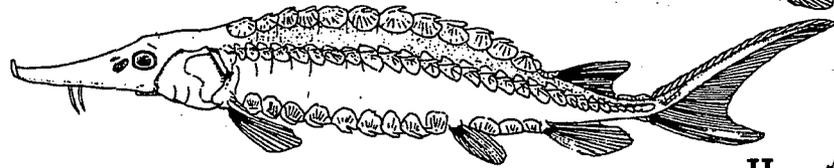
Anguillidae

B



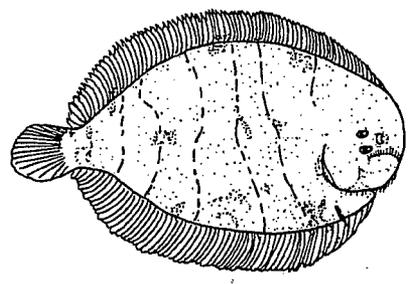
Ictaluridae

C



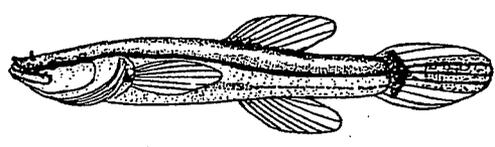
Acipenseridae

D



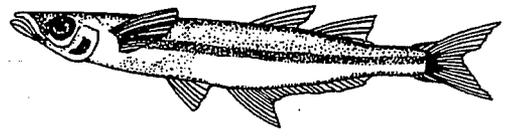
Soleidae

E



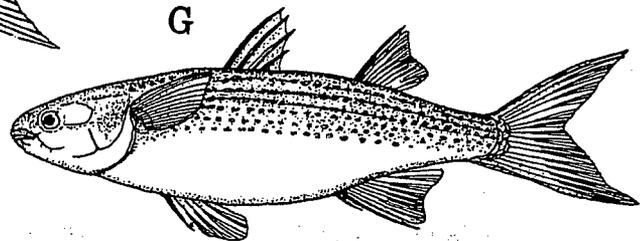
Amblyopsidae

F



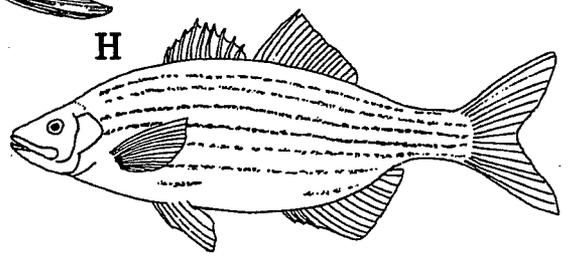
Atherinidae

G



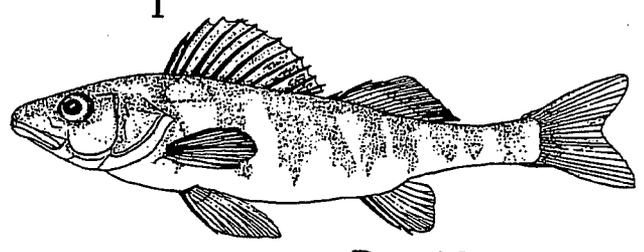
Mugilidae

H



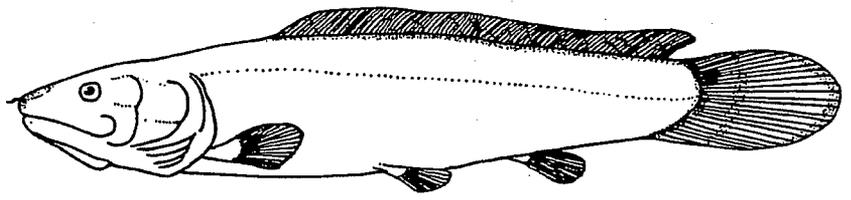
Percichthyidae

I



Percidae

J



Amiidae

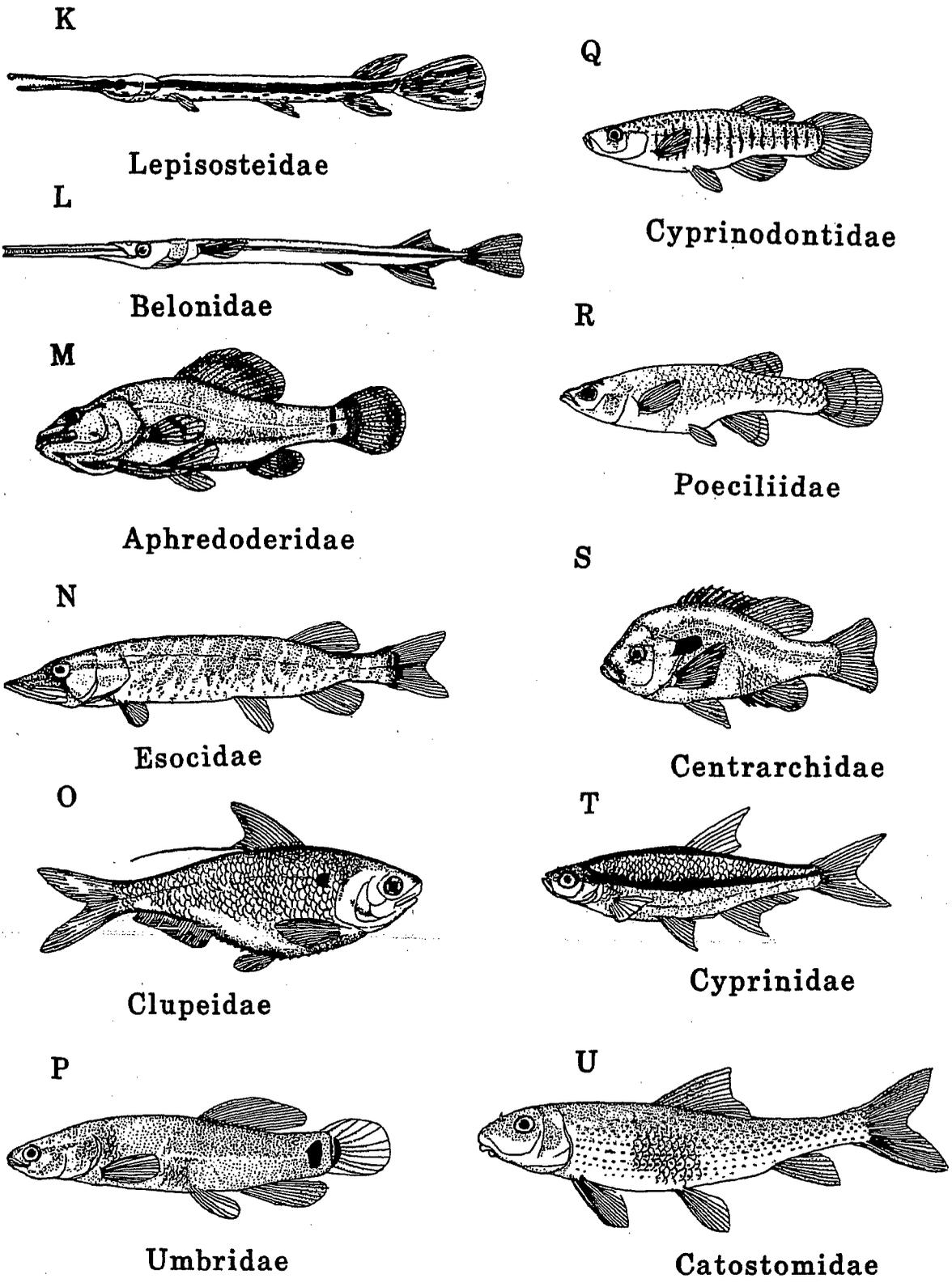


Figure. 9. Representatives of fish families occurring on the SRP.
 (Not drawn to scale).

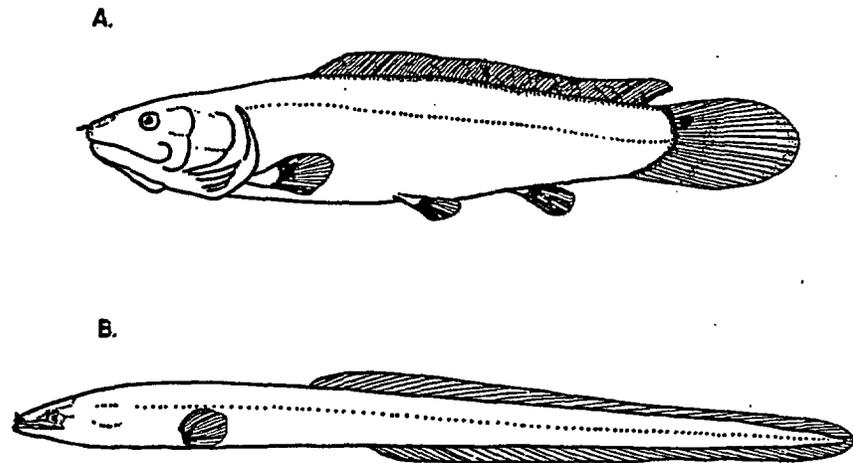


Fig. 10. Body form of bowfin, *Amia calva*, (A) and American eel, *Anguilla rostrata*, (B) demonstrating discrete separation of long dorsal fin (A) and continuous dorsal, caudal, and anal fins (B).

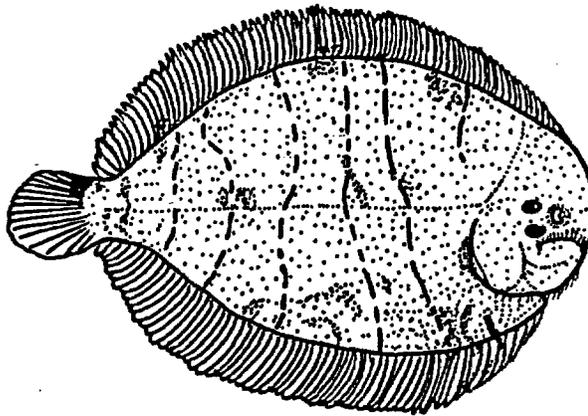


Fig. 11. Body form of hogchoker, *Trinectes maculatus*, demonstrating general location of eyes and fins

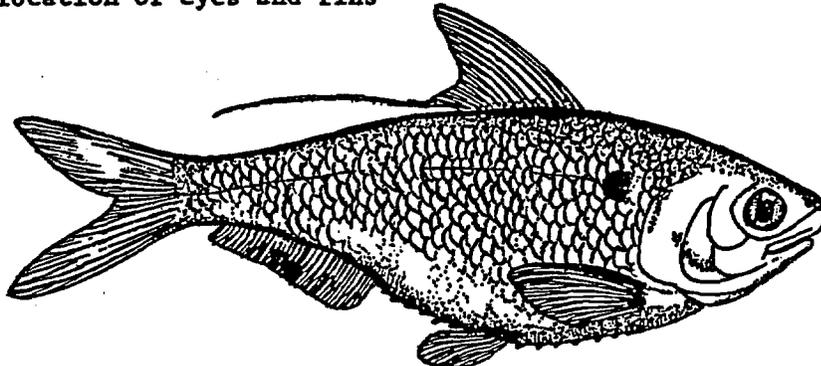


Fig. 12. Adipose eyelid, ventral sawtooth scales, and elongated dorsal fin ray in gizzard shad, *Dorosoma cepedianum*.

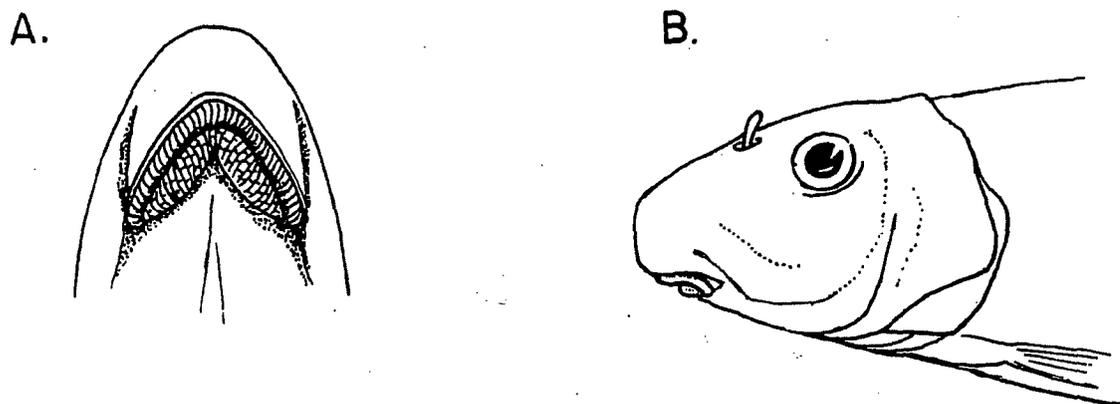


Figure 13. Sucker-like lips in silver redhorse, *Moxostoma anisurum*, (A) (after Blair et al. 1968; see Appendix I); horizontal mouth in spotted sucker, *Minytrema melanops*, (B) (after Eddy 1957; see Appendix I).

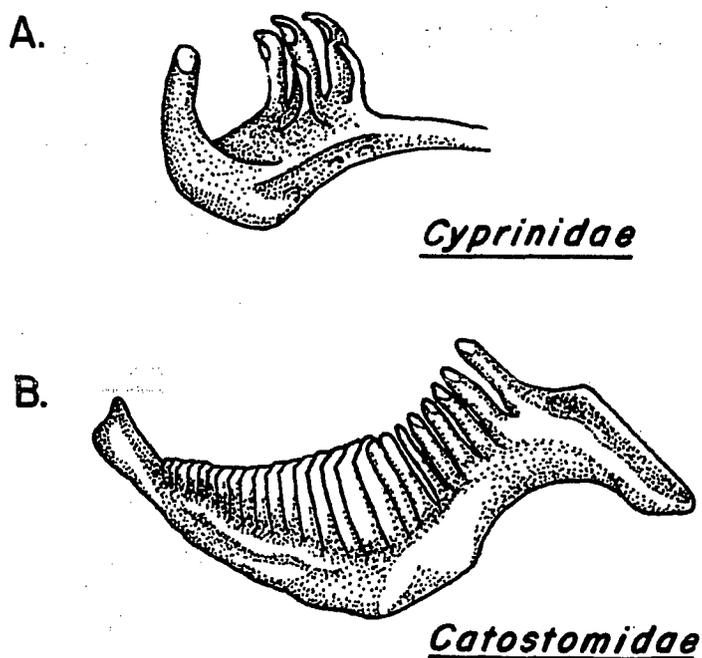
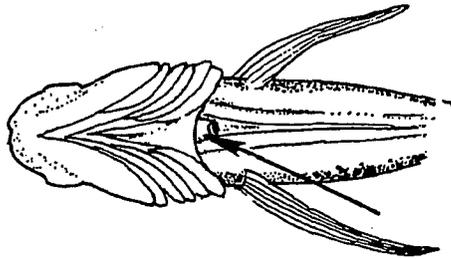
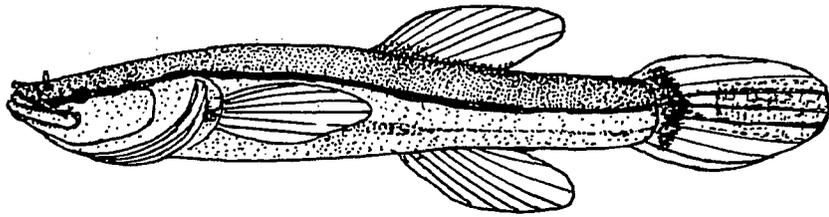


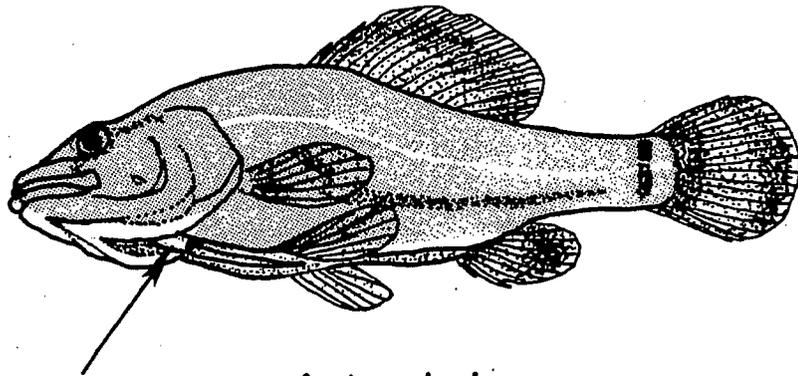
Figure 14. Comparison of pharyngeal teeth of members of the families Cyprinidae (A; based on Blair et al. 1968; see Appendix I) and Catostomidae (B; Hubbs and Lagler, 1947; see Appendix I).

A.



Chologaster cornuta

B.



Aphredoderus sayanus

Figure 15. Jugular location of the anus in swampfish, *Chologaster cornuta*, (A) and pirate perch, *Aphredoderus sayanus*, (B).

A KEY TO SPECIES AND SPECIES DESCRIPTIONS

ORDER - ACIPENSERIFORMES

STURGEON FAMILY - ACIPENSERIDAE

Sturgeons are ancient fishes that retain their primitive features -- a heterocercal caudal fin (Fig. 8A) and cartilaginous skeleton. The body is covered by several rows of bony plates or scutes with a few ganoid scales on the posterior portion. They have an inferior mouth with barbels which facilitate the location of food items. Sturgeons are large fishes and can tolerate a wide variety of salinities.

Acipenser oxyrhynchus Mitchill - Atlantic Sturgeon

Key Characters: Inferior mouth with barbels. Five series of bony plates on body. Anal rays 23 to 30.

SRP Distribution: Rare. A single larva was found in ichthyoplankton samples collected in 1977 in an oxbow channel along the Savannah River.

Habitat and Habits: Anadromous, spawning in rivers in the spring. Young sturgeon feed on aquatic invertebrates and gradually migrate to the ocean to mature. Adults occasionally become entangled in commercial shad nets.

Size: Maximum body size about 5 m.

ORDER - SEMIONOTIFORMES

GAR FAMILY - LEPISOSTEIDAE

Gars occur in freshwater habitats east of the Rocky Mountains. Two genera (Lepisosteus and Atractosteus) are currently recognized in this family. Gar are primitive fish with much cartilage in their skeleton. Their bodies are long, cylindrically shaped, and covered by thick, ganoid scales.

Key to SRP Species of Lepisosteus

1. Snout long and slender, the least width being from 13 to 26 times snout length; no spots on head.

.....Lepisosteus osseus - longnose gar
page 56

Snout short and broad, the least width being from 4.5 to 11 times snout length; dark head spots obvious and numerous.

..... Lepisosteus platyrhincus - Florida gar
page 56

Lepisosteus osseus (Linnaeus) - longnose gar

Key Characters: Snout very long and narrow with many sharp teeth. Body cylindrically shaped with dark spots on body and fins but not on the head.

SRP Distribution: Common. Found in Upper Three Runs Creek, Four Mile, Lower Three Runs, the Savannah River, intake canals, and the river swamp, but totally absent from the Par Pond reservoir system.

Habitat and Habits: Primarily found in sluggish water under overhanging cover but often attracted to current. Juveniles grow very rapidly, about 10 cm per month during their first summer. Food of individuals > 5 cm is primarily fish; food of smaller individuals is entomostracans and aquatic insects.

Size: Maximum length is 1.5 m. SRP maximum is 1.3 m, 5 kg. Length-weight relationship ($N = 41$, $r = 0.99$) is $\ln W = 3.828 (\ln TL) - 18.16$.

Lepisosteus platyrhincus DeKay - Florida Gar

Key Characters: Snout short and broad. Body cylindrically shaped with dark spots on head.

SRP Distribution: Rare. Rarely collected in the Savannah River. It has been collected in the lower section of Steel Creek, Four Mile Creek, an oxbow lake near the mouth of Upper Three Runs, Skinface Pond, and the Savannah River swamp.

Habitat and Habits: A species found in sloughs and rivers on the Coastal Plain of South Carolina, Georgia, and Florida.

Size: SRP maximum is 69.5 cm, 1.2 kg.

ORDER - AMIIFORMES

BOWFIN FAMILY - AMIIDAE

The bowfin family is an ancient family that has one living species, the bowfin, Amia calva. Bowfin have a cartilaginous skeleton, bony plates that cover the skull and throat area, and cycloid scales that cover the body. This species is easily identified by its long dorsal fin and rounded caudal, pectoral, pelvic and anal fins (Fig. 10A).

Amia calva Linnaeus - bowfin

Key Characters: Long dorsal fin nearly reaching to the caudal fin. Caudal, anal, pelvic, and pectoral fins are rounded. Males have a dark "eye spot" at caudal base.

SRP Distribution: Common. Abundant in the lower sections of major tributaries, intake canals, the river, and the Savannah River swamp. Also found in Par Pond and Skinface Pond.

Habitat and Habits: Bowfin are found in the sluggish sections of rivers having a muddy bottom. Bowfin spawn in a nest during the spring, but juveniles are rarely seen, and spawning localities on the SRP are not known. Bowfin feed on a variety of invertebrates and small fishes.

Size: SRP maximum is 82 cm, 4.5 kg. Length-weight relationship ($N = 24$, $r = 0.98$) is $\ln W = 2.955 (\ln TL) - 11.20$.

ORDER - ANGUILLIFORMES

EEL FAMILY - ANGUILLIDAE

The family Anguillidae is represented in eastern North America by one species, the American eel, Anguilla rostrata. Eels inhabit warm freshwater habitats in the Atlantic and Gulf drainage but are not commonly observed

because of their secretive behavior. Females are more frequently encountered in freshwater than males.

Anguilla rostrata Lesueur - American eel

Key Characters: Elongate body with continuous dorsal, caudal and anal fins. Pectoral fins present; pelvic fins are absent (Fig. 10B).

SRP Distribution: Abundant. In small tributaries, creeks and the Savannah River. One of the more abundant species in riverine systems on the SRP.

Habitat and Habits: American eels are catadromous, living in freshwater but spawning in the Atlantic Ocean. Juveniles migrate to freshwater streams to mature. Eels feed on live and dead animal matter.

Size: Maximum length is 120 cm. SRP maximum is 70 cm, 1.2 kg. Length-weight relationship ($N = 21$, $r = 0.99$) is $\ln W = 3.456 (\ln TL) - 15.87$.

ORDER - CLUPEIFORMES

HERRING FAMILY - CLUPEIDAE

Although many people regard "herring" as being strictly marine, several species inhabit fresh waters. Five have been found in the Savannah River and its tributaries on the SRP. Three species, the American shad (Alosa sapidissima), hickory shad (Alosa mediocris), and blueback herring (Alosa aestivalis) are anadromous, and consequently, use the Savannah River for spawning and rearing. The threadfin shad, Dorosoma petenense, has been introduced in the Savannah River, but is considered uncommon (McFarlane et al. 1978). Gizzard shad, Dorosoma cepedianum, are resident throughout the year.

Local members of this family are easily identified by the row of saw-toothed scales on the belly and the adipose eyelid (Fig. 12). Species of

herring occurring on the SRP, particularly the juveniles, are moderately difficult to identify because of morphological similarities.

Key to Species of Family Clupeidae:

1. Last ray of dorsal fin greatly elongated into a long filament (Fig. 12)..... 2
 Last ray of dorsal fin not elongated into a long filament..... 3
2. Anal fin with 25 to 36 rays, usually 29 to 35; mouth noticeably sub-terminal; snout blunt..... Dorosoma cepedianum - gizzard shad page 62
 Anal fin with 17 to 27 rays, usually 20-25; mouth terminal; snout not blunt..... Dorosoma petenense - threadfin shad page 62
3. Lower jaw projecting beyond upper jaw; 18 to 23 gill rakers on lower limb of gill arch, regardless of size.....
 Alosa mediocris - hickory shad page 60
 Lower jaw not projecting beyond upper jaw; more than 26 gill rakers on lower limb of gill arch 4
4. Cheek deeper than long; peritoneum pale; 59 to 73 gill rakers in lower limb of first arch in individuals 100-125 mm or more but may be as low as 26 in young (Dahlberg 1975); one or more spots in a longitudinal row behind opercle.... Alosa sapidissima - American shad page 61
 Cheek not deeper than long; peritoneum usually black; 41 to 52 gill rakers on lower limb of first gill arch in adults; dorsum of adults distinct blue-green..... Alosa aestivalis - blueback herring page 59

Alosa aestivalis (Mitchill) - blueback herring

Key Characters: Peritoneum usually black. Cheek longer than deep. Eye large, the diameter about equal to length of snout. Lower jaw not projecting beyond upper jaw. Teeth in lower jaw.

SRP Distribution: Abundant in the Savannah River, Savannah River swamp, and Lower Three Runs Creek and present in Par Pond system.

Habitat and Habits: Anadromous species that spawns in the Savannah River although sexually mature adults have been collected in Par Pond. It is not

known conclusively if the Par Pond population is a landlocked, breeding population, as the population is probably augmented each spring by passage of entrained larvae in cooling water during periods of reactor shutdown. Blueback herring were observed spawning in the braided channels of Steel Creek delta in 1978 and suspected to be spawning in Par Pond in 1970. The eggs, which hatch in a single day, and early larval stages adhere to aquatic vegetation in the narrow channels of clear water. Juveniles are attracted to the cooling water intake canals during the summer and are abundant there until November or December, feeding primarily on larval and pupal insects, copepods and cladocerans.

Size: Spawning adults (N = 32) were 273-314 mm TL and 220-310 g in weight. Variable stages of gonadal development rendered length-weight regressions of adults unreliable, but for juvenile fish collected in autumn (N = 72, r = 0.99, maximum TL = 96 mm) $\ln W = 2.820 (\ln TL) - 10.86$.

References: Burbidge 1974, Loesch and Lund 1977, Street 1969b, Street and Adams 1969, Adams and Street 1969, Giesy and Wiener 1977.

Alosa mediocris (Mitchill) - hickory shad

Key Characters: Easily identified as a clupeid by the adipose eyelid and row of sawtoothed scales on the belly. Lower jaw projecting beyond upper jaw. Lower limb of gill arch has 18 to 23 gill rakers.

SRP Distribution: Rare. Collected downstream of SRP on two occasions (ANSP 1953, 1955). This species does not ascend rivers as far upstream as its congeners.

Habitat and Habits: Anadromous species which spawns in the Savannah River but spawning as far upstream as the SRP has not been established.

Size: Maximum size about 435 mm and 1.4 kg.

References: Street 1969a, Street and Adams 1969.

Alosa sapidissima (Wilson) - American shad

Key Characters: Cheek deeper than long. Peritoneum pale. One or more spots behind opercles. Lower jaw not projecting beyond upper jaw.

SRP Distribution: Abundant. Commercially important species that is abundant during the spring and summer in the Savannah River.

Habitat and Habits: Anadromous fish that spawn in the Savannah River. Sportsmen fish for this species at the mouth of Steel Creek during the spring spawning run. Steel Creek is the only SRP stream that is known to be used for spawning; spawning activity is probably restricted to the lower, deeper reaches. Shad ascend the river in February as water temperatures attain 12-13°C. The adults persist in the river until June when water temperatures are about 20°C. Juveniles reared in the Savannah River may enter mouths of tributary streams to feed on planktonic organisms. Juveniles are attracted to the cooling water canals in late summer, feeding primarily on adult and pupal insects until December. They may be observed dimpling the water surface while feeding at dusk.

Size: Maximum size is 3 kg. Four males from the SRP were 420-477 mm and 466-915 g; four females were 515-567 mm and 1735-2050 g. For juveniles collected in autumn the length-weight relationship ($N = 85$, $r = 0.96$, maximum $TL = 126$ mm) is $\ln W = 2.812 (\ln TL) - 10.80$.

References: Leggett 1973, Godwin 1968, Vaughn 1967.

Dorosoma cepedianum (Lesueur) - gizzard shad

Key Characters: Long anal fin with usually 29 to 35 rays. The last ray of dorsal fin is elongated into a long filament (Fig. 12). Gizzard shad have a longer anal fin and a noticeably more inferior mouth than threadfin shad, which they superficially resemble.

SRP Distribution: Common. Gizzard shad are common in the Savannah River and swamp and the Par Pond system. They have been collected from Lower Three Runs, Four Mile Creek and Beaver Dam Creek. The populations are resident year round.

Habitat and Habits: Found in backwater areas and pools of creeks, large rivers, lakes and swamps. Feeds on phytoplankton and zooplankton. Spawns during April and early May.

Size: Maximum length to 50 cm. SRP maximum is 49.4 cm, 803 g. Length-weight relationship ($N = 79$, $r = 0.94$) is $\ln W = 3.489 (\ln TL) - 14.34$.

Dorosoma petenense (Günther) - threadfin shad

Key Characters: Last ray of dorsal fin elongated into a filament. Anal fin usually with 20 to 25 rays. This species can be confused with gizzard shad but threadfin shad have a shorter anal fin and a more terminal mouth.

SRP Distribution: Uncommon. Collected occasionally in the Savannah River but unknown from any lake or stream on the SRP.

Habitat and Habits: An introduced species in the Savannah River which is vulnerable to low water temperatures and commonly impinged at the cooling water pumping stations when water temperatures drop below 10°C. Threadfin shad feed on plankton. They are widely introduced as forage fish because of their small adult size.

Size: Maximum length is 25 cm. SRP maximum is 145 mm; 27 g. Length-weight relationship ($N = 88$, $r = 0.98$) is $\ln W = 3.117 (\ln TL) - 12.20$.

ORDER - SALMONIFORMES

MUDMINNOW FAMILY - UMBRIDAE

Mudminnows are inhabitants of streams and swamps. They are easily distinguished by their small size (up to 7.5 cm), posterior location of the dorsal fin, and non-protractile upper jaw. A single species, the eastern mudminnow, Umbra pygmaea, is found on the SRP. The body of this species has longitudinal streaks; a large vertical spot is found on the caudal peduncle.

Umbra pygmaea (DeKay) - eastern mudminnow

Key Characters: A large vertical, dark spot on the caudal peduncle. Rounded dorsal, caudal, anal, pelvic, and pectoral fins. Longitudinal stripes are clearly visible.

SRP Distribution: Uncommon. Mudminnows have been infrequently collected in the Savannah River, Upper Three Runs Creek, Pen Branch, Steel Creek, Lower Three Runs Creek. They also are present in Sarracenia Bay and Skinface Pond.

Habitat and Habits: Found mainly in swampy areas and sluggish streams. Copepods and trichopteran larvae are the major food items of mudminnows.

Size: SRP maximum is 113 mm, 18 g. Length-weight relationship ($N = 5$, $r = 0.99$) is $\ln W = 3.378 (\ln TL) - 13.10$.

PIKE FAMILY - ESOCIDAE

Members of the pike family have long cylindrically shaped bodies with duck-bill jaws and many large, sharp pointed teeth. The dorsal fin of esocids are typically posterior in location. All members of this family are predaceous, feeding primarily on fishes and other small organisms.

Two species of esocids are found on the SRP. The chain pickerel, Esox niger, is typically a lake form whereas the redbfin pickerel, Esox americanus, is more commonly found in the smaller streams and Carolina bays on the SRP. The two species are occasionally found together in the same habitat. Small juveniles of both species are found in the headwaters of SRP streams.

Key to Species of Esox:

1. Total length less than 7.5 times snout length; subocular bar vertical; body with chain-like reticulations; fins not heavily colored..... Esox niger - chain pickerel page 6
- Total length 8 or more times snout length; subocular bar inclined backward; no chain-like reticulations but white/yellow slanted bars on body; fins reddened..... Esox americanus - redbfin pickerel page 6.

Esox americanus Gmelin - redbfin pickerel

Key Characters: Subocular bar usually inclined backwards. Fins usually reddened. Snout short, 8.0 or more times into total length. Esox americanus americanus is the accepted subspecies on the SRP.

SRP Distribution: Abundant. Widely distributed on the Savannah River Plant; common to the Savannah River, abundant in small streams of all major creeks, Par Pond, and in many swamps and Carolina bays.

Habitat and Habits: Backwaters of small streams in shallow water, concentrated in areas having instream cover. Other fishes are the primary food item of subadults and adults, whereas zooplankton are consumed by young.

Size: SRP maximum is 353 mm, 288 g. Length-weight relationship ($N = 33$; $r = 0.98$) is $\ln W = 3.451 (\ln TL) - 14.23$.

Reference: Pflieger 1975.

Esox niger Lesueur - chain pickerel

Key Characters: Snout long, less than 7.5 times in total length. Subocular bar vertical. Fins not colored. May be confused with redbfin pickerel at small body sizes.

SRP Distribution: Common. Present in all major creeks and the Savannah River. Chain pickerel are common in Par Pond and Skinface Pond.

Habitat and Habits: Commonly found in deep pools of sluggish streams and around vegetation where they "stalk" their prey. Invertebrates are the principal food items of smaller pickerel (< 10 cm) whereas fish compose the diet of larger animals.

Size: Maximum weight of 4 kg. SRP maximum is 55 cm, 1.2 kg. Length-weight relationship ($N = 36$, $r = 0.99$) is $\ln W = 3.103 (\ln TL) - 12.63$.

ORDER - CYPRINIFORMES

MINNOW FAMILY - CYPRINIDAE

The minnow family is one of the larger families of fishes on the SRP and the largest group of freshwater fishes in the United States, having more species than any other family. The closest relatives to the minnows are the suckers; minnows lack the sucker-like mouths and the pharyngeal teeth differ. Minnows generally have pharyngeal teeth in 1 or 2 rows (carp have 3) while suckers always have these teeth in a single row (Fig. 14). Pharyngeal teeth are an important characteristic distinguishing many species. Several of the cyprinids, however, are extremely difficult to key to species. Characters, such as pharyngeal tooth counts and number of fin rays are variable and may overlap but still are extremely useful characters to distinguish certain species.

Cyprinids are abundant in the riverine and lacustrine habitats on the SRP. McFarlane et al. (1978) reported that 13 species have been collected from the Savannah River bordering the SRP; these vary in relative abundance from rare to abundant. In the tributary streams on the SRP, members of the family Cyprinidae have been collected from each of the five major creeks.

A Key to the Species of Cyprinidae

1. Mouth with barbel; barbel may be small and may be in a terminal position on the maxillary (Fig. 16)..... 2
 Mouth without barbel..... 5
2. Mouth with 2 barbels on each side of the upper jaw (Fig. 16C); pharyngeal teeth in 3 rows; strong serrated spine at origin of dorsal and anal fins; dorsal fin with more than 11 soft fin rays Cyprinus carpio - carp page 71
 Mouth with 1 barbel on each side of the upper jaw; pharyngeal teeth in 1 or 2 rows; spines absent, dorsal fin with fewer than 11 soft fin rays 3
3. Barbel not terminal but set below the maxilla and some distance forward from its posterior end (Fig. 16A); dorsal fin with a dark spot at origin; origin of dorsal fin behind pelvic fins..... Semotilus atromaculatus - creek chub page 78
 Barbel terminal on maxillary (Fig. 16B); dorsal fin without a dark spot at origin; origin of dorsal fin above or before pelvic fins 4
4. Mouth horizontal and inferior; snout extending beyond upper lip; eye longer than upper jaw; pharyngeal teeth 1-4-4-1; body with silvery stripe; dark broken outline of lateral line; breast without scales; melanophores on base of anal fin..... Hybopsis rubrifrons - rosyface chub page 72
 Mouth not horizontal and inferior; snout rounded, not extending beyond upper lip; pharyngeal teeth 4 - 4; may have dark lateral stripe..... Nocomis leptocephalus - bluehead chub page 73
5. Belly behind pelvic fins with a sharp scaleless keel (Fig. 17); adults silvery gold color; lateral line deeply down-curving; anal fin falcate and long, with 14-18 principal rays..... Notemigonus crysoleucas - golden shiner page 72
 Belly without a sharp scaleless keel; lateral line not deeply down-curving; anal fin shorter with fewer rays..... 6

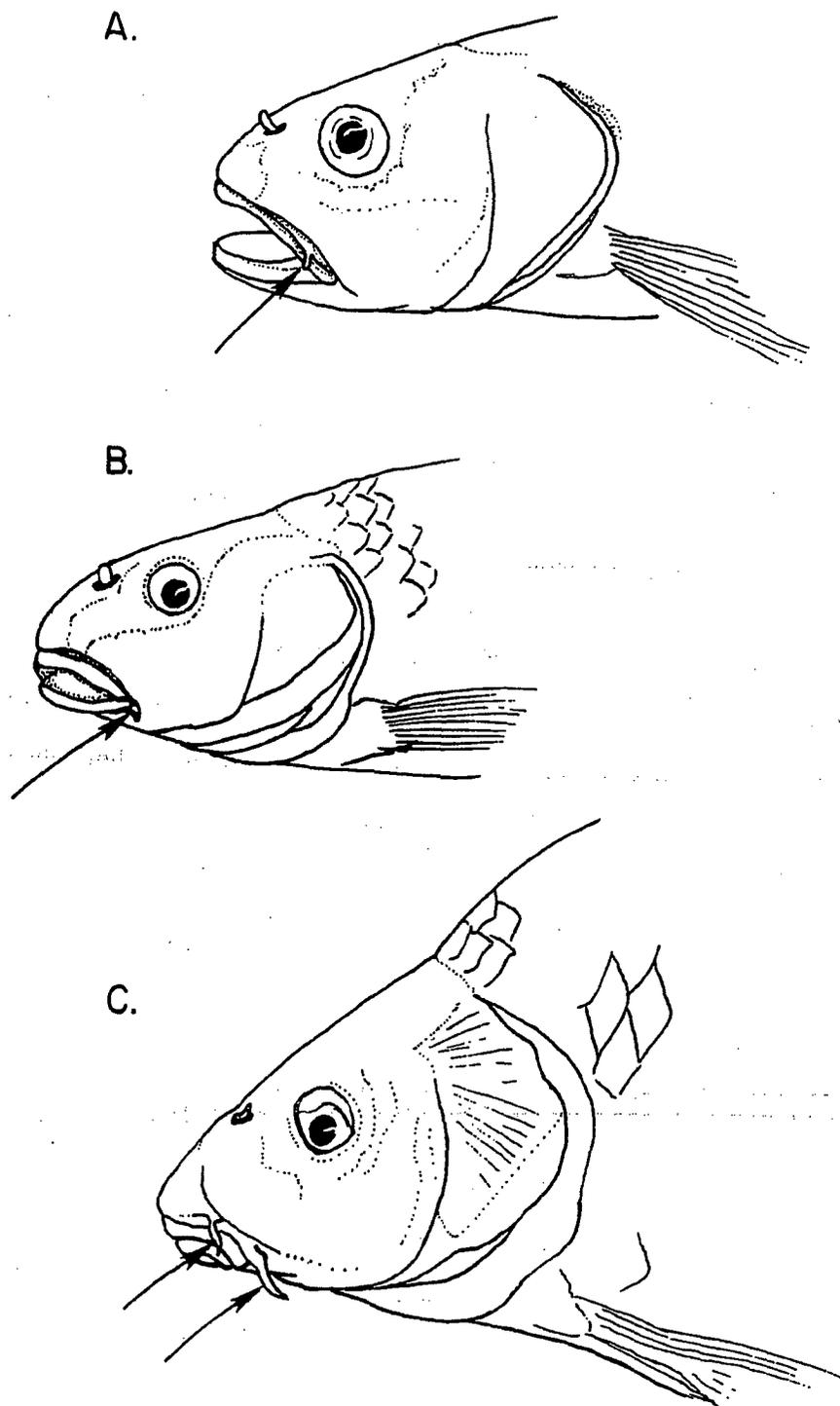


Figure 16. Barbel location (arrows) in creek chub, *Semotilus atromaculatus*, (A), bluehead chub, *Nocomis leptocephalus*, (B), and carp, *Cyprinus carpio*, (C) (after Blair et al. 1968) (See Appendix I).

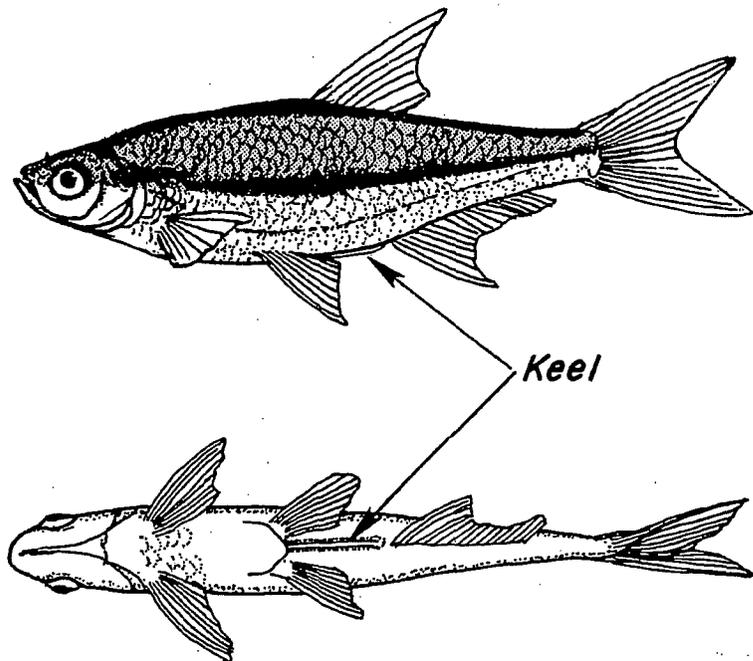


Figure 17. Location of the keel in golden shiner, Notemigonus crysoleucas.

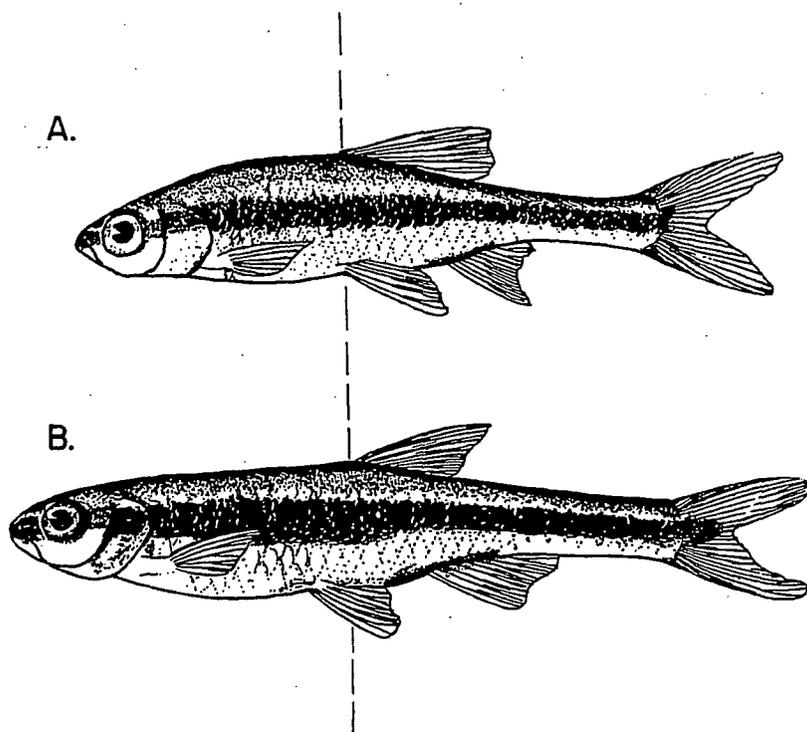


Figure 18. Location of pelvic fin relative to dorsal fin origin in (A) ironcolor shiner, Notropis chalybaeus, (B) and dusky shiner, N. cummingsae (after Eddy 1957; see Appendix I).

6. Mouth nearly horizontal and inferior, the maxillary ending below the posterior portion of the nostril; snout extending beyond lower jaw; silvery color with dark back; intestine long with several coils; teeth 4 - 4; peritoneum very black.....
 Hybognathus nuchalis - silvery minnow page 71
- Mouth horizontal or oblique; snout rarely extending beyond lower jaw; color silvery with a dark lateral stripe; teeth usually 1,4-4,1 or 2,4-4,2 but may be 5-5; intestine with only 1 anterior loop; peritoneum silvery or black.....genus Notropis 7
7. Pharyngeal teeth in single row, either 4-4 or 5-5..... 8
- Pharyngeal teeth in two rows, either 1,4-4,1 or 2,4-4,2..... 11
8. Pharyngeal teeth 5-5, strongly hooked and serrated; mouth very small and sharply oblique; dorsal rays typically 9; anal rays 8; maxilla extending only about $\frac{1}{2}$ distance to anterior of eye.....
Notropis emiliae - pugnose minnow page 74
- Pharyngeal teeth 4-4, not strongly hooked and serrated; mouth large and not sharply oblique; maxilla extending to greater than $\frac{1}{2}$ distance to anterior of eye..... 9
9. Caudal spot round, large and conspicuous with small dark triangles occurring at upper and lower edge of caudal base; lateral stripe extending to eye; lateral line incomplete (ending before caudal peduncle); anal rays usually 8; pharyngeal teeth 4-4; anal fin slightly falcate; mouth small.....
 Notropis maculatus - taillight shiner page 77
- Caudal spot small and inconspicuous; lateral stripe extending from below dorsal fin to caudal base; lateral line complete; anal rays 7 or 8; anal fins not falcate; mouth larger..... 10
10. Anal rays usually 8; pharyngeal teeth 4-4; interradiial pigment slight, anterior to the 6th ray of dorsal; lower sides of body and belly with little or no pigment (especially on caudal peduncle) except bordering anal base where it is intense; snout longer and pointed; black lateral stripe starting below dorsal fin extending to base of caudal fin; median fins light tipped.....
Notropis niveus - whitefin shiner page 77

- Anal rays 7; pharyngeal teeth 4-4; pigment on first few rays of dorsal fin; snout long but not pointed; lower jaw included; snout extending beyond lower jaw; dorsal origin over pelvic fins; broad dark lateral stripe starting below dorsal fin ending in a faint caudal spot..... Notropis leedsi - bannerfin shiner page 76
11. Anal rays usually 7; lateral stripe darker anteriorly; snout pointed; pigment around base of anal fin that extends to caudal fin as 2 or 3 broken stripes; pharyngeal teeth 2,4-4,2.....
.....Notropis petersoni - coastal shiner page 77
- Anal rays 8 or more; lateral stripe variable from wide and intensely dark to narrow and silvery; pigment not extending to caudal fin as 2 or 3 broken stripes; pharyngeal teeth 2,4-4,2 or 1,4-4,1..... 12
12. Pelvic fins under origin of dorsal fin (Fig. 18A)..... 13
- Pelvic fins anterior to origin of dorsal fins (Fig. 18B)..... 14
13. Pharyngeal teeth usually 1,4-4,1; anal rays usually 8; scales behind anal fin not pigmented; caudal spot may be present; lateral stripe narrow and silvery, with width less than diameter of eye; eye large; snout blunt; dorsal origin anterior to pelvic fins.....
.....Notropis hudsonius - spottail shiner page 75
- Pharyngeal teeth usually 2,4-4,2 (rarely 2,4-4,1); anal rays usually 8; dark lateral stripe extends through eye and snout; mouth very oblique and small, about 2/3 snout length; anal fin deeply falcate; caudal fin deeply forked; dorsal fin large; anterior ray of depressed dorsal greatly exceeding the posterior rays by 2-3 scale lengths on midline; vertical fins and sides above lateral stripe orange in breeding males; inner portion of lower jaw heavily pigmented; eye larger than snout; lateral line complete
.....Notropis chalybaeus - ironcolor shiner page 73
14. Anal rays usually 8; pharyngeal teeth 2,4-4,2; lateral stripe strong, almost equally developed throughout length and on caudal fin; opercle and preopercle heavily pigmented on upper half, devoid of pigment on lower half; no pigmentation from anal to caudal fin; eye small, diameter less than snout length; breeding males entirely red with yellow fins and white cap on head.....
..... Notropis lutipinnis - yellowfin shiner page 76
- Anal rays 9 or more; pharyngeal teeth 2,4-4,2 or 1,4-4,2; color of breeding males not as above..... 15
15. Anal rays usually 9 (10-11 is common); pharyngeal teeth 2,4-4,2; dorsal fin with a conspicuous horizontal black blotch; base of caudal fin marked with white or with 2 rosy spots (in fresh specimens) at base; lateral stripe wide and silvery; caudal spot smaller than eye
..... Notropis hypselopterus - sailfin shiner page 75
- Anal rays 10-11; pharyngeal teeth 1,4-4,1; dorsal fin without a conspicuous horizontal black blotch; lateral stripe wide, extending

around tip of snout; mouth small, extending to front of eye; eye large with diameter equal to or longer than snout.....
 Notropis cummingsae - dusky shiner page 74

Cyprinus carpio Linnaeus - carp

Key Characters: Mouth subterminal with 2 barbels on each side of the upper jaw (Fig. 16C). Dorsal and anal fins with serrated spines.

SRP Distribution: An introduced species uncommon to the SRP. Carp inhabit the Savannah River and swamp but rarely ascend streams. They are unknown from any of the reservoirs, but were captured by Humphries (1965) in Upper Three Runs Creek.

Habitat and Habits: Carp are found in sluggish sections of rivers usually over mud bottoms. Widely introduced into the U. S. from Europe because of esteemed food value. Carp feed primarily on benthos, plant materials, and plankton. They frequently roll and break the surface of the water with their backs. On the SRP, carp are most readily captured with trammel nets and by electrofishing in the cooling intake canals.

Size: The largest carp caught in North America was 27 kg. SRP maximum is 820 mm, 7.2 kg.

Hybognathus nuchalis Agassiz - silvery minnow

Key Characters: Large scales. Snout extends beyond lower jaw. Pharyngeal teeth 4-4 and flattened. Dorsal fin origin anterior to that of pelvic fins. Anal rays 8.

SRP Distribution: Abundant in the Savannah River and also present in Lower Three Runs Creek and reported from Four Mile Creek (Freeman 1954).

Habitat and Habits: Found mainly in large river systems and occasionally in smaller streams. Majority of fish collected on SRP were from the Savannah River (McFarlane et al. 1978).

Size: Maximum size about 12 cm.

Hybopsis rubrifrons (Jordan) - rosyface chub

Key Characters: Mouth inferior. Eye longer than upper jaw. Lower jaw included. Pharyngeal teeth 1,4-4,1. Anal rays 8. Black to silvery lateral stripe. Small barbels at end of maxillary.

SRP Distribution: Uncommon. A few specimens have been collected in the Savannah River and a small tributary of Upper Three Runs.

Habitat and Habits: Larger rivers and their tributaries.

Size: Maximum length is 10 cm. SRP maximum is 7.6 mm, 3.9 g. Length-weight relationship ($N = 28$, $r = 0.97$) is $\ln W = 3.055 (\ln TL) - 11.89$.

Notemigonus crysoleucas (Mitchill) - golden shiner

Key Characters: A deep-bodied minnow with a strongly up-turned but very small mouth. Lateral line complete and strongly decurved. A fleshy, scaleless keel present along midline of belly from anus to pelvic fin bases (Fig. 17).

SRP Distribution: Common in all creeks on the SRP, except absent from the Salkehatchie River. Uncommon in the Savannah River. Present in the Par Pond system, Skinface Pond, and Twin Lakes.

Habitat and Habits: Found in backwaters or slow moving sections of creeks, usually associated with vegetation. Often found schooling near the surface. Feeds on plant and animal matter. Spawns over algae or submerged aquatic

macrophytes when water temperatures warm to about 22°C. May spawn in association with sunfishes.

Size: Maximum length 20 cm.

Nocomis leptocephalus (Girard) - bluehead chub

Synonyms: Hybopsis bellicus (Freeman 1954), Nocomis bellicus (ANSP 1953), Hybopsis leptocephala (Blair et al. 1968).

Key Characters: Terminal barbel on maxillary (Fig. 16B). Mouth terminal. Snout rounded. Pharyngeal teeth 4-4; anal rays usually 7.

SRP Distribution: Common. Found in small tributaries of all creeks except the Salkehatchie River; rare in the Savannah River.

Habitat and Habits: A chub widely distributed in SRP streams; generally associated with stream cover. Individuals of this species are active stream inhabitants and can be seen darting from one area to another.

Size: SRP maximum 13.6 cm, 24 g.

Notropis chalybaeus (Cope) - ironcolor shiner

Synonyms: Hydrophlox chalybaeus (Fowler 1935).

Key Characters: Dark lateral stripe. Mouth small, about 2/3 snout length. Dorsal fin origin over pelvic fin (Fig. 18A). Long anterior rays of dorsal fin (extending 2-3 scales along midline). Pharyngeal teeth 2,4-4,2. Anal rays 8. Inner portion of lower jaw heavily pigmented.

SRP Distribution: Common. Found in Upper Three Runs Creek, Pen Branch, and Lower Three Runs Creek. Freeman (1954) also collected it in Four Mile Creek. Rare in the Savannah River.

Habitat and Habits: Strongly schooling minnow found in smaller tributaries and larger creeks of medium velocity with sandy bottoms. Spawning occurs

over sand where eggs adhere to the bottom. Invertebrate organisms are the primary food.

Size: Maximum length is 8 cm.

Notropis cummingsae Myers - dusky shiner

Key Characters: Breast scaly. Pelvic insertion anterior to dorsal fin (Fig. 18B). Wide lateral stripe extends around snout. Eye large, equal to or larger than snout. Pharyngeal teeth 1,4-4,1. Anal rays 10-11.

SRP Distribution: Common. Found in all major creeks but rare in the Savannah River. Not collected from Pen Branch recently but collected there by Freeman (1954) prior to plant operations.

Habitat and Habits: Found over sandy bottom streams having a perceptible current. The most abundant schooling minnow of second- and third-order SRP streams; found only in lower reaches of first-order streams.

Size: Maximum length 75 mm. SRP maximum 49 mm, 0.79 g. Length-weight relationship ($N = 31$, $r = 0.96$) is $\ln W = 3.172 (\ln TL) - 12.52$.

References: Hubbs and Raney 1951, McFarlane et al. 1976, Smith-Vaniz 1968.

Notropis emiliae (Hay) - pugnose minnow

Synonyms: Opsopoeodus emiliae (Blair et al. 1968).

Key Characters: Dorsal fin in adult males has dark-light-dark pigmentation pattern. Snout without concentration of pigment. Breast scaleless. Dorsal rays 9. Anal rays 8. Mouth very small and nearly vertically oblique. Pharyngeal teeth 5-5, hooked and serrated.

SRP Distribution: Rare. Not collected from any creeks on the SRP and rarely captured in the Savannah River.

Habitat and Habits: Large sluggish rivers or back water areas.

Size: Maximum length 8 cm. SRP maximum 4.7 cm, 0.9 g.

Notropis hudsonius (Clinton) - spottail shiner

Key Characters: Large minnow with silvery stripe; width of stripe smaller than diameter of eye. Eye large. Snout blunt and upper jaw included. Pharyngeal teeth usually 1,4-4,1. Anal rays usually 8. Dorsal origin anterior to pelvic fins.

SRP Distribution: Abundant in the Savannah River; uncommon in the lower reaches of Upper Three Runs and Steel Creek.

Habitat and Habits: A shiner found almost exclusively in large creeks and rivers with moderate to slow current. Feeds primarily on invertebrates but fish eggs and juvenile fishes also have been found in the diet.

Size: Maximum length 15 cm. SRP maximum 12.4 cm, 17.5 g. Length-weight relationship ($N = 100$, $r = 0.99$) is $\ln W = 3.085 (\ln TL) - 12.07$.

Reference: Wells and House 1974.

Notropis hypselopterus (Günther) - sailfin shiner

Synonyms: Notropis stonei (Fowler 1920); Notropis hypselopterus stonei is the subspecies on the SRP.

Key Characters: Conspicuous horizontal black blotch on dorsal fin. Lateral stripe dark and wider than the eye. Pelvic fins anterior to dorsal fin origin (Fig. 18B). Breast scaly.

SRP Distribution: Uncommon. Collected in small numbers from Lower Three Runs Creek, Four Mile Creek, Upper Three Runs, and the Salkehatchie River. Not collected in the Savannah River adjacent to the SRP.

Habitat and Habits: Flowing streams with perceptible current and having sandy or muddy bottom types.

Size: Maximum length 7 cm. SRP maximum 4.5 cm, 0.5 g. Length-weight relationship ($N = 83$, $r = 0.93$) is $\ln W = 3.431 (\ln TL) - 13.54$.

Reference: Fowler 1920.

Notropis leedsi Fowler - bannerfin shiner

Key Characters: Breast scaleless. Pigment on first few rays of dorsal fin. Lower jaw included. Broad lateral stripe below dorsal fin terminates as faint caudal spot. Pharyngeal teeth 4-4. Anal rays 8.

SRP Distribution: Uncommon in the Savannah River; not found in major tributary streams.

Habitat and Habits: Large rivers.

Size: SRP maximum 8 cm, 5.7 g. Length-weight relationship ($N = 25$, $r = 0.98$) is $\ln W = 3.132 (\ln TL) - 12.08$.

Reference: Fowler 1942.

Notropis lutipinnis (Jordan and Brayton) - yellowfin shiner

Synonyms: Hydrophlox lutipinnis (Jordan and Brayton 1878)

Key Characters: Breast scaleless. Dark lateral stripe from caudal fin to snout. Pharyngeal teeth 2,4-4,2. Anal rays 8. Anal to caudal fin without pigment. Fins yellow. Red with white fins and white cap on head during breeding season.

SRP Distribution: Abundant. The most abundant shiner in tributary streams on the SRP and the dominant minnow of first-order tributaries. Not found in the Savannah River.

Habitat and Habits: Small streams over sandy, gravel bottom types. Turns scarlet during the spawning season. Spawns over piles of fine to coarse gravel in shallow riffles.

Size: Maximum size is about 10 to 12 cm. SRP maximum is 7.4 cm, 3.62 g. Length-weight relationship ($N = 78$, $r = 0.96$) is $\ln W = 3.108 (\ln TL) - 12.18$.

Reference: McFarlane et al. 1976.

Notropis maculatus (Hay) - taillight shiner

Key Characters: Large, distinct caudal spot. Dark lateral stripe extending to eye. Tip of snout whitened. Anal fin slightly falcate. Mouth small. Lateral line incomplete.

SRP Distribution: Uncommon. Collected from all creeks except Pen Branch and the Salkehatchie River; rare in the Savannah River.

Habitat and Habits: Slow moving shoreline areas of streams having low gradient over muddy bottom.

Size: Maximum length 7 cm. SRP maximum 6.3 cm, 2.0 g. Length-weight relationship ($N = 6$, $r = 0.97$) is $\ln W = 3.795 (\ln TL) - 14.87$.

Notropis niveus (Cope) - whitefin shiner

Key Characters: Pigment on posterior dorsal rays. Breast without scales. Dark lateral stripe extending below dorsal fin to base of caudal fin. Jaws equal; snout long and pointed. Tip of median fins light in color. Pharyngeal teeth 4-4. Anal rays usually 8.

SRP Distribution: Rare. A few were collected from Lower Three Runs Creek by Freeman (1958) after the advent of SRP operations but none have been seen since. Uncommon in the Savannah River.

Habitat and Habits: Large rivers.

Size: SRP maximum 12.7 cm, 19.6 g. Length-weight relationship ($N = 19$, $r = 0.96$) is $\ln W = 3.611 (\ln TL) - 14.36$.

Notropis petersoni Fowler - coastal shiner

Key Characters: Pointed snout. Breast scaleless. Dorsal fin origin over pelvic fins. Pharyngeal teeth 2,4-4,2. Anal rays usually 7. Concentration of pigment at anal base extending to caudal fin as 2-3 broken lines. Lateral line delimited by melanophores.

SRP Distribution: Common. The only Notropis found in Par Pond. Commonly caught in all creeks except Pen Branch and the Salkehatchie River. Also, found at creek mouths; regularly caught in low numbers in the Savannah River and Skinface Pond.

Habitat and Habits: Lakes and slower flowing stretches of streams. Usually found over sandy bottoms. In Steel Creek it is most common in deep pools.

Size: Maximum length usually less than 8 cm. SRP maximum 7.6 cm, 3.5 g. Length-weight relationship ($N = 55$, $r = 0.98$) is $\ln W = 3.132 (\ln TL) - 12.06$.

Semotilus atromaculatus (Mitchill) - creek chub

Key Characters: Mouth with non-terminal barbel below maxilla (Fig. 16A). Dorsal fin with a large dark spot at base. Dorsal fin origin behind pelvic fins.

SRP Distribution: In small tributaries of all creeks except the Salkehatchie River. Not found in the Savannah River.

Habitat and Habits: Found under cover in small streams having moderate velocity and sandy bottoms. Fast swimmers which rapidly dart from one cover area to another. Creek chubs pile gravel for spawning in the late spring and summer. Food is aquatic insects and fish.

Size: Maximum length about 25 cm. SRP maximum 115 mm; 18 g. Length-weight relationship ($N = 41$, $r = 0.96$) is $\ln W = 3.417 (\ln TL) - 13.20$.

Reference: McFarlane et al. 1976.

SUCKER FAMILY - CATOSTOMIDAE

Members of the Catostomidae are soft-rayed fishes that have sucker-like mouths (Fig. 13). Most of the fishes in this family have thick lips that are

generally covered by folds of skin. Suckers are closely related to minnows but differ by having more than 10 dorsal rays (minnows have 10 or fewer dorsal rays) and the last pharyngeal arch contains a single row of comb-like teeth (Fig. 14A). Minnows either have more than one row of pharyngeal teeth or one row with five or fewer teeth.

Suckers are abundant in various habitats on the SRP. Some are found in small, higher gradient streams while other species inhabit the larger creeks, lakes, the Savannah River, and even Carolina bays.

Key to the Species of Catostomidae

1. Dorsal fin with 25 to 40 rays; anterior dorsal rays nearly three times as long as posterior dorsal rays Carpiodes cyprinus - quillback page 80
 Dorsal fin with 10 to 18 rays; anterior dorsal rays not more than twice as long as posterior dorsal rays..... 2
2. Top of head concave between eyes; eye behind middle of head; body with 4-6 conspicuous dark cross-bars (dorsal saddles)..... Hypentelium nigricans - northern hogsucker page 81
 Top of head not concave between eyes; eye nearly centered in head; body without cross-bars..... 3
3. Dorsal fin rays usually 14 or 15; rear margin of lower lip forming an acute angle (Fig. 13A); 12 scales around caudal peduncle..... Moxostoma anisurum - silver redhorse page 82
 Dorsal fin rays usually 12 or 13; rear margin of lower lip nearly straight or forming a slight angle..... 4
4. Scales on sides with dark spots at bases, forming stripes; snout extending well beyond upper lip (Fig. 13B); lateral line nearly complete (terminates near anal fin)..... Minytrema melanops - spotted sucker page 82
 Scales on sides without dark spots at bases but may appear as a single dark stripe; snout not extending beyond upper lip; lateral line absent. 5
5. Longitudinal scale rows 39-45; head small (3.5 - 4.2 in standard length); dorsal fin rays usually 10 (rarely 11)..... Erismyzon oblongus - creek chubsucker page 80

Longitudinal scale rows 34-38; head large (3.2 - 3.8 in standard length); dorsal fin rays usually 11 or 12.....
Erimyzon sucetta - lake chubsucker page 81

Carpiodes cyprinus (Lesueur) - quillback

Key Characters: Dorsal fin long with 25 to 40 rays. Anterior dorsal rays nearly three times the length of the posterior dorsal rays. Body heavy with large scales.

SRP Distribution: Rare. Quillback have not been collected in any creeks on the SRP; they are considered rare in adjacent Savannah River waters.

Habitat and Habits: An inhabitant of large rivers and large impoundments. Generally found over bottom types with organic matter. Food is diatoms, aquatic insects and algae.

Size: Maximum size about 2.5 kg.

Erimyzon oblongus (Mitchill) - creek chubsucker

Key Characters: Lateral line absent. Young with black longitudinal stripe. Scales small, 39-45 longitudinal scale rows. Easily confused with E. sucetta. Fins amber in young juveniles.

SRP Distribution: Common. Found in tributaries of all major creeks on SRP. Rare in the Savannah River.

Habitat and Habits: Found in smaller streams with low to moderate gradient. Not found in any lakes or swamps. Aquatic insects, microcrustaceans, and algae constitute the diet of creek chubsuckers.

Size: Maximum length about 25 cm. Length-weight relationship (N = 85, $r = 0.99$) is $\ln W = 3.34 (\ln TL) - 12.56$.

Erimyzon sucetta (Lacépède) - lake chubsucker

Key Characters: Lateral line absent. Young with black longitudinal stripe, fins reddened in young. Scales large, longitudinal scales 34-38.

SRP Distribution: Common. A few lake chubsuckers have been collected from all creeks on the SRP. They are present in Par Pond and other SRP ponds but rare in the Savannah River.

Habitat and Habits: Chubsuckers are found in standing waters with organic matter on the bottom and are generally located around cover. They spawn in the spring in streams and along lake shorelines. Lake chubsuckers feed primarily on microcrustaceans and chironomid larvae. These are considered important forage fish for large fish predators.

Size: Maximum length about 25 cm. Length-weight relationship ($N = 27$, $r = 0.99$) is $\ln W = 3.34 (\ln TL) - 13.00$.

Hypentelium nigricans (Lesueur) - northern hogsucker

Key Characters: A large bony head with eyes set closer to gill cover than to tip of snout. Head concave between eyes. Four to six cross-bars that extend forward onto sides.

SRP Distribution: Common: Found in Upper Three Runs Creek, Pen Branch and Steel Creek. Not collected from any lentic waters on SRP.

Habitat and Habits: Found in streams with clean gravel substrate having perceptible flow. Usually found in riffles. Darts rapidly from one area to the next. Overturns rocks when feeding. Spring spawner over fine substrate.

Size: Maximum size about 42 cm.

Minytrema melanops (Rafinesque) - spotted sucker

Key Characters: Lateral line nearly complete. Silvery with a dark distinct spot on each scale forming lateral stripes. Mouth distinctly horizontal and inferior (Fig. 13B).

SRP Distribution: Abundant. Collected in mouths and lower reaches of Upper Three Runs, Lower Three Runs and backwaters of Four Mile Creek. The most abundant sucker in the Savannah River. Commonly collected in Par Pond.

Habitat and Habits: Clear sluggish streams or lentic waters. Intolerant of turbid waters and industrial pollutants (Trautman 1957).

Size: Maximum length about 50 cm. SRP maximum 49 cm, 1493 g. Length-weight relationship ($N = 112$, $r = 0.99$) is $\ln W = 3.1 (\ln TL) - 11.97$.

Moxostoma anisurum (Rafinesque) - silver redhorse

Key Characters: Protractile premaxillary. Lateral line complete. Air bladder with three sections. Caudal fin rounded and slightly forked. Dorsal fin rounded. Scales large, 12 around caudal peduncle. Transverse creases in plicae. Rear margin of lower lip forming an acute angle (Fig. 13A).

SRP Distribution: Common in deeper pools at mouths of Lower Three Runs Creek and Upper Three Runs Creek. Uncommon in the Savannah River adjacent to the SRP.

Habitat and Habits: Deeper slow flowing waters that are clear. Found in open water. Spawn in springtime at about 13.5 C. Food consists mainly of ephemeropteran, trichopteran, and dipteran larvae.

Size: Maximum length over 60 cm. SRP maximum 49.8 cm, 1341 g. Length-weight relationship ($N = 41$, $r = 0.99$) is $\ln W = 2.96 (\ln TL) - 11.14$.

Reference: Jenkins 1970.

ORDER SILURIFORMES

CATFISH FAMILY - ICTALURIDAE

Ictalurids are easily distinguished by their broad flat heads, sharp pectoral and dorsal spines, scaleless bodies, and barbels on the upper and lower jaws. Three well-known common names are used for fishes in this family: catfishes, bullheads, and madtoms.

Members of Ictaluridae are common in a wide range of waters on the SRP from the smaller tributary streams to the Savannah River. Ictalurids are not often seen by untrained observers because of their clandestine habits--hiding under logs, stones, or other debris and in undercut banks. Madtoms should be handled carefully as their poisonous pectoral spines can inflict a painful sting.

A Key to the Species of Ictaluridae

- | | | |
|----|--|---------|
| 1. | Caudal fin forked..... | 2 |
| | Caudal fin rounded or square, not forked | 3 |
| 2. | Anal fin rays 18-26 (\bar{x} = 23); tail lobes not pointed, upper lobe longer than lower lobe; body without small dark spots; head flattened..... | |
| | <u>Ictalurus catus</u> - white catfish | page 86 |
| | Anal fin rays 24-29; tail lobes pointed, upper lobe about equal to lower lobe; body with small irregular spots; head rounded in young specimens; somewhat flattened in larger specimens..... | |
| | <u>Ictalurus punctatus</u> - channel catfish | page 88 |
| 3. | Adipose fin free at its posterior end (Fig. 19A)..... | 4 |
| | Adipose fin adnate to back (Fig. 19B)..... | 8 |
| 4. | Anal fin rays less than 16; band of teeth in upper jaw with backward lateral extensions (Fig. 19C); caudal fin truncated; head flattened.... | |
| | <u>Pylodictis olivaris</u> - flathead catfish | page 90 |
| | Anal fin having 16 or more rays; band of teeth in upper jaw without backward lateral extensions (Fig. 19D); head not flattened..... | 5 |

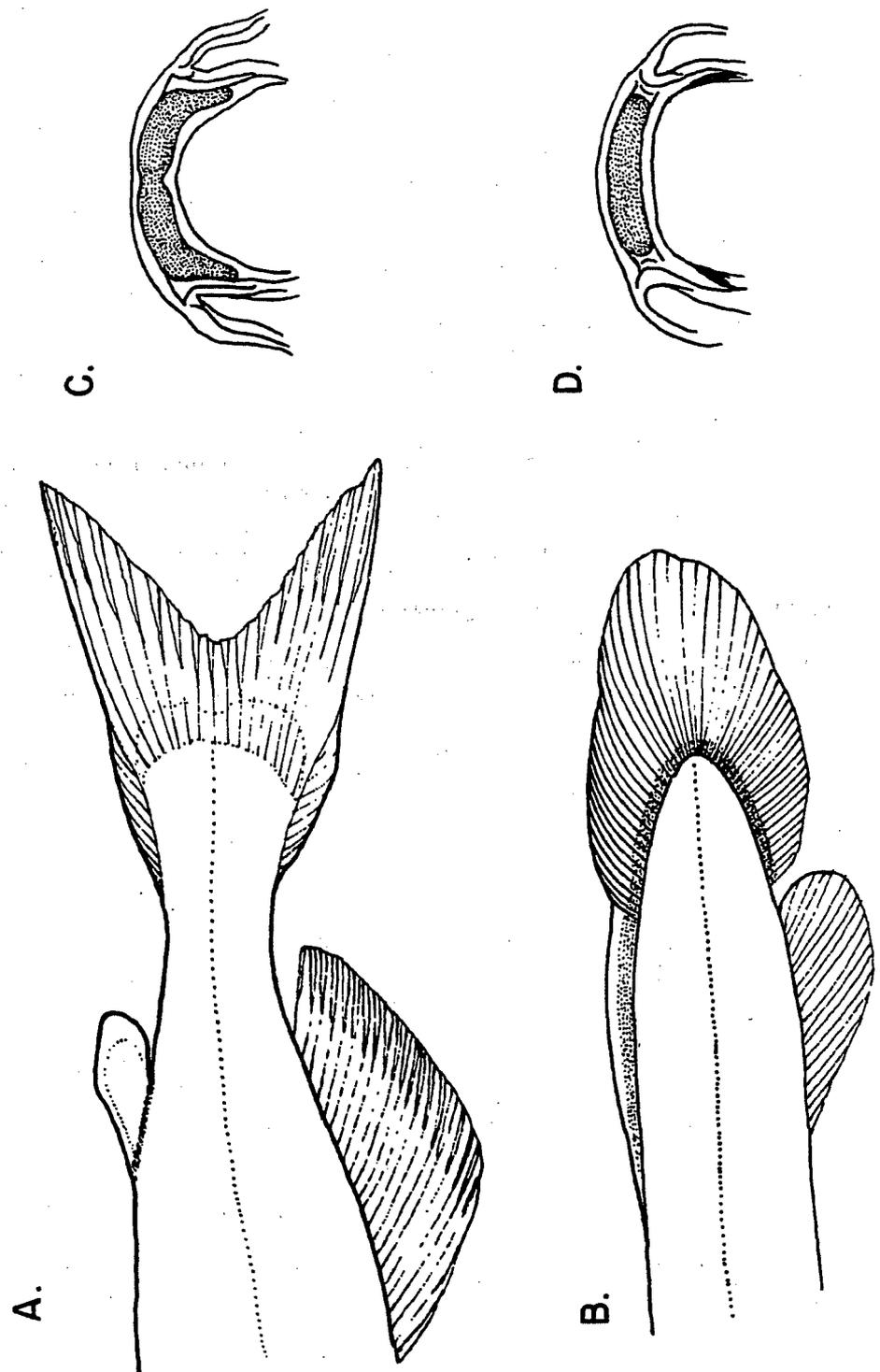


Figure 19.

Adipose fin type (A - *Ictalurus punctatus*; B - *Noturus* sp.) and appearance of premaxillary teeth (C - *Pylodictis olivaris*; D - *Ictalurus* sp.) in members of the family Ictaluridae (after Forbes and Richardson 1920; see Appendix I).

5. Chin barbels white or pink but never dark (barbels on larger forms may be grayish); anal fin rays 25 to 28; anterior rays of anal fin only slightly longer than posterior rays.....
Ictalurus natalis - yellow bullhead page 86
- Chin barbels with melanophores, usually black (occasionally whitish); anal fin rays 25 or fewer; anterior rays of anal fin distinctly longer than posterior rays..... 6
6. Body mottled; mouth terminal or nearly so; pectoral spines with many large serrae on posterior edge; anal fin rays 22 to 25; no dark streak across base of dorsal fin.....
Ictalurus nebulosus - brown bullhead page 87
- Body not mottled; mouth subterminal to strongly inferior; pectoral spines with small serrae; dark streak across base of dorsal fin (may be obscured by tissue in larger forms)..... 7
7. Pectoral spines with serrae on anterior and (number of anal rays minus number of gill rakers) posterior edge; anal fin rays 19-24; gill rakers 11-14; character index 8-13 (rarely 6 or 7); mouth subterminal to moderately inferior.....
 Ictalurus brunneus - snail bullhead page 85
- Pectoral spines with serrae on posterior edge; anal fin rays 16-22; gill rakers 12-17; character index 1-7 (rarely 8 or 9); mouth moderately to strongly inferior.....
 Ictalurus platycephalus - flat bullhead page 87
8. Pectoral spines without serrae on posterior edges..... 9
- Pectoral spines with serrae on posterior edges (both left and right spines need to be examined); serrae long and sharp; body long and tapering..... Noturus insignis - margined madtom page 89
9. Lower jaw shorter than upper (included); body and fins with numerous chromatophores (spotting); pectoral spine short and slender, about 1/3 length of head; no thin lateral stripe.....
Noturus leptacanthus - speckled madtom page 89
- Jaws equal; body and fins without spotting; pectoral spine long and stout, about 1/2 length of head.....
Noturus gyrinus - tadpole madtom page 88

Ictalurus brunneus (Jordan) - snail bullhead

Key Characters: Caudal fin rounded. Adipose fin free, its posterior end not attached. Mouth subterminal to moderately inferior. Pectoral spines with small serrae on anterior and posterior surfaces. Anal rays 19-24. Gill

rakers 11-14. Character index 8-13 (rarely 6 or 7). Commonly confused with I. platycephalus.

SRP Distribution: Rare. Specimens known from the Savannah River and Steel Creek.

Habitat and Habits: Larger creeks and rivers supporting snail populations. Diet believed to consist primarily of snails.

Size: Maximum length about 28 cm. SRP maximum 28 cm, 240 g. Length-weight relationship ($N = 7$, $r = 0.99$) is $\ln W = 2.77 (\ln TL) - 10.08$.

Reference: Yerger and Relyea 1968.

Ictalurus catus (Linnaeus) - white catfish

Key Characters: Anal rays 18-26. Caudal fin not deeply forked. Head flattened. Body without small dark spots. Tail lobes blunt not pointed. Often confused with I. punctatus.

SRP Distribution: Rare in the Savannah River. Collected in Steel Creek, Upper Three Runs Creek, and Lower Three Runs Creek, and probably occurs in lower sections of all major creeks. Some specimens of I. punctatus in earlier surveys were misidentified as I. catus.

Habitat and Habits: Found in waters of intermediate velocity and having firm bottom types. Feed predominately on fish but also on vegetative material and aquatic insects.

Size: Maximum length about 120 cm. SRP maximum 64 cm, 3690 g. Length-weight relationship ($N = 6$, $r = .99$) is $\ln W = 3.213 (\ln TL) - 12.62$.

Ictalurus natalis (Lesueur) - yellow bullhead

Key Characters: Rounded caudal fins. Anal fin rays 25 to 28; anterior rays about same length as posterior rays. Chin barbels white or pink in young becoming gradually darker. Mouth terminal. Belly usually yellowish. May be

confused with I. platycephalus or I. brunneus, but juveniles lack melanophores in chin barbels.

SRP Distribution: Abundant. Found in all creeks on the SRP. Rare in the Savannah River. Abundant in lakes and ponds on the SRP.

Habitat and Habits: Sluggish waters; clear or turbid. Commonly associated with instream cover and undercut banks in streams. Feeds on aquatic invertebrates and some fish.

Size: Maximum length about 55 cm. SRP maximum 31.0 cm, 420 g. Length-weight relationship ($N = 10$, $r = 0.99$) is $\ln W = 3.112 (\ln TL) - 11.85$.

Ictalurus nebulosus (Lesueur) - brown bullhead

Key Characters: Mottled body. Mouth terminal. Pectoral spines with long, sharp serrae on posterior edge. Anal fin rays 22 to 25. Perhaps the most frequently misidentified catfish on the SRP and likely much rarer than reported.

SRP Distribution: Uncommon. Collected in Upper Three Runs, Four Mile, Pen Branch and Steel Creeks. Also reported by previous investigators in Lower Three Runs Creek. Rare in the Savannah River adjacent to the SRP. Also found in several farm ponds and the Par Pond system.

Habitat and Habits: Quiet areas in streams and ponds having a muddy bottom type. Spawn in spring, utilizing a nest; males provide protection. Zooplankton, plants, aquatic invertebrates, and fish are eaten.

Size: Maximum length about 55 cm.

Ictalurus platycephalus (Girard) - flat bullhead

Key Characters: Fins edged with black. Pectoral spines with serrae on posterior edge. Anal fin rays 16-22. Gill rakers 12-17. Character index 1-7 (rarely 8 or 9). Mouth inferior. Commonly confused with I. brunneus.

SRP Distribution: Common. Collected in all creeks except the Salkehatchie River. Abundant in the lower sections of creeks and common in the Savannah River. Collected in Par Pond and probably found in farm ponds.

Habitat and Habits: Slow moving streams, backwater areas and pools with muddy bottom types. Benthic organisms are consumed for food.

Size: SRP maximum 47 cm, 555 g. Length-weight relationship ($N = 50$, $r = 0.99$) is $\ln W = 3.22 (\ln TL) - 12.66$.

Reference: Yerger and Relyea 1968.

Ictalurus punctatus (Rafinesque) - channel catfish

Key Characters: Deeply forked tail. Small irregular dark spots on body (especially in young). Head rounded in young, somewhat flattened in larger specimens. Commonly confused with I. catus.

SRP Distribution: A common, introduced species commercially harvested in the Savannah River. Common in the lower reaches of Upper Three Runs, less common in other streams. Occasionally collected in Par Pond.

Habitat and Habits: Prefer rapidly moving water at head end of pools and below dams. Feed on aquatic insects, shellfish and fishes.

Size: Maximum size about 10 kg. SRP maximum 53.0 cm, 1630 g. Length-weight relationship ($N = 66$, $r = 0.99$) is $\ln W = 3.135 (\ln TL) - 12.50$.

Reference: Humphries 1965.

Noturus gyrinus (Mitchill) - tadpole madtom

Key Characters: Adipose fin adnate to back (Fig. 19B). No serrae on pectoral spines; pectoral spine about 2/3 length of fin. Jaws equal in length. Yellowish brown above, pale below. Thin lateral stripe present.

SRP Distribution: Common. Distributed in smaller tributaries and major creeks; not collected in Pen Branch. Not collected from the Salkehatchie River by the authors, although Freeman (1954) reported them there; found in the Par Pond system. Rare in the Savannah River.

Habitat and Habits: Sheltered areas beneath streambanks and between rocks in streams experiencing high velocities. Also found in ponds and backwater areas of streams. Feeds on entomostracans and chironomids.

Size: Maximum length about 15 cm. SRP maximum 9 cm, 4.95 g. Length-weight relationship ($N = 11$, $r = 0.99$) is $\ln W = 2.97 (\ln TL) - 11.70$.

Noturus insignis (Richardson) - margined madtom

Synonyms: Noturus marginatus; Pimelodus insignis (Richardson 1836)

Key Characters: Adipose fin adnate to back (Fig. 19B). Pectoral fin long, posterior edge with sharp serrae. Body long and tapering to caudal fin.

SRP Distribution: Uncommon. Collected from Upper Three Runs, Pen Branch and Steel Creeks. Also taken in an earlier survey in Lower Three Runs Creek. Not found in the Savannah River.

Habitat and Habits: Creeks with low gradient having soft bottoms. Feed on insects and fish.

Size: Maximum length about 30 cm.

Reference: Hubbs and Raney 1944.

Noturus leptacanthus (Jordan) - speckled madtom

Key Characters: Adipose fin adnate to back (Fig. 19B). Pectoral spine without serrae and less than $\frac{1}{2}$ length of fin. Body long and speckled. Fins dark. Lower jaw included.

SRP Distribution: Abundant. Collected from all major creeks but the Salkehatchie River. Collected in the Savannah River but considered rare.

Habitat and Habits: Small to large creeks with low to medium gradient. Feeds on aquatic invertebrates and fish. Frequently associated with algal mats.

Size: Maximum length about 8 cm. SRP maximum 6.3 cm, 2.25 g. Length-weight relationship ($N = 40$, $r = 0.98$) is $\ln W = 3.01 (\ln TL) - 11.78$.

Pylodictis olivaris (Rafinesque) - flathead catfish

Key Characters: Truncated caudal fin. Band of teeth in upper jaw with backward lateral extensions (Fig. 19C). Anal fin rays fewer than 16.

SRP Distribution: A rare, introduced species reported from the Savannah River (ANSP 1955) downstream of the SRP and from Par Pond (Clugston 1973a).

Habitat and Habits: Large impoundments and large rivers. Found below dams behind cover; feed in riffles. Adults generally remain under cover. Juveniles feed on aquatic insects; adults eat predominately fish.

Size: Maximum size about 45 kg.

ORDER - PERCOPSIFORMES

CAVEFISH FAMILY - AMBLYOPSIDAE

Members of the cavefish family are diverse. Some cavefish do not have eyes, although functional eyes occur in the only SRP species, the swampfish (Chologaster cornuta). All six species in this family are confined to eastern North America; all but C. cornuta are found in caves. This species has a flat naked head and no pelvic fins. The anus in adults is located in the jugular position.

Chologaster cornuta Agassiz - swampfish.

Key Characters: Head flattened. Rounded dorsal fin directly above anal fin. Pelvic fins absent. Caudal fin and dorsal surface of body dark. Anus jugular in adults (Fig. 15A). Dark vertical bands on caudal fin.

SRP Distribution: Rare. Collected from Lower Three Runs Creek, the Salkehatchie River, and the Savannah River. Previously collected from Upper Three Runs. Probably occurs in all creek systems.

Habitat and Habits: Swamps, backwater areas of larger rivers and springs with detritus substrate.

Size: Maximum length about 5 cm.

PIRATE PERCH FAMILY - APHREDODERIDAE

This family contains a single species, the pirate perch, Aphredoderus sayanus. An interesting feature of this species is the jugular location of the anus in adults (Fig. 15B). The location of the anus gradually migrates forward as the fish increases in size until the anus attains a position under the throat in adults.

Aphredoderus sayanus (Gilliams) - pirate perch

Key Characters: Jugular position of anus; large mouth. Well-developed lateral line. Dark vertical band on caudal peduncle. Body color dark olive to gray; body may be speckled. Dorsal spines 3 with 2 anal spines.

SRP Distribution: Abundant. One of the more ubiquitous fish on the SRP. Collected from all streams, Par Pond, and Skinface Pond but rare in the Savannah River.

Habitat and Habits: Collected around undercut banks and instream cover in streams and lakes. Occurs in shallow water (< 30 cm). This species exhibits

a predatory feeding behavior. Pirate perch spawn in a nest which is subsequently guarded.

Size: SRP maximum 14.5 cm, 28 g. Length-weight relationship ($N = 62$, $r = 0.98$) is $\ln W = 3.05 (\ln TL) - 11.53$.

ORDER - ATHERINIFORMES

NEEDLEFISH FAMILY - BELONIDAE

Belonids are generally considered marine fishes but a few specimens have been captured in the Savannah River. Members of the family are easily recognized by their long slender bodies with both jaws greatly elongated to form a beak. Needlefish superficially resemble gar (Lepisosteus) but can be easily distinguished by their silvery coloration and the absence of ganoid scales.

Strongylura marina (Walbaum) - Atlantic needlefish

Key Characters: Body rounded. Jaws elongated. Gill rakers absent. Anal fin rays 16 to 20. Dorsal fin rays 14 to 17. Lateral line low on body. Fins without spines. Body soft, scales small and flexible.

SRP Distribution: Rare. A few collected in cooling intake canal off Savannah River. Probably enter mouths of larger tributaries.

Habitat and Habits: Found around docks and trees or some other type of cover.

Size: SRP maximum 32.5 cm, 48.5 g.

KILLIFISH FAMILY - CYPRINODONTIDAE

Killifish possess small upturned mouths for surface feeding. Most are small fishes rarely exceeding 10 cm in total length. The caudal fin is rounded and the lateral line is partially developed. Pelvic fins are abdominal in position. Fertilization is external.

Fundulus lineolatus, the lined topminnow, has been the only species of killifish collected on the SRP.

Fundulus lineolatus (Agassiz) - lined topminnow

Synonyms: Zygonectes notti (Fowler 1945); Fundulus notti (ANSP 1961); Fundulus dispar lineolatus (ANSP 1957).

Key Characters: Small body size with protruding lower jaw with the mouth opening dorsally. Concentration of melanophores below eye. Top of head flattened. Dorsal fin located posteriorly. The sex of adult Fundulus lineolatus can be determined by the direction of the stripes (bands) on the body; males have vertical bands and orange on top of their head; females have longitudinal stripes and lack the orange cap. Both vertical bands and longitudinal stripes are apparent in juvenile fish.

SRP Distribution: Common. Occurs in all major creeks on the SRP and has been occasionally collected from the Savannah River and Skinface Pond.

Habitat and Habits: A species collected in sluggish streams, backwaters, and swamps. Topminnows feed on small crustaceans and insects. They are late spring and early summer spawners.

Size: SRP maximum 7.5 cm, 3.8 g. Length-weight relationship (N = 46, $r = 0.98$) is $\ln W = 3.34 (\ln TL) - 13.01$.

Reference: Brown 1957, 1958; Rivas 1966; Goodyear 1970.

TOPMINNOW FAMILY - POECILIIDAE

The mosquitofish, Gambusia affinis, is the only poeciliid on the SRP. Gambusia look similar to members of the family Cyprinodontidae and are often confused with the killifishes. Both are small fishes, but Gambusia lack stripes; sexually mature male G. affinis have a modified anal fin used as an intromittent organ.

Because of their ubiquity, abundance, and ease of collection, G. affinis have been used widely as research animals on the SRP. Their mode of reproduction, being livebearers, and sexual dimorphism have also contributed to their widespread use in many studies. Their abundance in thermally altered environments has been well documented (Smoak 1959, Ferens and Murphy 1974, Bennett and Goodyear 1979).

Gambusia affinis (Baird and Girard) - mosquitofish

Synonyms: Gambusia holbrooki (Fowler 1945); G. a. holbrooki is the recognized subspecies on the SRP.

Key Characters: Body small, head flattened. Caudal, dorsal, and anal fins round, no distinct stripes or bands. Dorsal fin rays 8. Anal rays 10. Modified anal fin in males. Gravid females with dark lateral spot. Maximum body size 6 cm.

SRP Distribution: Abundant. Found in nearly all aquatic environments on the SRP including Carolina bays and farm ponds. Particularly abundant in thermally influenced streams, swamps, and impoundments.

Habitat and Habits: Slow moving streams, backwaters of streams with higher gradient, ponds, Carolina bays, and lakes with various bottom types (mud, silt, sand, gravel). Bear live young. SRP mosquitofish feed on cladocerans, rotifers, copepods, larval and adult dipterans, and ostracods.

Size: SRP maximum 5.2 cm, 1.25 g. Length-weight relationship ($N = 70$, $r = 0.98$) is $\ln W = 3.04 (\ln TL) - 4.88$.

References: Aho et al. 1976, Cherry et al. 1976, Falke and Smith 1974, Bennett and Goodyear 1979, Goodyear et al. 1972, Goodyear and Ferguson 1969, Goodyear 1973.

SILVERSIDE FAMILY - ATHERINIDAE

Members of the silverside family are slender fishes rarely attaining lengths over 10 cm. Atherinids can be readily identified by their divided dorsal fin; the spinous section has four spines followed by a larger soft-rayed section. Lower jaw extending beyond upper jaw. Snout dorso-ventrally flattened.

The single representative of this family on the Savannah River Plant is the brook silverside, Labidesthes sicculus. They are commonly seen in schools jumping out of the water to avoid predators. Brook silversides are used as food items by larger fishes and have been stocked as prey for predatory fishes by many state fishery management agencies.

Labidesthes sicculus (Cope) - brook silverside

Key Characters: Body long and thin with a pointed snout (viewed dorsally). Premaxillary triangular-shaped, forming a beak when viewed from above. Pre-dorsal scales crowded, more than 23. Pale green color with a wide, silvery band.

SRP Distribution: Common. Silversides have been collected from all creeks except Pen Branch and the Salkehatchie River. They are common in the Savannah River and abundant in Par Pond system.

Habitat and Habits: A schooling, pelagic fish. Found actively swimming in schools and feeding on plankton organisms. In lotic habitats, brook silver-sides are more common in still, back waters.

Size: Maximum length about 10 cm. SRP maximum 8.4 cm, 3.8 g. Length-weight relationship ($N = 64$, $r = 0.98$) is $\ln W = 3.04 (\ln TL) - 12.22$.

Reference: Frietsche et al. 1979.

ORDER - PERCIFORMES

TEMPERATE BASS FAMILY - PERCICHTHYIDAE

The temperate bass family is represented on the SRP by two species, the white bass, Morone chrysops, and the striped bass, Morone saxatilis. The similarities between these species can cause some confusion in identification. Hybrids between the two species have been stocked in Savannah River reservoirs upstream of the SRP.

Because of the sport-fish interest in striped bass, much research has been undertaken to evaluate the spawning habits of this species throughout its range. The Savannah River may be the only watershed where striped bass migrate downstream, rather than upstream, to spawn (Dudley et al. 1977). Observations of striped bass in SRP streams are limited to late summer or winter. There is no evidence that they spawn upstream or on the SRP. Striped bass are an important sportfish at the New Savannah Bluff Lock and Dam, upstream from the SRP.

Fish in this family can be distinguished by their 7 dark longitudinal stripes along the sides of the body, moderately large mouths, separation of spiny and soft dorsal fins, and the presence of three anal fin spines.

Key to Species of Percichthyidae

1. Scales small, lateral line scales 57 to 67; lateral stripes not interrupted and not interspaced by secondary rows of fainter stripes; depth of body less than 1/3 standard length; teeth on back of tongue in 2 parallel patches..... Morone saxatilis - striped bass page 97
- Scales large, lateral line scales 52 to 58; lateral stripes on sides usually interrupted, and consisting of rows of primary stripes interspaced by fainter secondary stripes; depth of body more than 1/3 standard length; teeth on back of tongue in a single patch.....
..... Morone chrysops - white bass page 97

Morone chrysops (Rafinesque) - white bass

Synonyms: Perca chrysops, Lepibema chrysops (Fowler 1945), Roccus chrysops (ANSP 1963).

Key Characters: Separation of spiny and soft dorsal fins. Mouth moderately large. Longitudinal stripes (7) on sides broken. Depth of body more than 1/3 standard length. Lateral line scales 52 to 58. Teeth on back of tongue in a single patch.

SRP Distribution: A rare, introduced species reported only from the Savannah River (McFarlane et al. 1978).

Habitat and Habits: Large sluggish rivers and impoundments. A schooling fish that is commonly found around cover. Concentrates in shallow water during spring while spawning. Feeds on aquatic invertebrates and fish.

Size: Maximum size about 3 kg.

Morone saxatilis (Walbaum) - striped bass

Synonyms: Roccus saxatilis

Key Characters: Separation of spiny and soft dorsal fins. Mouth moderately large. Longitudinal stripes (7) on sides not broken. Depth of body less than 1/3 standard length. Scales small, lateral line scales 57 to 67. Teeth on back of tongue in 2 parallel patches.

SRP Distribution: The Savannah River and Upper Three Runs Creek.

Habitat and Habits: Large rivers and reservoirs. Pelagic species that commonly feeds in schools. Most landlocked populations originated from embryos taken from the Santee Cooper stock in eastern South Carolina. Feeds primarily on fish. An important sport fish.

Size: Maximum size about 45 kg. SRP maximum about 10 kg.

References: Dudley et al. 1977, Smith 1968.

SUNFISH FAMILY - CENTRARCHIDAE

The sunfish family is the largest family of fishes on the SRP. Seventeen species of centrarchids have been collected in lotic and lacustrine habitats on the site. Family representatives are relatively easy to identify, although the identification of juveniles is difficult. Length of the pectoral fins and gill rakers and the number of spines are key characters used to identify some of these species. The spinous and soft rayed portions of the dorsal fin are characteristically united in members of this family. Mouth size varies from small to very large.

Centrarchids are known to many people because of their popularity as sport fishes. The largemouth bass, Micropterus salmoides, reaches a larger size than any other member of this family on the SRP. Most centrarchids, because of their secretive habits and preferred habitats, are rarely seen by most observers. Pygmy sunfishes, for example, inhabit sluggish streams having marshy, backwater areas; the banded sunfishes are generally found in clear, moving waters with dense growth of aquatic vegetation.

Key to the Species of Centrarchidae

1. Lateral line absent; dorsal fin spines 4 or 5; usually 1 to 3 dark spots on side below origin of dorsal fin; rounded pectoral; pelvic fins pointed and long; vertical bands on body; maximum size less than 5 cm Elassoma zonatum - banded pygmy sunfish page 105
- Lateral line complete or nearly complete; dorsal fin spines 5 to 13; maximum size greater than 5 cm.. 2
2. Base of dorsal fin equal to or slightly longer than base of anal fin... 3
- Base of dorsal fin much longer (about 5X) than base of anal fin..... 5
3. Dorsal fin spines more than 10; anal fin spines usually 7 or 8; young with an ocellus located in posterior end of soft dorsal fin; each scale with a dark spot..... Centrarchus macropterus - flier page 104
- Dorsal fin spines fewer than 10; anal fin spines fewer than 7, usually 6; dorsal fin spot, if present, not ocellated; some scales may have spots but not all..... 4
4. Dorsal fin spines 7 or 8; distance from eye to front of dorsal fin base about equal to length of base of dorsal fin.....
- Pomoxis nigromaculatus - black crappie page 112
- Dorsal fin spines 5 or 6; distance from eye to front of dorsal fin base greater than length of base of dorsal fin
- Pomoxis annularis - white crappie page 112
5. Caudal fin rounded 6
- Caudal fin shallow to deeply forked..... 9
6. Mouth large, maxillary extending behind middle of eye; anal fin spines 5 or 6; sides with dark scales giving appearance of 5 indistinct dark longitudinal stripes; scales cycloid.....
- Acantharchus pomotis - mud sunfish page 104
- Mouth small, maxillary barely extending to front of eye; anal spines 3 or 4; stripes, if present, are vertical; scales ctenoid..... 7
7. Front of dorsal fin dark; dorsal spines 10; palatine teeth absent; sides with dark vertical bands.....
- Enneacanthus chaetodon blackbanded sunfish page 105
- Front of dorsal fin not dark; dorsal fin spines usually 9; palatine teeth present; sides may have distinct to indistinct vertical bands (bands more noticeable in young).....
- Enneacanthus gloriosus - bluespotted sunfish page 106
8. Body elongate and slender, greatest depth usually 1/3 standard length (except in very large adults); spinous dorsal fin and soft dorsal

- fin nearly separate; dark lateral stripe; scales small, lateral line with 55 or more scales..... Micropterus salmoides-largemouth bass page 111
- Body deep and compressed, greatest depth usually more than 1/3 standard length; spinous dorsal fin and soft dorsal fin completely united; no dark, lateral stripe; scales large, lateral line with fewer than 55 scales..... genus Lepomis 9
9. Tongue with teeth; mouth large, maxillary extending to middle of eye; several distinct dark lines radiating back from eye..... Lepomis gulosus - warmouth page 108
- Tongue without teeth; mouth small (maxillary extending only to front of eye) or large; no distinct dark lines radiating back from eye..... 10
10. Opercle stiff to the posterior bony margin; posterior end of opercular flap usually fractures if bent sharply forward..... 11
- Opercle flexible to the posterior margin; posterior end of opercular flap may be bent sharply forward without fracturing opercular bond..... 14
11. Pectoral fins short and rounded, tips not reaching nostril when laid forward over the cheek..... 12
- Pectoral fins long and pointed, tips reaching nostril when laid forward over the cheek..... 13
12. Mouth large, maxillary extending to middle of eye; gill rakers long when depressed extending to base of 2nd or 3rd raker below; all scales not pigmented Lepomis cyanellus green sunfish page 107
- Mouth small to moderate, maxillary extending to front of eye; gill rakers short, not extending to base of 2nd or 3rd raker below; each scale pigmented at base; sides usually with numerous dark spots scattered over body (less noticeable in young) Lepomis punctatus-spotted sunfish page 110
13. Opercle with a small, red, semicircular spot near its margin; anal fin and posterior of dorsal fin with distinct spots (prolonged preservation may bleach spots); first anal fin spine equal in length to diameter of eye; rear margin of opercle stiff (excluding flap)..... Lepomis gibbosus - pumpkinseed page 107
- Opercle margined in scarlet; no spots on anal or dorsal fins; first anal fin spine shorter than diameter of eye; rear margin of opercle thin and flexible..... Lepomis microlophus-redear sunfish page 110
14. Pectoral fins rounded; gill rakers short and "nob-like" (Fig. 20A); opercular membrane not dark to its margin, bordered by greenish, red or white Lepomis marginatus-dollar sunfish page 109

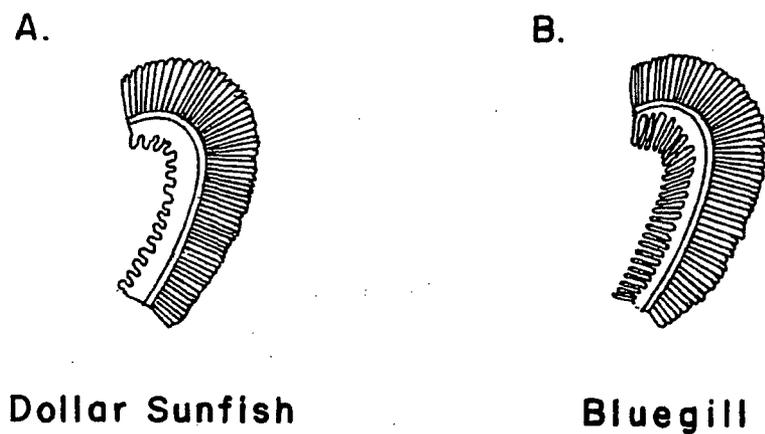


Figure 20. Appearance of nob-like (A) and long (B) gill rakers in Lepomis (after Eddy 1957; see Appendix I).

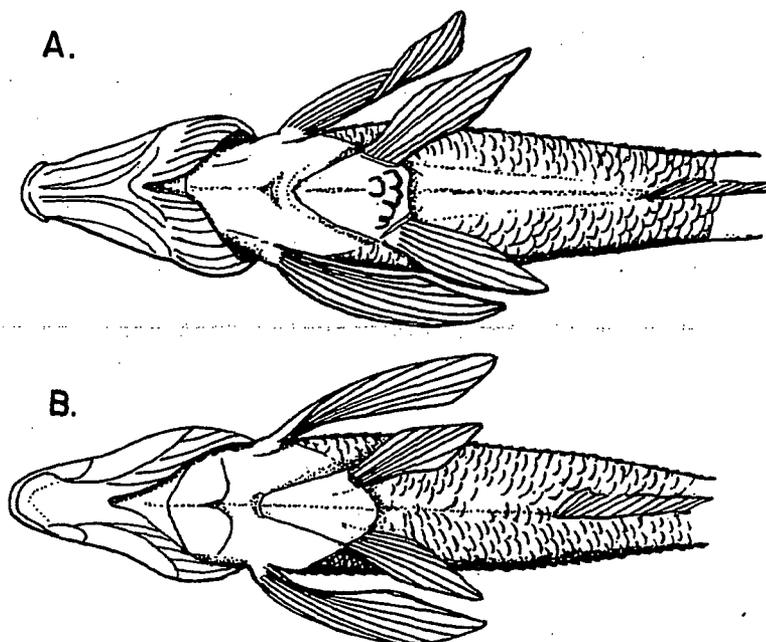


Figure 21. Ventral scale development between pelvic fins and anus in Percina (A) and selected Etheostoma (B after Eddy 1957; see Appendix I).

Table 4. Characters useful in the identification of the species of Centrarchidae.

Species	Mouth ¹	Gill Rakers ²	Dorsal Fin Spines	Dorsal Fin Coloration	Pectoral Fin	Anal Fin Spines	Caudal Fin	Other
mud sunfish	large		12		rounded	5	convex	horizontal bands on head
flier	moderate		11-12	spotted	moderately pointed	7-8	emarginate	ocellus present in young
banded pygmy sunfish	moderate		4-5		pointed	3	convex	lateral line absent
black-banded sunfish	small		10	front of fin black	rounded	6	convex	vertical bars on sides
blue-spotted sunfish	moderate		9	spotted	rounded	6	convex	
redbreast sunfish	moderate	short	10		pointed	3	emarginate	blue lines on cheek
green sunfish	large	long	10	dark blotch	short, rounded	3	emarginate	
pumpkinseed	small	short	10	spotted	long, pointed	3	emarginate	blue lines on cheek
warmouth	large	short	10	may have blotch	rounded	3	emarginate	dark lines on head; teeth on tongue

Table 4. Continued.

Species	Mouth ¹	Gill Rakers ²	Dorsal Fin Spines	Dorsal Fin Coloration	Pectoral Fin	Anal Fin Spines	Caudal Fin	Other
bluegill	small	long	10	dark blotch	long, pointed	3	emarginate	vertical bars on sides
dollar sunfish	small	short	10		moderately pointed	3	emarginate	
redear sunfish	small	short	10		long, pointed	3	emarginate	
spotted sunfish	moderate	long	10		short, rounded	3	emarginate	each scale on side spotted
largemouth bass	very large		10		moderately rounded	3	emarginate	lateral stripe; deeply notched dorsal fin
white crappie	large		6	mottled	moderately rounded	6	emarginate	
black crappie	large		7-8	reticulated	moderately rounded	6	emarginate	distinct vertical bars on sides

¹In relationship to a vertical line extending upward from the posterior margin of the upper jaw,
 small - line does not reach eye
 moderate - line reaches anterior margin of eye
 large - line reaches pupil of eye
 very large - line extends posterior to eye

²Short - gill rakers twice (or less) as long as wide
 Long - gill rakers several times longer than wide

Pectoral fins pointed, or, if fin appears round, gill rakers long and not "nob-like"; opercular membrane dark to its margin.....
 Lepomis macrochirus-bluegill page 109

Gill rakers short, length about 2X width and, when depressed, not extending to base of 2nd raker below; pectoral fin short, extending to eye when bent forward; opercular lobe stiff and dark to margin.....
 Lepomis auritus-redbreast sunfish page 106

A summary of characters most useful in identifying sunfishes is presented in Table 4.

Acantharchus pomotis (Baird) - mud sunfish

Key Characters: Mouth large, maxillary extending to middle of eye. Anal fin spines 5 or 6. Scales cycloid. Presence of 5 or 6 longitudinal stripes to caudal fin.

SRP Distribution: Uncommon, but occurring in small tributary streams of all creeks on the SRP. Rare in Savannah River. Found in Sarracenia Bay and in tributaries of Par Pond.

Habitat and Habits: Slow moving, small sluggish tributaries and Carolina bays having a bottom type of high organic matter and vegetation. Adults "rest" head down in weeds and are active at night. Spawn in mid-spring.

Size: Maximum size about 21 cm and 190 g. SRP maximum 15.6 cm, 87 g. Length-weight relationship ($N = 12$, $r = 0.99$) is $\ln W = 3.34 (\ln TL) - 12.44$.

Centrarchus macropterus (Lacépède) - flier

Key Characters: Body flattened laterally. Dorsal spines more than 10. Anal spines usually 7 or 8. Young with blue bands and dark spot outlined in orange (ocellus) on posterior dorsal fin. Base of dorsal fin equal to length of anal fin.

SRP Distribution: Uncommon. Based on recent and previous surveys, fliers occur in small numbers in all major creeks. Also found in some Carolina bays, Skinface Pond, Twin Lakes, and occasionally in the Savannah River.

Habitat and Habits: Backwater area of streams and Carolina bays having extensive growths of submergent and emergent vegetation. Spawns in nests. Feeds on cladocerans and aquatic insects.

Size: Maximum size about 20 cm and 450 g. SRP maximum 19 cm, 122 g. Length-weight relationship ($N = 71$, $r = .99$) is $\ln W = 3.13 (\ln TL) - 11.54$.

Elassoma zonatum Jordan - banded pygmy sunfish

Key Characters: Small body size. Lateral line absent. Dorsal fin spines 4 or 5. One to three dark spots on side below origin of dorsal fin.

SRP Distribution: Uncommon. Collected at various times from all major creeks. Not collected recently from Four Mile Creek and Pen Branch. Collected from shoreline areas and tributaries of Par Pond system, Moon Lake, Sarracenia Bay, and Skinface Pond.

Habitat and Habits: Swamps, Carolina bays, and backwaters of streams having abundant growths of vegetation or high organic matter. Spawn over vegetation. Food is crustaceans and insects.

Size: Maximum length about 4 cm.

Enneacanthus chaetodon (Baird) - blackbanded sunfish

Synonyms: Mesogonistus c. chaetodon (Freeman 1954).

Key Characters: Caudal fin rounded. Mouth small. Front of dorsal fin dark. Dorsal spines usually 9. Sides usually with distinct, broad vertical bands.

SRP Distribution: Uncommon. Collected only from Upper Three Runs Creek. This is the only known locality for this species in the Savannah River drainage.

Habitat and Habits: Backwater areas having low current and areas with dense aquatic vegetation (e.g. Valisineria sp. beds).

Size: Maximum length about 10 cm.

Reference: Jenkins et al. 1975.

Enneacanthus gloriosus (Holbrook) - bluespotted sunfish

Key Characters: Caudal fin rounded. Mouth small. No darkening of dorsal fin. Dorsal fin spines 9. Opercular spot smaller than pupil. Sides without distinct vertical bands. Few to no spots on spiny dorsal fin.

SRP Distribution: Common. Collected at various times in most major creeks, except Four Mile and Upper Three Runs. Also collected in Skinface Pond. Rare in the Savannah River.

Habitat and Habits: Found in streams with abundant vegetation. Spawn over mats of algae or in nests. Feed primarily on small crustaceans, aquatic insects, and molluscs.

Size: Maximum length about 10 cm. SRP maximum 7.7 cm, 10 g. Length-weight relationship ($N = 56$, $r = 0.99$) is $\ln W = 3.20 (\ln TL) - 11.76$.

Lepomis auritus (Linnaeus) - redbreast sunfish

Key Characters: Anal fin spines 3. Mouth small. Opercle long (adults) flexible and black. Pointed pectoral fins extending to eye. Gill raker length about 2X width. Prominent wavy blue lines on cheek. Body more elongate than other Lepomis species.

SRP Distribution: Abundant. Found in all creeks (except the Salkehatchie River), the Savannah River and swamp, the Par Pond system, and most ponds.

Habitat and Habits: Pool areas of higher gradient streams to open water in lower gradient streams. Littoral areas of lakes and ponds. Usually associ-

ated with cover during the day. Insects constitute the bulk of the diet.

Spawns during spring.

Size: Maximum size about 24 cm and 312 g. SRP maximum 23.2 cm, 310 g.

Length-weight relationship ($N = 100$, $r = .97$) is $\ln W = 3.01 (\ln TL) - 10.99$.

References: Lattimore and Gibbons 1974, Hogan 1977.

Lepomis cyanellus Rafinesque - green sunfish

Key Characters: Forked caudal fin. Maxillary extending behind middle of eye. Opercle stiff to posterior margin. Pectoral fins short and rounded.

Dorsal spot at posterior of dorsal fin. Gill rakers long.

SRP Distribution: Rare. Collected during earlier surveys in Upper Three Runs (Whitworth 1969) and Lower Three Runs (Freeman 1958) Creeks. Not collected during recent surveys. An introduced species in the Savannah River (Dahlberg and Scott 1971b); its present occurrence on SRP requires verification. Green sunfish may be confused with warmouths, which frequently have a large spot in the dorsal fin on SRP.

Habitat and Habits: Warm, muddy-bottomed, turbid pools in streams. Associated with vegetation in reservoirs and ponds. Juveniles consume zooplankton then shift with increased body size to aquatic insects and fish.

Size: Maximum size of 27 cm and 408 g.

Lepomis gibbosus (Linnaeus) - pumpkinseed

Synonyms: Pomotis gibbosus (Fowler 1945)

Key Characters: Gibbous-shaped. Caudal fin forked. Opercle stiff to margin. Pectoral fins long and pointed. Gill rakers short and curved. Opercle with a small red semicircular spot near margin. Anal and posterior of dorsal fin with spots. Often confused with L. microlophus. SRP specimens are dif-

ated with cover during the day. Insects constitute the bulk of the diet. Spawns during spring.

Size: Maximum size about 24 cm and 312 g. SRP maximum 23.2 cm, 310 g. Length-weight relationship ($N = 100$, $r = .97$) is $\ln W = 3.01 (\ln TL) - 10.99$.

References: Lattimore and Gibbons 1974, Hogan 1977.

Lepomis cyanellus Rafinesque - green sunfish

Key Characters: Forked caudal fin. Maxillary extending behind middle of eye. Opercle stiff to posterior margin. Pectoral fins short and rounded. Dorsal spot at posterior of dorsal fin. Gill rakers long.

SRP Distribution: Rare. Collected during earlier surveys in Upper Three Runs (Whitworth 1969) and Lower Three Runs (Freeman 1958) Creeks. Not collected during recent surveys. An introduced species in the Savannah River (Dahlberg and Scott 1971b); its present occurrence on SRP requires verification. Green sunfish may be confused with warmouths, which frequently have a large spot in the dorsal fin on SRP.

Habitat and Habits: Warm, muddy-bottomed, turbid pools in streams. Associated with vegetation in reservoirs and ponds. Juveniles consume zooplankton then shift with increased body size to aquatic insects and fish.

Size: Maximum size of 27 cm and 408 g.

Lepomis gibbosus (Linnaeus) - pumpkinseed

Synonyms: Pomotis gibbosus (Fowler 1945)

Key Characters: Gibbous-shaped. Caudal fin forked. Opercle stiff to margin. Pectoral fins long and pointed. Gill rakers short and curved. Opercle with a small red semicircular spot near margin. Anal and posterior of dorsal fin with spots. Often confused with L. microlophus. SRP specimens are dif-

difficult to separate from L. microlophus on the basis of pectoral fin length.

SRP Distribution: Rare in the Savannah River, which is the southernmost limit of distribution of the species. Reported from Four Mile Creek in an earlier survey (Freeman 1954).

Habitat and Habits: Lives in cooler waters than other Lepomis. Quiet clean water with slight amount of organic debris and aquatic vegetation. Nest near shore and manifest parental care of nest and young. Feed on crustaceans, snails, insects, and fish during day.

Size: Maximum size about 40 cm and 450 g. SRP maximum 24 cm, 315g. Length-weight relationship ($N = 67$, $r = 0.99$) is $\ln W = 3.13 (\ln TL) - 11.54$.

Lepomis gulosus (Cuvier) - warmouth

Synonyms: Chaenobryttus coronarius (Fowler 1945, Freeman 1954).

Key Characters: Mouth large, maxillary extending behind middle of eye. Forked caudal fin. Three anal fin spines. Dark stripes radiating from eye to opercle. Teeth patch on tongue.

SRP Distribution: Abundant. Collected from all major creeks on SRP. Common in the Savannah River, abundant in the Par Pond system and farm ponds, and occasionally collected in Carolina bays.

Habitat and Habits: Juveniles inhabit areas of dense vegetation while adults are found in more open water. Occurs in slower waters of tributary streams, larger creeks, farm ponds, Carolina bays, and reservoirs. Aggressive feeders; insects, crayfish and fish are main food items. Spawn in nest near a stump or clump of vegetation during spring and summer.

Size: Maximum length 28 cm. SRP maximum 24 cm, 298 g. Length-weight relationship ($N = 100$, $r = 0.99$) is $\ln W = 3.10 (\ln TL) - 11.34$.

Lepomis macrochirus Rafinesque - bluegill

Synonyms: Ichthelis macrochira (Fowler 1945)

Key Characters: Opercle flexible (stiff in young). Pectoral fins long and pointed. Gill rakers long, 6X width. Dark spot at base of soft dorsal fin. Juveniles with dark, straight distinct vertical bands with distinct margins. SRP Distribution: Common. Found in all major tributaries, the Par Pond system, and farm ponds. Bluegill are abundant in the Savannah River.

Habitat and Habits: Ponds, lakes and sluggish streams. Larval bluegill experience a limnetic stage for about two months and then migrate to occupy shallow, on-shore areas. Larger fish are found in more open waters. Adults feed on crayfish, fish and terrestrial and aquatic insects. Aquatic vegetation may be present but is probably incidental. An important forage fish for largemouth bass. Colonial spawner with two peaks spawning activity in the late spring and summer. Commonly feed on surface.

Size: Maximum length about 30 cm. SRP maximum 27 cm, 302 g. Length-weight relationship ($N = 100$, $r = .99$) is $\ln W = 3.10 (\ln TL) - 11.39$.

References: Avise and Smith 1974a, 1974b; Bennett 1972b; Beisser 1978; Benke and Benke 1975; Murphy et al. 1976; Goodyear and Bennett 1979; Johnson 1976; Yardley et al. 1974.

Lepomis marginatus (Holbrook) - dollar sunfish

Key Characters: Opercle flexible to its posterior margin. Pectoral fins round. Opercular membrane not dark to its margin, bordered by green, red, or white. Gill rakers short, rounded and "nob-like" (Fig. 20A).

SRP Distribution: Abundant. A widely distributed species occurring in all major tributaries, streams and most farm ponds. Rarely collected in the Savannah River.

Habitat and Habits: Undercut banks, surrounding cover (logs, branches, rocks, etc.) in small streams. More abundant in smaller streams. Active in littoral areas of ponds and lakes. Food items are aquatic invertebrates and small fish.

Size: Maximum length about 18 cm. SRP maximum 14 cm, 138 g. Length-weight relationship ($N = 66$, $r = 0.99$) is $\ln W = 3.17 (\ln TL) - 11.78$.

Lepomis microlophus (Günther) redear sunfish

Key Characters: Opercle long, wide, and stiff to its posterior margin and margined in scarlet. Pectoral fins long and pointed. Gill rakers short. No spots on anal and dorsal fins. May be confused with L. gibbosus.

SRP Distribution: Common. Collected from all major creeks on the SRP except the Salkehatchie River; common in the Savannah River. Commonly collected in Twin Lakes and occasionally in Par Pond system. Introduced into Skinface Pond.

Habitat and Habits: Large, warm rivers, bayous, lakes and ponds. Spawn in spring and summer in nests grouped in colonies around submerged vegetation. Insect larvae, snails, and cladocerans are important food items. Seldom feed on surface.

Size: Maximum size 35.5 cm and 1270 g. SRP maximum 28 cm, 470 g. Length-weight relationship ($N = 100$, $r = 0.99$) is $\ln W = 3.28 (\ln TL) - 12.33$.

Lepomis punctatus (Valenciennes) - spotted sunfish

Key Characters: Opercle stiff. Opercular lobe short and black. Pectoral fins short and rounded. Mouth moderate, maxillary extending to front of eye. Gill rakers short and curved. Sides may have dark spots scattered over body.

SRP Distribution: Abundant. Collected from all major creeks on the SRP except the Salkehatchie River. Uncommon in the Savannah River. Found in the Par Pond system and in farm ponds.

Habitat and Habits: Found in a greater diversity of habitats than other Lepomis. Collected from small, sandy bottomed, moderate gradient tributaries to large, low gradient creeks. Usually found around vegetation or other forms of cover. Summer spawners; males savagely protect the nest.

Size: Maximum size about 17 cm. SRP maximum 17 cm, 119 g. Length-weight relationship ($N = 58$, $r = 0.98$) is $\ln W = 3.16 (\ln TL) - 11.45$.

Micropterus salmoides (Lacépède) - largemouth bass

Synonyms: Huro floridana (Fowler 1945).

Key Characters: Caudal fin forked. Mouth large, maxillary extending behind eye. Spinous dorsal separated from soft dorsal fin by a deep notch extending nearly to base of fin. Body elongated. Dark, wide, lateral band present.

SRP Distribution: Common. Found in the Savannah River, the swamp, and all major creeks on the SRP. Abundant in Par Pond system and collected in Dicks Pond, Skinface Pond, and B-Swamp.

Habitat and Habits: Prefer nonflowing clear waters with aquatic vegetation. Cover is an important factor affecting abundance in creeks, lakes, and reservoirs. Spawn from March - May; males afford parental care to nest and young. Bass feed on entomostracans, insect larvae, and fish. Fish, however, are the primary dietary component of adults.

Size: Maximum size about 10 kg. SRP maximum from the river 34 cm, 440 g. Maximum from Par Pond 60 cm, 5 kg. Length-weight relationship ($N = 53$, $r = 0.99$) is $\ln W = 3.09 (\ln TL) - 11.73$.

References: Bennett 1972a, 1979; Bennett and Gibbons 1972c, 1974, 1975; Dupont 1976; Esch et al. 1976; Eure 1974, 1976a, 1976b, Eure and Esch 1974; Gibbons et al. 1972; Gibbons and Bennett 1973; Gibbons et al. 1978; Goodyear and Boyd 1972; Harvey 1964; Holland et al. 1974; Quinn et al. 1978; Siler 1975; Smith and Scott 1975.

Pomoxis annularis Rafinesque - white crappie

Key Characters: Gibbous shape. Length of anal fin base equal to length of dorsal fin base. Dorsal and anal spines usually 5 or 6. Distance from eye to front of dorsal fin base greater than length of base of dorsal fin.

SRP Distribution: Rare. An introduced species, formerly more common than P. nigromaculatus in the Savannah River but now rare. This change in abundance may be associated with reduced turbidity and lower water temperatures in the river since construction of Clarks Hill Dam. Also collected in Lower Three Runs Creek.

Habitat and Habits: Inhabit lakes, bayous and slow moving streams and rivers. More abundant in turbid than clear waters. Spawn under over-hanging banks or tree roots. Young crappies feed on entomostracans and aquatic insects while adults feed on fish when available. Feeding occurs mostly at dusk.

Size: Maximum size about 37 cm.

Pomoxis nigromaculatus (Lesueur) - black crappie

Key Characters: Gibbous shape. Dorsal spines 7 or 8. Length of anal fin base equal to length of dorsal fin base. Distance from eye to front of dorsal fin base equal to base of dorsal fin.

SRP Distribution: Common. Collected from major tributaries on the SRP except Pen Branch, Steel Creek and the Salkehatchie River. Common in the Savannah River and the Par Pond system.

Habitat and Habits: Prefer clear, deep, cool waters of both lotic and lentic habitats. Spawn in early spring over gravel or sand nests at the base of vegetation or other cover. Food of juveniles is entomostracans; food of adults is insects and forage fish. Black crappie have become more abundant in the Savannah River since the completion of Clarks Hill Dam.

Size: Maximum size about 37 cm. SRP maximum 33 cm, 414 g. Length-weight relationship ($N = 66$, $r = 0.98$) is $\ln W = 3.33 (\ln TL) - 13.01$.

Reference: Bennett 1972b.

PERCH FAMILY - PERCIDAE

Percids are an important family of freshwater fishes represented by seven species on the Savannah River Plant. Only one of these, the yellow perch, Perca flavescens, is commonly seen. Yellow perch are frequently captured by angling. The remaining six species are darters, fishes that are found over sand and gravel bottoms and rapidly "dart" from one area to the next.

Members of the Percidae are characterized by having the spiny and soft portions of the dorsal fin completely separated and the anal fin with one or two spines. Even some ichthyologists have difficulty identifying darters because of their intraspecific variability and interspecific similarities. Few simple taxonomic characters have been recognized for separating the species.

A useful introduction to darter biology is provided by Winn (1958).

Key to the Species of Percidae

1. Mouth large, maxilla extending to middle of eye; posterior upper border of maxilla not concealed under preorbital; preopercle strongly serrate; branchiostegal rays 7 or 8; pseudobranchiae well developed; body size in adults large (>250 mm);
 Perca flavescens - yellow perch page 119
- Mouth small, maxilla not extending to middle of eye; maxilla concealed posteriorly by preorbital; preopercle entire or weakly serrate; branchiostegal rays usually 6; pseudobranchiae poorly developed or absent; adults small (<125 mm)..... 2
2. Lateral line complete or nearly complete (occasionally incomplete in E. olmstedii) 4
- Lateral line incomplete, usually extending to median of soft dorsal fin 3
3. Preopercle not serrate; snout blunt; dorsal fin formula VIII to XII, 9 to 12; anal fin formula II, 6-9; scales along lateral line 40-63; sides marked with about nine (9) blotches or dark bands; caudal base with a vertical row or 3 or 4 dark spots
Etheostoma fusiforme - swamp darter page 116
- Preopercle serrate; snout blunt; dorsal fin formula X to XI - 12 to 15; anal II, 6 to 8; lateral line highly elevated, with 28-38 pores; scales along lateral line usually 50-58; dorsal saddles and blotches absent; lateral blotches large and irregular; base of caudal with vertical row of 4 spots
 Etheostoma serriferum - sawcheek darter page 119
4. Area of anal fin usually as large as area of soft dorsal fin; mouth terminal; "diamond-shaped" blotches along each side (diamonds may appear as dark, wide band in juveniles); belly without scales.....
 Percina nigrofasciata - blackbanded darter page 119
- Area of anal fin usually smaller than area of soft dorsal fin; mouth terminal or slightly inferior; sides without diamond blotches..... 5
5. Premaxillary protractile, separated from snout by a complete groove (frenum absent; Fig. 22A)..... 6
- Premaxillary not protractile, not entirely separated from snout by a groove (frenum present), but connected anteriorly by a fleshy bridge (Fig. 22B)..... 7
6. Snout very blunt; belly completely naked; sides with 9-11 "W" or "X" markings; anal spines thin and flexible, about equal in length;.....
Etheostoma olmstedii - tessellated darter page 118

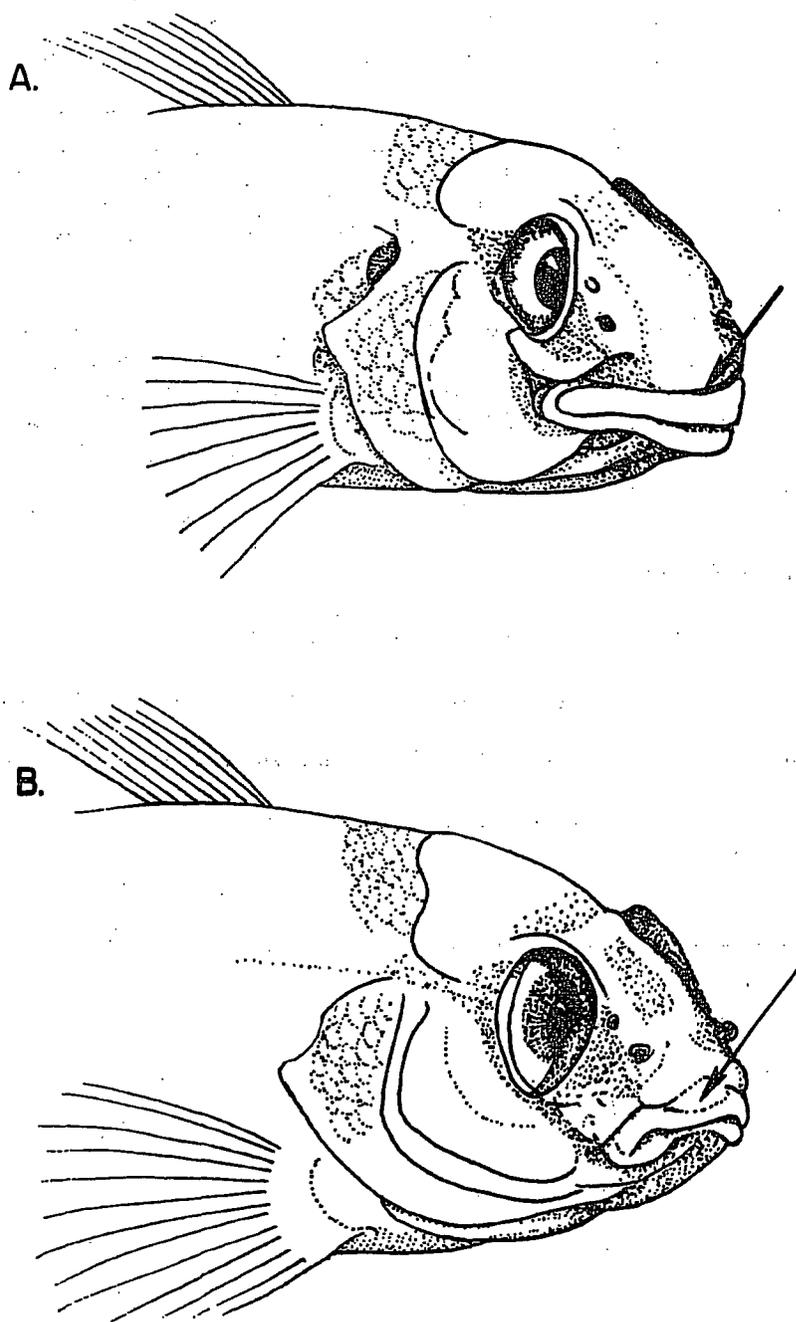


Figure 22. Comparison of protractile (A) and non-protractile (B) premaxillaries in percid fishes. Note absence (A) and presence (B) of frenum, as indicated by arrow (after Blair et al. 1968). (See Appendix I).

Snout a gentle curve from eye level to snout tip; belly naked anteriorly only; sides without "W" or "X" markings; anal spines typically two, the first heavy and thick and being appreciably thicker than 2nd spine.....Etheostoma inscriptum - turquoise darter page 118

7. Cheeks naked or with a few deeply imbedded scales; predorsal partially scaled; scales along lateral line fewer than 45; dorsal fin formula X or XII-11 to 13; anal II, 8 or 9; dorsal blotches absent but 5 blotches on upper sides near dorsal base; infraorbital bar forming an arc curving downward and backward; preorbital bar present.....
.....Etheostoma fricksium - Savannah darter page 116

Cheeks well scaled; predorsal heavily scaled; scales small, more than 45 on lateral line; dorsal X or XI, 11 to 13; anal II, 7-9; dorsal blotches usually 7 or 8; males with 10 red or red-orange bars alternating with green on sides; predorsal area with 2 poorly to well-developed dark blotches; prepectoral dark spot usually present; infraorbital canal complete with usually 8 pores.....
..... Etheostoma hopkinsi - Christmas darter page 117

Etheostoma fricksium Hildebrand - Savannah darter

Synonyms: Poecilichthys fricksia (Freeman 1954)

Key Characters: Body elongate and slender. Dorsal fin with completely separated spiny and soft portions. Lateral line nearly complete. Cheeks usually without scales. Belly scaled. Scales along lateral line fewer than 45. Indistinct vertical bands on caudal peduncle. Preorbital bar present.

SRP Distribution: Rare. Reported from Upper Three Runs, Lower Three Runs and Steel Creek. Unknown in the Savannah River at SRP.

Habitat and Habits: Found only in clear streams with a sand or gravel bottom. Food is primarily aquatic insects.

Size: Maximum length about 7 cm.

Reference: Hilderbrand 1923.

Etheostoma fusiforme (Girard) - swamp darter

Synonyms: Etheostoma barratti (Freeman 1954); Boleichthys fusiformis (Fowler 1945); Hololepis barratti (ANSP 1953)

Key Characters: Body elongate and slender. Spiny and soft portions of dorsal fin separated. Lateral line incomplete. Snout blunt. Caudal base with a row of 3 or 4 dark spots.

SRP Distribution: Rare. Collected from all creeks except Four Mile and Pen Branch. This is the only darter known from Par Pond system; it is rare in the Savannah River.

Habitat and Habits: Swamps and backwaters of streams, sloughs and reservoirs, sluggish streams, and lentic waters having sandy or clay bottoms.

Size: Maximum length about 5 cm. SRP maximum 49 cm, 1 g.

Reference: Collette 1962.

Etheostoma hopkinsi (Fowler) - Christmas darter

Key Characters: Body elongate and slender. Spiny and soft portions of dorsal fin separated. Lateral line nearly complete. Snout pointed. Cheeks well scaled. More than 45 scales on lateral line. Prepectoral dark spot usually present. A very brightly colored darter especially during spawning. Can be confused with E. fricksium.

SRP Distribution: Common. Collected from all major creeks except Lower Three Runs and the Salkehatchie River. Rarely encountered in the Savannah River.

Habitat and Habits: Clear streams with moderate to high gradient over a gravel substrate. Food is primarily aquatic insects and small crustaceans.

Size: Maximum length about 8 cm. SRP maximum 7.4 cm, 3.5 g. Length-weight relationship ($N = 24$, $r = 0.99$) is $\ln W = 3.20 (\ln TL) - 12.62$.

References: Bailey and Richards 1963, Fowler 1945.

Etheostoma inscriptum (Jordan and Brayton) - turquoise darter

Synonym: Poecilichthys inscriptum (ANSP 1953)

Key Characters: Snout forming a gentle curve from eye to tip of snout. Anal spines typically two, the first heavy and thick and appreciably thicker than 2nd spine. Frenum absent.

SRP Distribution: A rare species below the Fall Line reported by ANSP in 1952 but not verified by any subsequent collection from SRP.

Habitat and Habits: Clear streams with gravel substrate.

Size: Maximum size about 6 cm.

Etheostoma olmstedi Storer - tessellated darter

Synonyms: Boleosoma sp., in part (Freeman 1954); Boleosoma nigrum (Fowler 1945); Etheostoma nigra (ANSP 1955).

Key Characters: Body elongate and slender. Spiny and soft portions of dorsal fin separated. Lateral line complete. Snout very blunt, mouth slightly oblique. Sides with 9-11 "W" or "X" markings. Frenum absent (Fig. 22A). Dorsal surface with 6 saddle-like blotches. Preocular bar present.

SRP Distribution: Abundant. Collected from major creeks on SRP except the Salkehatchie River. Rare in the Savannah River.

Habitat and Habits: Clear streams with moderate to low gradient. Large sand to gravel substrate is required. Deposits eggs on underside of rocks. Feeds on insects and entomostracans.

Size: Maximum length 10 cm. SRP maximum 6.5 cm, 2.3 g. Length-weight relationship ($N = 13$, $r = 0.98$) is $\ln W = 2.89 (\ln TL) - 11.32$.

Reference: Cole 1967.

Etheostoma serriferum (Hubbs and Cannon) - sawcheek darter

Synonyms: Boleosoma sp., in part (Freeman 1954).

Key Characters: Body elongate and slender. Spiny and soft portions of dorsal fin separated. Lateral line incomplete and highly elevated. Snout blunt. Preopercle serrate. Base of caudal fin with vertical row of 4 spots.

SRP Distribution: Uncommon. Collected from Steel Creek and Upper Three Runs.

Habitat and Habits: Clear, fast moving waters with sandy to gravelly bottoms. Voracious feeders on small insects and crustaceans.

Size: Maximum length 7 cm. SRP maximum 5.8 cm, 1.49 g. Length-weight relationship ($N = 11$, $r = 0.90$) is $\ln W = 3.58 (\ln TL) - 14.18$.

Reference: Collette 1962.

Perca flavescens (Mitchill) - yellow perch

Key Characters: Spiny and soft portions of dorsal fin separated. Mouth large, maxilla extending to middle of eye. Pseudobranch well developed. Preopercle strongly serrate. Body with orange fins and dark vertical bars.

SRP Distribution: Common. An introduced species in the Savannah River, common in the river and swamp and collected in Par Pond and all major creeks.

Habitat and Habits: Inhabits bayous, sluggish streams, rivers and lakes. Requires vegetation as a medium for egg incubation. Feeds primarily on fish.

Size: Maximum length about 40 cm. SRP maximum 29 cm, 318 g. Length-weight relationship ($N = 123$, $r = 0.98$) is $\ln W = 3.19 (\ln TL) - 12.44$.

Percina nigrofasciata (Agassiz) - blackbanded darter

Synonyms: Hadropterus nigrofasciatus (Freeman 1954); Percina nigrofasciatus (Fowler 1945).

Key Characters: Spiny and soft portions of dorsal fin separated. Area of anal fin usually as large as area of soft dorsal fin. Mouth terminal. Sides with 10-11 diamond shaped blotches along each side. Frenum present (Fig. 22B). Spiny, enlarged scale(s) between pelvic fins (Fig. 21A).

SRP Distribution: Common. Collected from major creeks except the Salkehatchie River. Rare in the Savannah River.

Habitat and Habits: Clear, fast moving streams with gravel and rubble bottom types. Food is primarily aquatic insects.

Size: Maximum length about 7 cm.

References: Crawford 1956, Fowler 1942, Mathur 1973.

MULLET FAMILY - MUGILIDAE

A single representative, the striped mullet, Mugil cephalus, of the family Mugilidae, occurs on the SRP. Although mullet are considered marine they migrate upstream and are found in the Savannah River and major tributaries.

Mullet can be readily identified by their weak mouths, small 4-spined dorsal fin separated from the soft rayed portion, and high fin location of the pectorals. The mouth is an inverted "V". Mulletts have adipose eyelids like herring.

Mugil cephalus Linnaeus - striped mullet

Key Characters: Adipose eyelid. Dorsal fin separated; four spines followed by soft rayed portion. Pectorals high on body. Body dark dorsally to silvery below and stout. Mouth an inverted "V". May be confused with atherinids except atherinids have dorso-ventrally flattened heads and larger mouths.

SRP Distribution: Uncommon. Found throughout the year in small numbers in the Savannah River, the intake canals, and the river swamp. Also collected from Lower Three Runs and below the confluence of Steel Creek and Pen Branch.

Habitat and Habits: Open waters of large rivers.

Size: Maximum length about 60 cm. SRP maximum 43 cm, 1100 g. Length-weight relationship ($N = 19$, $r = 0.98$) is $\ln W = 3.38 (\ln TL) - 13.54$.

Reference: Dahlberg 1975.

ORDER - PLEURONECTIFORMES

SOLE FAMILY - SOLEIDAE

The family Soleidae is a family of small flatfishes normally associated with marine ecosystems; however, they also venture upstream to the SRP in the Savannah River. Members of this family have eyes on the right side of the head (Fig. 11). Mouth is small and curved. Lateral line present and straight.

Trinectes maculatus (Bloch and Schneider) - hogchoker

Key Characters: Pectoral fins absent. Seven or eight cross bars on a dorsal surface, ventral surface is light. Body flat and small (Fig. 11).

SRP Distribution: Uncommon. Found on sandbars in the Savannah River. Enters intake canals, Steel Creek, Lower Three Runs Creek, and the mouth of Pen Branch.

Habitat and Habits: Inhabits slow moving waters of shallow to medium depth, with sandy bottoms.

Size: Maximum length about 15 cm. SRP maximum 10.5 cm, 31 g. Length-weight relationship ($N = 12$, $r = 0.99$) is $\ln W = 2.97 (\ln TL) - 10.44$.

Reference: Dahlberg 1975.

Glossary

Adipose eyelid: a transparent tissue that covers part of the eyeball.

Adnate adipose fin: a fleshy, median dorsal structure behind the dorsal fin that is attached to the caudal fin.

Anadromous: living at sea and spawning in freshwater.

Barbel: a fleshy, tactile protuberance in the form of a flap or threadlike structure.

Braided: division of a stream/river channel into numerous channels.

Branchiostegal ray: a long, curved, and often flattened bone supporting the membrane below the gill cover.

Catadromous: spawning in oceans and living in freshwater.

Caudal peduncle: the slender section of the fish supporting the tail fin behind the anal fin.

Ctenoid: a type of scale bearing small spines on the posterior surface.

Cycloid: a type of scale, roughly circular, without small spines on the posterior surface.

Character index: an arithmetic determination made by subtracting the number of gill rakers from the number of anal rays.

Emarginate: margin notched.

Entire: margin smooth, not notched.

Falcate: a fin shape that is sickle-shaped or concave margin.

Fin insertion: the anterior-most or uppermost end of a fin base.

Frenum: a piece of tissue connecting the upper lip with the snout and preventing protrusion of the upper lip.

Ganoid scale: a type of hard fish scale covered by an enamel-like substance.

Gibbous-shaped: round, flat body appearance.

Gill rakers: slender rod-like to blunt, knob-like projections on the inner edge of a gill arch (structure supporting gill; Fig. 20).

Gill isthmus: the ventral surface of a fish between the two gill chambers.

Heterocercal: a type of tail in which the vertebrae curve upward into the large lobe of the caudal fin.

Homocercal: a type of tail in which the vertebrae end at the caudal fin and the lobes are about equal.

Included: the condition in which the upper jaw extends beyond the lower jaw.

Jugular: pertaining to the throat region.

Keel: a raised ridge on the body.

Lacustrine: standing water.

Lentic: standing water.

Limnetic larval stage: early life history stage spent in waters away from the shoreline.

Lotic: running water.

Maxilla (maxillary): the posterior-most bone on the upper jaw; the premaxilla is the anterior bone.

Melanophore: a black pigment cell.

Naked: scaleless.

Nape: dorsal area between the skull and insertion of the dorsal fin.

Operculum (opercle): the gill cover; divided into a preopercle and opercle (Fig. 7).

Palatine teeth: teeth on the anterior ventral surface of the skull near the naris.

Peritoneum: the lining of the body cavity; may be light or dark.

Pharyngeal teeth: teeth in the throat region, usually 5th pharyngeal arch.

Plica (pl. plicae): fleshy, folded lips of fishes.

Predorsal scales: a row of scales crossing the midline between the origin of the dorsal fin and the posterior-most point of the skull.

Preoperculomandibular pores: small pores extending in front of the operculum and onto the lower jaw.

Pseudobranch: a structure resembling a gill on the inner surface and upper edge of the gill cover.

Serrae (serra sing.): tooth-like structures along an edge.

Acknowledgments

Field research and much of the manuscript preparation was carried out under Contract EY-76-C-09-0819 between the University of Georgia and the Department of Energy. Two major field and compilation efforts were supported by the Savannah River National Environmental Research Park Program. The final manuscript preparation was aided by the College of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow.

An intensive field effort was made possible by the cooperation of numerous individuals associated with the Savannah River Ecology Laboratory. Special thanks are extended to Dr. Janalee Caldwell and Joseph R. McAuliffe for their tireless efforts. Sherry E. Williams, C. T. Garten, J. C. Murphy, B. C. Moore, and Tim Smith aided in field collecting. Drs. J. G. Wiener and Don Schure and Ms. Judith Greene-McLeod graciously shared their unpublished data on a number of fish collections.

Particular thanks go to Dr. J. Whitfield Gibbons who provided encouragement and assistance throughout the study as well as field data on several species and habitats. Dr. W. R. Taylor of the National Museum of Natural History, assisted in the identification and construction of the key for Ictalurids. Dr. Edgar N. Gramblin, also of the National Museum of Natural History, provided invaluable assistance in locating Dr. Freeman's earlier collection from the SRP. Messrs. R. F. Frietsche and R. D. Miracle of the Savannah River Laboratory significantly advanced our knowledge of the Savannah River ichthyofauna and aided in the identification of specimens and construction of the cyprinid keys. Ms. Jean Coleman made all the drawings. Ms. Tonya Willingham typed numerous draft copies of the text. Ms. Janell Gregory, Karen K. Patterson, and J. Whitfield Gibbons provided editorial assistance and helped with manuscript preparation. The typing of Mrs. Barbara Schoeffler also is appreciated.

- Benke, A. C. and S. S. Benke. 1975. Comparative dynamics and life histories of coexisting dragonfly populations. *Ecology* 56(2):302-317. (Includes a list of fishes known from Dicks Pond).
- Bennett, D. H. 1972a. Preliminary examination of body temperatures of largemouth bass (Micropterus salmoides) from an artificially heated reservoir. *Archiv. Hydrobiologia* 68:376-381. (vertical distribution in heated reservoir).
- _____. 1972b. Length-weight relationships and condition factors of fishes from a South Carolina reservoir receiving thermal effluent. *Progressive Fish Culturist* 34:85-87. (bluegill, black crappie).
- Bennett, D. H. and J. W. Gibbons. 1972. Food of largemouth bass (Micropterus salmoides) from a South Carolina reservoir receiving heated effluent. *Transactions of the American Fisheries Society* 101:650-654.
- _____. 1974. Growth and condition of juvenile largemouth bass from a reservoir receiving thermal effluent. Pages 246-254 in J. W. Gibbons and R. R. Sharitz, (editors) *Thermal Ecology*. Atomic Energy Commission Symposium Series (CONF-730505).
- _____. 1975. Reproductive cycles of largemouth bass (Micropterus salmoides) in a cooling reservoir. *Transactions of the American Fisheries Society* 104:77-82.
- Bennett, D. H. and C. P. Goodyear. 1979. Response of mosquitofish to thermal effluent. Pages 498-510 in J. Thorp and J. W. Gibbons, (editors). *Energy and Environmental Stress in Aquatic Systems*. Department of Energy Symposium Series 48 (CONF-771114).
- Bennett, D. H. 1979. Behavioral thermoregulation of largemouth bass (Micropterus salmoides) in a reservoir receiving thermal effluent. *Archiv fur Hydrobiologia* 86:193-203.

- Blair, W. F., A. P. Blair, P. Brodkorb, F. R. Cagle, and G. A. Moore. 1968. Vertebrates of the United States. McGraw-Hill, Incorporated, New York. 616 p. (a key to the fishes of the contiguous United States; illustrations of some SRP species).
- Brown, J. L. 1957. A key to the species and subspecies of the cyprinodont genus Fundulus in the United States and Canada east of the continental divide. Journal Washington Academy of Science 47(3):69-77.
- _____. 1958. Geographic variation in southeastern populations in the cyprinodont fish Fundulus notti (Agassiz). American Midland Naturalist 59:477-488.
- Burbidge, R. G. 1974. Distribution, growth, selective feeding, and energy transformations of the young-of-the-year blueback herring, Alosa aestivalis (Mitchill), in the James River, Virginia. Transactions of the American Fisheries Society 103(2):297-311.
- Carlander, K. D. 1969. Handbook of freshwater fishery biology, Volume 1. Iowa State University Press, Ames. 752 p. (useful morphometric and life history data on many SRP fishes).
- _____. 1977. Handbook of Freshwater Fishery Biology, Volume 2. Iowa State University Press, Ames (useful morphometric and life history data on SRP sunfishes).
- Cherry, D. S., R. K. Guthrie, J. H. Rodgers, Jr., J. Cairns, Jr., and K. L. Dickson. 1976. Responses of Mosquitofish (Gambusia affinis) to ash effluent and thermal stress. Transactions of the American Fisheries Society 105(6): 686-694. (mosquitofish studies from Beaverdam Creek).
- Clugston, J. P. 1973a. The effects of heated effluents from a nuclear reactor on species diversity, abundance, reproduction, and movement of

- fish. Ph.D. Dissertation University of Georgia, Athens. 104 p. (the only study of the complete ichthyofauna of Par Pond).
- Clugston, J. P. 1973b. The fishes of Lower Three Runs Creek and the Par Pond reservoir system of the Savannah River Plant, South Carolina. Savannah River Laboratory, Aiken, S. C. TID-26216. 12 p.
- Cole, C. F. 1967. A study of the eastern Johnny Darter, Etheostoma olmstedii Storer (Teleostei, Percidae). Chesapeake Science 8:28-51.
- Collette, B. B. 1962. The swamp darters of the subgenus Hololepis (Pisces, Percidae). Tulane Studies in Zoology 9(4):115-212. (Etheostoma fusi-forme, E. serriferum).
- Crawford, R. W. 1956. A study of the distribution and taxonomy of the percid fish Percina nigrofasciata (Agassiz). Tulane Studies in Zoology 4(1):1-55.
- Dahlberg, M. D. 1975. Guide to the coastal fishes of Georgia and nearby states. University of Georgia Press, Athens. 187 p. (information regarding the marine and anadromous fishes of SRP).
- Dahlberg, M. D., and D. C. Scott. 1971a. The freshwater fishes of Georgia. Bulletin Georgia Academy of Science 29(1):1-64. (an important work on the distribution of fishes in Georgia, including the Savannah River).
- _____. 1971b. Introductions of freshwater fishes in Georgia. Bulletin Georgia Academy of Science 29(4):245-252. (documents the known introduction of six SRP fishes into the Savannah River).
- Douglas, N. H. 1974. Freshwater fishes of Louisiana. Claitor's Publishing Division. Baton Rouge. 443 p.
- Dudley, R. G., A. W. Mullis, and J. W. Terrell. 1977. Movements of adult striped bass (Morone saxatilis) in the Savannah River, Georgia. Transactions of the American Fisheries Society 106(4):314-322.

- Dupont, S. P. 1976. The behavior of largemouth bass (Micropterus salmoides) in a reservoir receiving a heated effluent. M.S. Thesis, University of Georgia.
- Eddy, S. 1957. How to know the freshwater fishes. W. C. Brown Company, Dubuque, Iowa, 253 p.
- _____. 1969. How to know the freshwater fishes. William C. Brown Company, Dubuque, Iowa. 286 p. (a useful key with illustrations to identify most SRP species).
- Esch, G. W., T. C. Hazen, R. V. Dimock, Jr. and J. W. Gibbons. 1976. Thermal effluent and the epizootiology of the ciliate Epistylis and the bacterium Aeromonas in association with centrarchid fish. Transactions of the American Microscopic Society 95:687-693.
- Eure, H. E. 1974. Studies on the effects of thermal effluent on the population dynamics of helminth parasites of the largemouth bass, Micropterus salmoides. Ph.D. Dissertation, Wake Forest University, Winston-Salem, North Carolina. 95 p.
- _____. 1976a. Seasonal abundance of Neoechinorhynchus cylindratus taken from largemouth bass (Micropterus salmoides) in a heated reservoir. Parasitology 73:355-370.
- _____. 1976b. Seasonal abundance of Proteocephalus ambloplitis (Cestoidea:Proteocephalidae) from largemouth bass living in a heated reservoir. Parasitology 73:205-212.
- Eure, H. E. and G. W. Esch. 1974. Effects of thermal effluent on the population dynamics of Helminth parasites in largemouth bass. Pages 207-215 in J. W. Gibbons and R. R. Sharitz, (editors) Thermal Ecology. Atomic Energy Commission Symposium Series (CONF-730505).

- Falke, J. D. and M. H. Smith. 1974. Effects of thermal effluent on fat content of the mosquitofish. Pages 100-108 in J. W. Gibbons and R. R. Sharitz, (editors) Thermal Ecology. Atomic Energy Commission Symposium Series (CONF-730505).
- Ferens, M. C. and T. M. Murphy. 1974. Effects of thermal effluents on populations of mosquitofish. Pages 237-245 In J. W. Gibbons and R. R. Sharitz, (editors) Thermal Ecology. Atomic Energy Commission Symposium Series (CONF-730505).
- Forbes, S. A. and R. E. Richardson. 1920. The fishes of Illinois. Second Edition. Illinois Natural History Survey. Circular 3.
- Fowler, H. W. 1920. Description of a new cyprinid fish (Notropis stonei) with notes on other fishes obtained in the United States. Proceeding of the Academy of Natural Sciences of Philadelphia. Pages 391-393. (a redescription of Notropis hypselopterus under synonym N. stonei).
- Fowler, H. W. 1935. Notes on South Carolina freshwater fishes. Contributions from Charleston Museum No. 7. Pages 6-28. (contains illustrations of 27 SRP species).
- _____. 1942. Description of six new fresh-water fishes (Cyprinidae and Percidae) from the southeastern U. S. Nat. Acad. Natural Sci. of Philadelphia.
- _____. 1945. A study of the fishes of the southern piedmont and coastal plain. Academy of Natural Sciences of Philadelphia. Monograph No. 7. (the original description of Etheostoma hopkinsi; many illustrations of SRP fishes).
- Freeman, H. W. 1952. New distributional records for fishes of the Savannah River Basin, South Carolina. Copeia 4:269.

- _____. 1954. Fishes of the Savannah River Operations Area. University of South Carolina Publication Series III. Biology 1(3):117-158. (the pre-operational baseline study of SRP stream fishes).
- _____. 1958. Fish Species of Lower Three Runs Creek on Savannah River Plant (Unpublished report U. S. Atomic Energy Commission, 35 p.).
- Frietsche, R. A., R. D. Miracle, and R. W. McFarlane. 1979. Larvae and juveniles of the brook silverside, Labidesthes sicculus. p. 189-193 in R. Wallus & C. W. Voitlander, Freshwater Larval Fishes, Tenn. Valley Author., Norris, TN.
- Gibbons, J. W., J. T. Hook and D. L. Forney. 1972. Winter responses of largemouth bass to heated effluent from a nuclear reactor. Progressive Fish Culturist 34(2):88-90.
- Gibbons, J. W. and D. H. Bennett. 1973. Abundance and local movement of largemouth bass (Micropterus salmoides) in a reservoir receiving heated effluent from a reactor. Pages 524-427 in D. J. Nelson. (editor), Proceedings of the 3rd National Symposium of Radioecology. (CONF-710501-P1).
- Gibbons, J. W. and R. R. Sharitz. 1974. Thermal alteration of aquatic ecosystems. American Scientist 62:660-670.
- _____. 1981. Thermal ecology: Environmental teachings at a nuclear reactor site. BioScience 31:293-298.
- Gibbons, J. W., R. R. Sharitz, and I. L. Brisbin. 1980. Thermal ecology research on the Savannah River Plant: A review. Nuclear Safety 21: 367-379.
- Gibbons, J. W., R. R. Sharitz, F. G. Howell, and M. H. Smith. 1975. Ecology of artificially heated streams, swamps and reservoirs on the Savannah River Plant. IAEA-SM-187/13, Vienna. Pages 389-400.

- Gibbons, J. W., D. H. Bennett, G. W. Esch, and T. C. Hazen. 1978. Effects of thermal effluent on body condition of largemouth bass. *Nature* 247: 470-471.
- Giesy, J. P. and J. G. Wiener. 1977. Frequency distribution of trace metal concentrations in five freshwater fishes. *Transactions of the American Fisheries Society* 106:393-403. (*Alosa aestivalis*, *Notemigonus crysoleucas*, *Notropis petersoni*, *Esox niger*, *Lepomis macrochirus*, *Labidesthes sicculus*).
- Godwin, W. F. 1968. The shad fishery of the Altamaha River, Georgia. Georgia Marine Fisheries Division Contribution Series No. 8. 39 p.
- Gold, D. D., D. C. Scott, A. Hirsch, C. C. Ruchhoft, and L. R. Setter. 1954. Interim Report on the Savannah River Studies. U. S. Department of Health, Education and Welfare. U. S. Public Health Service. Cincinnati, Ohio, 257 p. (a preoperational survey of Savannah River fishes).
- Goodyear, C. P. 1970. Terrestrial and aquatic orientation in the starhead topminnow, *Fundulus notti*. *Science* 168:603-605.
- _____ 1973. Learned orientation in the predator avoidance behavior of mosquitofish *Gambusia affinis*. *Behavior* 45:191-224.
- Goodyear, C. P., and C. E. Boyd. 1972. Elemental composition of largemouth bass (*Micropterus salmoides*). *Transactions of the American Fisheries Society* 101:545-547.
- Goodyear, C. P., C. E. Boyd, and R. J. Beyers. 1972. Relationships between primary productivity and mosquitofish (*Gambusia affinis*) production in large microcosms. *Limnology and Oceanography* 17:445-450.
- Goodyear, C. P., and D. E. Ferguson. 1969. Suncompass orientation in the mosquitofish, *Gambusia affinis*. *Animal Behavior* 17:639-640.

- Goodyear, C. P. and D. H. Bennett. 1979. Sun compass orientation of immature bluegill. Transactions of the American Fisheries Society 108:555-559.
- Harvey, R. S. 1964. Uptake of radionuclides by fresh water algae and fish. Health Physics 10:243-247. (Lepomis macrochirus, Micropterus salmoides, Ictalurus natalis).
- Hildebrand, S. F. 1923. Annotated list of fishes collected in the vicinity of Augusta, Georgia, with description of a new darter. Bulletin U. S. Bureau Fisheries Volume 39:1-8.
- Hogan, D. C. 1977. Distribution and relative abundance of prey fish in a reservoir receiving a heated effluent. M.S. Thesis. University of Georgia, Athens. (Alosa aestivalis, Notropis petersoni, Lepomis auritus, Lepomis macrochirus).
- Holland, W. E., M. H. Smith, J. W. Gibbons, and D. H. Brown. 1974. Thermal tolerances of fish from a reservoir receiving heated effluent from a nuclear reactor. Physiological Zoology 47:110-118. (Lepomis macrochirus).
- Hubbs, C. L. and K. F. Lagler. 1947. Fishes of the Great Lakes Region. Cranbrook Institute of Science. Bulletin No. 26. 186 pages.
- _____. 1958. Fishes of the Great Lakes Region. Cranbrook Institute of Science. Revised Edition. Bulletin No. 26. 213 pages.
- Hubbs, C. L. and E. C. Raney. 1944. Systematic notes on North American siluroid fishes of the genus Schilbeodes. Occasional Papers of the Museum of Zoology. University of Michigan No. 487, 40 p. (Noturus insignis).
- _____. 1951. Status, subspecies, and variations of Notropis cummingsae, a cyprinid fish of the southeastern United States. Occasional Papers of the Museum of Zoology. University of Michigan No. 535. 27 p.

- Humphries, R. L. 1965. A study of the movements of channel catfish Ictalurus lacustris punctatus, in the Savannah River and one of its tributaries within the AEC Savannah River Operations area. Institute of Radiation Ecology. University of Georgia, Athens. TID-21791. 53 p.
- Jenkins, R. E. 1970. Systematic studies of the catostomid fish tribe Moxostomatini. Ph.D. Dissertation. Cornell University. University Microfilms 71-14, 641, 818 p. (Hypentelium, Moxostoma).
- Jenkins, R. E., L. A. Revelle, and T. Zorach. 1975. Records of the black-banded sunfish, Enneacanthus chaetodon, and comments on the southeastern Virginia freshwater ichthyofauna. Virginia Journal of Science 26(3): 128-134.
- Johnson, S. R. 1976. The food habits of bluegill, Lepomis macrochirus, and largemouth bass, Micropterus salmoides, in reservoirs receiving heated effluent from a nuclear reactor. M.S. Thesis. University of Georgia, Athens.
- Jordan, D. S. and A. W. Brayton. 1878. Contributions to the North American Ichthyology. Based primarily on the collections of the United States National Museum. III. A. On the distribution of the fishes of the Allegheny Region of South Carolina, Georgia, and Tennessee with descriptions of new and little known species. Bulletin United States National Museum 12:1-95.
- Langley, T. M. and W. L. Marter. 1973. The Savannah River Plant site. Savannah River Laboratory, Aiken, South Carolina DP-1323. 175 p. (physical description of the SRP and its biota).
- Lattimore, R. E. and J. W. Gibbons. 1974. Body condition and stomach contents of fish inhabiting thermally altered areas. American Midland Naturalist 95:215-219. (Lepomis auritus, L. punctatus, Enneacanthus gloriosus).

- Leggett, W. C. 1973. The migrations of the shad. *Scientific American* 228(3):92-98.
- Loesch, J. G. and W. A. Lund, Jr. 1977. A contribution to the life history of the blueback herring, *Alosa aestivalis*. *Transactions of the American Fisheries Society* 106(6):583-589.
- Loyacano, H. A., Jr. 1975. A list of freshwater fishes of South Carolina. South Carolina Agricultural Experiment Station. Clemson University, Clemson, South Carolina Bulletin No. 580. 8 p.
- Mathur, D. 1973. Some aspects of the life history of the blackbanded darter, *Percina nigrofasciata* (Agassiz) in Halawakee Creek, Alabama. *American Midland Naturalist* 89(2):381-393.
- McFarlane, R. W. 1976. Fish diversity in adjacent ambient, thermal and post-thermal freshwater streams. Pages 268-271 in G. W. Esch and R. W. McFarlane, (editors). *Thermal Ecology II. Energy, Research and Development Administration Symposium Series 40 (CONF-750425)*. (SRP stream fishes).
- McFarlane, R. W., B. C. Moore and S. E. Williams. 1976. Thermal tolerance of stream cyprinid minnows. In: G. W. Esch and R. W. McFarlane (Eds.), *Thermal Ecology II. ERDA Symp. Ser. (CONF-750425)*. (*Notropis cumming-sae*, *N. lutipinnis*, *Semotilus atromaculatus*).
- McFarlane, R. W., R. F. Frietsche and R. D. Miracle. 1978. Impingement and entrainment of fishes at the Savannah River Plant. E. I. duPont de Nemours and Co. DP-1491. Aiken, South Carolina. 68 p.
- _____. 1979. Community structure and differential impingement of Savannah River Fishes. *Proceedings of the Annual Conference of the South Eastern Association of Fish & Wildlife Agencies* 33:628-638.

- Murphy, J. C., C. T. Garten, Jr., M. H. Smith, and E. A. Standora. 1976. Thermal tolerance and respiratory movement of bluegill from two populations tested at different levels of acclimation temperature. Pages 145-147 in G. W. Esch and R. W. McFarlane, (editors). Thermal Ecology II. Energy, Research and Development Administration Symposium Series 40 (CONF-750425).
- Murphy, J. C. and J. W. Gibbons. 1977. Bibliography of aquatic and thermal studies conducted on the Savannah River Plant. Revision I. Savannah River Ecology Laboratory, Aiken, South Carolina. 26 p.
- Parker, E. D., M. R. Hirshfield and J. W. Gibbons. 1973. Ecological comparisons of thermally affected aquatic environments. Journal of the Water Pollution Control Federation 45(4):726-733.
- Patrick, R., J. Cairns, Jr. and S. S. Roback. 1967. An ecosystematic study of the fauna and flora of the Savannah River. Proceedings of the Academy of Natural Sciences of Philadelphia 118(5):109-407. (a ten year review of the ANSP collections).
- Pflieger, W. L. 1975. The fishes of Missouri. Missouri Department of Conservation. 343 p. (comprehensive review of Missouri fishes).
- Quinn, T., G. W. Esch, T. C. Hazen, and J. W. Gibbons. 1978. Long range movement and homing by largemouth bass (Micropterus salmoides) in thermally altered reservoir. Copeia. 3:542-545.
- Richardson, J. 1836. Fauna Boreali-Americana, or the zoology of the northern parts of British America, containing descriptions of the objects of natural history collected on the late northern land expeditions, under the command of Sir John Franklin, R.N. London and Norwich, Volume 3, the Fish.

- Ricker, W. E. 1973. Linear regression in fishery research. Journal of the Fisheries Research Board of Canada 30:409-434.
- Rivas, L. R. 1966. The taxonomic status of the cyprinodontid fishes Fundulus notti and F. lineolatus. Copeia. 2:353-354.
- Siler, J. R. 1975. The distribution of fishes in two cooling reservoirs with different heat loads. M.S. Thesis. University of Georgia, Athens. (Par Pond; Micropterus salmoides, Lepomis macrochirus, Ictalurus platycephalus, Erismyzon sucetta).
- Siple, G. E. 1967. Geology and ground water of the Savannah River Plant and vicinity South Carolina. Geological Survey Water-Supply Paper. No. 1841. 113 p.
- Smith, L. D. 1968. Notes on the distribution, relative abundance and growth of juvenile anadromous fish in the Altamaha River system, Georgia, with specific reference to striped bass, Roccus saxatilis (Walbaum). Georgia Marine Fisheries Division Contribution Series No. 1. 22 p.
- Smith, M. H. and S. L. Scott. 1975. Thermal tolerance and biochemical polymorphism of immature largemouth bass Micropterus salmoides Lacepede. Bulletin of the Georgia Academy of Sciences 34:180-184.
- Smith-Vaniz, W. F. 1968. Freshwater fishes of Alabama. Auburn University Agricultural Experiment Station (information on SRP species and photographs of SRP specimens).
- Smoak, C. H., Jr. 1959. Some considerations in the upper thermal tolerance on Gambusia affinis holbrooki (Girard) in the Savannah River Plant area. South Carolina Academy of Sciences. p. 44-53.
- Street, M. W. 1969a. Fecundity of the hickory shad in the Altamaha River, Georgia. Georgia Marine Fisheries Division Contribution Series No. 14. 11 p.

- _____. 1969b. Fecundity of the blueback herring in Georgia. Georgia Marine Fisheries Division Contribution Series No. 17. 15 p.
- Street, M. W. and J. G. Adams. 1969. Aging of hickory shad and blueback herring in Georgia by the scale method. Georgia Marine Fisheries Division Contribution Series No. 18. 13 p.
- Tilly, L. J. 1975. Changes in water chemistry and primary productivity of a reactor cooling reservoir (Par Pond). Pages 394-407 in Mineral Cycling in Southeastern Ecosystems. F. G. Howell, J. B. Gentry, and M. H. Smith, editors. Energy Research Development Administration Symposium Series (CONF-740513).
- Trautman, M. B. 1957. The fishes of Ohio. The Ohio State University Press. 683 p.
- Vaughn, T. L. 1967. Fecundity of the American shad in the Altamaha River system. Georgia Marine Fisheries Division Contribution Series No. 3. 9 p.
- Wells, L., and R. House. 1974. Life history of the spottail shiner (*Notropis hudsonius*) in southeastern Lake Michigan, the Kalamazoo River, and western Lake Erie. Bureau Sport Fisheries and Wildlife Research Report 78. 10 p.
- Whitworth, W. R. 1969. Unpublished list of fishes from the Savannah River Plant. University of Connecticut, Storrs.
- Wiener, J. G. and M. H. Smith. 1981. Studies of Aquatic and Terrestrial Environments of the Savannah River Plant, South Carolina: A Bibliography. SRO-NERP-7. Savannah River Ecology Laboratory, Aiken, SC. 131 pp.
- Winn, H. E. 1958. Comparative reproductive behavior and ecology of fourteen species of darters (Pisces - Percidae). Ecological Monographs 28(2): 155-191.

Yardley, D., J. C. Avise, J. W. Gibbons and M. H. Smith. 1974. Biochemical genetics of sunfish. III. Genetic subdivision of fish populations inhabiting heated waters. Pages 255-263 in J. W. Gibbons and R. R. Sharitz, (editors). Thermal Ecology. Atomic Energy Commission Symposium Series (CONF-730505). (Gambusia affinis, Lepomis macrochirus, Micropterus salmoides).

Yerger, R. W. and K. Relyea. 1968. The flatheaded bullheads (Pisces: Ictaluridae) of the southeastern United States, and a new species of Ictalurus from the Gulf Coast. Copeia. 2:361-384. (description of Ictalurus brunneus as distinguished from I. platycephalus, includes data from Savannah River specimens).

INDEX

- Acantharchus
pomotis 99,104
- Acipenser
oxyrhynchus 55
- Acipenseridae 55
- Acipenseriformes 55
- aestivalis, Alosa 58,59
- affinis, Gambusia 94
- Alosa
aestivalis 58,59
mediocris 58,59,60
sapidissima 58,59,61
- Amblyopsidae 90
- American eel 57,58
- American shad 61,59,58
- americanus, Esox 64
- Amia
calva 57
- Amiidae 57
- Amiiformes 57
- Anguilla
rostrata 57,58
- Anguillidae 57
- Anguilliformes 57
- anisurum, Moxostoma 79,82
- annularis, Pomoxis 99,112
- Aphredoderus
sayanus 91
- Aphredoderidae 91
- Atherinidae 95,120
- Atheriniformes 92
- Atlantic needlefish 92
- Atlantic sturgeon 55
- Atractosteus 55
- atromaculatus, Semotilus 66,78
- auritus, Lepomis 104,106,123
- banded pygmy sunfish 99,105
- bannerfin shiner 70,76
- bass, largemouth 19,98,100,111
 bass, striped 96,97
 bass, white 96,97
- Belonidae 92
- blackbanded darter 114,119
- blackbanded sunfish 99,105
- black crappie 99,112
- blueback herring 58,59
- bluehead chub 66,73
- black bullhead 123
- bluegill 104,109
- bluespotted sunfish 99,106
- Boleosoma 118,119
nigrum 118

- bowfin 57
- brook silverside 95
- Boleichthys fusiformis 116
- brown bullhead 85,87
- brunneus, Ictalurus 85,87
- bullhead
 flat 85,87
 snail 85
 brown 85,87
 yellow 85,86
- calva, Amia 57
- caprodes, Percina 123
- carp 66,71
- carpio, Cyprinus 66,71
- Carpiodes
 carpio 123
 cyprinus 79,80
 velifer 123
- Catfish 83
 channel 83,88
 white 83,86
 flathead 83,90
- Catostomidae 78
- catus, Ictalurus 83,86,88
- cavefish 90
- Centrarchidae 98
- Centrarchus
 macropterus 99,104
- cepedianum, Dorosoma 58,59,62
- cephalus, Mugil 120
- chaetodon, Enneacanthus 99,105
- chain pickerel 64,65
- chalybaeus, Notropis 70,73
- channel catfish 83,88
- Chaenobryttus coronatus 108
- Chologaster
 cornuta 90,91
- Christmas darter 116,117
- chrysops, Morone 96,97
- chub
 creek 66,78
 rosyface 66,72
 bluehead 66,73
- chubsucker
 creek 79,80
 lake 81,82
- Clupeidae 58,59
- Clupeiformes 58
- coastal shiner 70,77
- Coosa shiner 122
- coosae, Micropterus 123
- cornuta, Chologaster 90,91
- crappie
 black 99,112
 white 99,112
- creek club 66,78
- creek chubsucker 79,80
- crysoleucas, Notemigonus 66,72
- cummingsae, Notropis 71,74
- cyanellus, Lepomis 100,107

Cyprinidae 65

Cypriniformes 65

Cyprinodontidae 93

Cyprinus

carpio 66,71

cyprinus, Carpiodes 79,80

darter

blackbanded 114,119

Christmas 116,117

tessellated 114,118

turquoise 116,118

sawcheek 114,119

Savannah 116

swamp 114,116

dollar sunfish 100,109

Dorosoma

cepedianum 58,59,62

petenense 58,59,62

dusky shiner 71,74

eastern mudminnow 63

eel

American 57, 58

Elassoma

zonatum 99,105

emiliae, Notropis 69,74

Enneacanthus

chaetodon 99,105

gloriosus 99,106

Erimyzon

oblongus 79,80

sucetta 80,81

Esocidae 63

Esox

niger 64,65

americanus 64

Etheostoma

fricksium 116,117

fusiforme 114,116

barratti 116

hopkinsi 116,117

nigra 118

inscriptum 116,118

olmstedii 114,118

serriferum 114,119

flat bullhead 85,87

flathead catfish 83,90

flavescens, Perca 113,114,119

flier 99,104

Florida gar 56

fricksium, Etheostoma 116,117

Fundulus 19

lineolatus 93

Fundulus notti 93

Fundulus dispar lineolatus 93

fusiforme, Etheostoma 114,116

Gambusia 19

affinis 94

G. holbrooki 94

gar 55

Florida 56

longnose 55,56

gibbosus, Lepomis 100,107,110

gizzard shad 58,59,62

gloriosus, Enneacanthus 99,106

golden shiner 66,72

green sunfish 100,107

gulosus, Lepomis 100,108

gyrinus, Noturus 85,88

herring, blueback 58,59

Hadropterus nigrofasciatus 119

highfin carpsucker 123

hickory shad 58,59,60

hogchoker 121

hogsucker, northern 79,81

hopkinsi, Etheostoma 116,117

holbrooki, Gambusia affinis 94

Hololepis barratti 116

hudsonius, Notropis 70,75

Huro floridana 111

Hybognathus
nuchalis 69,71

Hybopsis
rubrifrons 66,72

Hybopsis bellicus 73

Hybopsis leptcephala 73

Hydrophlox 73
chalybaeus 73
lutipinnis 76

Hypentelium
nigricans 79,81

hypselopterus, Notropis 70,75

Ictaluridae 83

Ictalurus

brunneus 85,87

catus 83,86,88

melas 123

natalis 85,86

nebulosus 85,87

platycephalus 85,86,87

punctatus 83,86,88

Ichthelis macrochira 109

inscriptum, Etheostoma 116,118

insignis, Noturus 85,89

ironcolor shiner 70,73

killifish 93

Labidesthes

sicculus 95

lake chubsucker 80,81

largemouth bass 19,98,100,111

leedsi, Notropis 70,76

Lepisosteidae 55

Lepisosteus 55,92

oculatus 122

osseus 55,56

platyrhincus 56,122

Lepibema chrysops 97

Lepomis

auritus 104,106,123

cyaneillus 100,107

gibbosus 100,107,110

gulosus 100,108

macrochirus 104,109

marginatus 100,109,123

- megalotis 123
microlophus 100,107,108,110
punctatus 100,110
- leptacanthus, Noturus 85,89
- leptocephalus, Nocomis 66,73,122
- lined topminnow 93
- lineolatus, Fundulus 93
- logperch 123
- longear sunfish 123
- longnose gar 55,56
- lutipinnis, Notropis 70,76
- macrochirus, Lepomis 104,109
- macropterus, Centrarchus 99,104
- maculatus, Notropis 69,77
- maculatus, Trinectes 121,123
- madtom
 - marginated 85,89
 - tadpole 85,88
 - speckled 85,89
- marginatus, Lepomis 100,109,123
- marina, Strongylura 92
- margined madtom 85,89
- mediocris, Alosa 58,59,60
- melanops, Minytrema 79,82
- Mesogonistus c. chaetodon 105
- microlophus, Lepomis 100,107,108,110
- Micropterus
 - coosae 123
 - salmoides 98,100,111
- minnow 65
 - silvery 69,71
 - pugnose 69,74
- Minytrema
 - melanops 79,82
- Monrone
 - chrysops 96,97
 - saxatilis 96,97
- mosquitofish 94
- Moxostoma
 - anisurum 79,82
- mudminnow, eastern 63
- mud sunfish 99,104
- Mugil
 - cephalus 120
- Mugilidae 120
- mullet, striped 120
- Myrophis punctatus 122
- natalis, Ictalurus 85,86
- nebulosus, Ictalurus 85,87
- needlefish, Atlantic 92
- niger, Esox 64,65
- nigricans, Hypentelium 79,81
- nigrofasciata, Percina 114,119,123
- nigromaculatus, Pomoxis 99,112
- niveus, Notropis 69,77

Nocomis

leptocephalus 66,73,122
micropogon 122

Nocomis bellicus 73

northern hogsucker 79,81

Notemigonus

crysoleucas 66,72

Notropis

chalybaeus 70,73
cummingsae 71,74
emiliae 69,74
hudsonius 70,75
hypselopterus 70,75
hypselopterus stonei 75
leedsi 70,76
lutipinnis 70,76
maculatus 69,77
niveus 69,77
petersoni 70,77,122
spilopterus 122
stonei 75
xaenocephalus 122

Noturus

gyrinus 85,88
insignis 85,89
leptacanthus 85,89
marginatus 89

nuchalis, Hybognathus 69,71

oblongus, Erimyzon 80,79

Opsopoeodus emiliae 74

olivaris, Pylodictus 83,90

olmstedii, Etheostoma 114,118

osseus, Lepisosteus 55,56

oxyrhynchus, Acipenser 55

Perca

flavescens 113,114,119

P. chrysops 97

perch

pirate 91
 yellow 113,114,119

Percichthyidae 96

Percidae 113

Perciformes 96

Percina

caprodes 123
nigrofasciata 114,119,123
nigrofasciatus 119

Percopsiformes 90

petenense, Dorosoma 58,59,62

petersoni, Notropis 70,77,122

pickerel

chain 64,65
 redfin 64

pike 63

Pimelodus insignis 89

pirate perch 91

platycephalus, Ictalurus 85,86,87

platyrhincus, Lepisosteus 56,122

Pleuronectiformes 121

Poeciliidae 94

Poecilichthys

fricksia 116
inscriptum 118

pomotis, Acantharchus 99,104

Pomotis gibbosus 107

Pomoxis

annularis 99,112
nigromaculatus 99,112

pugnose minnow 69,74

pumpkinseed 100,107

punctatus, Ictalurus 83,86,88

punctatus, Lepomis 100,110

pygmaea, Umbra 63

pygmy sunfish (banded) 99,105

Pylodictus

olivaris 83,90

quillback 79,80

redbreast sunfish 104,106

redeer sunfish 100,110

redest bass 123

redfin pickerel 64

redhorse, silver 79,82

river chub 122

river carpsucker 123

Roccus chrysops 97

R. saxatilis 97

rostrata, Anguilla 57,58

rosyface chub 66,72

rubrifrons, Hybopsis 66,72

sailfin shiner 70,75

salmoides, Micropterus 98,100,111

Salmoniformes 63

sapidissima, Alosa 58,59,61

Savannah darter 116

sawcheek darter 114,119

saxatilis, Morone 96,97

sayanus, Aphredoderus 91

Semionotiformes 55

Semotilus

atromaculatus 66,78

serriferum, Etheostoma 114,119

shad

American 59,61
 gizzard 58,59,62
 hickory 59,60
 threadfin 58,59,62

shiner

bannerfin 70,76
 coastal 70,77
 dusky 71,74
 golden 66,72
 ironcolor 70,73
 sailfin 70,75
 spottail 70,75
 taillight 69,77
 whitefin 69,77
 yellowfin 70,76

sicculus, Labidesthes 95

Siluriformes 83

silver redhorse 79,82

silverside, brook 95

- silvery minnow 69,71
 snail bullhead 85
 sole 121
 Soleidae 121
 speckled madtom 85,89
 speckled worm eel 122
 spotfin shiner 122
 spottail shiner 70,75
 spotted gar 122
 spotted sucker 79,82
 spotted sunfish 100,110
 striped bass 97
 striped mullet 120
Strongylura
 marina 92
 sturgeon
 Atlantic 55
sucetta, Erimyzon 80,81
 sucker, spotted 79,82
 sunfish 98
 banded pygmy 99,105
 blackbanded 99,105
 bluegill 104,109
 bluespotted 99,106
 dollar 100,109
 flier 99,104
 green 100,107
 largemouth bass 19,98,100,111
 mud 99,104
 pumpkinseed 100,107
 redbreast 104,106
 redeer 100,110
 spotted 100,110
 warmouth 100,108
 swamp darter 114,116
 swampfish 90,91
 taillight shiner 69,77
 tadpole madtom 85,88
 temperate bass 96
 tessellated darter 114,118
 threadfin shad 58,59,62
 topminnow, lined 93
Trinectes
 fasciatus 123
 maculatus 121, 123
 turquoise darter 116,118
Umbra
 pygmaea 63
 Umbridae 63
 warmouth 100,108
 white bass 96,97
 white catfish 83,86
 white crappie 99,112
 whitefin shiner 69,77
 yellow bullhead 85,86
 yellowfin shiner 70,76
 yellow perch 113,114,119
zonatum, Elassoma 99,105
Zygonectes nofti 93

APPENDIX I

Figures 6, 7A, 8, 13A, 14A, 16C, 22

From Vertebrates of the United States by W. F. Blair, A. P. Blair, P. Brad Korb, F. R. Cagle, and G. A. Moore. Copyright[©] 1968 McGraw-Hill Book Company. Used by permission of McGraw-Hill Book Company.

Figures 7B, 14B

From Fishes of the Great Lakes Region by Carl L. Hubbs and Karl L. Lagler. Copyright[©] 1947, 1958 The University of Michigan. Used by permission of the University of Michigan Press.

Figures 6, 13B, 18, 20, 21

From How to Know the Freshwater Fishes by S. Eddy. Used by permission of William C. Brown Company.

Figure 19

From The Fishes of Illinois by Forbes, S. A. and R. E. Richardson. 1920. The fishes of Illinois Second Edition. Illinois Natural History Survey. Circular 3. Used by permission of Illinois Natural History Survey.

NOTES