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EFFECTS OF THERMAL DISCHARGES ON THE DISTRIBUTION AND ABUNDANCE OF ADULT FISHES IN THE SAVANNAH RIVER AND SELECTED TRIBUTARIES. ANNUAL REPORT. NOVEMBER 1984-AUGUST 1985

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Effects of Thermal Discharges on the Distribution and Abundance of Adult Fishes in the Savannah River and Selected Tributaries. Annual Report. November 1984 - August 1985.

Michael H. Paller
Bruce M. Saul

Environmental & Chemical Sciences, Inc.
P. O. Box 1393
Aiken, South Carolina 29802

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E. I. du Pont de Nemours & Company
Savannah River Laboratory
Aiken, South Carolina 29808

John Gladden
Program Advisor

Environmental & Chemical Sciences, Inc.
P. O. Box 1393
Aiken, South Carolina 29802

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

FIGURES

FIGURES (continued)

TABLES

TABLES (continued)

EXECUTIVE SUMMARY

1. A study of the juvenile and adult fish community in streams draining the SRP and in the Savannah River in the area of the SRP was conducted between September 1984 and September 1985. The study included sample stations in the Savannah River, the SRP intake canals, and most onsite creeks. Most sites were sampled quarterly; however, a limited number of swamp sites were also sampled weekly during the winter to determine if fish congregated in thermal areas when normal water temperatures were low.

2. The major objectives of this study were to examine the abundance and distribution of fishes near the Savannah River Plant in relation to thermal discharges into the river, creeks, and floodplain swamps and to determine the rate of impingement of adult and juvenile fishes on the intake screens at the SRP pumphouses.

3. Approximately 10,000 fishes were collected by electrofishing and hoop netting during the November 1984 - August 1985 sampling period. The most abundant fishes (excluding minnows) taken by electrofishing were the redbreast sunfish (41.6%), spotted sucker (8.8%), spotted sunfish (8.2%), largemouth bass (5.7%), bluegill (5.6%), and American eel (5.4%). The most abundant fishes taken by hoop netting were

the flat bullhead (38.0%), channel catfish (11.9%), bluegill (9.4%), white catfish (7.9%), black crappie (6.5%), and redbreast sunfish (5.5%).

4. To evaluate habitat preference, the study area was divided into intake canals, thermal river, nonthermal river, nonthermal creek, and thermal creeks. The thermal creeks included highly thermal Four Mile Creek, moderately thermal Beaver Dam Creek, and refuge areas in Pen Branch. The thermal river consisted of the South Carolina side of the river transect just below Beaver Dam Creek (RM 152.0) and the one just below Four Mile Creek (RM 150.4).

5. Dominant species in the intake canals were the bluegill, redbreast sunfish, and black crappie. Dominant species in the nonthermal river were the redbreast sunfish, spotted sunfish, spotted sucker, largemouth bass, channel catfish, white catfish, and flat bullhead. Dominant species in the nonthermal creeks were fairly similar to river species except that the catfishes were not as well represented. The thermal river and creek habitats differed from the nonthermal habitats in having higher percentages (although often lower numbers) of channel catfish, white catfish, largemouth bass, and coastal shiner and a lower percentage of flat bullhead. Exceptions occurred in Pen Branch refuge areas and portions of Four Mile Creek, where mosquitofish were the dominant, and sometimes only, species present.

6. Fish collected by electrofishing were used to estimate catch per unit effort as the number of fish/100 m of shoreline. CPUE averaged 3.8 fish/100 m during November, 1.6 fish/100 m during February, 4.4 fish/100 m during May, and 7.2 fish/100 m during August. The relatively low average CPUE during February was probably the result of high water levels that enabled fish to move out of the river and creeks and into the flooded swamp.

7. Electrofishing CPUE was highly variable at most sample stations, but generally 0.0 fish/100 m were collected in the segment of Four Mile Creek receiving reactor discharge. The only exception was in August, when C-Reactor was down and temperatures in Four Mile Creek were ambient. At this time, CPUE in Four Mile Creek was within the range of that in the other creeks. CPUE in moderately thermal Beaver Dam Creek was variable and exhibited no obvious relationship to temperature. CPUE in the thermal river habitats directly downstream from the mouths of the thermal creeks never exhibited unusual reductions.

8. Hoop netting catch per unit effort was expressed as number of fish collected per net day. In general, hoop netting CPUE was highly variable and exhibited no consistent habitat- or temperature-related patterns. The only exception was Four Mile Creek, where CPUE was consistently low (0.0 - 0.3

fish/net day). CPUE in Beaver Dam Creek was somewhat higher (0.0 - 0.7 fish/net day) and basically comparable to that in the nonthermal creeks. There was no evidence of reduced CPUE in the thermal river habitat.

9. Concentrated sampling in the thermal creeks (and appropriate control creeks) during the overwintering program suggested that redear sunfish, channel catfish, longnose gar, black crappie, and gizzard shad congregated in moderately heated areas. The American eel, spotted sucker, and flat bullhead avoided the thermal habitats. Fish appeared to congregate to the greatest extent in the thermal river habitat, which was heated only 2 - 3°C above ambient. However, there was slight evidence of congregation in Beaver Dam Creek, which was approximately 7°C above ambient. Fish avoided Four Mile Creek, where temperatures were very warm, occasionally exceeding 35°C.

10. The relationship between fish distribution and temperature was examined using data collected from Four Mile Creek over a three-year period. CPUE was unrelated to temperature at temperatures under 30°C, variable with an increased proportion of no fish in a sample at temperatures between 30 and 35°C, and zero at temperatures above 35°C. Sunfishes, largemouth bass, gar, and gizzard shad were the dominant species in the 30 - 35°C range. Shannon-Weaver diversity and species number

were independent of temperature at temperatures below 35°C, but were zero at higher temperatures.

11. An average of 7.7 fish weighing a total of 466.4 g were impinged daily on the SRP intake screens during the 1984/1985 impingement study. The most commonly impinged fishes were shad/herring and sunfishes. The 1G canal had the highest impingement rate, with 4.3 fish/day. Impingement rates were lower during the 1984/1985 sampling period than during earlier years, probably because fish were less abundant in the intake canals due to low river levels and habitat alterations caused by dredging.

1.0 INTRODUCTION

The Savannah River watershed includes western South Carolina, eastern Georgia, and a small portion of southwestern North Carolina. It is formed by the confluence of the Tugaloo and Seneca Rivers in northeast Georgia and flows southeast through the Piedmont and Coastal Plain to the Atlantic Ocean. In its mid- and lower reaches, it is broad with extensive floodplain swamps and numerous tributaries. The substrate consists of various combinations of silt, sand, and clay. The river is influenced by dredging, sewage discharge, and industrial inputs, and water flow is controlled by a system of reservoirs, locks, and dams.

In 1951 the Savannah River Plant (SRP) was established near Aiken, South Carolina, to produce nuclear materials for national defense. During the time period covered in this report, the SRP was operating three nuclear reactors and a coal-fired steam generating plant (400 D area). C- and K-Reactors are cooled by water pumped from the Savannah River and returned to the river through Four Mile Creek or the Pen Branch/Steel Creek system, respectively. Cooling water pumped from the Savannah River for the 400 D power plant returns to the river through Beaver Dam Creek. Thermal effluents discharged into these creeks flow through a floodplain swamp before reentering the Savannah River through breaks in a natural levee that separates the swamp from the river. P-Reactor utilizes a large, man-made cooling pond on the upper reaches of Lower Three Runs Creek and requires only pond make-up water from the Savannah River. Prior to being placed on stand-by in 1968, L-Reactor discharged cooling water into Steel Creek, which flows into the Savannah River near the southern boundary of the SRP. The data presented in this report was collected prior to the November 1985 re-start of L-Reactor.

The thermal plumes created in the Savannah River by SRP effluents vary in size and temperature as a result of changes in reactor operation, Savannah River water level, and season of the year. When the river is low, effluents from the thermal creeks discharge directly into the river, producing plumes along the South Carolina shore. Infrared surveys taken in August (1982) indicate that during midsummer the plume from Four Mile Creek may be more than 10°C above ambient at the egress from the swamp (Bristow and Doak 1983), but that the plume dissipates quickly due to dilution by the much larger Savannah River. The August (1982) infrared survey also indicated that the temperature of the Four Mile Creek plume had dropped to approximately 2°C above ambient 400 m downstream of the discharge point. During colder months the 2°C isotherm extends further downstream because of the greater temperature difference between the creek water exiting the swamp and the river.

When the Savannah River is high enough to inundate the SRP floodplain swamp, no thermal plumes are discharged into the river. Under flood conditions the river overflows into the floodplain swamp, and the heated water is forced along the upland edge of the swamp, parallel to the river, instead of flowing across the flood-plain perpendicular to the river and entering the main river channel quickly. When the thermal discharges remain in the floodplain for longer than usual periods of time, cooling and dilution occur in the floodplain swamp, and thermal plumes are not observed in the river channel.

Thermal plumes influence the movement and distribution of fishes. Fish can avoid areas of high water temperatures, while areas with moderately elevated temperatures can attract fish when water temperatures are normally cool (e.g., winter or spring). With attraction come potential problems from crowding, such as increased incidence of disease and reduced food availability. Other potential deleterious thermal effects are altered reproductive cycles and reduced body condition due to increased metabolic requirements. Thermal plumes also can act as barriers to migratory fishes. This effect would not be expected in the Savannah River, however, since the plumes created by SRP discharges tend to hug the South Carolina shore (Shines and Tinney 1983). However, more subtle effects such as the possible attraction of spawning fish to thermal areas may interfere with normal spawning movements.

Although the fishes of the Savannah River have been studied, only recently have efforts been directed towards understanding the effects of SRP discharges on fish movement and distribution. McFarlane et al. (1978) and the Georgia Game and Fish Division (1982) examined fish populations near the SRP for species occurrence and relative abundance as part of an assessment of impingement rates at the SRP pumphouses. In 1982 a more comprehensive quarterly sampling program was initiated to determine species occurrence, relative abundance, and distribution of adult fishes in the Savannah River, intake canals, and the lower reaches of thermal and nonthermal creeks draining the SRP, and impingement rates on the intake screens of SRP pump stations (ECS 1983). This study, witn additions and refinements, was conducted quarterly from October 1982 through August 1985. In addition to the quarterly sampling program, a weekly program was initiated in 1984 to obtain more data on fish congregation and distribution in and around the mouths of the thermal creeks during the winter.

The objectives of the adult fish sampling program were:

1. To determine the composition of the adult and juvenile fish communities in the Savannah River near the SRP and in the creeks and swamps on the SRP.

2. To determine how these fishes are distributed in relation to habitat, season, and thermal discharges.

3. To determine the maximum temperatures at which important species and fish communities occur.

4. To determine the extent to which fishes congregate in thermal areas during the winter and whether overwintering in heated areas affects physical condition or disease incidence.

5. To determine the magnitude of yearly variations in the abundance and community composition of fisnes in creeks on the SRP and in the river near the SRP.

6. To determine the number and kinds of fishes impinged at the SRP pumphouses on the Savannah River and factors affecting impingement.

The results of the November 1984 - August 1985 quarterly, 1985/1986 overwintering, and impingement monitoring programs are presented in this report.

2.0 STUDY AREA

The Savannah River channel is approximately 80 - 110 m wide in the area of the SRP and is bordered on the South Carolina side by an extensive floodplain swamp. A natural levee separates the river and the swamp. On the Georgia side, higher ground is often separated from the river channel by a narrow, forested floodplain. Current velocity, discharge, and water depth vary considerably over time due to rainfall patterns and discharge rates at upstream locks and dams. River discharge in the study area varies from over 20,000 cfs in the late winter and spring to approximately 5000 cfs during low water periods in late summer (Bennett et al. 1983, 1984, and 1985). The Savannah River is usually turbid and well oxygenated. The river bottom is typically sand and silt.

Savannah River water for the SRP cooling requirements is withdrawn at three pumphouses located at RM 157.1 (1G pumphouse), 155.3 (3G pumphouse), and 155.2 (5G pumphouse). The 1G and 3G pumphouses have intake canals that are approximately 30 - 79 m wide, 410 - 550 m long, and 2 or more meters deep, depending on river level. Both have a mud substrate and a shoreline largely without trees except for willows (_Salix_ sp.) near the canal mouths. Extensive beds of submerged macrophytes develop along portions of the canal shorelines during the summer. The third intake structure (5G) is located on the river, without a significant intake canal.

Five Savannah River tributaries arise on or pass through the SRP before flowing into the Savannah River: Upper Three Runs Creek (RM 157.2), Beaver Dam Creek (152.1), Four Mile Creek (150.6), Steel Creek (RM 141.6), and Lower Three Runs Creek (RM 129.0; Figure 2-1). A sixth creek, Pen Branch, does not flow to the Savannah River, but coalesces with Steel Creek in the floodplain swamp. Pen Branch waters enter the Savannah River through the Steel Creek channel. Upper Three Runs Creek is the largest and northernmost Savannah River tributary on the SRP (Figure 2-1). It has never received thermal effluents. In its upper reaches, it consists of a shaded channel bordered by a narrow forested floodplain. Near the mouth it is approximately 16 m wide during low water and is bordered by cypress (*Taxodium distichum*) and tupelo (*Nyssa aquatica*) along the banks. Instream cover is provided by submerged logs, leaf accumulations, and overhanging branches in this and the other SRP creeks. There were three sample stations in Upper Three Runs Creek, two in the mid-reaches and one at the mouth.

Beaver Dam Creek begins in D-Area and flows south, parallel to Four Mile Creek, to the Savannah River (Figure 2-1). Since Beaver Dam Creek and Four Mile Creek are in close proximity, there is some mixing of their discharges in the Savannah River floodplain swamp. Beaver Dam Creek receives thermal effluent from the coal-fired power station in D-Area and formerly received non-thermal effluent water from the heavy water production facility.

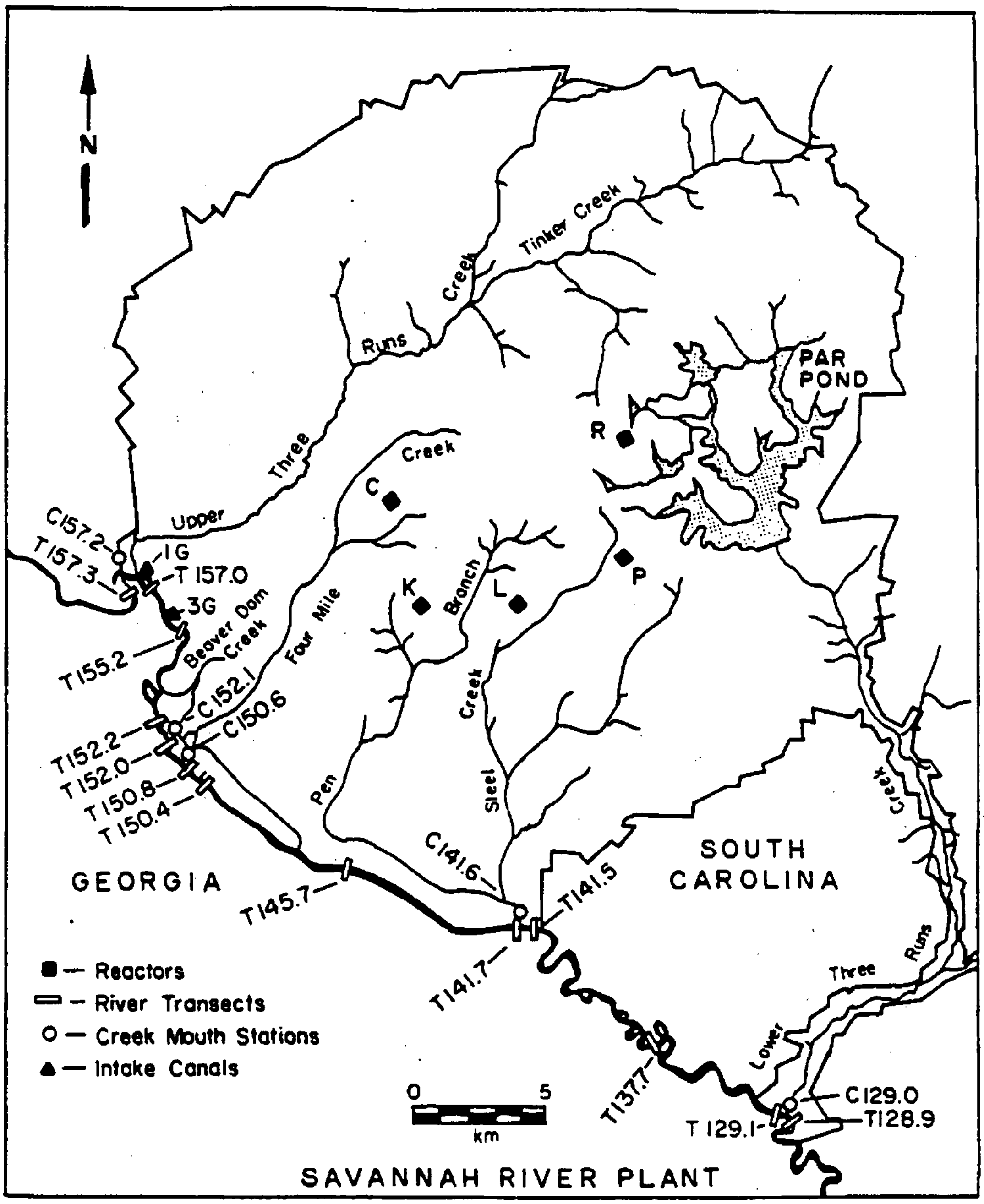

Figure 2-1. A map of the Savannah River Plant and adjoining Savannah River indicating the major streams which drain the site, and the sampling locations on the river, in the creek mouths, and intake canals. November 1984 - August 1985.

Three of the sample stations in Beaver Dam Creek were located in the area of the Savannah River floodplain swamp that Beaver Dam Creek traverses on its way to the river. The first was in a narrow vegetation-lined channel flowing through the upper floodplain. The second station was farther downstream in a broad slough with large amounts of submerged and emergent vegetation. The last swamp station was approximately 0.6 km from the river in a swampy channel lined by willows and a few cypress. The remaining station was in the creek mouth.

Four Mile Creek is approximately 24 km long and flows south from near C-Reactor to the Savannah River. When C-Reactor is operating, heated Savannah River water ($\geq 70^{\circ}C$) is discharged into the upper reaches of Four Mile Creek, making most of the stream thermal. Lateral to the main channel are cooler shallows and backwaters supporting thick mats of blue-green algae. In its lower reaches, Four Mile Creek broadens and its channel becomes braided.

Four Mile Creek has deposited an extensive delta at the point where it enters the Savannah River floodplain swamp. The delta has dead cypress and tupelo trees and extensive blue-green algal mats. Downstream of the delta is an area of swamp with elevated water temperatures and partial tree kill. Temperatures and water levels vary widely at this location, depending upon reactor operation and Savannah River level. When the Savannah River floods, water from Four Mile Creek flows along the northern boundary of the floodplain swamp rather than taking a more direct route to the Savannah River. Under flood conditions, fishes and other organisms may enter areas that are usually inacessible because of high temperatures (Paller and Osteen 1985).

There were seven sampling stations on Four Mile Creek: one in the mid-reaches (at Road A), one approximately 8 km below C-Reactor one at the delta head (Road A-13), three in the thermal swamp below the delta, and one in the creek mouth.

Pen Branch is located between Four Mile Creek and Steel Creek and discharges into the Savannah River floodplain swamp rather than flowing directly to the Savannah River. The upper reaches of Pen Branch consist of a fairly well defined channel with side channels and backwaters lateral to the main channel. Temperatures in the main channel sometimes exceed 40°C due to discharge from K-Reactor. Two sample stations were located in the somewhat cooler side channels lateral to the main channel and a third was located along an elevated boardwalk extending across the thermal delta formed where Pen Branch enters the floodplain swamp.

Steel Creek originates near P-Reactor and flows south for 16 km to the Savannah River floodplain swamp (Figure 2-1). The upper portion of this 16 km reach is channelized, with a sand and pebble substrate. As Steel Creek descends from the Aiken plateau to the riverine floodplain swamp, the channel broadens and eventually splits into multiple channels interspersed with marshy areas.

Steel Creek began receiving thermal effluent from P-Reactor and L-Reactor in 1954. In 1963 thermal effluent from P-Reactor was diverted into Par Pond, and in 1968 L-Reactor was put on stand-by, ending the regular release of thermal effluent into Steel Creek. During this study, Steel Creek had not recovered from the impact of thermal effluents to pre-effluent conditions (Kondratieff and Kondratieff 1984) and was considered a post-thermal stream.

Steel Creek has an extensive delta where it enters the Savannah River floodplain as a result of sediment deposition that occurred primarily during the time Steel Creek was receiving thermal discharge and increased flow. Sediment deposition now continues at a reduced rate (Smith et al. 1981). Tree kill was extensive in the delta and adjoining swamp, which resulted in an open canopy and large areas of submerged and emergent herbaceous macrophytes. The delta/swamp area is drained by numerous braided channels that eventually coalesce and continue for approximately 1.6 km before Steel Creek enters the Savannah River. The only sample station in Steel Creek was located in the creek mouth.

Lower Three Runs Creek is the southernmost creek draining the SRP (Figure 2-1). In 1958 its headwaters were impounded to form Par Pond, a 1012 ha reservoir currently used for recirculating cooling water for P-Reactor. Lower Three Runs Creek receives overflow from Par Pond, but does not receive effluent from other SRP sources.

There were three sampling stations on Lower Three Runs Creek: at Road A-18, Road A, and in the creek mouth. These stations were in relatively broad, shaded channels.

3.0 METHODS AND MATERIALS

3.1 QUARTERLY SAMPLING

3.1.1 Sampling Stations and Schedule

The quarterly adult and juvenile fish study began in late 1982 with a small sampling program that included six river sample stations, two intake canal sample stations, and three creek mouth sample stations. The program was expanded in May 1983 to include 12 river sample stations, two intake canal sample stations, and five creek mouth sample stations. The 1985 program was expanded to 13 Savannah River stations, two intake canals, the creek mouths (Figure 2-1; Table 3-1), and 15 additional sample stations in the channels and swamps of all the major creeks that drain the SRP except Steel Creek (Figure 3-1; Table 3-2).

The quarterly samples discussed in this report were taken during November 1984 (27 November - 29 November), February 1985 (13 February - 15 February), May 1985 (9 May - 10 May), and August 1985 (7 August - 8 August). Each sample station was sampled once during each quarter. This represented a change in the 1983 and 1984 methodology when four electrofishing samples were made at each station within a period of one to two weeks. Results from 1983 and 1984 indicated that the first sample provided the best estimate of catch per unit effort (CPUE), while later samples had reduced CPUEs, presumably due to avoidance by fishes of the electrofishing boat and our disturbance of the sample area (Paller and Osteen 1985; Paller et al. 1984). Because only one sample was taken at each transect during each quarter of the 1985 program, it

Table 3-1. Sampling stations for the Savannah River adult and juvenile quarterly fisheries study. November 1984 - August 1985.

River Mile	Sampling Station Location
River Transect[a]	
128.9	below Lower Three Runs Creek
129.1	above Lower Three Runs Creek
137.7	below Steel Creek
141.5	below Steel Creek
141.7	above Steel Creek
145.7	below Four Mile Creek
150.4	below Four Mile Creek
150.8	above Four Mile Creek
152.0	below Beaver Dam Creek
152.2	above Beaver Dam Creek
155.2	below 5G pumphouse
157.0	below 1G canal
157.3	above 1G canal and Upper Three Runs Creek
Intake Canal[a]	
157.1	1G canal
155.3	3G canal
Creek Mouth[b]	
129.0	Lower Three Runs Creek
141.6	Steel Creek
150.6	Four Mile Creek
152.1	Beaver Dam Creek
157.2	Upper Three Runs Creek

[a] 300 m along each bank.
[b] 150 m along each bank.

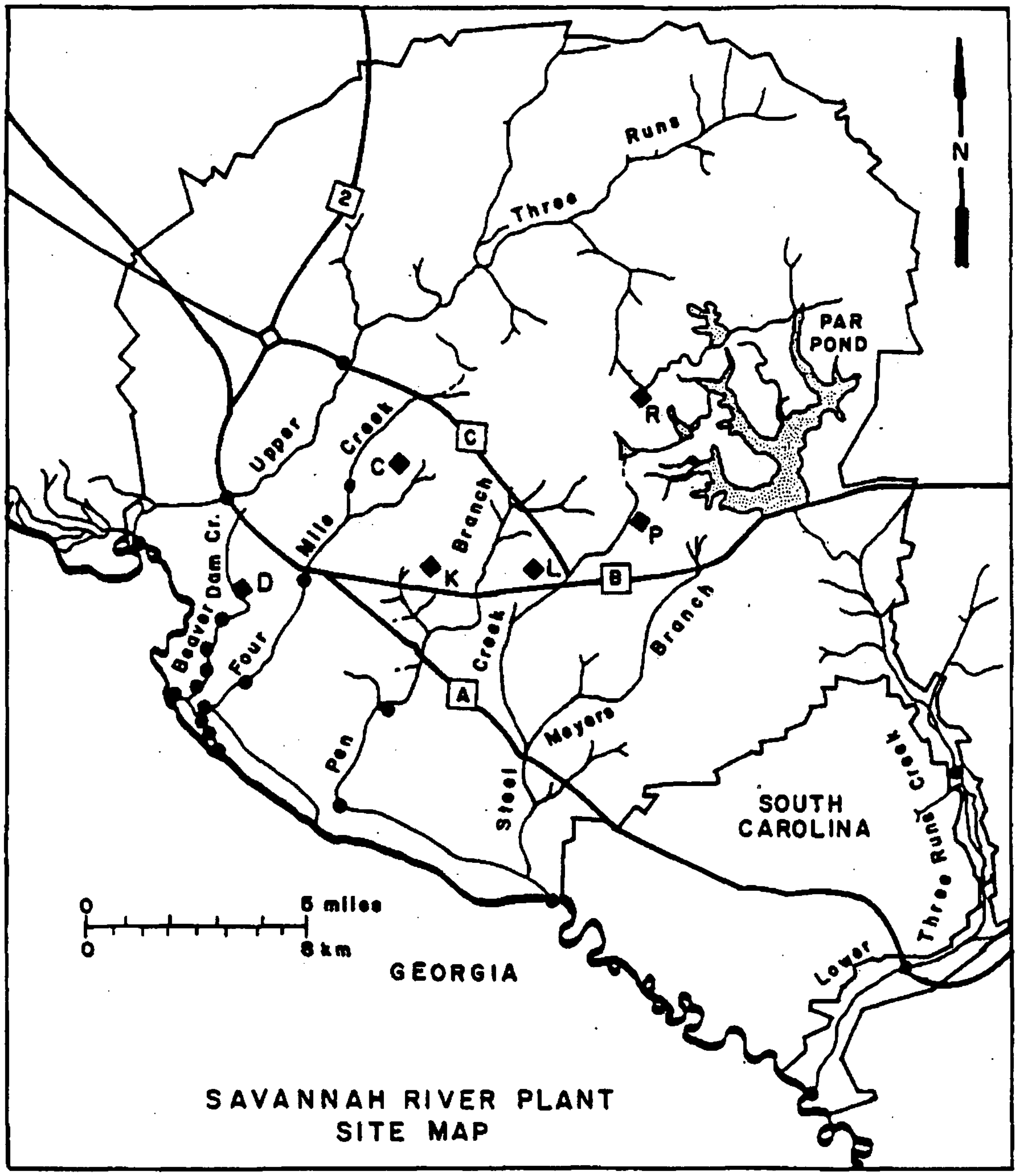

Figure 3-1. A map of the Savannah River Plant indicating the sampling locations on the streams which drain the SRP. These stations were sampled only during the 1984/1985 sampling program. November 1984 - August 1985.

Table 3-2. Adult and juvenile fish quarterly electrofisning stations in the channels and swamps of Upper Three Runs Creek, Beaver Dam Creek, Four Mile Creek, Pen Branch, and Lower Three Runs Creek that were added to the sampling program for the 1984/1985 study period. November 1984 - August 1985.

Station Designation	Location	Method
1	Upper Three Runs Creek - Road C	3 - 100 m sections, boat
2	Upper Three Runs Creek - Road A	3 - 100 m sections, boat
5	Beaver Dam Creek - Road A-12.2	3 - 100 m sections, boat
6	Beaver Dam Creek - just above slough	3 - 100 m sections, boat
7	Beaver Dam Creek - slough	3 - 100 m sections, boat
8	Beaver Dam Creek - swamp	3 - 100 m sections, boat
13	Four Mile Creek - Road A	refuge area - backpack
14	Four Mile Creek - Road A-13	refuge area - backpack
15	Four Mile Creek - swamp 1	3 - 100 m sections, boat
16	Four Mile Creek - swamp 2	3 - 100 m sections, boat
17	Four Mile Creek - swamp 3	3 - 100 m sections, boat
21	Pen Branch - Road A-13.2	refuge area - backpack
22	Pen Branch delta - boardwalk	backpack from boardwalk
53	Lower Three Runs Creek - Road A-18	3 - 100 m sections, boat
44	Lower Three Runs Creek - Road A	3 - 100 m sections, boat

was not possible to calculate population estimates using mark - recapture data as was done during 1982, 1983 and 1984. Since the estimates from 1982 - 1984 appeared to provide sufficient population data, it was felt that this aspect of the program could be deleted without serious loss of information, and sampling effort instead shifted to the additional creek channel and swamp locations as described above.

3.1.2 Electrofishing Procedures

Electrofishing samples were taken at all sample stations. All river and intake canal sample stations consisted of a right and left bank, with 300 m marked off along each bank and subdivided into contiguous 100 m sections. All creek mouth sample stations consisted of 300 m divided between right and left banks. For analysis, each creek mouth sample station was treated as three 100 m sections.

Electrofishing at the river, intake canal, and creek mouth sample stations was conducted from an aluminum boat equipped with a 4500-2 watt, 230-VAC, gasoline-powered generator. The current to the electrodes was controlled by a Smith Root Model VI electrofisher. A four-electrode array was mounted on a boom and suspended in the water approximately 3 m beyond the bow of the boat. The metal hull of the boat served as the negative electrode. An electrical field that stunned the fishes was established between the boom and the boat. At all stations, a 60-Hz pulsed-DC voltage of 1050-V peak with a 5-ms pulse width was used.

Current to the electrodes was controlled by two foot switches, one used by a netter standing on the bow of the boat and the other by the boat operator. These foot switches served both as a mechanisms to provide intermittent electrical current and as safety measures.

To electrofish, the boat was moved slowly upstream and the electrical field was directed near the shore and around any logs or bushes in the near-shore area. During flood periods, high water eliminated a well-defined shoreline in many areas, so electrofishing samples were collected near the brush line. Fishes stunned by the electrical field were scooped from the water with wooden-handled nets. Fish from each 100 m transect were placed in separate holding tanks. When a large school of minnows or other small fish was shocked, only a representative sample was collected.

Most upper creek and swamp stations (Table 3-2) were sampled by electrofishing three 100 m sections with a boat-mounted shocker as previously described; however, there were exceptions. The sample stations in Four Mile Creek near Road A (Station 13) and Road A-13 (Station 14) and in Pen Branch near Road A-13.2 (Station 21) consisted only of shallow refuge areas lateral to the main channel. The main channel was often too hot (> 40°C) to support fish or to sample safely. These refuge areas were qualitatively sampled with a backpack electrofisher. The Pen Branch delta (Station 22) was too shallow and obstructed to access by boat and was sampled qualitatively by backpack electroshocking from a boardwalk. Electrofishing catches made with the backpack electroshocker were not expressed as fish/100 m because of difficulties in estimating distances at most of the backpack stations, which usually consisted of a series of small, isolated pools.

3.1.3 Hoop Netting Procedures

Hoop netting samples were collected at all river transects, intake canals, and creek mouths (Table 3-1). During each quarter, one net was set near each bank at the river and intake canal stations and one net was set in each creek (25 - 125 m upstream from the creek mouth), with the mouths of the nets facing downstream. All nets were checked at the end of 72 h, resulting in a total of three net days of effort per bank at each river and canal sample station and three net days of effort in each creek mouth. Each hoop net was approximately 1 m in diameter and 4 m long, stretched over seven fiberglass hoops. The net mesh was 37 mm in the body of the net and 25 mm in the cod end.

3.1.4 Parameters Measured

All fish were identified to species and recorded along with location, time, date, and method of capture. All fishes were weighed (nearest g) and measured (total length to nearest mm) immediately after the sample collection was completed. Fish identifications were based on taxonomic keys by Smith (1907), Blair et al. (1957), Smith-Vaniz (1968), Carr and Goin (1969), Dahlberg (1974), Menhinick (1975) and Bennett and McFarlane (1983). Nomenclature is consistent with Robins et al.

(1980). Common names are used in this report, and corresponding scientific names are presented in Appendix 1.

Other parameters measured in conjunction with electrofishing were shocking time in each section, temperature, dissolved oxygen, pH, conductivity, alkalinity, and current velocity. Chemical and physical parameters were measured near the surface along both banks at each river and canal sample station. The only exception was current velocity, which was measured in mid-channel at each sampling station. Chemical and physical parameters were measured in mid-channel near the surface in the creeks.

Water current velocity was measured with a General Oceanics Model 2030 current meter or a General Oceanics remote reading flow meter. When the Model 2030 was used, the meter was suspended about 0.5 m from the boat at a depth of 0.5 m for 100 sec. Velocities were calculated utilizing calibration constants supplied by General Oceanics. When the remote reading model was used, the sensor was lowered to approximately 0.5 m below the surface and the velocity read directly from the meter.

Alkalinity determinations were made in the laboratory on subsurface samples packed in ice in the field and kept on ice until processed. Sample volumes of 200 ml were titrated with 0.02N H_2SO_4 to pH 4.3 - 4.7; the acid volume and pH were recorded; additional acid was added to lower the pH 0.3 units and the final acid volume recorded (APHA 1980; Method 403 for low alkalinity sample). An Orion Model 407A Specific Ion Meter and a Beckman combination electrode were used for the titrations. The meter system was standardized in buffers of pH 7 and pH 4 before use.

Dissolved oxygen was measured with a Hydrolab Model VI or a Horiba Model U7. Measurements were taken by lowering the sonde to the proper depth, starting the circulating motor, and reading the meter after a minimum delay of 5 min. Measurements were taken approximately 0.5 m below the surface. All instruments were calibrated at the beginning of each day by submerging them in air-saturated water.

Both the Hydrolab and Horiba water quality monitors had pH functions that permitted direct measurement of water pH in the field. The pH systems of both monitors were calibrated in the laboratory prior to each day's use, following the procedures given by the instrument manufacturer. pH was measured approximately 0.5 m below the surface. If the in situ pH measuring system malfunctioned, the pH of the alkalinity samples was measured and recorded in the laboratory.

Specific conductance was measured with a Hydrolab Model VI or Horiba Model U7. Performance of the instrument was checked daily with KCl solutions. Water temperature was measured with the same instrument.

3.2 OVERWINTERING STUDY

3.2.1 Sampling Stations and Schedule

The overwintering program included two thermal creeks (Four Mile Creek and Beaver Dam Creek), two nonthermal creeks (Steel Creek and Lower Three Runs Creek), and the eight river transects (RM 128.9, RM 129.1, RM 141.5, RM 141.7, RM 150.4, RM 150.8, RM 152.0, and RM 152.2) that bracketed the four creek mouths (Figure 3-1). There were three 100 m shoreline transects in Four Mile Creek and three in Beaver Dam Creek. In each thermal creek, one 100 m shoreline transect was located in the creek mouth, one was located farther upstream in the mid-reaches of the floodplain swamp, and one was located in the upper reaches of the floodplain swamp. The presence of three sample stations at varying distances from the creek mouth permitted an evaluation of fish distribution in relation to temperature in the thermal creeks. In the nonthermal creeks, all three 100 m transects were located in the creek mouths. The use of three fixed transects in the thermal creeks during 1985 represented a departure from the methodology employed during 1983 - 1984, when moving sample stations were used in the thermal creeks to track fish movement in relation to temperature. The moving sample stations were abandoned because of difficulties in separating the effects of temperature and habitat on catch rate. All stations were sampled biweekly in November and April and weekly in December, January, February, and March. When samping dates overlapped, data collected for the quarterly sampling program was used in the overwintering program.

3.2.2 Electrofishing Procedures

Electrofishing sample stations at the river transects consisted of three contiguous 100 m sections along each bank (total of six sections). Electrofishing sample stations in the mouths of the nonthermal creeks consisted of three contiguous 100 m sections. Electrofishing sample stations in the thermal creeks consisted of one 100 m section at each of the three stations. Electrofishing equipment and procedures were as described for the quarterly program.

3.2.3 Hoop Netting Procedures

Two hoop nets were set at each river sample station (one along each bank). One hoop net was set in the mouth of each creek. Each hoop net was set for three days, making a total of six net days of effort at each river sample station and three net days of effort in each creek mouth for each sample. Hoop net dimensions were as described for the quarterly program.

3.2.4 Parameters Measured

Field data was collected and recorded as described for the quarterly sampling program. The only difference was that chemical and physical parameters were measured near the surface and near the bottom instead of just near the surface.

3.3 IMPINGEMENT STUDY

Collections of fish impinged in a 24 h period on the traveling screens at 1G, 3G, and 5G pumphouses were made on 97 days between September 1984 and September 1985. Sampling days were selected with a random number generator and days numbered 1 to 366. Each collection was made by clamping a 5 mm mesh tubular net approximately 7.5 m long and 1.0 m in diameter to the 0.3 m diameter pipe that carries the debris away from the traveling screens at the pumphouses. The distal end of the net was tied closed, and the debris washed from the traveling screens over a 24 h period was collected. Fish were removed from the debris and returned to the laboratory for analysis.

In the laboratory each fish was identified, weighed (nearest g), and its total length (nearest mm) measured when possible. Some specimens were decayed, suggesting that they were dead before they were impinged. However, since the time of death was unknown, they were included in the counts but not in the total weights of fish impinged.

Pumping rates, number of pumps, and volumes of water pumped each sampling day were obtained from the Savannah River Plant Power Department. Volume passing through each intake was used to calculate impingement rates. The impingement rate is the number of fish collected over a 24 h period divided by the total volume of water pumped during the same time period. These values are expressed as the number of fish impinged per million cubic meters and allow comparisons of impingement rates between pumphouses.

3.4 DATA ANALYSIS

Electrofishing catches made with the boat-mounted electroshocker were expressed as fish per 100 m of shoreline. Hoop net catches were expressed as number of fish per net day. Differences in catch between habitats and other parameters were evaluated by analysis of variance and Scheffe's tests. Scheffe's tests were used after the analysis of variance to determine which group means were significantly different. The data were log transformed to reduce heteroscedacity (Sokal and Ronlf 1981). The critical level of significance to evaluate all statistical tests was set at 0.05.

Condition factor (K; Bennett 1972) was calculated for major species and compared between fish from thermal and nonthermal habitats. Condition factor was calculated as:

$$K = \frac{100 \times \text{weight (g)}}{\text{total length (cm)}}.$$

Species richness and Shannon-Weaver diversity were calculated for the electrofishing samples taken from Four Mile Creek. Species richness was calculated as the number of fish species per sample. Shannon-Weaver diversity (H'; Odum 1971) was calculated as:

$$H' = \Sigma \ (n/N) \log (n/N)$$

where n = number of individuals per species and N = total number of individuals.

All calculations were performed on an IBM 3081 computer using SAS (1982) software. Computer programs used in all data analyses and computations are included in Appendix 2. Programs applying to specific tables are indicated by footnote and those applying to figures by notation in the legend.

4.0 RESULTS

4.1 FISHES CAPTURED

Ten thousand thirty-two adult and juvenile fishes were collected during the November 1984 - August 1985 studies. Of this total, 7,345 were collected during the quarterly program and 2,687 were collected during the overwintering program. Three species (needlefish, river goby, and sailfin shiner) collected during the 1985 sample year had not been captured as adults during earlier sampling efforts. The addition of these three species brings the total number of species collected since the initiation of sampling in August 1982 to 74 (Appendix 1).

In the following analysis, results from the quarterly and overwintering programs will be discussed separately, since the objectives of the two programs were different: the quarterly program to assess annual patterns of distribution and abundance throughout the study area, and the overwintering program to assess fish distribution near the thermal discharges during the winter.

4.2 QUARTERLY STUDY

The quarterly study was designed and implemented to determine the species composition, relative abundance, and distribution of adult and juvenile fishes in the vicinity of the Savannah River Plant (SRP). Because fish collecting techniques often are selective for certain species, several methods were used. The resulting data were analyzed separately for each method.

4.2.1 Relative Abundance

On the basis of total electrofishing catch from all stations, the most abundant fishes by number (excluding minnows and other small fishes) were the redbreast sunfish (22.2%), spotted sucker (15.0%), largemouth bass (8.8%), bluegill (8.8%), and the American eel (5.9%; Table 4-1). All of the other species collected by electrofishing were present in numbers under 5% of the total. Relative abundance by weight gave greater prominence to the larger fish. On the basis of weight, spotted suckers (33.8%) and bowfin (32.2%) were dominant, followed by largemouth bass (5.6%) and redbreast sunfish (3.7%).

Since the relative abundance estimates for 1985 were influenced by large numbers of fish captured at the "new" electrofishing sample stations in the swamps and upper reaches of the creeks (see Section 3.1.1), the 1985 relative abundance estimates cannot be compared directly to the relative abundance estimates for previous years. In order to make comparisons between 1985 and previous years, relative abundance was calculated separately for the "old" electrofishing stations (those in the river, intake canals, and creek mouths). The dominant species based on number at the old electrofishing stations were redbreast sunfish (23.9%), spotted sunfish (12.9%), spotted sucker (12.6%), bluegill (9.5%), largemouth bass (8.7%), and bowfin (5.3%; Table 4-1). This was fairly similar to the 1984 results when redbreast sunfish (16.7%), bluegill (14.1%), largemouth bass (8.9%), spotted sucker (8.5%), spotted sunfish (7.9%), chain pickerel (5.0%), and bowfin (5.0%) were dominant (Paller and Osteen 1985), indicating the basic sta-

Table 4-1. Species, excluding minnows and small fishes, caught by electrofishing and hoop netting the Savannah River, intake canals, and tributary creeks on the SRP. Samples taken quarterly in November, February, May, and August. November 1984 - August 1985.

Species	Old Electro-fishing Stations[a]		New Electro-fishing Stations[b]		Total Electrofishing		Hoop Netting[c]	
	Percent Number	Percent Weight	Percent Number	Percent Weight	Percent Number	Percent Weight	Percent Number	Percent Weight
longnose gar	0.7	0.9	1.5	7.6	0.9	2.5	3.0	7.0
bowfin	5.3	36.4	3.7	18.7	4.9	32.2	2.5	16.6
American eel	3.3	1.8	13.1	6.2	5.9	2.9	0.0	0.0
blueback herring	0.3	<0.1	0.0	0.0	0.1	<0.1	0.0	0.0
American shad	0.8	0.2	0.7	1.5	0.8	0.5	0.5	0.4
gizzard shad	1.8	1.5	1.0	1.3	1.6	1.5	0.7	0.7
unid. clupeid	0.2		0.0		0.1		0.0	0.0
redfin pickerel	0.8	0.1	0.8	0.1	0.8	0.1	0.0	0.0
chain pickerel	1.3	1.0	1.5	1.6	1.4	1.1	0.0	0.0
unid. pickerel	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.2
golden shiner	0.2	<0.1	0.5	<0.1	0.3	<0.1	0.0	0.0
quillback carpsucker	0.1	2.8	0.0	0.0	0.1	2.1	0.0	0.0
unid. carpsucker	0.1	<0.1	0.0	0.0	0.1	<0.1	0.0	0.0
creek chubsucker	0.1	0.1	0.3	0.4	0.1	0.2	0.2	0.1
lake chubsucker	0.1	<0.1	0.3	0.2	0.1	0.1	0.0	0.0
unid. chubsucker	0.1	<0.1	0.8	<0.1	0.3	0.2	0.0	0.0
spotted sucker	12.6	34.3	21.5	32.0	15.0	33.8	2.2	4.6
silver redhorse	0.5	2.4	0.2	1.0	0.4	2.1	0.7	1.7

[a]Old stations were sample stations in the Savannah River, intake canals, and creek mouths that had been sampled during previous years of the study (1982 - 1984).
[b]New stations were sample stations in the swamps and upper reaches of Upper Three Runs Creek, Beaver Dam Creek, Four Mile Creek, Pen Branch, and Lower Three Runs Creek that were added to the program in 1985.
[c]Stations in the Savannah River, intake canals, and the mouths of SRP tributary creeks.

Table 4-1. (continued). Species, excluding minnows and small fishes, caught by electrofishing a hoop netting in the Savannah River, intake canals, and tributary creeks on the SR Samples taken quarterly in November, February, May, and August. November 1984 -Augu 1985.

Species	Old Electro-fishing Stations[a]		New Electro-fishing Stations[b]		Total Electrofishing		Hoop Netting[c]	
	Percent Number	Percent Weight	Percent Number	Percent Weight	Percent Number	Percent Weight	Percent Number	Percent Weight
snail bullhead	0.2	<0.1	0.0	0.0	0.1	<0.1	0.0	0.0
white catfish	0.1	0.1	0.0	0.0	<0.1	0.1	7.9	22.7
yellow bullhead	0.0	0.0	0.2	0.2	<0.1	0.1	0.0	0.0
flat bullhead	0.5	0.1	0.2	0.1	0.4	0.1	38.0	15.9
channel catfish	0.8	2.3	1.7	7.5	1.0	3.5	11.9	18.2
pirate perch	1.7	<0.1	2.2	<0.1	1.8	<0.1	0.0	0.0
needlefish	0.1	<0.1	0.0	0.0	<0.1	<0.1	0.0	0.0
striped bass	0.0	0.0	0.2	0.0	<0.1	0.0	0.2	0.6
flier	0.1	<0.1	0.0	0.0	<0.1	<0.1	3.2	0.7
bluespotted sunfish	0.2	<0.1	0.3	<0.1	0.3	<0.1	0.0	0.0
redbreast sunfish	23.9	3.3	17.2	5.0	22.2	3.7	5.5	1.9
pumpkinseed	0.4	<0.1	0.0	0.0	0.3	<0.1	0.2	0.1
warmouth	1.4	0.2	3.4	1.4	1.9	0.5	0.5	0.2
bluegill	9.5	0.8	3.0	0.7	7.8	0.8	9.4	2.7
dollar sunfish	2.5	0.1	6.4	0.2	3.5	0.1	0.0	0.0
redear sunfish	2.6	1.0	1.3	0.9	2.3	1.0	3.0	1.3
spotted sunfish	12.9	1.5	5.7	0.6	11.0	1.3	1.5	0.2
Lepomis spp.	0.0	0.0	0.2	<0.1	<1.0	<0.1	0.5	0.2
redeye bass	0.1	<0.1	0.0	0.0	0.1	<0.1	0.0	0.0

[a] Old stations were sample stations in the Savannah River, intake canals, and creek mouths that had been sampled during previous years of the study (1982 - 1984).

[b] New stations were sample stations in the swamps and upper reaches of Upper Three Runs Creek, Beaver Dam Creek, Four Mile Creek, Pen Branch, and Lower Three Runs Creek that were added to the program in 1985.

[c] Stations in the Savannah River, intake canals, and the mouths of SRP tributary creeks.

Table 4-1. (continued). Species, excluding minnows and small fishes, caught by electrofishing and hoop netting in the Savannah River, intake canals, and tributary creeks on the SRP. Samples taken quarterly in November, February, May, and August. November 1984 -August 1985.

Species	Old Electro-fishing Stations[a]		New Electro-fishing Stations[b]		Total Electrofishing		Hoop Netting[c]	
	Percent Number	Percent Weight	Percent Number	Percent Weight	Percent Number	Percent Weight	Percent Number	Percent Weight
largemouth bass	8.7	3.9	8.9	11.1	8.8	5.6	0.2	0.3
black crappie	0.8	0.4	0.0	0.0	0.6	0.3	6.5	2.7
yellow perch	2.8	0.8	2.0	0.4	2.6	0.7	0.7	0.5
striped mullet	2.5	3.8	0.3	0.6	1.9	3.1	0.2	0.5
hogchoker	0.1	<0.1	0.0	0.0	0.1	<0.1	0.0	0.0
unknown	0.0	0.0	0.7	<0.7	0.2	0.2	0.0	0.0
Total Weight (kg)		402.7		126.3		529.0		164.0
Total Number	1666		594		2260		403	
Total Percent	100.0	99.8	99.8	100.0	99.9	99.9	99.7	100.0
Number of Species[d]	35		27		36		23	

NOTE: EFHNN01 and1 EFHNWT1 were used to compute the data presented under total electrofishing and hoop netting columns.

[a]Old stations were sample stations in the Savannah River, intake canals, and creek mouths that had been sampled during previous years of the study (1982 - 1984).

[b]New stations were sample stations in the swamps and upper reaches of Upper Three Runs Creek, Beaver Dam Creek, Four Mile Creek, Pen Branch, and Lower Three Runs Creek that were added to the program in 1985.

[c]Stations in the Savannah River, intake canals, and the mouths of SRP tributary creeks.

[d]Unidentified pickerel are not included in taxa counts if identified pickerel are present; unidentified carpsuckers are not included if identified carpsuckers are present; unidentified chubsuckers are not included if identified chubsuckers are present; unidentified sunfish are not included if identified sunfish are present; unknown fish are not included.

bility of the fish community in the study area. A total of 1,666 fish was captured from the "old" sample stations during 1985, considerably fewer than during previous years (6,520 in October 1982 to August 1983 and 4,844 in November 1983 to August 1984; Paller et al. 1984; Paller and Osteen 1985). The reduced catch during 1985 was due to the fact that each sample station was sampled only once per quarter rather than four times as in previous years (see Section 3.1.1).

The most abundant fishes taken by hoop netting were the flat bullhead (38.0%), channel catfish (11.9%), bluegill (9.4%), white catfish (7.9%), black crappie (6.5%), and redbreast sunfish (5.5%; Table 4-1). None of the other fishes captured by hoop netting were present in numbers exceeding 3.2% of the total catch. This pattern was generally similar to that in 1984, when the flat bullhead (29.2%), channel catfish (21.0%), redbreast sunfish (9.2%), white catfish (9.0%), black crappie (6.8%), longnose gar (5.6%), and bluegill (5.2%) were dominant (Paller and Osteen 1985). Dominant species by weight in the hoop netting collections made during 1985 were white catfish (22.7%), channel catfish (18.2%), bowfin (16.6%), flat bullhead (15.9%), longnose gar (7.0%), and spotted suckers (4.6%). Hoop netting relative abundance values are directly comparable between 1984 and 1985, since the same sample stations were studied during both years (hoop netting collections were not made at the new sample stations in the swamps and upper reaches of the creeks).

The relative abundance of the minnows and other small fishes collected by electrofishing could only be determined in a general way because many that were electroshocked were not captured. Approximately 2,641 shiners (genus Notropis) were collected, making them the most abundant type of small fish (94%) in the study area (Table 4-2). We collected the following species of shiners: bannerfin shiner, coastal shiner, whitefin shiner, spottail shiner, yellowfin shiner, ironcolor shiner, dusky shiner, sailfin shiner, and pugnose minnow. A total of 165 other small fishes were collected and included chubs, minnows, darters, madtoms, brook silverside, banded pygmy sunfish, juvenile American shad, and juvenile blueback herring.

The data suggest that the fish community in the study area was diverse, with representatives from all trophic levels (Scott and Crossman 1973). The dominant predators were largemouth bass, bowfin, channel catfish, pickerel, longnose gar, and white catfish. There was a variety of smaller predators, including the sunfishes (particularly the redbreast sunfish and bluegill), flat bullheads, American eel, and a few other species. All these smaller predators feed largely on macroinvertebrates and represent an intermediate trophic level between these organisms and the large carnivores. Many of these fishes are capable of exploiting food groups (e.g., plankton, detritus, and burrowing macroinvertebrates) that are largely or partially inaccessible to other fishes. Lastly, there were the very small forage fishes such as minnows, shiners, and brook silverside. These feed on zooplankton and small macro-

Table 4-2. Minnows and other small fishes collected by electrofishing in the Savannah River, SRP intake canals, and tributary creeks. November 1984 - August 1985.

	Number	Percent
blueback herring	5	0.2
American shad	9	0.3
Eastern silvery minnow	2	0.1
rosyface chub	20	0.7
bluehead chub	34	1.2
golden shiner	6	0.2
ironcolor shiner	135	4.8
dusky shiner	488	17.4
pugnose minnow	25	0.9
spottail shiner	292	10.4
sailfin shiner	74	2.6
bannerfin shiner	131	4.7
yellowfin shiner	50	1.8
whitefin shiner	101	3.6
coastal shiner	1112	39.6
Notropis spp.	233	8.3
tadpole madtom	4	0.1
margined madtom	1	<0.1
unidentified madtom	1	<0.1
lined topminnow	5	0.2
mosquitofish	4	0.1
brook silverside	15	0.5
banded pygmy sunfish	3	0.1
Savannah darter	16	0.6
tesselated darter	24	0.9
blackbanded darter	13	0.5
Etheostoma spp.	1	<0.1
river goby	2	0.1
Total fish	2806	99.9

invertebrates and provide forage for both the small carnivores and the younger large carnivores.

4.2.2 Relative Abundance By Habitat

To evaluate habitat preference, the study area was divided into intake canals, thermal river, nonthermal river, thermal creek, and nonthermal creek. The sample stations on thermal creeks included those on Beaver Dam Creek (mean of 23.5°C; Table 4-3) and Four Mile Creek (mean of 31.9°C; Table 4-3). The nonthermal creek sample stations were located on Upper Three Runs Creek (mean of 15.5°C), Lower Three Runs Creek (mean of 17.2°C), and Steel Creek (mean of 14.9°C). We considered the thermal river stations as those just below the mouths of the thermal creeks (RM 150.4 and 152.0 South Carolina bank only, mean of 17.3°C). The nonthermal river stations included all the remaining river sample stations (mean of 15.7°C). The intake canals were similar to the river stations (mean of 15.9°C). Oxygen concentrations at all sample stations remained above a mean of 4.3 mg O_2/L and pH ranged from 4.6 - 8.4 (Table 4-3).

The dominant species in the electrofishing collections from the intake canals were bluegill (30.3% by number) and redbreast sunfish (19.6% by number; Table 4-4). The dominant species in the hoop netting collections were the bluegill (26.3% by number) and black crappie (23.7% by number; Table 4-5). The bluegill and black crappie composed a greater percentage of the total catch in the intake canals than in the river or creeks. The relative abundance of these species in the canals may reflect a preference

Table 4-3. Mean (and range) of physical-chemical parameters measured at each sampling station on or near the SRP during the quarterly sampling program. November 1984 - August 1985.

Station	N[a]	Temperature °C (min-max)	Dissolved oxygen mg O_2/L (min-max)	pH (min-max)	Conductivity µS/cm (min-max)	Alkalinity mg $CaCO_3$/L (min-max)	Current cm/sec (min-max)
River Transects							
128.9	24	15.6 (6.0- 22.8)	6.7 (6.3- 7.8)	6.1 (4.8- 6.8)	76.8 (60.0- 89.0)	17.8 (14.0- 20.3)	77.5 (77.0- 78.0)
129.1	24	15.8 (6.0- 23.1)	6.3 (5.0- 7.2)	6.0 (4.8- 6.8)	77.4 (60.0- 90.0)	16.9 (13.5- 19.0)	65.5 (48.0- 83.0)
137.7	22	16.2 (6.5- 23.8)	6.7 (6.4- 7.0)	6.5 (4.9- 7.5)	76.2 (63.0- 91.0)	17.7 (13.8- 20.4)	80.1 (72.0- 88.0)
141.5	22	15.6 (6.5- 23.5)	7.8 (6.0-10.6)	6.5 (5.7- 7.5)	77.3 (64.0- 92.0)	17.6 (14.0- 20.5)	66.4 (62.0- 69.0)
141.7	23	16.0 (6.0- 23.7)	7.7 (6.2-10.2)	6.6 (6.2- 7.4)	78.1 (62.0- 92.0)	17.5 (14.5- 20.0)	72.7 (64.0- 84.0)
145.7	16	15.9 (6.0- 23.7)	7.1 (5.7-10.6)	6.4 (6.0- 6.9)	78.1 (62.0- 87.0)	17.0 (13.1- 18.5)	74.5 (74.0- 75.0)
150.4 (GA)	12	16.1 (6.6- 23.5)	8.1 (7.5- 9.2)	6.4 (6.1- 6.7)	86.5 (69.0-100.0)	18.4 (15.0- 20.8)	70.3 (61.0- 82.0)
150.4 (SC)	12	17.9 (7.5- 24.5)	7.3 (6.4- 8.4)	6.3 (6.2- 6.4)	81.8 (70.0- 91.0)	18.1 (13.8- 20.5)	70.3 (61.0- 82.0)
150.8	22	15.8 (6.5- 23.5)	7.9 (6.6- 9.5)	6.4 (6.0- 7.1)	90.5 (71.0- 99.0)	20.9 (15.0- 28.0)	67.7 (57.0- 76.0)
152.0 (GA)	12	15.8 (6.4- 23.5)	7.7 (6.7- 8.6)	6.4 (6.2- 6.7)	85.3 (71.0- 95.0)	20.5 (15.3- 27.3)	67.0 (58.0- 77.0)
152.0 (SC)	12	16.6 (6.5- 23.5)	7.5 (6.7- 8.8)	6.6 (6.4- 6.8)	83.0 (62.0- 95.0)	17.4 (14.8- 19.8)	67.0 (58.0- 77.0)
152.2	20	15.3 (5.3- 23.0)	7.7 (6.7- 8.9)	6.6 (6.2- 7.1)	86.0 (68.0- 97.0)	18.1 (15.3- 20.9)	67.2 (59.0- 80.0)
155.2	23	15.9 (6.0- 24.1)	7.3 (5.9- 7.9)	6.1 (5.2- 7.0)	76.4 (60.0- 90.0)	17.7 (15.0- 20.8)	71.3 (62.0- 80.0)

[a]Differences in sample size are largely due to differences in the number of replicates at each sample station rather than to differences in the frequency of sampling.

Table 4-3. (continued). Mean (and range) of physical-chemical parameters measured at each sampling station on or near the SRP during the quarterly sampling program. November 1984 - August 1985.

Station	N[a]	Temperature °C (min-max)	Dissolved oxygen mg O_2/L (min-max)	pH (min-max)	Conductivity µS/cm (min-max)	Alkalinity mg $CaCO_3$/L (min-max)	Current cm/sec (min-max)
River Transects (continued)							
157.0	22	15.5 (5.9-22.4)	8.0 (7.4- 9.2)	6.2 (5.5-7.4)	74.2 (59.0- 86.0)	17.8 (14.5-21.0)	76.4 (68.0- 90.0)
157.3	23	15.0 (5.8-22.3)	7.7 (6.6- 9.8)	6.4 (5.6-7.3)	77.0 (61.0- 92.0)	19.8 (15.0-27.8)	86.6 (66.0-115.0)
Intake Canal							
155.3	22	16.1 (6.1-22.6)	7.7 (6.7- 8.9)	6.2 (5.6-7.1)	72.1 (51.0- 95.0)	13.9 (15.0-21.0)	-[b]
157.1	23	15.7 (6.0-22.9)	7.5 (6.1- 8.7)	6.1 (4.7-7.3)	67.2 (56.0- 79.0)	14.5 (13.0-16.3)	-[b]
Creek Transects							
Lower Three Runs Creek							
53 (Road A-18)	12	18.3 (14.3-25.4)	6.4 (5.6- 6.9)	6.9 (6.2-7.6)	97.0 (84.0-111.0)	-[b]	45.5 (16.0- 75.0)
44 (Road A)	12	18.3 (13.1-26.1)	6.5 (5.5- 7.4)	6.9 (6.6-7.4)	109.0 (90.0-143.0)	-[b]	16.8 (12.0- 24.0)
129.0 (mouth)	11	14.8 (6.0-22.6)	6.4 (5.8- 7.0)	6.4 (4.9-7.1)	88.6 (60.0-110.0)	32.0 (14.5-42.3)	26.0 (10.0- 48.0)
Steel Creek							
141.6 (mouth)	11	14.9 (4.5-24.0)	8.1 (6.3- 9.8)	6.9 (6.4-7.4)	70.9 (60.0- 86.0)	17.6 (9.5-25.4)	25.6 (11.0- 44.0)

[b]Data not collected.

Table 4-3. (continued). Mean (and range) of physical-chemical parameters measured at each sampling station on or near the SRP during the quarterly sampling program. November 1984 - August 1985.

Station	N[a]	Temperature °C (min-max)	Dissolved oxygen mg O_2/L (min-max)	pH (min-max)	Conductivity μ S/cm (min-max)	Alkalinity mg $CaCO_3$/L (min-max)	Current cm/sec (min-max)
Creek Transects (continued)							
Four Mile Creek							
13 (Road A)	4	18.2 (11.1- 27.7)	4.8 (1.8- 9.2)	6.1 (5.4- 7.3)	70.0 (51.0- 80.0)	-	-
14 (Road A-13)	4	20.8 (10.2- 30.6)	5.5 (0.8-10.6)	6.2 (4.6- 8.4)	83.3 (>1 - 101)	-	-
15 (swamp 1)	9	37.3 (35.0- 39.0)	5.7 (5.4- 5.9)	7.4 (6.7-7.8)	61.7 (30.0- 78.0)	15.5 (-[b])	36.0 (32.0- 40.0)
16 (swamp 2)	8	36.8 (33.2- 39.0)	5.4 (4.7- 5.9)	6.8 (6.1-7.7)	66.3 (40.0- 78.0)	16.0 (-[b])	37.5 (35.0- 40.0)
17 (swamp 3)	9	34.6 (31.1- 37.5)	5.1 (4.8- 5.3)	6.6 (6.4-6.8)	72.0 (60.0- 82.0)	16.0 (-[b])	71.0 (62.0- 80.0)
150.6 (mouth)	15	25.9 (10.5- 37.6)	6.1 (4.8- 7.1)	6.7 (6.4-7.2)	73.2 (49.0- 87.0)	13.4 (12.5-14.3)	39.7 (17.0- 62.0)
Beaver Dam Creek							
5 (Road A-12.2)	12	26.7 (16.8- 33.1)	6.8 (5.7- 7.4)	6.6 (5.3-7.3)	82.5 (40.0-135.0)	19.0 (-[b])	79.8 (48.0-130.0)
6 (above slough)	12	24.9 (17.8- 31.0)	6.9 (6.2- 8.5)	6.8 (6.1-7.9)	94.5 (81.0-112.0)	17.3 (-[b])	52.5 (45.0- 60.0)
7 (slough)	12	24.0 (17.2- 29.1)	6.2 (5.4- 7.7)	6.8 (6.1-8.0)	90.8 (78.0-102.0)	18.3 (-[b])	37.0 (28.0- 50.0)
8 (swamp)	12	22.6 (15.1- 28.0)	5.8 (5.3- 6.2)	7.0 (6.3-8.0)	93.0 (76.0-102.0)	18.6 (-[b])	72.0 (48.0- 88.0)
152.1 (mouth)	12	19.3 (5.7- 26.1)	6.2 (4.3- 9.1)	6.7 (6.2-7.6)	86.5 (62.0-100.0)	16.6 (15.8-17.8)	52.0 (20.0- 74.0)

[a]Missing samples.

Table 4-3. (continued). Mean (and range) of physical-chemical parameters measured at each sampling station on or near the SRP during the quarterly sampling program. November 1984 - August 1985.

Station	N[a]	Temperature °C (min-max)	Dissolved oxygen mg O_2/L (min-max)	pH (min-max)	Conductivity µS/cm (min-max)	Alkalinity mg $CaCO_3$/L (min-max)	Current cm/sec (min-max)
				Creek Transects (continued)			
Upper Three Runs Creek							
1 (Road C)	12	16.1 (8.9- 22.7)	7.5 (6.6- 8.1)	6.1 (5.2- 7.0)	21.3 (17.0- 27.0)	33.8 (-[b])	62.0 (40.0- 97.0)
2 (Road A)	12	16.3 (8.4- 22.7)	8.1 (6.0- 8.2)	6.2 (5.2- 7.2)	24.3 (19.0- 38.0)	35.0 (-[b])	45.3 (32.0- 58.0)
157.2 (mouth)	12	14.1 (6.0- 20.6)	8.0 (6.7- 8.8)	5.9 (4.7- 7.6)	36.5 (22.0- 80.0)	34.4 (30.0- 36.3)	24.7 (22.0- 30.0)
Pen Branch Creek							
21 (Road A-13.3)	5	23.4 (18.0- 32.6)	7.7 (7.0- 9.7)	6.1 (5.5- 7.0)	79.4 (69.0- 88.0)	18.1 (-[b])	77.0 (-[b])
22 (Delta)	11	26.0 (17.5- 34.1)	8.2 (6.6- 9.8)	7.5 (7.2- 8.0)	83.0 (74.0- 90.0)	16.8 (-[b])	20.0 (18.0- 22.0)

NOTE: EFHNTE2A was used to compute the data presented in this table.
[a]Differences in sample size are largely due to differences in the number of replicates at each sample station rather than to differences in the frequency of sampling.
[b]Data not collected.

Table 4-4. Relative abundance of fishes caught by electrofishing in the thermal and nonthermal areas of the Savannah River, the intake canals, and the thermal and nonthermal tributary creeks on the SRP. November 1984 - August 1985.

	Percent Number					Percent Weight				
	River			Creeks		River			Creeks	
Taxa	Nonthermal[a]	Thermal[b]	Intake Canal	Nonthermal Creeks[c]	Thermal Creeks[d]	Nonthermal	Thermal	Intake Canal	Nonthermal Creeks	Thermal Creeks
longnose gar	0.7	1.0	0.4	0.7	2.6	0.7	2.3	0.1	7.4	5.1
bowfin	6.7	2.1	1.8	3.2	5.2	38.2	12.9	37.8	18.9	25.9
American eel	2.6	0	0	17.3	4.8	1.2	0	0	10.1	2.4
blueback herring	0.3	2.1	0	0	0	<0.1	0.1	0	0	0
American shad	1.1	2.1	0	0.6	0.4	0.2	0.1	0	1.9	<0.1
gizzard shad	1.5	1.0	4.0	0	3.0	1.4	1.8	4.3	0	3.3
redfin pickerel	0.4	2.1	1.8	0.9	0.9	<0.1	0.2	0.2	0.1	0.2
chain pickerel	1.2	0	2.6	1.7	0.4	1.1	0	0.8	1.3	1.3
golden shiner	0.3	1.0	0	0.6	0	<0.1	0.2	0	<0.1	0
quillback carpsucker	0.2	0	0	0	0	3.5	0	0	0	0
unid. carpsucker	0.2	0	0	0	0	<0.1	0	0	0	0
creek chubsucker	0.1	0	0	0.4	0	0.2	0	0	0.5	0
lake chubsucker	0.1	0	0	0.4	0	<0.1	0	0	0.2	0
unid. chubsucker	0.1	0	0	0.9	0	<0.1	0	0	<0.1	0
spotted sucker	14.8	15.5	4.4	24.2	6.1	35.2	53.1	32.0	35.0	17.0
silver redhorse	0.7	0	0.4	0.2	0	2.8	0	3.3	1.3	0
snail bullhead	0.1	0	0	0.2	0.4	<0.1	0	0	<0.1	<0.1
white catfish	0.1	0	0	0	0	0.1	0	0	0	0
yellow bullhead	0	0	0	0	0.4	0	0	0	0	0.5
brown bullhead	0	0	0	0	0	0	0	0	0	0
flat bullhead	0.7	0	0	0.2	0.4	0.1	0	0	0.1	0.1
channel catfish	0.3	2.1	0	0.4	7.0	0.9	9.1	0	2.5	19.7
pirate perch	1.8	1.0	0.4	3.4	0.4	<0.1	<0.1	<0.1	0.1	<0.1
needlefish	0	1.0	0	0	0	0	0.4	0	0	0
flier	0.1	0	0	0	0	<0.1	0	0	0	0
bluespotted sunfish	0.2	0	0.4	0.6	0	<0.1	0	0.1	<0.1	0
redbreast sunfish	25.2	21.6	19.6	18.2	19.6	2.6	1.2	2.0	7.9	4.5
pumpkinseed	0	0.4	0.4	0	0	<0.1	0	0.1	0	0
warmouth	1.0	1.2	1.8	3.4	2.2	0.2	0.1	0.1	1.6	0.5
bluegill	5.2	4.7	30.3	4.7	4.8	0.5	0.3	4.1	0.7	1.1

[a] All river transects except those just below Beaver Dam Creek and Four Mile Creek.
[b] RM 152.0 below Beaver Dam Creek and 150.4 below Four Mile Creek.
[c] Upper Three Runs Creek, Steel Creek, and Lower Three Runs Creek.
[d] Beaver Dam Creek, Four Mile Creek, and Pen Branch.

Table 4-4. (continued). Relative abundance of fishes caught by electrofishing in the thermal and nonthermal areas of the Savannah River, the intake canals, and the thermal and nonthermal tributary creeks on the SRP. November 1984 - August 1985[a].

	Percent Number					Percent Weight				
	River			Creeks		River			Creeks	
Taxa	Nonthermal[a]	Thermal[b]	Intake Canal	Nonthermal Creeks[c]	Thermal Creeks[d]	Nonthermal	Thermal	Intake Canal	Nonthermal Creeks	Thermal Creeks
dollar sunfish	2.2	1.0	5.2	0.9	14.8	0.1	0.1	0.6	0.1	0.3
redear sunfish	2.4	1.0	5.5	0.9	1.7	1.0	1.0	2.4	0.5	1.3
spotted sunfish	15.5	17.5	1.1	6.1	9.6	1.4	2.7	0.4	1.0	0.7
Lepomis spp.	0	0	0	0.0	0.4	0	0	0	0.0	<0.1
unid. sunfish	0	0	0	0	0	0	0	0	0	0
redeye bass	0.2	0	0	0	0	<0.1	0	0	0	0
largemouth bass	8.7	16.5	8.5	5.6	13.5	3.8	7.3	4.0	6.6	14.7
white crappie	0	0	0	0	0	0	0	0	0	0
black crappie	1.0	0	0.4	0.2	0	0.4	0	0.5	0.1	0
yellow perch	1.1	1.0	10.0	3.5	0	0.3	0.5	4.0	1.4	0
striped mullet	3.0	4.1	1.1	0	0.9	4.0	6.6	3.3	0	1.2
hogchoker	0.2	0	0	0	0	<0.1	0	0	0	0
unknown	0	0	0	0.7	0.4	0	0	0	0.8	<0.1
Total Percent	100.0	100.0	100.1	100.1	99.9	99.9	99.9	100.1	100.1	99.8
Total Number	1125	97	271	537	230					
Total Weight (g)						324,220	21,350	26,347	99,469	57,664
Number of Taxa[e]	33	21	20	25	21					
Number of 100m electroshocking section in each area	72	6	12	21	27	72	6	12	21	27

NOTE: EFHNWT3 and EFHNNO3 were used to compute the data presented in this table.

[a]All river transects except those just below Beaver Dam Creek and Four Mile Creek.
[b]RM 152.0 below Beaver Dam Creek and 150.4 below Four Mile Creek.
[c]Upper Three Runs Creek, Steel Creek, and Lower Three Runs Creek.
[d]Beaver Dam Creek, Four Mile Creek, and Pen Branch.
[e]Unidentified Clupeidae were not included in taxa counts if identified Clupeidae were present; unidentified suckers were not included if identified suckers were present; unidentified sunfish were not included if identified sunfish were present; unkown taxa were not included.

Table 4-5. Relative abundance of fishes caught by hoop netting in the thermal and nonthermal areas of the Savannah River, the intake canals, and the thermal and nonthermal tributary creeks on the SRP. November 1984 - August 1985.

	Percent Number					Percent Weight				
	River			Creeks		River			Creeks	
Taxa	Nonthermal[a]	Thermal[b]	Intake Canal	Non-thermal Creeks[c]	Thermal Creeks[d]	Nonthermal	Thermal	Intake Canal	Non-thermal Creeks	Thermal Creeks
spotted gar	0	0	0	0	0	0	0	0	0	0
longnose gar	3.8	0	0	4.0	0	8.6	0	0	4.8	0
bowfin	2.1	0	0	16.0	0	15.9	0	0	52.9	0
American eel	0	0	0	0	0	0	0	0	0	0
blueback herring	0	0	0	0	0	0	0	0	0	0
American shad	0	0	0	8.0	0	0	0	0	4.6	0
gizzard shad	1.0	0	0	0	0	0.9	0	0	0	0
threadfin shad	0	0	0	0	0	0	0	0	0	0
redfin pickerel	0	0	0	0	0	0	0	0	0	0
chain pickerel	0	0	0	0	0	0	0	0	0	0
unid. pickerel	0.7	0	0	0	0	0.3	0	0	0	0
golden shiner	0	0	0	0	0	0	0	0	0	0
quillback carpsucker	0	0	0	0	0	0	0	0	0	0
unid. carpsucker	0	0	0	0	0	0	0	0	0	0
creek chubsucker	0.4	0	0	0	0	0.1	0	0	0	0
lake chubsucker	0	0	0	0	0	0	0	0	0	0
spotted sucker	2.4	2.1	2.6	0	0	5.7	1.7	2.1	0	0
unid. chubsucker	0	0	0	0	0	0	0	0	0	0
silver redhorse	1.0	0	0	0	0	2.2	0	0	0	0
snail bullhead	0	0	0	0	0	0	0	0	0	0
white catfish	6.3	23.4	0	4.0	33.3	20.3	42.4	0	18.7	55.6
yellow bullhead	0	0	0	0	0	0	0	0	0	0
brown bullhead	0	0	0	0	0	0	0	0	0	0
flat bullhead	48.4	10.6	2.6	32.0	0	19.0	4.6	4.7	10.3	0
channel catfish	10.5	34.0	0	0	33.3	18.2	34.4	0	0	32.4
pirate perch	0	0	0	0	0	0	0	0	0	0
needlefish	0	0	0	0	0	0	0	0	0	0
striped bass	0.4	0	0	0	0	0.8	0	0	0	0
mud sunfish	0	0	0	0	0	0	0	0	0	0
flier	2.8	0	13.2	0	0	0.6	0	9.0	0	0
bluespotted sunfish	0	0	0	0	0	0	0	0	0	0
redbreast sunfish	4.2	10.6	10.5	4.0	0	1.3	4.4	13.3	1.4	0
pumpkinseed	0	0	2.6	0	0	0	0	2.0	0	0
warmouth	0	2.1	0	4.0	0	0	1.6	0	0.7	0
bluegill	8.0	4.3	26.3	12.0	0	1.8	1.8	28.0	4.7	0

[a] All river transects except those just below Beaver Dam Creek and Four Mile Creek.
[b] RMs 152.0 below Beaver Dam Creek and 150.4 below Four Mile Creek.
[c] Upper Three Runs Creek, Steel Creek, and Lower Three Runs Creek.
[d] Beaver Dam Creek and Four Mile Creek

Table 4-5. (continued). Relative abundance of fishes caught by hoop netting in the thermal and nonthermal areas of the Savannah River, the intake canals, and the thermal and nonthermal tributary creeks on the SRP. November 1984 - August 1985[a].

	Percent Number					Percent Weight				
	River			Creeks		River			Creeks	
Taxa	Nonthermal[a]	Thermal[b]	Intake Canal	Nonthermal Creeks[c]	Thermal Creeks[d]	Nonthermal	Thermal	Intake Canal	Nonthermal Creeks	Thermal Creeks
dollar sunfish	0	0	0	0	0	0	0	0	0	0
redear sunfish	1.0	2.1	13.2	4.0	33.3	0.7	2.5	8.5	<0.1	11.9
spotted sunfish	1.0	2.1	0	8.0	0	0.1	0.2	0	0.7	0
Lepomis spp.	0	0	5.3	0	0	0	0	7.0	0	0
unid. sunfish	0	0	0	0	0	0	0	0	0	0
redeye bass	0	0	0	0	0	0	0	0	0	0
largemouth bass	0	2.1	0	0	0	0	3.0	0	0	0
white crappie	0	0	0	0	0	0	0	0	0	0
black crappie	4.9	4.3	23.7	4.0	0	2.4	1.5	25.4	1.2	0
yellow perch	0.7	2.1	0	0	0	0.4	1.8	0	0	0
striped mullet	0.4	0	0	0	0	0.6	0	0	0	0
hogchoker	0	0	0	0	0	0	0	0	0	0
unknown	0	0	0	0	0	0	0	0	0	0
Total Percent	100.0	99.8	100.0	100.0	99.9	99.9	99.9	118.0	100.0	99.9
Total Number	287	47	38	25	6					
Total Weight (g)						124,783	17,076	4,506	13,882	3,756
Number of Taxa[e]	19	12	9	11	3					
Number of nets set/quarter	24	2	4	3	2					

NOTE: EFHNWT3 and EFHNNO3 were used to compute the data presented in this table.

[a]All river transects except those just below Beaver Dam Creek and Four Mile Creek.
[b]RMs 152.0 below Beaver Dam Creek and 150.4 below Four Mile Creek.
[c]Upper Three Runs Creek, Steel Creek, and Lower Three Runs Creek.
[d]Beaver Dam Creek, Four Mile Creek, and Pen Branch.
[e]Unidentified Clupeidae were not included in taxa counts if identified Clupeidae were present; unidentified suckers were not included if identified suckers were present; unidentified sunfish were not included if identified sunfish were present; unkown taxa were not included.

for quiet waters. Unlike earlier years, chain pickerel were relatively uncommon in the intake canals (Paller and Osteen 1985; Paller et al. 1984) probably because most macrophyte growth was removed from the canals by dredging during early summer 1985. Macrophyte beds constitute ideal habitat for chain pickerel (Pflieger 1975).

The dominant species in the electrofishing collections from the river (both thermal and nonthermal habitats) were redbreast sunfish, spotted sunfish, spotted sucker, and largemouth bass. The dominant species in the hoop netting collections were channel catfish, white catfish, and flat bullhead. The relative abundance of several of these species differed between the thermal and non-thermal river habitats. Largemouth bass, channel catfish, and white catfish represented a greater percentage of the total collection at the thermal river sample stations than at the nonthermal river sample stations. Based on the sample method (either electrofishing, Table 4-4, or hoop netting, Table 4-5) most effective for each species, these species constituted 16.5, 34.0, and 23.4%, respectively, of the fish collected from the thermal river habitat and 8.7, 10.5, and 6.3%, respectively, of the fish collected from the nonthermal river habitat. In contrast, flat bullheads were much less abundant in the thermal river habitat (10.6% of the hoop netting catch) than in the nonthermal river habitat (48.4% of the hoop netting catch). The other dominant river species, redbreast sunfish, spotted sunfish, and spotted sucker, were either less common in the thermal river (redbreast sunfish) or occurred with almost equal abundance in both river habitats.

Comparable differences existed between the thermal and nonthermal creeks. Largemouth bass composed 13.5% of the electrofishing catch from the thermal creeks and 5.6% from the nonthermal creeks (Table 4-4). Channel catfish constituted 7.0% of the electrofishing catch from the thermal creeks and 0.4% from the nonthermal creeks (few channel catfish were collected from the creeks by hoop netting; Table 4-5). Neither white catfish nor flat bullheads were captured in sufficient numbers in the creeks to reliably evaluate relative abundance. The combined data from the river and creeks suggest that largemouth bass, channel catfish, and white catfish are important components of the thermal habitats on the Savannah River Plant. These species, along with redbreast and redear sunfish, were also dominant in the thermal habitats during earlier years (Paller et al. 1984; Paller and Osteen 1985). The flat bullhead, in contrast, avoided the thermal habitats in 1985 as it did in earlier years.

Spotted suckers, redbreast sunfish, and the American eel dominated the electrofishing collections from the nonthermal creeks, constituting 24.2%, 18.2%, and 17.3% of the catch, respectively by number. The next most abundant species were the spotted sunfish (6.1%), largemouth bass (5.6%), and bluegill (4.7%; Table 4-4). Numerically dominant species in the hoop net collections were the flat bullhead (32.0%), bowfin (16.0%), bluegill (12.0%), and spotted sunfish (8.0%; Table 4-5). Species composition (as indicated by electrofishing) was different in the thermal creeks, which were dominated by the redbreast sunfish (19.6%), dollar sunfish (14.8%), and largemouth bass (13.5%). Other numerically important species were the spotted sunfish (9.6%) and channel catfish (7.0%). The spotted sucker and American eel that dominated the electrofishing catch from the nonthermal creeks constituted only 6.1% and 4.8%, respectively, of the catch from the thermal creeks. Only six fish were collected from the thermal creeks by hoop netting.

The minnows and other small fishes also differed in relative abundance between the five major habitats in the study area. Shiners (genus Notropis) were dominant in all habitats, constituting 94.3% of the electrofishing catch from the nonthermal river, 98.6% from the thermal river, 80.0% from the intake canals, 93.1% from the nonthermal creeks, and 100.1% from the thermal creeks (Table 4-6). While shiners were dominant in all habitats, specific shiner species seemed to show decided preferences. Spottail shiners were important in the river and in closely associated intake canals, representing 8.3 - 25.4% of the catch from these habitats, but were rare in the creeks (0.1 - 1.0% of the total catch). Coastal shiners made up 64.7% of the catch from the thermal river, but only 35.2% of the catch from the nonthermal river. This pattern was duplicated in the creeks, where the coastal shiner constituted 87.3% of the catch from the thermal creeks, but only 37.0% of the catch from the nonthermal creeks.

Table 4-6. Relative abundance of minnows and other small fishes collected by electrofishing in the thermal and nonthermal areas of the Savannah River, the intake canals, and the thermal and nonthermal tributary creeks on the SRP. November 1984 - August 1985.

	River						Creeks			
	Nonthermal[a]		Thermal[b]		Intake Canals		Nonthermal[c]		Thermal[d]	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
blueback herring	5	0.5	0	0.0	0	0.0	0	0.0	0	0.0
American shad	9	0.8	0	0.0	0	0.0	0	0.0	0	0.0
Eastern silvery minnow	2	0.2	0	0.0	0	0.0	0	0.0	0	0.0
rosyface chub	19	1.8	0	0.0	0	0.0	1	0.1	0	0.0
bluehead chub	2	0.2	0	0.0	0	0.0	32	2.2	0	0.0
golden shiner	3	0.3	1	0.6	0	0.0	2	0.1	0	0.0
ironcolor shiner	27	2.5	1	0.6	3	20.0	104	7.1	0	0.0
dusky shiner	40	3.7	1	0.6	0	0.0	445	30.5	2	2.0
pugnose minnow	16	1.5	4	2.6	1	6.7	4	0.3	0	0.0
spottail shiner	274	25.4	13	8.3	2	13.3	2	0.1	1	1.0
sailfin shiner	0	0.0	0	0.0	0	0.0	73	5.0	1	1.0
bannerfin shiner	113	10.5	12	7.7	0	0.0	3	0.2	3	3.0
yellowfin shiner	0	0.0	0	0.0	0	0.0	50	3.4	0	0.0
whitefin shiner	92	8.5	5	3.2	0	0.0	4	0.3	0	0.0
coastal shiner	379	35.2	101	64.7	5	33.3	538	36.9	89	88.1
Notropis spp.	75	7.0	17	10.9	1	6.7	135	9.3	5	5.0
tadpole madtom	0	0.0	0	0.0	0	0.0	4	0.3	0	0.0
margined madtom	0	0.0	0	0.0	0	0.0	1	0.1	0	0.0
unidentified madtom	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0
lined topminnow	0	0.0	0	0.0	1	6.7	4	0.3	0	0.0
mosquitofish	0	0.0	0	0.0	0	0.0	4	0.3	0	0.0
brook silverside	7	0.6	1	0.6	0	0.0	7	0.5	0	0.0
banded pygmy sunfish	0	0.0	0	0.0	2	13.3	1	0.1	0	0.0
Savannah darter	0	0.0	0	0.0	0	0.0	16	1.1	0	0.0
tesselated darter	11	1.0	0	0.0	0	0.0	13	0.9	0	0.0
blackbanded darter	0	0.0	0	0.0	0	0.0	13	0.9	0	0.0
Etheostoma spp.	0	0.0	0	0.0	0	0.0	1	0.1	0	0.0
river goby	2	0.2	0	0.0	0	0.0	0	0.0	0	0.0
Total fish	1077	100.0	156	99.8	15	100.0	1457	100.1	101	100.1

[a]All river transects except those just below Beaver Dam Creek and Four Mile Creek.
[b]RMs 152.0 below Beaver Dam Creek and 150.4 below Four Mile Creek.
[c]Upper Three Runs Creek, Steel Creek, and Lower Three Runs Creek.
[d]Beaver Dam Creek, Four Mile Creek, and Pen Branch.

Thus, like the largemouth bass, channel catfish, and white catfish, the coastal shiner appears to be an important species in the thermal habitats.

The preceding descriptions emphasize species composition over the entire year; however, species composition exhibited considerable seasonal variation. Spotted suckers made up 48.9% of the electrofishing collection from the Savannah River (nonthermal) during February, but only 9.5 - 21.8% during the other months (November 1984, May 1985, and August 1985; Table 4-7). During May yellow perch constituted from 2.5 - 23.9% of the electrofishing collection from all habitats but the thermal creeks (where they were not collected). However, they never represented greater than 6.1% of the catch during the other months, and were not collected at all in many samples. Flat bullhead dominated the nonthermal river hoop netting collections during November and February (63.5 - 62.9%), but were less abundant during May and August (28.4 - 12.9%; Table 4-8). These seasonal variations in abundance could have been due to mortality, recruitment, changes in water level that affected collection efficiency, or seasonal changes in behavior and habitat preference that affected capturability. Some of these factors will be discussed more fully in the next section.

4.2.3 Electrofishing Catch Per Unit Effort

Electrofishing catch per unit effort ranged from 0.0 fish/100 m to 21.3 fish/100 m during November (Table 4-9). The lowest CPUEs were in Four Mile Creek (0.0 fish/100 m). CPUE was also relatively low in the mouth of Beaver Dam Creek (0.7 fish/100 m),

Table 4-7. Seasonal changes in the relative abundance (% number) of the most common fishes captured by electrofishing in thermal and nonthermal areas of the Savannah River, the intake canals, and the thermal and nonthermal tributary creeks on the SRP. November 1984 - August 1985.

	November 1984					February 1985					May 1985					August 1985				
Species	NTR[a]	TR[b]	IC[c]	NTC[d]	TC[e]	NTR	TR	IC	NTC	TC	NTR	TR	IC	NTC	TC	NTR	TR	IC	NTC	TC
Nonanadromous Fishes																				
bowfin	1.4	0.0	1.3	1.4	6.8	8.5	14.3	10.0	2.5	7.1	5.0	0.0	0.0	3.2	5.1	9.0	3.6	2.6	6.3	2.6
American eel	3.6	0.0	0.0	21.8	8.5	0.0	0.0	0.0	19.8	5.4	3.8	0.0	0.0	15.1	5.1	1.9	0.0	0.0	13.7	1.3
shad	1.8	0.0	0.0	0.0	1.7	2.1	0.0	0.0	0.0	8.9	0.8	0.0	0.0	0.0	0.0	1.6	3.6	9.6	0.0	1.3
pickerel	3.2	2.8	9.3	2.8	1.7	8.5	0.0	10.0	1.2	3.6	0.8	3.8	2.8	3.7	0.0	1.0	0.0	1.7	1.1	0.0
spotted sucker	9.5	11.1	0.0	28.9	1.7	48.9	71.4	20.0	22.2	10.7	21.8	19.2	11.3	22.4	0.0	11.5	3.6	1.7	23.2	9.2
sunfish	54.5	61.1	74.7	31.6	49.1	14.9	0.0	40.0	30.9	48.2	52.7	34.6	57.7	36.1	69.4	54.0	53.6	63.5	40.2	51.3
largemouth bass	15.5	11.1	9.3	2.1	25.4	2.1	0.0	20.0	8.6	5.4	4.6	15.4	1.4	4.6	5.1	8.4	28.6	11.6	10.5	14.5
black crappie	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	1.4	0.5	0.0	1.3	0.0	0.0	0.0	0.0
yellow perch	1.4	0.0	4.0	1.4	0.0	0.0	0.0	0.0	1.2	0.0	2.5	3.8	23.9	6.8	0.0	0.5	0.0	6.1	1.1	0.0
Anadromous Fishes																				
blueback herring	0.0	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
American shad	2.3	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	1.4	0.0	1.0	0.0	0.0	0.0	1.3
striped bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
all other species	5.9	2.8	1.3	9.8	5.1	14.9	14.3	0.0	13.6	10.7	7.1	23.1	1.4	6.5	15.5	9.4	7.1	3.5	4.3	18.4
Total Number	220	36	75	142	59	47	7	10	81	56	239	26	71	219	39	619	28	115	107	64
Total Species	21	11	12	16	14	14	3	5	15	15	25	12	14	20	10	29	9	14	16	14
Number of 100 m electroshocking sections in each area	72	6	12	21	27	72	6	12	21	27	72	6	12	21	27	72	6	12	21	27

NOTE: EM9NN02 was used to compute the data presented in this table.

[a]All river transects except those just below Beaver Dam Creek and Four Mile Creek.
[b]RMs 152.0 below Beaver Dam Creek and 150.4 below Four Mile Creek.
[c]Intake canals.
[d]Upper Three Runs Creek, Steel Creek, and Lower Three Runs Creek.
[e]Four Mile Creek, Beaver Dam Creek, and Pen Branch.

Table 4-8. Seasonal changes in the relative abundance (% number) of the most common fishes captured by hoopnetting in the thermal and nonthermal areas of the Savannah River, the intake canals, and the thermal and nonthermal tributary creeks on the SRP. November 1984 -August 1985.

	November 1984					February 1985					May 1985					August 1985				
Species	NTR[a]	TR[b]	IC[c]	NTC[d]	TC[e]	NTR	TR	IC	NTC	TC	NTR	TR	IC	NTC	TC	NTR	TR	IC	NTC	TC
Nonanadromous Fishes																				
gar	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.9	0.0	0.0	14.3	0.0	1.6	0.0	0.0	0.0	0.0
American eel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
spotted sucker	1.0	0.0	0.0	0.0	0.0	6.2	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	0.0	0.0
white catfish	6.3	33.3	0.0	0.0	0.0	1.0	33.3	0.0	0.0	0.0	9.4	33.3	0.0	14.3	100.0	12.9	0.0	0.0	0.0	0.0
flat bullhead	63.5	33.3	0.0	71.4	0.0	62.9	20.0	14.3	40.0	0.0	28.4	0.0	0.0	0.0	0.0	12.9	7.1	0.0	0.0	0.0
channel catfish	7.3	0.0	0.0	0.0	0.0	6.2	20.0	0.0	0.0	0.0	0.0	33.3	0.0	0.0	0.0	27.4	57.1	0.0	0.0	100.0
sunfish[f]	9.4	33.3	100.0	28.6	100.0	13.4	13.3	85.7	0.0	0.0	25.0	26.7	50.0	14.3	0.0	30.6	28.6	76.5	83.3	0.0
black crappie	1.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	12.5	6.7	50.0	0.0	0.0	11.3	7.1	17.7	16.7	0.0
Anadromous Fishes																				
blueback herring	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
American shad	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.6	0.0	0.0	0.0	0.0	0.0	0.0
striped bass	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
all other species	8.3	0.0	0.0	0.0	0.0	7.2	6.7	0.0	60.0	0.0	3.1	0.0	0.0	28.6	0.0	3.2	0.0	0.0	0.0	0.0
Total Number	96	3	2	7	2	97	15	7	5	0	32	15	12	7	2	62	14	17	6	2
Total Species	21	3	1	2	1	14	7	4	2	0	8	6	3	5	1	10	7	6	5	1
Number of nets set in each area	24	2	4	3	2	24	2	4	3	2	24	2	4	3	2	24	2	4		

NOTE: EFHNN02 was used to compute the data presented in this table.

[a] All river transects except those just below Beaver Dam Creek and Four Mile Creek.
[b] RMs 152.0 below Beaver Dam Creek and 150.4 below Four Mile Creek.
[c] Intake canals.
[d] Upper Three Runs Creek, Steel Creek, and Lower Three Runs Creek.
[e] Four Mile Creek and Beaver Dam Creek.
[f] Includes several species of *Lepomis*.

Table 4-9. Mean catch per unit effort (no./100 m of shoreline) at electrofishing sample sites in the Savannah River, intake canals, and the thermal and nonthermal tributary creeks on the SRP. November 1984 - August 198

	November 1984		February 1985		May 1985		August 19	
Station	SC bank	GA bank	SC bank	GA bank	SC bank	GA bank	SC bank	G ba
River transect								
157.3	6.7	5.7	0.0	0.3	2.7	1.7	2.7	11
157.0	2.3	4.7	1.0	1.0	1.3	4.0	4.0	6
155.2	3.7	5.7	0.0	0.3	2.0	3.0	0.3	14
152.2	1.0	1.7	6.7	0.0	0.0	3.7	3.3	4
152.0	7.7	0.3	0.7	1.7	3.0	1.0	5.7	12
150.8	5.7	3.0	0.3	0.7	3.7	2.3	3.3	3
150.4	4.3	2.3	1.7	1.7	5.7	3.7	3.7	9
145.7	2.0	1.0	0.0	0.0	-	-[a]	10.3	6.
141.7	4.7	1.3	0.7	0.0	9.7	5.7	6.3	11
141.5	2.7	3.3	0.0	0.0	2.7	4.7	19.0	6
137.7	3.7	0.7	1.0	0.0	9.7	0.7	22.7	9
129.1	2.0	6.3	3.0	0.0	9.7	4.0	15.3	6
128.9	2.0	1.0	0.7	3.0	3.3	0.7	12.0	3
Intake canals								
157.1 (1G canal)	13.0[b]	1.0[c]	0.3	1.0	10.0	5.3	10.3	1.
155.3 (3G canal)	5.3	5.7	0.7	1.3	7.0	1.3	15.3	11.

[a]No data.
[b]Right bank when looking towards the pumphouse.
[c]Left bank when looking towards the pumphouse.

Table 4-9. (continued). Mean catch per unit effort (no./100 m of shoreline) at electrofishing sample sites in the Savannah River, intake canals, and the thermal and nonthermal tributary creeks on the SRP. November 1984 – August 1985.

Station	November 1984	February 1985	May 1985	August 1985
Nonthermal creek mouths				
Upper Three Runs Creek				
1 (Road C)	4.0	6.3	1.7	2.7
2 (Road A)	4.3	2.0	5.0	3.3
157.2 (mouth)	7.3[d]	0.3	10.0	2.3
Steel Creek				
141.6 (mouth)	0.3	0.0	7.3	5.7
Lower Three Runs Creek				
53 (Road A-18)	21.3	12.3	26.7	6.0
44 (Road A)	4.3	5.7	16.7	6.7
129.0 (mouth)	5.7	0.3	5.7	5.0
Thermal creek				
Four Mile Creek				
15 (swamp 1)	0.0	0.0	0.0	–[e]
16 (swamp 2)	0.0	0.0	0.0	–[e]
17 (swamp 3)	0.0	0.0	0.0	–[e]
150.6 (mouth)	0.0	0.0	0.0	2.3
Beaver Dam Creek				
5 (road A-12.2)	0.0	0.7	0.7	1.0
6 (just above slough)	4.0	5.3	3.0	5.3
7 (slough)	8.7	6.7	1.0	8.7
8 (swamp)	3.3	5.3	0.3	1.7
152.1 (mouth)	0.7	0.7	1.7	2.3
Mean (all stations)	3.8	1.6	4.4	7.1

NOTE: EFHNBAN was used to compute the data presented in this table.

[d]Since the creeks were relatively narrow, only an overall mean for both banks is presented.
[e]Sample stations were inaccessible due to low water.

but no lower than in Steel Creek (0.3 fish/100 m) or at RM 152.0 on the Georgia side (0.3 fish/100 m). Fish apparently avoided Four Mile Creek on the November sample dates because of high temperatures (mean of 35.7°C compared with 14.0°C in the nonthermal creeks; Table 4-10). Temperatures were lower in Beaver Dam Creek (mean of 22.4°C) than in Four Mile Creek and were within the tolerance range of most Savannah River fishes (Brown 1974). Thus, the low catch rates from Beaver Dam Creek may have been due to factors unrelated to temperature, such as fly ash accumulation or metal toxicity (Firth et al. 1986). In general, CPUE was highly variable between sample stations, probably reflecting local variations in habitat. From the perspective of SRP operations, the most important aspect of the November electrofishing CPUE data was the zero catch in the mouth of Four Mile Creek.

The sample stations were divided into six groups for analysis of variance: nonthermal creek, intake canal, thermal river, nonthermal river, Beaver Dam Creek, and Four Mile Creek. Beaver Dam Creek and Four Mile Creek were separated because of the relatively large temperature difference between them (they were not separated in the relative abundance calculations because the number of fish collected from Four Mile Creek was too small to calculate reliable percentages). The results of the ANOVA indicated significant differences ($p \leq 0.05$) between habitats during November (Appendix 3 Table 1). Further analyses using Scheffe's tests showed that CPUE in Four Mile Creek was significantly lower than in all other habitats. There were no other differences between habitats.

Table 4-10. Mean (standard error) quarterly electrofishing catch per unit effort (CPUE;no./100 m) and mean (standard error) temperature (°C) in the thermal and nonthermal areas of the Savannah River, the intake canals, and the thermal and nonthermal tributary creeks on the SRP. November 1984 - August 1985.

Habitat	November 1984 Mean CPUE	November 1984 Mean °C	February 1985 Mean CPUE	February 1985 Mean °C	May 1985 Mean CPUE	May 1985 Mean °C	August 1985 Mean CPUE	August 1985 Mean °C
Nonthermal river	3.1 (0.0)[a]	14.5 (0.1)	0.9 (0.0)	6.2 (0.0)	3.6 (0.0)	18.8 (0.1)	8.6 (0.1)	23.1 (0.1)
River thermal plume area	6.0 (0.7)	17.5 (0.4)	1.2 (0.5)	7.0 (0.2)	4.4 (1.8)	20.5 (0.3)	4.7 (0.4)	24.0 (0.2)
Intake canals	6.3 (0.2)	14.0 (0.0)	0.8 (0.0)	6.1 (0.0)	5.9 (0.1)	18.6 (0.0)	9.6 (0.2)	22.5 (0.0)
Nonthermal creek	6.7 (1.4)	14.0 (0.5)	3.8 (0.9)	11.8 (1.7)	10.4 (1.8)	20.0 (0.4)	4.5 (1.0)	24.5 (0.4)
Thermal creek[b]								
Four Mile Creek	0.0 (0.0)	35.7 (1.1)	0.0 (0.0)	24.0 (5.6)	0.0 (0.0)	38.3 (0.4)	2.3 (0.2)	24.6 (0.0)
Beaver Dam Creek	3.3 (0.7)	22.4 (1.3)	3.7 (0.3)	14.5 (2.2)	1.3 (0.7)	27.9 (0.9)	3.8 (0.3)	28.3 (1.6)

NOTE: EFHNGRO, EFHNNOT1, EFHNNOT2, And EFHNOT were used to compute the data in this table.

[a]Approximately 72 samples were taken each quarter in the nonthermal river habitat: six in the thermal river habitat, 12 in the intake canals, 21 in the nonthermal creek habitat, 12 in Four Mile Creek, and 15 in Beaver Dam Creek.

[b]Four Mile and Beaver Dam Creek are separate because they differed in temperature.

CPUE was relatively low during February, averaging 1.6 fish/100 m at all stations, compared with 3.8 fish/100 m during November (Table 4-9). The low CPUE during February may have been related to river level. River elevation averaged 27.9 m during February 1985 sample period (Figure 4-1). When river elevation exceeds 27.7 m, the floodplain becomes inundated and fish can move out of the sample area onto the floodplain. Low CPUEs during high water periods have also been observed during earlier years (Figure 4-2).

Apart from being very low at most sample stations, CPUE exhibited few interpretable patterns during February 1985. The only important exception was Four Mile Creek, where CPUE was 0.0 fish/100 m (Tables 4-9, 4-10). While CPUE was 0.0 fish/100 m at some of the other sample stations during February, these stations exhibited positive CPUEs during other months. In contrast, 0.0 fish/100 m was observed in Four Mile Creek during November as well as February, indicating a consistent scarcity of fishes in this stream. The mean temperature in Four Mile Creek on the February 1985 sample dates was comparatively moderate (24.0^{o}C; Table 4-10) due to the temporary intrusion of ambient temperature river water into the lower reaches of Four Mile Creek during a brief flood period (Figure 4-1). While temperatures in the lower reaches of Four Mile Creek were moderate during the flood period, they were higher and extremely variable during the rest of February (Figure 4-3). The temporary cooling of Four Mile Creek (due to intrusion of river water) may have been of insufficient duration to permit

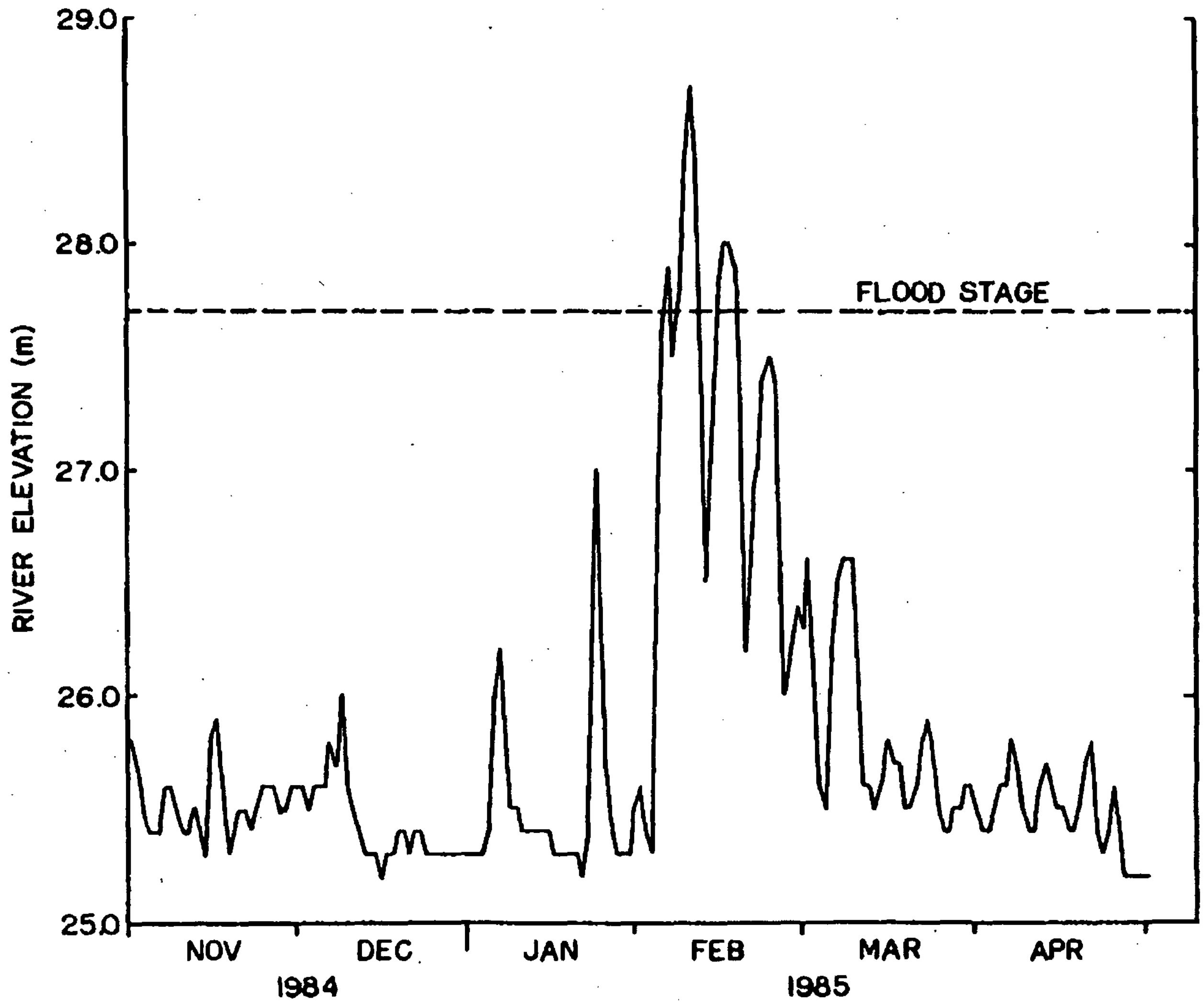

Figure 4-1. Elevation of the Savannah River at the Augusta, Georgia gauging station from November 1984 - April 1985.

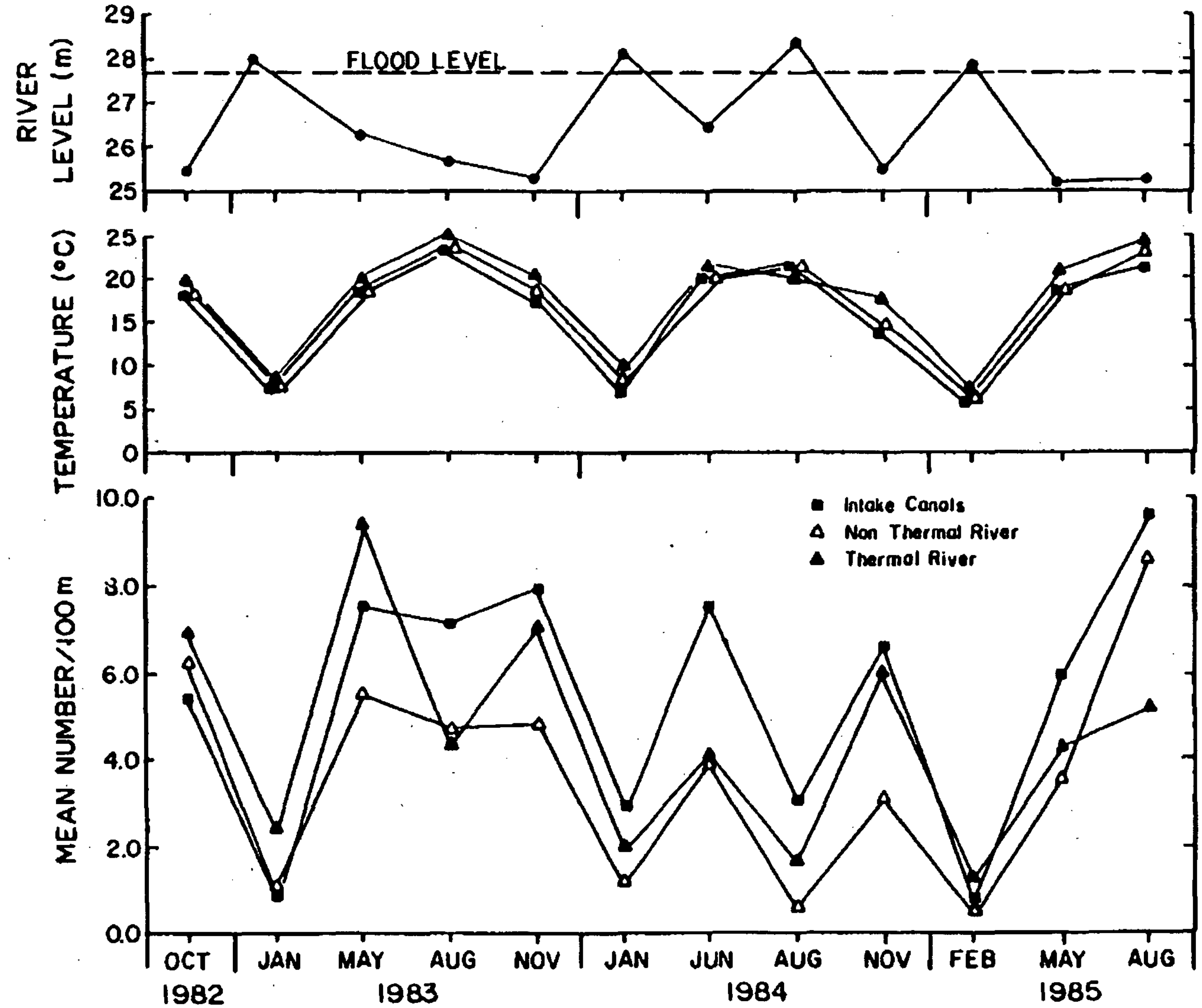

Figure 4-2. River level, mean temperature (°C) and mean number of fish/100 m collected by electrofishing in the thermal and nonthermal areas of the Savannah River and the intake canals during the adult fisheries program. October 1982 - August 1985.

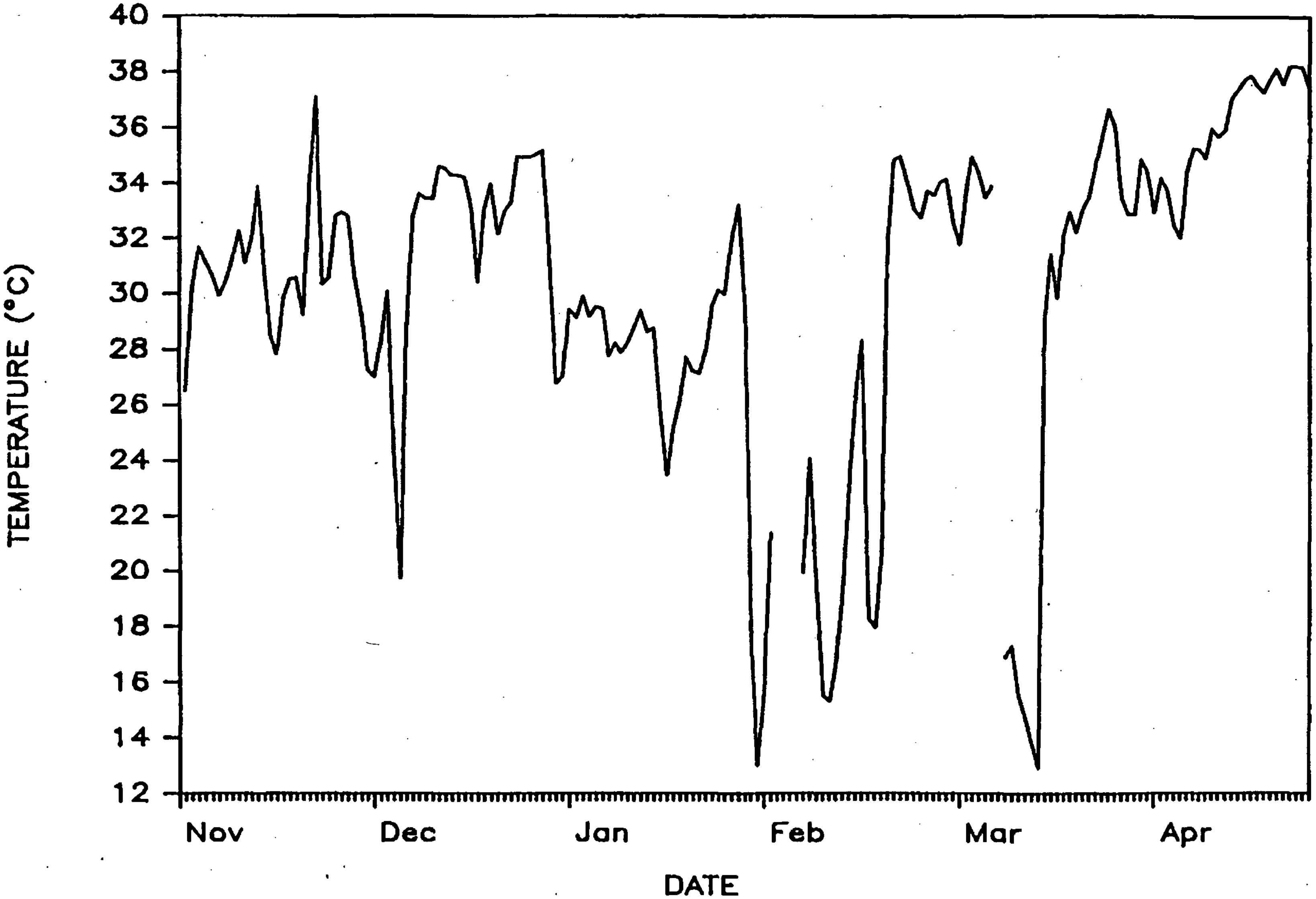

Figure 4-3. Mean daily temperature (average of the daily maximum and minimum) in the mouth of Four Mile Creek (recorded with an Orion Model J thermograph). November 1984 April 1985.

fish to reenter the creek mouth, thus explaining the absence of fish where temperatures were moderate.

The lack of fishes in Four Mile Creek during February 1985 is consistent with the relatively low CPUE in Four Mile Creek during January 1984, but quite different from the high CPUE observed in Four Mile Creek during January 1983 (Figure 4-4). During January 1983, electrofishing CPUE was approximately 2 - 10 times higher in Four Mile Creek than at the other sample stations. Differences between 1984 - 1985 and 1983 are probably due to temperature. During 1984, temperatures over the January 10 - 19 sample period ranged from 7.0 - 30.0°C (range not shown in Figure 4-4, which indicates mean temperature only). Such temperature fluctuations are inimical to most fishes (Brown 1974). During 1985, similar temperature fluctuations occurred (due to large changes in river level; Figures 4-1 and 4-3). During January 1983, in contrast, temperatures in Four Mile Creek were more moderate, ranging from 7.9 - 14.8°C on the sample dates.

Mean temperature in Beaver Dam Creek on the February 1985 sample date was 14.5°C, only slightly higher than in the nonthermal creeks (11.8°C; Table 4-10). As with Four Mile Creek, this was due to inundation of the lower reaches of the creek with relatively cool river water. Mean CPUE in Beaver Dam Creek (3.7 fish/100 m) was approximately the same as in the nonthermal creeks (3.8 fish/100 m).

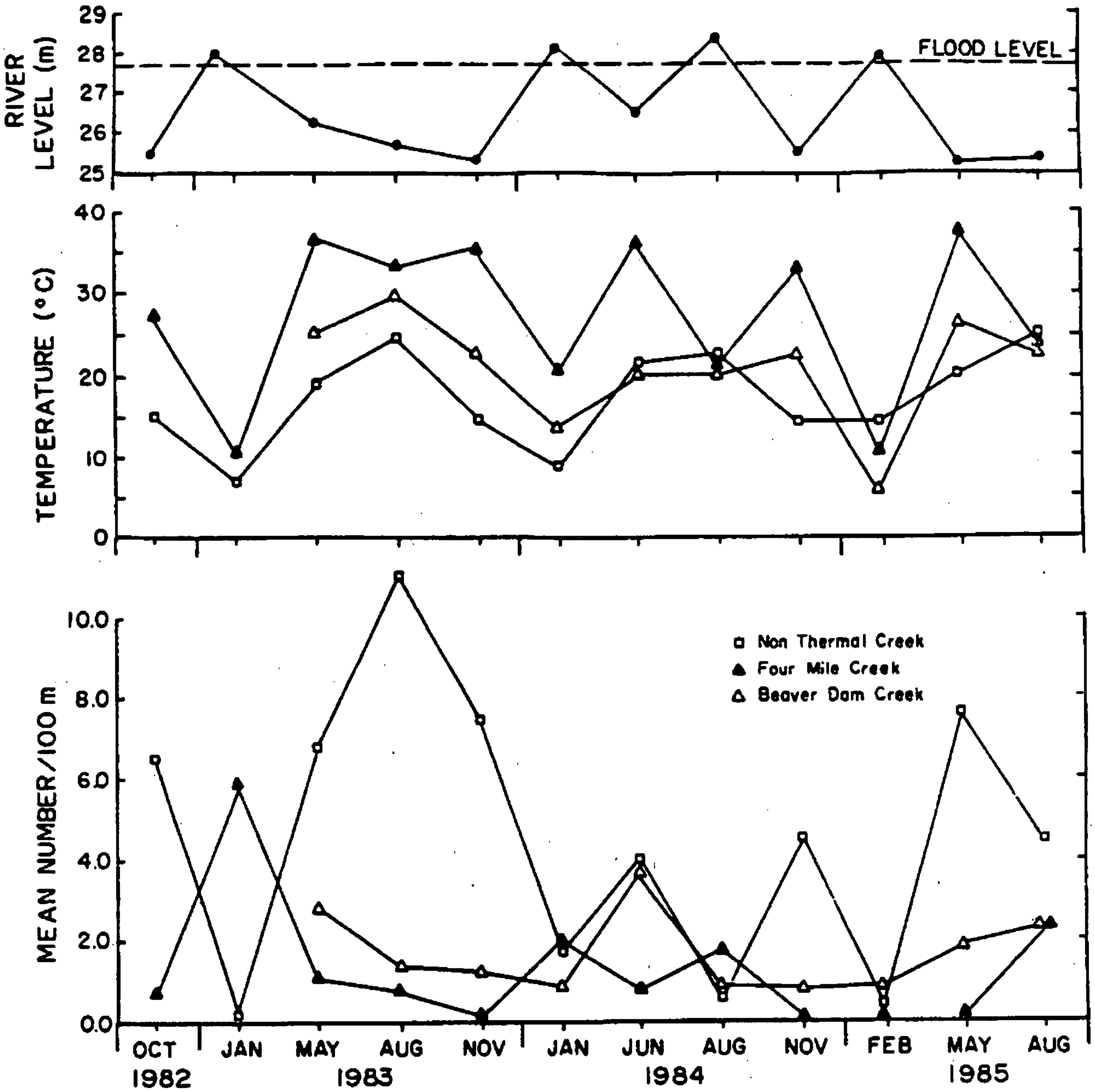

Figure 4-4. River level, mean temperature (°C), and mean number of fish/100 m collected by electrofishing in the nonthermal creeks (Upper Three Runs Creek, Steel Creek, and Lower Three Runs Creek), Four Mile Creek and Beaver Dam Creek during the adult fisheries program. Only data from the creek mouths are included in these plots. October 1982 - August 1985.

Analysis of variance indicated signficant ($p \leq 0.01$) differences among habitats during the February sample period (Appendix 3 Table 2). Further testing with the Scheffe's procedure indicated a lack of distinct groupings. While Four Mile Creek, with no fish, had a lower catch than any other habitat, it was not significantly different from the nonthermal river transects, intake canals, or thermal river transects, where catch rates were also rather low and highly variable.

CPUE increased during the May sampling period, averaging 4.4 fish/100 m at all sample stations (Table 4-9). The increase in CPUE from February was probably a result of lower water levels (mean river elevation was 25.2 m compared with 27.9 m in February), which concentrated the fish in the river and creek channels. Increased water temperatures that enhanced the movement and activity of the fishes, thus increasing their chance of capture, may have also contributed to the higher catches. CPUE at each sample station was highly variable, ranging from 0.0 to 26.7 fish/100 m. As in previous months, much of this variability was probably due to local habitat factors such as depth, current velocity, and amount of shelter.

CPUE was 0.0 fish/100 m in Four Mile Creek on the May sample date. Mean temperature in Four Mile Creek on the May sample date was 38.3°C. CPUE in Beaver Dam Creek averaged 1.3 fish/100 m and CPUE in the nonthermal creeks, 10.4 fish/100 m. Analysis of variance and Scheffe's tests indicated that CPUE was significantly

($p \leq 0.05$) lower in Four Mile Creek than in all other habitats but Beaver Dam Creek (Appendix 3 Table 3). CPUE in Beaver Dam Creek was comparable to that in the river and the intake canals, but significantly lower than that in the nonthermal creeks. Water temperature in Beaver Dam Creek was only 27.9°C on the May sampling date, suggesting that the relatively low CPUE in Beaver Dam Creek was not temperature related.

Mean CPUE at all stations together was relatively high during August, averaging 7.1 fish/100 m, compared with 4.4 fish/100 m in May, 1.6 fish/100 m in February, and 3.8 fish/100 m in November. Relatively high catch rates in August were also observed during 1983 (mean of 5.5 fish/100 m). In contrast, catch rates during August 1984 were relatively low (mean of 1.0 fish/100 m). The low catch rate during August 1984 was probably due to flooding (mean river elevation of 28.4 m on the sample dates). In contrast, the river level was low during the August 1985 sample period (25.3 m; Figure 4-2), thus keeping the fish concentrated in the river channel, where they could be more effectively sampled.

CPUE was highly variable between sample stations during August 1985, ranging from 0.3 fish/100 m near the South Carolina bank at RM 155.2 to 22.7 fish/100 m near the South Carolina bank at RM 137.7 (Table 4-9). Mean CPUE in Four Mile Creek and Beaver Dam Creek was 2.3 and 3.8 fish/100 m, respectively, during the August 1985 sample (because of low water levels, only the mouth of Four Mile Creek was accessible for sampling during 1986; Table 4-9). August was the first quarter during the 1985 sample year in which fish were collected from the mouth of Four Mile Creek. Temperatures were at ambient levels (24.6°C; Table 4-10) in the mouth of Four Mile Creek during August 1985 due to reactor outage. Scheffe's tests (Appendix 3 Table 4) indicated a lack of significant differences among habitats during August.

The results of the 1985 quarterly electrofishing program generally exhibited the same trends observed during earlier years. CPUE in the mouth of Four Mile Creek was generally low when the mean temperature was much above 30.0°C (Figure 4-4). Such conditions usually occurred when the reactor was operating during the spring, summer, and fall quarters. An exception occurred during August 1984 when the Savannah River flooded, inundating Four Mile Creek with relatively cool river water. During the winter, CPUE in Four Mile Creek was more variable, sometimes exceeding that in the other habitats. This variability was temperature related. During November 1984, mean temperature in Four Mile Creek during the winter reached 35.7°C, causing fish to avoid the stream. During January 1983, in contrast, mean temperatures were only slightly above ambient (10.7°C), resulting in the apparent congregation of some fishes in Four Mile Creek. While catch rates in Beaver Dam Creek were sometimes lower than those in the nonthermal creeks, they were never zero, as in tne much warmer Four Mile Creek. Catch rates in Beaver Dam Creek were not correlated with temperature (Figure 4-4).

Catch rates in the river and intake canals over the three-year course of this study appeared to be more closely related to river level than to any other measured parameter (Figure 4-2). Flood conditions were commonly associated with low catches. Flood conditions permitted the fish to move out of the sample area onto the floodplain, generally "diluted" the fish in relation to the area sampled, and made sampling more difficult by affecting the maneuverability of the electrofishing boat and netting efficiency.

The relatively slight temperature elevations observed at the thermal river sample stations below the mouths of the thermal creeks did not reduce CPUE in those areas. CPUE at the thermal river transects was either fairly similar to CPUE at the nonthermal transects or higher. The apparent tendency of some fishes to congregate in the thermal river areas during the winter will be discussed more fully in Section 4.3.

4.2.4 Hoop Netting Catch Per Unit Effort

In order to compare hoop net collections between sample stations and dates, the total number of fishes collected from each station was divided by the total number of days the net was fished to produce catch per unit effort (CPUE) values (number/net day). CPUEs between different sample stations were not compared statistically because of the high variability of the hoop netting catch data. The variability of the hoop netting data was due to the influences of changes in water level, current pattern, amount of cover, and fish behavior on hoop netting efficiency.

Mean CPUE was highly variable during November 1984, ranging from 0.0 to 6.0 fish/net day (Table 4-11). In general, obvious

Table 4-11. Mean catch per unit effort (no./net day) at hoop netting sample sites in the Savannah River, intake canals, and nonthermal and thermal creek mouths of tributary creeks on the SRP. November 1984 - August 1985.

Station	November 1984 SC bank	November 1984 GA bank	February 1985 SC bank	February 1985 GA bank	May 1985 SC bank	May 1985 GA bank	August 1985 SC bank	August 1985 GA bank
River transect								
157.3	0.0	0.3	7.3	0.3	0.3	0.0	2.7	2.7
157.0	0.0	0.0	0.3	2.3	0.0	1.3	1.0	5.7
155.2	1.3	2.3	0.0	0.0	0.0	0.0	1.7	2.3
152.2	0.3	0.0	0.0	1.0	0.0	1.0	0.3	0.0
152.0	1.0	0.3	1.7	0.7	1.3	2.0	0.7	0.3
150.8	0.7	3.0	1.0	0.0	0.0	0.0	0.0	1.7
150.4	0.0	3.0	3.3	0.0	3.7	0.0	4.0	0.0
145.7	2.7	1.0	0.0	0.0	-[a]	-	0.3	0.0
141.7	0.3	0.7	0.3	0.3	3.3	0.0	0.0	0.0
141.5	0.0	2.0	0.0	0.0	0.7	0.3	0.0	0.0
137.7	1.3	0.3	11.0	0.0	1.0	0.0	0.3	0.7
129.1	6.0	4.0	0.0	0.7	0.3	-	0.3	0.0
128.9	0.0	2.3	0.0	7.0	0.3	0.0	0.3	0.3
Intake canals								
157.1 (1G canal)	0.0	0.7	0.3	0.7	3.3	1.0	0.7	1.0
155.3 (3G canal)	0.0	0.0	1.3	0.0	0.0	0.3	2.3	1.7
Nonthermal creek mouths								
157.2 (Upper Three Runs Creek)	0.7[b]		0.0		0.3		0.7	
141.6 (Steel Creek)	2.0		1.0		0.7		0.0	
129.0 (Lower Three Runs Creek)	0.0		0.7		1.0		1.3	
Thermal creek mouths								
150.6 (Four Mile Creek)	0.0		0.0		0.3		0.0	
152.1 (Beaver Dam Creek)	0.7		0.0		0.3		0.7	

NOTE: EFHNBAN was used to compute the data presented in this table.

[a] No data.
[b] Since the creek mouths were relatively narrow, only a single net was placed in the mouth, rather than one near each bank as in the river.

relationships between stations and substantive reasons for station-to-station differences were lacking. The only exception was the mouth of Four Mile Creek, where CPUE was 0.0 fish/net day. This finding corroborates the electrofishing results that also indicated an absence of fish in the mouth of Four Mile Creek during November (Table 4-9), when temperatures were high. Mean CPUE in the mouth of Beaver Dam Creek (0.7 fish net/day), where temperatures were only moderately elevated was comparable with that in the nonthermal creeks (0.0 - 2.0).

As in November, CPUE was highly variable during February, ranging between 0.0 and 11.0 fish/net day (Table 4-11). Interpretable relationships between stations were not obvious. CPUEs in the mouth of Four Mile Creek and Beaver Dam Creek were 0.0 fish/net day despite the fact that temperatures were moderate in the lower reaches of both streams (10.5°C and 5.7°C, respectively; Table 4-12) due to Savannah River flooding. The lack of fish in the Four Mile Creek collections may have been due to extreme temperature variability, as described for the electrofishing data (Section 4.2.3). Alternatively, the 0.0 fish/net day CPUE in Four Mile Creek could have been due to chance, since 0.0 fish/net day values were recorded from several other sample stations in nonthermal areas.

In May and August, CPUE remained highly variable, exhibiting few interpretable relationships between stations. CPUEs in the mouth of Four Mile Creek were 0.3 fish/net day in May and 0.0 fish/net day in August, compared with 0.3 fish/net day - 1.0

Table 4-12. Mean (standard error) hoop netting catch per unit effort (CPUE no./100 m) and mean (1 standard error) temperature (°C) in the thermal and nonthermal areas of the Savannah River, the intake canals, and the thermal and nonthermal creek mouths of tributary creeks on the SRP. November 1984 - August 1985.

Habitat	November 1984 Mean CPUE[a]	November 1984 Mean °C	February 1985 Mean CPUE	February 1985 Mean °C	May 1985 Mean CPUE	May 1985 Mean °C	August 1985 Mean CPUE	August 1985 Mean °C
Nonthermal river	1.3 (0.0)[a]	14.5 (0.1)	1.3 (0.1)	6.2 (0.0)	0.5 (0.0)	18.8 (0.1)	0.9 (0.0)	23.1 (0.1)
River thermal plume area	0.5 (0.1)	17.5 (0.4)	2.5 (0.1)	7.0 (2.2)	2.5 (0.1)	20.5 (0.3)	2.4 (0.2)	24.0 (0.0)
Intake canals	0.2 (0.0)	14.0 (0.0)	0.6 (0.0)	6.1 (0.0)	1.2 (0.1)	18.6 (0.0)	1.4 (0.0)	22.5 (0.0)
Nonthermal creek[b]	0.9 (0.1)	14.0 (0.5)	0.6 (0.0)	14.0 (1.5)	0.7 (0.0)	20.0 (0.4)	0.7 (0.0)	24.5 (0.4)
Thermal creek								
Four Mile Creek[b]	0.0	33.0	0.0	10.5	0.3	37.6	0.0	24.3
Beaver Dam Creek[b]	0.7	22.5	0.0	5.7	0.3	26.1	0.7	23.0

NOTE: EFHNGRO, EFHNNOT1, EFHNNOT2, and EFHNOT were used to compute the data in this table.

[a]Approximate number of nets set per quarter was 24 in the nonthermal river, two in the river thermal plume area, four in the intake canals, three in the nonthermal creeks, one in Four Mile Creek, and one in Beaver Dam Creek.

[b]Hoop net sample stations were located only in the creek mouths, instead of throughout the creeks as were the electrofishing sample stations.

fish/net day in the mouths of the nonthermal creeks during May and 0.0 fish/net day - 1.3 fish/net day in the mouths of the nonthermal creeks during August. CPUEs in moderately thermal Beaver Dam Creek (0.7 fish/net day) were higher than in Four Mile Creek (0.0 fish/net day) in August. The temperature in the mouth of Beaver Dam Creek was approximately 23.0°C on the August sampling date.

An overview of the 1985 hoop net CPUE data can be provided by separating the sample stations into several categories based on macrohabitat and temperature. The categories are ambient river, thermal river (i.e., river stations just downstream of the thermal creeks), intake canals, nonthermal creek mouths, Beaver Dam Creek mouth, and Four Mile Creek mouth. Except for the mouth of Four Mile Creek, these categories exhibited no consistent habitat- or temperature-related differences (Table 4-12). CPUE was consistently low (0.0 - 0.3 fish/net day) in the mouth of Four Mile Creek presumably due to high temperatures. Temperatures in the mouth of Four Mile Creek were 33.0°C in November and 37.6°C in May. Temperatures were only 10.5°C in February, but this was probably due to a temporary intrusion of cool river water into the creek mouth during a brief flood period. Temperature in the mouth of Four Mile Creek was 24.3°C on the August sampling date due to a reactor outage. Since Four Mile Creek received no thermal effluent after May 1985, the low catch from Four Mile Creek during August may not have been temperature related. CPUEs in the moderately thermal (5.7 - 26.1°C) mouth of Beaver Dam Creek were somewhat higher (0.0 - 0.7 fish/net day) than in the mouth of Four

Mile Creek and basically comparable with those in the nonthermal creeks.

The trends in CPUE exhibited during the 1985 quarterly hoop netting program were fairly similar to those exhibited during earlier years. CPUE has generally been low in the mouth of Four Mile Creek (Figure 4-5). CPUE in the mouth of Beaver Dam Creek usually has been somewhat higher, although often below that in the nonthermal creeks. CPUE at the thermal river transects has usually equaled or exceeded that at the nonthermal river transects (Figure 4-6). While the association between river level and CPUE was not quite as strong with the hoop net data as with the electrofishing data, high river levels (above 27.7 m) were generally associated with low CPUEs, particularly in the river. An apparent exception occurred in February 1985, when high river levels were not associated with reduced CPUE in the river, possibly because the river was at flood stage for such a brief period of time (Figure 4-1).

4.2.5 Refuge Areas

Lateral to the main channels of the thermal creeks are side channels, marshes, and pools where some cooling occurs and water temperatures are comparatively moderate. Backpack electrofishing sample stations in such "refuge areas" were located at Four Mile Creek near Road A (Station 13), Four Mile Creek near Road A-13 (Station 14), and at Pen Branch Creek near Road A-13.2 (Station 21; Figure 3-1). Backpack electrofishing was also conducted from the boardwalk in the Pen Branch delta (Station 22). The station

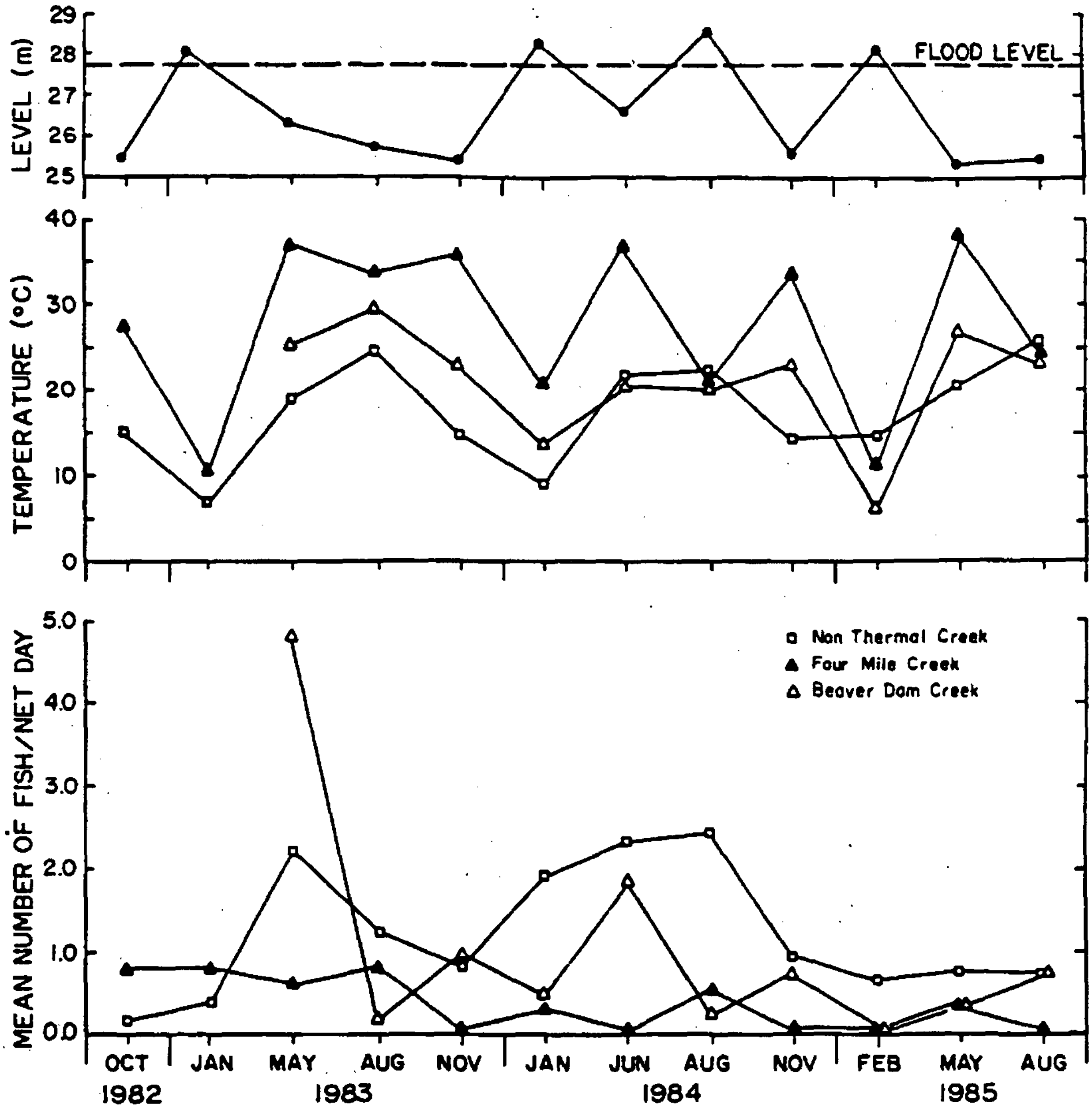

Figure 4-5. River level, mean temperature (°C), and mean number of fish/net day collected by hoop netting in the mouths of the nonthermal creeks, Four Mile Creek, and Beaver Dam Creek during the adult fisheries program. October 1982 - August 1985.

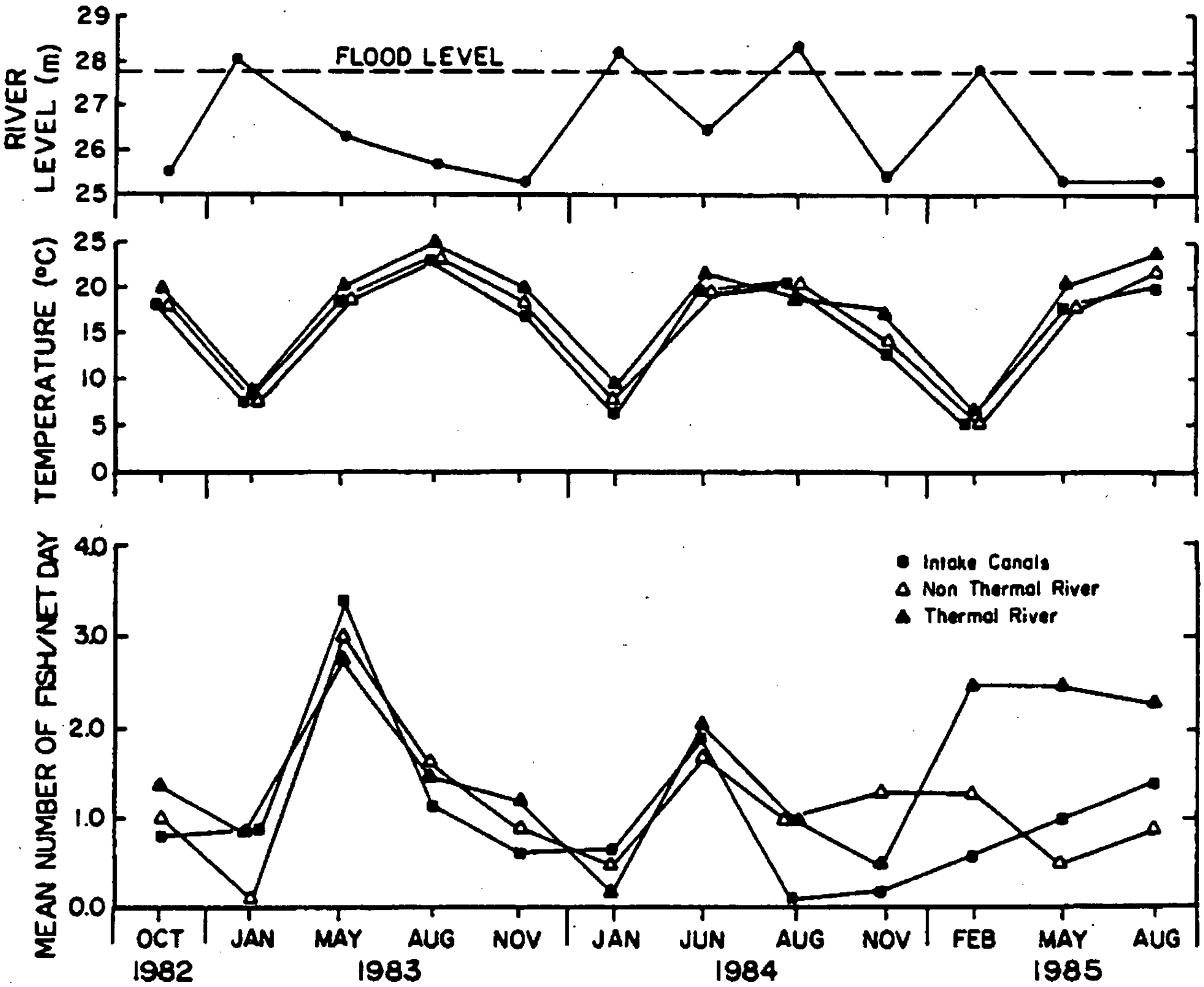

Figure 4-6. River level, mean temperature (°C), and mean number of fish/net day collected by hoop netting in the thermal and non-thermal areas of the Savannah Rvier and the intake canals during the adult fisheries program. October 1982 - August 1985.

in the Pen Branch delta included several of the channels that flow through the delta as well as adjacent marshy areas outside the main channels.

Five species were collected from the refuge areas. Mosquitofish were the dominant species at all sample sites except Station 21. They composed 100% of the catch at Station 13, 100% at Station 14, 36.4% at Station 21, and 97.0% at Station 22 (Table 4-13). Other species collected from the refuge areas include dollar sunfish, spotted sunfish, redbreast sunfish, and pirate perch. Temperatures at the refuge areas ranged from 11.1 - 27.7°C at Station 13, 10.2 - 30.6°C at Station 14, 18.0 - 32.6°C at Station 21, and 17.5 - 34.1°C at Station 22.

Samples from the refuge areas indicate very limited diversity and dominance by mosquitofish and sunfishes. Both groups are relatively tolerant of high temperatures (Brown 1974 and Section 4.1 of this report), a necessary attribute for survival in the refuge areas, where temperatures can reach high levels and fluctuate widely due to changes in reactor operation and water level. The refuge areas constitute a potentially important source for recolonization of the thermal streams when temperatures drop to acceptable levels during periods of reactor outage or flooding.

4.3 OVERWINTERING

The basic objective of the overwintering study was to determine the extent to which fishes congregated in and around the thermal discharges during the winter months. To evaluate over-

Table 4-13. Number of fish and temperature (^{o}C) at creek refuge areas. These include Station 13 (Four Mile Creek - Road A), Station 14 (Four Mile Creek - Road A13), Station 21 (Pen Branch Creek - Road A13.2), and Station 22 (Pen Branch delta - boardwalk). November 1984 -August 1985.

Station	Species	Number	Percent	Temperature (^{o}C) Mean	Range
13	mosquitofish	100	100.0	18.2	11.1 - 27.7
14	mosquitofish	37	100.0	20.8	10.2 - 30.6
21	dollar sunfish	3	6.8	23.4	18.0 - 32.6
	unid. sunfish	25	56.8		
	mosquitofish	16	36.4		
	Total	44	100.0		
22	dollar sunfish	29	2.4	26.0	17.5 - 34.1
	spotted sunfish	5	0.4		
	redbreast sunfish	1	0.1		
	pirate perch	1	0.1		
	mosquitofish	1179	97.0		
	Total	1215	100.0		

NOTE: EFHNREF was used to compute the data presented in this table.

wintering in the thermal plumes, the study area was divided into four habitats:

1. River thermal plume area - sample stations on the South Carolina bank of the Savannah River just below the thermal discharges from Four Mile and Beaver Dam Creeks (mean of 14.7°C over all sampling dates, Table 4-14);

2. Nonthermal river (mean of 12.2°C);

3. Nonthermal creeks - Steel Creek (mean of 12.1°C) and Lower Three Runs Creek (mean of 11.8°C); and

4. Thermal creeks - Four Mile Creek (mean of 30.1°C) and Beaver Dam Creek (mean of 19.0°C).

4.3.1 Catch per Unit Effort in Thermal and Nonthermal Habitats

Sample stations were located in the mouth of Four Mile Creek and at two locations in the Four Mile Creek swamp (Zone 1, Zone 2, and Zone 3; Table 4-14). Mean electroshocking CPUE was highest in the mouth (1.2 fish/100 m; Table 4-15), considerably lower in the lower swamp station (Zone 2; 0.6 fish/100 m), and lowest at the upper swamp sample station (Zone 3; 0.3 fish/100 m). This trend in catch per unit effort was inversely correlated with temperature, which averaged 28.8°C in the mouth, 30.1°C at the lower swamp sample station, and 31.1°C (Table 4-14) at the upper swamp sample station. Largemouth bass, sunfishes, bowfin, gar, and gizzard shad were the dominant taxa.

Electroshocking CPUE at the three sample stations in Beaver Dam Creek exhibited a different pattern than CPUE in Four Mile Creek. The highest mean CPUE in Beaver Dam Creek was in the lower swamp (Zone 2) (4.8 fish/100 m; Table 4-16). Mean CPUE at the upper swamp sample station was lower (2.6 fish/100 m), and mean CPUE in the creek mouth was lowest (1.7 fish/100 m). Temperatures

Table 4-14. Mean (and range) of physical-chemical parameters measured at each sampling station during the fisheries overwintering sampling program. November 1984 - April 1985.

River Mile	N[a]	Temperature °C (min-max)	Dissolved oxygen mg O_2/L (min-max)	pH (min-max)	Conductivity µS/cm (min-max)	Alkalinity mg $CaCO_3$/L (min-max)	Current cm/sec (min-max)
River Transects							
128.9	104	12.5 (6.0- 21.3)	7.5 (5.5-10.6)	6.4 (4.8- 8.9)	78.9 (15.0- 94.0)	18.0 (12.3- 39.5)	81.6 (34.0-107.0)
129.1	108	12.5 (6.0- 19.3)	7.3 (5.2-10.2)	6.4 (4.8- 7.7)	79.6 (40.0-113.0)	17.1 (12.0- 19.8)	76.4 (38.0-120.0)
141.5	110	12.5 (5.1- 19.0)	8.1 (4.9-12.0)	6.7 (5.7- 8.3)	79.3 (55.0- 98.0)	17.2 (9.5- 21.0)	75.2 (41.0- 110.0)
141.7	105	12.6 (6.0- 19.5)	8.0 (5.6-11.3)	6.7 (5.8- 8.4)	76.5 (20.0- 99.0)	17.3 (11.0- 22.3)	82.8 (47.0- 115.0)
150.4 (GA)	53	11.6 (6.5- 17.5)	8.0 (6.1-10.2)	6.5 (4.3- 8.2)	74.1 (11.0- 96.0)	17.7 (12.8- 20.0)	79.9 (45.0- 122.0)
150.4 (SC)	53	15.6 (6.0- 36.6)	7.6 (5.6- 9.4)	6.4 (4.3- 8.0)	72.5 (35.0- 93.0)	16.4 (11.5- 18.8)	81.3 (45.0- 122.0)
150.8	113	12.2 (6.0- 18.4)	7.9 (6.0-10.2)	6.5 (4.8- 8.2)	76.3 (9.0- 99.0)	17.8 (13.3- 22.3)	79.8 (41.0- 133.0)
152.0 (GA)	60	11.6 (6.0- 17.6)	8.0 (4.5-10.4)	6.3 (4.9- 7.5)	72.9 (17.0- 94.0)	17.8 (13.0- 22.3)	79.2 (43.0- 109.0)
152.0 (SC)	47	13.7 (6.5- 18.5)	7.5 (5.7- 9.8)	6.3 (4.8- 7.5)	73.6 (30.0- 92.0)	17.1 (12.3- 19.8)	78.9 (43.0- 109.0)
152.2	96	11.7 (5.3- 17.2)	7.9 (4.8-10.0)	6.3 (4.7- 8.3)	72.6 (16.0- 94.0)	18.2 (12.5- 27.8)	79.4 (48.0- 125.0)

[a] Differences in sample size are largely due to differences in the number of replicates at each sample station rather than to differences in the frequency of sampling.
[b] Data nor collected.

Table 4-14. (continued). Mean (and range) of physical-chemical parameters measured at each sampling station during the fisheries overwintering sampling program. November 1984 - April 1985.

River Mile	N[a]	Temperature °C (min-max)	Dissolved oxygen mg O_2/L (min-max)	pH (min-max)	Conductivity µS/cm (min-max)	Alkalinity mg $CaCO_3$/L (min-max)	Current cm/sec (min-max)
			Creek Transects				
Lower Three Runs Creek							
129.0 (mouth)	54[a]	11.8 (5.0- 18.7)	7.3 (4.7-11.2)	6.4 (4.9- 7.7)	79.8 (20.0- 96.0)	30.0 (11.8- 39.5)	22.8 (4.0- 44.0)
Steel Creek							
141.6 (mouth)	56[a]	12.1 (4.4- 21.0)	7.6 (2.2-12.4)	6.8 (5.8- 8.1)	74.3 (49.0- 98.0)	17.2 (9.5- 21.5)	34.2 (5.0- 64.0)
Four Mile Creek							
Zone 3 (swamp)	19	31.1 (11.5- 39.8)	5.7 (4.0- 8.2)	6.8 (5.6- 7.9)	70.0 (17.0- 86.0)	13.6 (5.3- 18.5)	28.1 (2.0- 67.0)
Zone 2 (swamp)	18	30.1 (11.5- 38.0)	5.7 (1.2- 8.3)	6.6 (5.6- 8.0)	70.1 (17.0- 87.0)	13.7 (5.3- 18.5)	31.0 (10.0- 67.0)
Zone 1 (mouth)	16[a]	28.8 (11.5- 38.0)	5.8 (4.1- 7.5)	6.3 (5.2- 6.8)	68.4 (20.0- 84.0)	13.7 (5.3- 18.5)	32.7 (10.0- 67.0)
Beaver Dam							
Zone 3 (swamp)	18	19.8 (11.5- 24.6)	6.6 (2.8- 8.5)	5.9 (4.0- 7.9)	79.3 (39.0-104.0)	16.1 (11.3- 18.0)	46.6 (26.0- 78.0)
Zone 2 (swamp)	19	18.7 (10.9- 24.3)	6.2 (3.0- 8.7)	6.2 (4.8- 8.0)	80.9 (40.0- 99.0)	15.4 (7.3- 18.0)	32.1 (22.0- 78.0)
Zone 1 (mouth)	17[a]	18.6 (10.0- 25.5)	6.2 (2.8- 8.6)	6.2 (4.8- 7.2)	80.5 (40.0- 99.0)	15.2 (7.3- 18.0)	48.1 (10.0- 98.0)

NOTE: EPHNTE2B was used to compute the data presented in this table.

[a]There were three 100 m transects in the mouth of Lower Three Runs and Steel Creeks and one 100 m transect in the mouths of Beaver Dam and Four Mile Creek.

Table 4-15. Relative abundance and catch per unit effort (CPUE) of fishes caught by electrofishing at the three over-wintering electrofishing sampling zones in Four Mile Creek. November 1984 - April 1985.

Species	Zone 1 Mouth %	Zone 1 Mouth CPUE	Zone 2 Lower Swamp %	Zone 2 Lower Swamp CPUE	Zone 3 Upper Swamp %	Zone 3 Upper Swamp CPUE
spotted gar			7.7	0.05		
longnose gar	13.8	0.16	30.8	0.19		
bowfin	4.3	0.05	23.0	0.14	20.0	0.05
gizzard shad	31.9	0.37				
lake chubsucker	4.6	0.05				
spotted sucker	18.2	0.21				
redbreast sunfish			7.7	0.05	20.0	0.05
bluegill			7.7	0.05	20.0	0.05
largemouth bass	27.3	0.32	23.0	0.14	40.0	0.10
Total	100.1	1.16	99.9	0.62	100.0	0.25
Number collected	23		13		5	

NOTE: RIVERDAT5 was used to compute the data presented in this table.

Table 4-16. Relative abundance and catch per unit effort (CPUE) of fishes caught by electrofishing at the three over-wintering sampling zones in Beaver Dam Creek. November 1984 - April 1985.

Species	Zone 1 Mouth %	Zone 1 Mouth CPUE	Zone 2 Lower Swamp %	Zone 2 Lower Swamp CPUE	Zone 3 Upper Swamp %	Zone 3 Upper Swamp CPUE
longnose gar	2.9	0.05			5.3	0.14
bowfin	8.8	0.15	10.8	0.52		
American eel	2.9	0.05	1.0	0.05	3.8	0.10
blueback herring	2.9	0.05				
American shad			1.0	0.05		
gizzard shad	11.8	0.20	6.8	0.33	3.9	0.10
redfin pickerel			1.0	0.05		
chain pickerel	2.9	0.05	3.9	0.19		
spotted sucker	14.7	0.25	4.0	0.19	1.9	0.05
silver redhorse	2.9	0.05				
yellow bullhead			2.0	0.10		
flat bullhead	5.9	0.10	1.0	0.05		
channel catfish			1.0	0.05	3.9	0.10
pirate perch			1.0	0.05		
striped bass	2.9	0.05			2.0	0.05
flier	2.9	0.05				
redbreast sunfish	11.8	0.20	10.9	0.52	43.2	1.14
warmouth			5.0	0.24		
bluegill			4.0	0.19	2.0	0.05
dollar sunfish			3.0	0.14	2.0	0.05
redear sunfish	2.9	0.05	5.0	0.24	3.9	0.10
spotted sunfish	14.7	0.25	30.6	1.48	7.8	0.38
largemouth bass	8.8	0.15	5.9	0.29	15.7	0.38
black crappie			2.0	0.10		
Total	99.7	1.70	100.3	4.83	100.0	2.64
Number collected	34		103		51	

NOTE: RIVERDAT5 was used to compute the data presented in this table.

in Beaver Dam Creek were considerably lower than in Four Mile Creek, averaging 18.6°C in the mouth, 18.7°C at the lower swamp station, and 19.8°C at the upper swamp station (Table 4-14).

To obtain more information on overwintering in heated areas, CPUE was compared between thermal and nonthermal river sample stations and between thermal and nonthermal creeks. Only the creek mouth sample stations from the thermal creeks were used in this comparison, to make the thermal creek data more comparable with the nonthermal creek data.

Several species exhibited higher CPUEs in the thermal habitats than in the nonthermal habitats. Longnose gar were caught at higher rates in thermal habitats by both electrofishing and hoop netting. Mean hoop net CPUEs for this species ranged from 0.1 - 0.2 fish/net day in the nonthermal habitats in contrast to 0.4 - 0.6 fish/net day in the thermal habitats (Table 4-17). Comparable values for electrofishing were 0.00 - 0.01 fish/100 m in the nonthermal habitats and 0.03 - 0.16 fish/100 m in the thermal habitats (Table 4-18). The redear sunfish exhibited higher electrofishing and hoop netting CPUEs in the thermal river than in the nonthermal river and in mildly thermal Beaver Dam Creek than in the nonthermal creeks, although catch rates in the highly thermal Four Mile Creek were not particularly high. Like the redear sunfish, the channel catfish exhibited higher hoop netting CPUEs in the thermal river (0.32 fish/net day) than in the nonthermal river (0.08) and in Beaver Dam Creek (0.27) than in the nonthermal creeks (0.09), but exhibited only moderate catch rates

Table 4-17. Number, relative abundance, and catch per unit effort (CPUE; no./net/day) of fishes caught by hoop netting during the overwintering program in thermal and nonthermal areas of the Savannah River, and thermal and nonthermal tributary creeks on the SRP. November 1984 - April 1985.

Species	River						Creek								
	Nonthermal[a]			Thermal[b]			Nonthermal[c]			Four Mile			Beaver Dam		
	No.	%	CPUE	No.	%	CPUE	No.	%	CPUE	No.	%	CPUE	No.	%	DPUE
spotted gar	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
longnose gar	11	0.7	0.01	5	2.3	0.04	3	1.7	0.02	4	16.0	0.06	4	5.5	0.06
bowfin	17	1.1	0.02	3	1.4	0.02	2	1.1	0.02	2	8.0	0.03	2	2.7	0.03
American eel	8	0.5	0.01	1	0.5	0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
blueback herring	2	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	6	8.2	0.10
American shad	7	0.4	0.01	0	0.0	0.00	1	0.6	0.01	0	0.0	0.00	0	0.0	0.00
gizzard shad	23	1.5	0.03	0	0.0	0.00	4	2.2	0.03	0	0.0	0.00	1	1.4	0.02
unid. pickerel	2	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
chain pickerel	0	0.0	0.00	1	0.5	0.01	1	0.6	0.01	0	0.0	0.00	0	0.0	0.00
creek chubsucker	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	1	4.0	0.02	0	0.0	0.00
spotted sucker	46	2.9	0.05	3	1.4	0.02	7	3.9	0.06	0	0.0	0.00	0	0.0	0.00
northern hogsucker	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
silver redhorse	8	0.5	0.01	1	0.5	0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
white catfish	48	3.1	0.05	10	4.5	0.08	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
yellow bullhead	2	0.1	<0.01	2	0.9	0.02	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
brown bullhead	5	0.3	0.01	2	0.9	0.02	0	0.0	0.00	0	0.0	0.00	3	4.1	0.05
flat bullhead	966	61.5	1.10	73	33.2	0.58	85	47.5	0.67	0	0.0	0.00	13	17.8	0.21
channel catfish	74	4.7	0.08	40	18.2	0.32	11	6.1	0.09	4	16.0	0.06	17	23.3	0.27
striped bass	4	0.3	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
flier	10	0.6	0.01	4	1.8	0.03	1	0.6	0.01	0	0.0	0.00	4	5.5	0.06

[a]All sample stations on the river except those below Four Mile and Beaver Dam Creeks.
[b]RMs 150.4, below Four Mile Creek, and 152.0, below Beaver Dam Creek.
[c]Mouths of Steel Creek and Lower Three Runs Creek.
[d]Mouths of Four Mile and Beaver Dam Creeks.

Table 4-17. (continued). Number, relative abundance, and catch per unit effort (CPUE; no./net/day) of fishes caught by hoop netting during the overwintering program in thermal and nonthermal areas of the Savannah River, and thermal and nonthermal tributary creeks on the SRP. November 1984 - April 1985.

	River						Creek								
	Nonthermal[a]			Thermal[b]			Nonthermal[c]			Four Mile			Beaver Dam		
Species	No.	%	CPUE	No.	%	CPUE	No.	%	CPUE	No.	%	CPUE	No.	%	CPUE
redbreast sunfish	124	7.9	0.14	17	7.7	0.13	31	17.3	0.25	1	4.0	0.02	5	6.8	0.08
green sunfish	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
pumpkinseed	3	0.2	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
warmouth	10	0.6	0.01	2	0.9	0.02	3	1.7	0.02	0	0.0	0.00	0	0.0	0.00
bluegill	78	5.0	0.09	19	8.6	0.15	11	6.1	0.09	7	28.0	0.11	2	2.7	0.03
dollar sunfish	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
redear sunfish	32	2.0	0.04	16	7.3	0.13	5	2.8	0.04	4	16.0	0.06	6	8.2	0.10
spotted sunfish	26	1.7	0.03	10	4.5	0.08	5	2.8	0.04	0	0.0	0.00	0	0.0	0.00
Lepomis sp.	5	0.3	0.01	1	0.5	0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
largemouth bass	1	0.1	<0.01	0	0.0	0.00	1	0.6	0.01	0	0.0	0.00	0	0.0	0.00
black crappie	44	2.8	0.05	10	4.5	0.08	2	1.1	0.02	2	8.0	0.03	10	13.7	0.16
yellow perch	9	0.6	0.01	0	0.0	0.00	6	3.4	0.05	0	0.0	0.00	0	0.0	0.00
striped mullet	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
hogchoker	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
Totals	1571	100.2	1.77	220	100.1	1.76	179	100.1	1.44	25	100.0	0.39	73	99.9	1.17
Number of species	31			18			17			8			12		
Number of nets set per week in each area	14			2			2			1			1		

NOTE: RIVERDAT2 was used to compute the data presented in this table.

[a]All sample stations on the river except those below Four Mile and Beaver Dam Creeks.
[b]RMs 150.4, below Four Mile Creek, and 152.0, below Beaver Dam Creek.
[c]Mouths of Steel Creek and Lower Three Runs Creek.
[d]Mouths of Four Mile and Beaver Dam Creeks.

Table 4-18. Number, relative abundance, and catch per unit effort (CPUE; no./100 m) of fishes caught by electrofishing during the overwintering program in thermal and nonthermal areas of the Savannah River, and thermal and nonthermal tributary creeks on the SRP. November 1984 - April 1985.

	River						Creek								
	Nonthermal[a]			Thermal[b]			Nonthermal[c]			Four Mile			Beaver Dam		
Species	No.	%	CPUE	No.	%	CPUE	No.	%	CPUE	No.	%	CPUE	No.	%	CPUE
spotted gar	3	0.2	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
longnose gar	13	0.8	0.01	4	0.7	0.03	1	0.3	0.01	3	13.6	0.16	1	2.9	0.05
bowfin	106	6.6	0.12	19	3.3	0.15	16	5.4	0.13	1	4.6	0.05	3	8.8	0.15
American eel	35	2.2	0.04	4	0.7	0.03	58	19.7	0.46	0	0.0	0.00	1	2.9	0.05
blueback herring	6	0.4	0.01	1	0.2	0.01	0	0.0	0.00	0	0.0	0.00	1	2.9	0.05
American shad	18	1.1	0.02	6	1.1	0.05	4	1.4	0.03	0	0.0	0.00	0	0.0	0.00
gizzard shad	28	1.8	0.03	48	8.4	0.38	14	4.8	0.11	7	31.8	0.37	4	11.8	0.20
threadfin shad	0	0.0	0.00	94	16.4	0.75	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
redfin pickerel	12	0.8	0.01	2	0.4	0.02	3	1.0	0.02	0	0.0	0.00	0	0.0	0.00
chain pickerel	13	0.8	0.01	4	0.7	0.03	1	0.3	0.01	0	0.0	0.00	1	2.9	0.05
quillback carpsucker	1	0.1	<0.01	1	0.2	0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
highfin carpsucker	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
lake chubsucker	1	0.1	<0.01	1	0.2	0.01	0	0.0	0.00	1	4.6	0.05	0	0.0	0.00
spotted sucker	207	13.0	0.23	99	17.3	0.79	56	19.0	0.44	4	18.2	0.21	5	14.7	0.25
unid. chubsucker	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
northern hogsucker	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
silver redhorse	3	0.2	<0.01	1	0.2	0.01	0	0.0	0.00	0	0.0	0.00	1	2.9	0.05
snail bullhead	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
white catfish	2	0.1	<0.01	1	0.2	0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
yellow bullhead	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
brown bullhead	0	0.0	0.00	1	0.2	0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
flat bullhead	5	0.3	0.01	0	0.0	0.00	7	2.4	0.06	0	0.0	0.00	2	5.9	0.10
channel catfish	3	0.2	<0.01	3	0.5	0.02	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00

[a] All sample stations on the river except those below Four Mile and Beaver Dam Creeks.
[b] RM 150.4, below Four Mile Creek, and 152.0, below Beaver Dam Creek.
[c] Mouths of Steel Creek and Lower Three Runs Creek.
[d] Mouths of Four Mile and Beaver Dam Creeks.

Table 4-18. (continued). Number, relative abundance, and catch per unit effort (CPUE; no./100 m) of fishes caught by electrofishing during the overwintering program in thermal and nonthermal areas of the Savannah River, and thermal and nonthermal tributary creeks on the SRP. November 1984 - April 1985.

	River						Creek								
	Nonthermal[a]			Thermal[b]			Nonthermal[c]			Four Mile			Beaver Dam		
Species	No.	%	CPUE	No.	%	CPUE	No.	%	CPUE	No.	%	CPUE	No.	%	CPUE
pirate perch	62	3.9	0.07	5	0.9	0.04	15	5.1	0.12	0	0.0	0.00	0	0.0	0.00
striped bass	15	0.9	0.02	15	2.6	0.12	2	0.7	0.02	0	0.0	0.00	1	2.9	0.05
flier	3	0.2	<0.01	1	0.2	0.01	1	0.3	0.01	0	0.0	0.00	1	2.9	0.05
bluespotted sunfish	2	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
redbreast sunfish	355	22.2	0.40	74	13.0	0.59	37	12.6	0.29	0	0.0	0.00	4	11.8	0.20
pumpkinseed	2	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
warmouth	38	2.4	0.04	2	0.4	0.02	8	2.7	0.06	0	0.0	0.00	0	0.0	0.00
bluegill	102	6.4	0.12	24	4.2	0.19	20	6.8	0.16	0	0.0	0.00	0	0.0	0.00
dollar sunfish	15	0.9	0.02	6	1.1	0.05	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
redear sunfish	42	2.6	0.05	18	3.2	0.14	3	1.0	0.02	0	0.0	0.00	1	2.9	0.05
spotted sunfish	250	15.7	0.28	35	6.1	0.28	12	4.1	0.10	0	0.0	0.00	5	14.7	0.25
Lepomis sp.	5	0.3	0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
redeye bass	3	0.2	<0.01	1	0.2	0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
largemouth bass	140	8.8	0.16	47	8.2	0.37	26	8.8	0.21	6	27.3	0.32	3	8.8	0.15
black crappie	18	1.1	0.02	8	1.4	0.06	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
yellow perch	33	2.1	0.04	4	0.7	0.03	10	3.4	0.08	0	0.0	0.00	0	0.0	0.00
striped mullet	44	2.8	0.05	42	7.4	0.33	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
hogchoker	7	0.4	0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
Totals	1596	100.2	1.78	571	100.3	4.55	294	99.8	2.34	22	100.1	1.16	33	99.7	1.70
Number of Species	36			30			19			6			15		
Number of 100 m electoshocking sections	42			6			6			1			1		

NOTE: RIVERDAT2 was used to compute the data presented in this table.

[a]All sample stations on the river except those below Four Mile and Beaver Dam Creeks.
[b]RM 150.4, below Four Mile Creek, and 152.0, below Beaver Dam Creek.
[c]Mouths of Steel Creek and Lower Three Runs Creek.
[d]Mouths of Four Mile and Beaver Dam Creeks.

in Four Mile Creek (0.06). Other taxa that exhibited relatively high catch rates in the thermal habitats were the bluegill and gizzard shad, although for the latter taxa this tendency was indicated only by the electrofishing samples. Most of the species that exhibited higher catch rates in the thermal habitats during 1985 exhibited the same pattern during 1984 (Paller and Osteen, 1985).

While some species tended to congregate in the heated habitats, many species did not, and some seemed to avoid them. Hoop netting CPUE for the flat bullhead ranged from 0.67 - 1.10 fish/net day in the nonthermal habitats, compared with 0.00 - 0.58 fish/net day in the thermal habitats (Table 4-18). American eels exhibited much lower catch rates in the thermal creeks (0.00 - 0.05 fish/100 m, Table 4-17) than in the nonthermal creeks (0.46 fish/100 m). Spotted suckers exhibited higher electrofishing catch rates at the thermal river sample stations (0.79 fish/100 m) than at the nonthermal river sample stations (0.23 fish/100 m), but exhibited lower catch rates in the thermal creeks (0.21-0.25 fish/100 m) than in the nonthermal creeks (0.44 fish/100 m). The flat bullhead, American eel, and spotted sucker exhibited relatively low catch rates in the thermal habitats during 1984 (Paller and Osteen 1985). Other taxa that exhibited low catch rates in the thermal creeks were the yellow perch and pirate perch.

4.3.2 Temporal Changes in Thermal and Nonthermal Habitats

4.3.2.1 Electrofishing Catch per Unit Effort

To analyze temporal changes in fish distribution during the winter, CPUE (all species together) in the nonthermal and thermal habitats was calculated for each week of the study. While electrofishing CPUE was quite variable on a weekly basis in both the thermal and nonthermal creek mouths, there was a tendency towards lower catch rates in Four Mile Creek (Figure 4-7). The mean catch rate in the mouth of Four Mile Creek over all sampling dates was 1.2 fish/100 m, compared with 2.3 in the mouth of Steel Creek and 2.9 in the mouth of Lower Three Runs Creek (Table 4-19). These differences were not significant (at $p \leq 0.05$), however, because of temporal variations in catch rate. During the winter of 1983/1984, in contrast, fish appeared to congregate in Four Mile Creek (Paller and Osteen 1985). The low catch rates in Four Mile Creek during the winter of 1984/1985 may have been related to high temperatures (sometimes exceeding 35°C). Such extreme temperatures repel fishes rather than attract them (Brown 1974). During 1983/1984, in contrast, temperatures in Four Mile Creek were comparatively moderate (under 15°C) during all of February and much of January and March. During November 1983 and April 1984, when water temperatures often exceeded 30°C, catch rates were comparatively low.

Temperatures in Beaver Dam Creek were considerably lower than in Four Mile Creek, never exceeding 25°C and generally remaining 5 - 10°C above the temperatures in the nonthermal creeks (Figure 4-

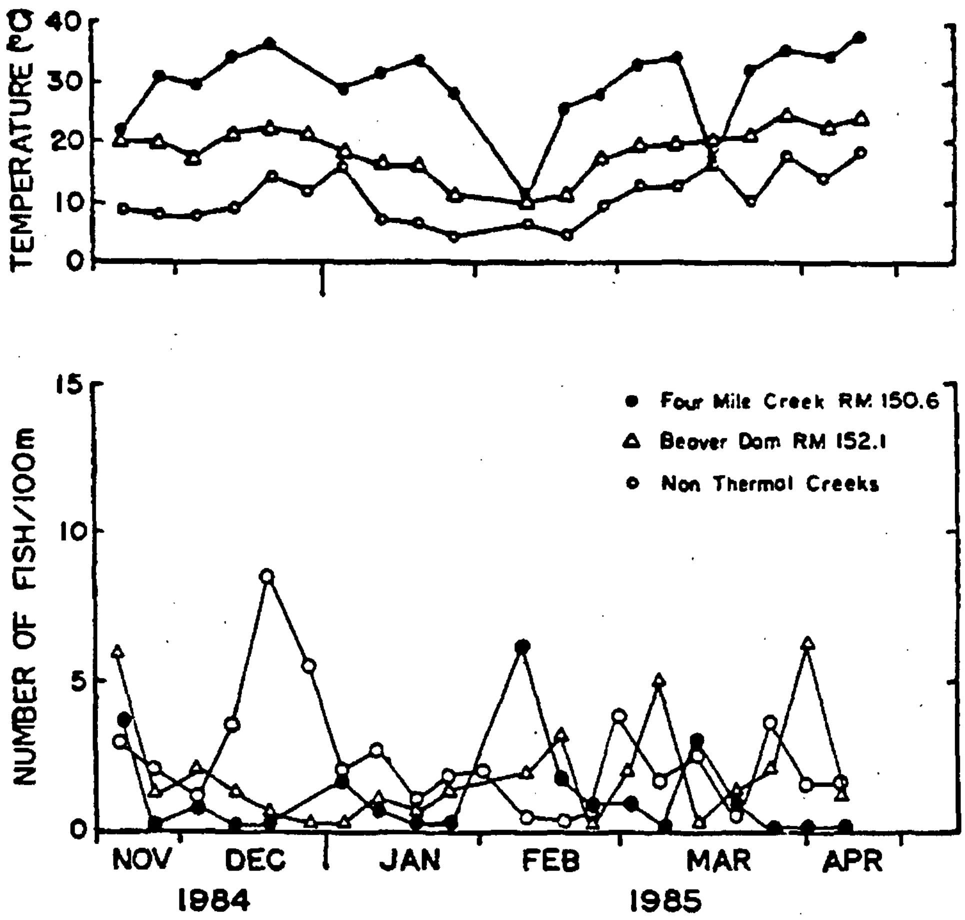

Figure 4-7. Mean number of fish/100 m collected by electrofishing and mean temperature (°C) in Four Mile Creek, Beaver Dam Creek, and the nonthermal creeks (Upper Three Runs Creek, Steel Creek, Lower Three Runs Creek; RIVERDAT3 and RIVERDAT4). November 1984 - August 1985.

Table 4-19. Mean electrofishing catch per unit effort (no./100 m) at habitats sampled during the overwintering study. November 1984 - April 1985.

Habitat	Mean	n[a]	Standard Error	Coefficient of Variation	Range
Beaver Dam Creek	1.7	20	0.4	113.1	0- 6
Four Mile Creek	1.2	19	0.4	141.8	0- 6
Steel Creek	2.3	63	0.3	111.4	0-11
Lower Three Runs Creek	2.9	63	0.5	139.7	0-22
Thermal River[b]	4.6	126	0.7	151.9	0-73
Nonthermal River[c]	1.8	881	0.1	156.0	0-27

NOTE: RIVERDAT1 was used to compute the data presented in this table.

[a]Differences in sample size reflect differences in the number of replicates taken in each area, not differences in sampling frequency.
[b]RMs 150.4, below Four Mile Creek, and 152.0, below Beaver Dam Creek.
[c]All other river transects.

7). Catch rates in Beaver Dam Creek were variable, but usually exceeded those in Four Mile Creek. The mean catch rate in the mouth of Beaver Dam Creek over all sampling dates was 1.7 fish/100 m, compared with 2.3 fish/100 m in Steel Creek and 2.9 fish/100 m in Lower Three Runs Creek (Table 4-19). Differences between Beaver Dam Creek and the nonthermal creeks were not significant at $p \leq 0.05$ (Appendix 3 Table 5).

The thermal river sample stations were generally 2 - 3°C warmer than the nonthermal river sample stations (Figure 4-8). Electrofishing catch rates in the thermal river habitat were highly variable, but almost always higher than the catch rates in the nonthermal river habitat (Figure 4-8). The mean electrofishing catch rate over all overwintering sample dates was 4.6 fish/100 m at the thermal river sample stations, compared with 1.8 fish/100 m at the nonthermal river sample stations (Table 4-19). Higher catch rates at the thermal river sample stations than at the nonthermal river sample stations were also observed during the winter of 1983/1984 (Paller and Osteen 1984).

In summary, the 1984/1985 overwintering electrofishing data suggests some congregation of fishes in the mildly heated reaches of the Savannah River just below the thermal creeks but no overall aggregation in mildly thermal Beaver Dam Creek. In contrast, most fishes avoided Four Mile Creek, which was often heated to temperatures in excess of 35°C. Responses to thermal habitats varied among species, with some species attracted to thermal areas and others avoiding them. Except for less aggregation in the

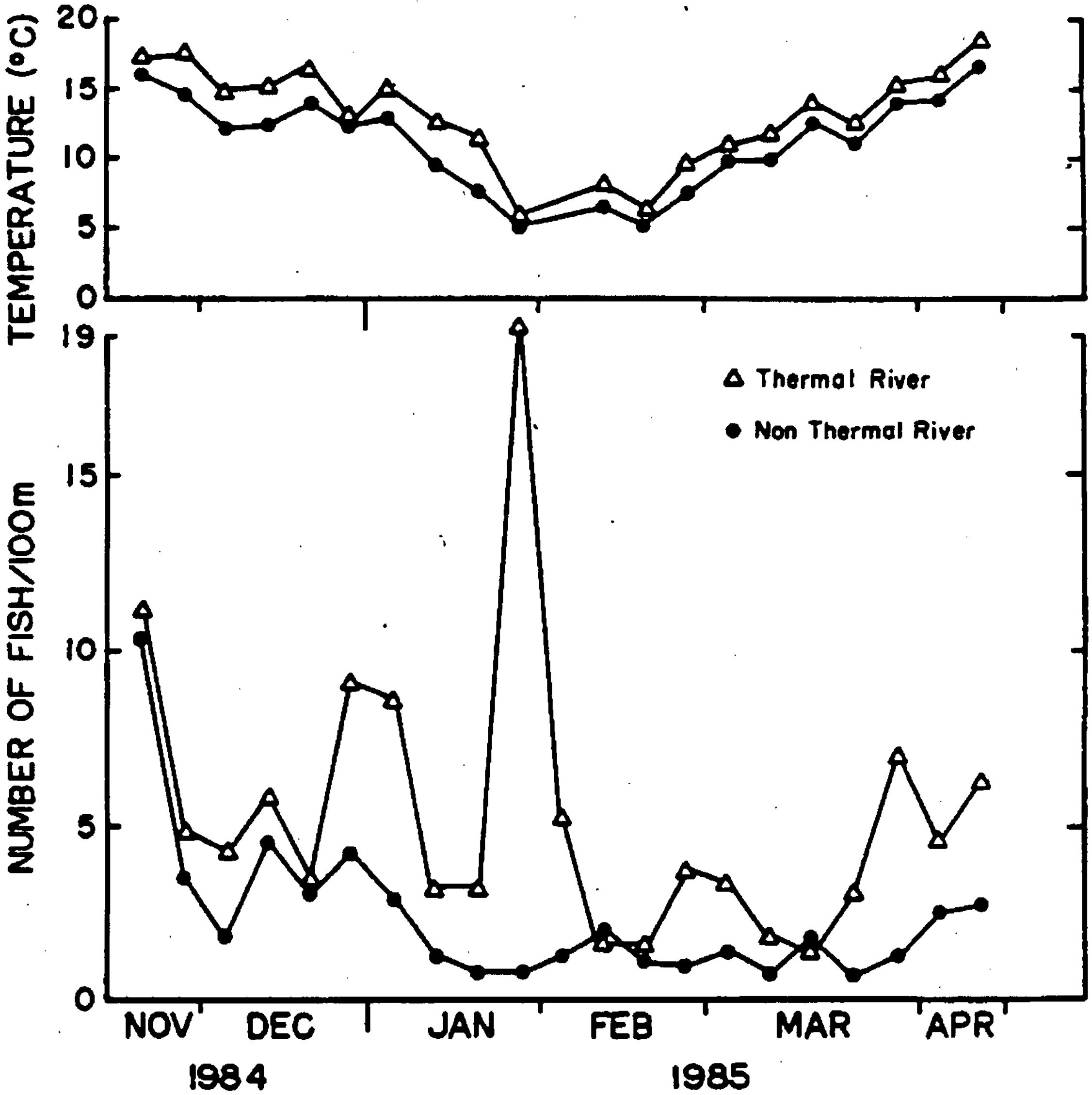

Figure 4-8. Mean number of fish/100 m collected by electrofishing and mean temperature (°C) in thermal and nonthermal areas of the Savannah River (RIVERDAT3 and RIVERDAT4). November 1984 - August 1985.

thermal creeks during the winter of 1984/1985, these findings are fairly similar to those of the 1983/1984 over-wintering programs.

4.3.2.2 Hoop Netting Catch per Unit Effort

Hoop netting CPUE was more variable than electrofishing CPUE. Because of this high variability, the data from the two thermal creeks (Four Mile Creek and Beaver Dam Creek) were averaged together in the graphic presentations to improve clarity. While CPUE in the thermal and nonthermal creek mouths overlapped somewhat, there was a clear tendency towards higher CPUEs in the nonthermal creeks (Table 4-20). CPUE in the nonthermal creeks was higher than CPUE in the thermal creeks on 17 of the 21 sample dates (Figure 4-9).

Like the catches from the thermal and nonthermal creeks, hoop netting catches from the thermal and nonthermal river sample stations were highly variable (Table 4-20; Figure 4-10). CPUE in the two habitats overlapped considerably and exhibited no consistent differences. These results were different from the electrofishing results, which indicated congregation in portions of the river heated by the thermal discharges.

The results of the hoop net program differed from the results of the electrofishing program, the latter suggesting that fish congregated to varying degrees in the thermal river habitats. The high variation of the hoop netting catches may partly account for the discrepancy between electrofishing and hoop netting results. Another factor is that hoop netting was selective for species such

Table 4-20. Mean hoop net catch per unit effort (no./net day) at habitats sampled during the overwintering study. November 1984 - April 1985.

Habitat	Mean	n[a]	Standard Error	Coefficient of Variation	Range
Beaver Dam Creek	1.2	63	0.2	129.9	0 - 6
Four Mile Creek	0.4	63	0.1	179.1	0 - 2
Steel Creek	0.7	60	0.2	192.0	0 - 6
Lower Three Runs Creek	2.3	62	0.4	149.2	0 -16
Thermal River	1.8	126	0.2	140.5	0 -17
Nonthermal River[c]	1.8	873	0.1	205.6	0 -39

NOTE: RIVERDAT1 was used to compute the data presented in this table.

[a]Differences in sample size reflect differences in the number of replicates taken in each area, not differences in sampling frequency.
[b]RMs 150.4, below Four Mile Creek, and 152.0, below Beaver Dam Creek.
[c]All other river transects.

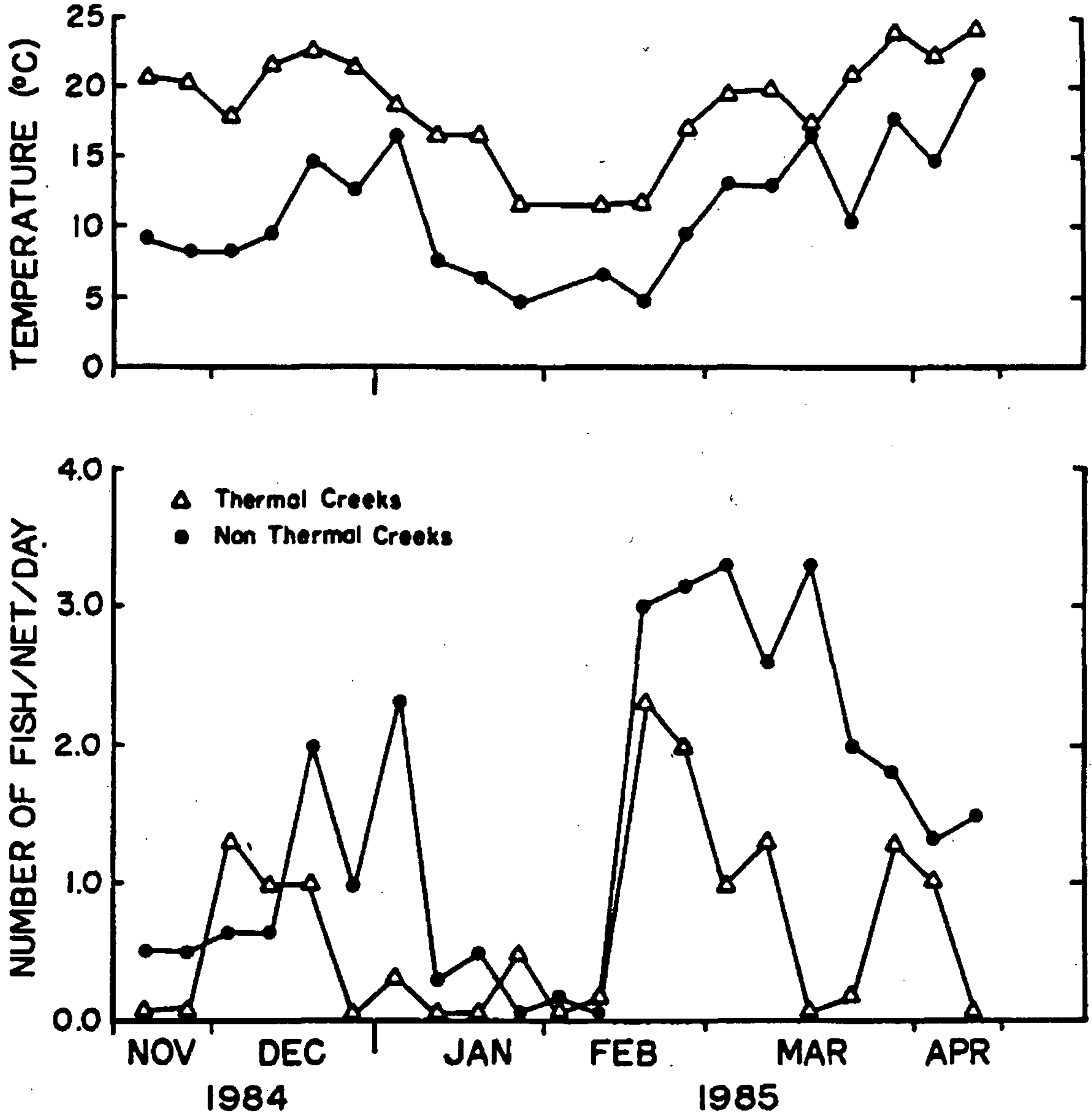

Figure 4-9. Mean number of fish/net day collected by hoop netting and mean temperature (°C) in thermal (Beaver Dam Creek, Four Mile Creek) and nonthermal (Steel Creek and Lower Three Runs Creek) creeks (RIVERDAT3 and RIVERDAT4). November 1984 - August 1985.

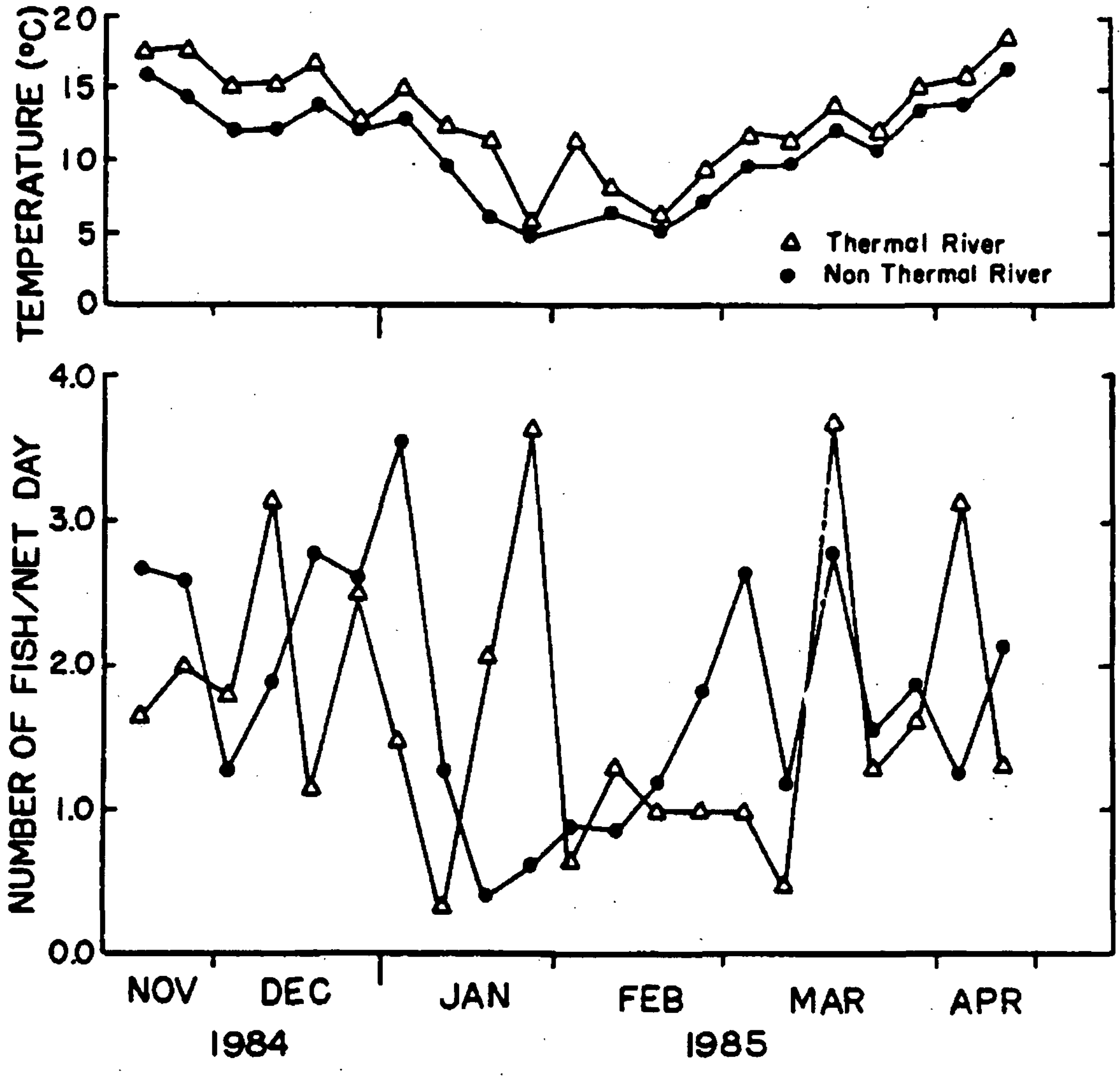

Figure 4-10. Mean number of fish/net day collected by hoop netting and mean temperature (°C) in thermal (RM 150.4 and RM 152.0) and nonthermal (all other river transects) river transects (RIVERDAT3 and RIVERDAT4). November 1984 - August 1985.

as the flat bullhead, which avoided high temperatures while electrofishing was selective for species, such as the largemouth bass and sunfishes, which were attracted to, or at least did not avoid, high temperatures.

4.3.3 Coefficient of Condition

The congregation of fishes in the thermal areas during the winter suggested the possibility of negative effects due to temperature-induced increases in metabolic rate. The latter factor could raise food requirements at a time when natural food production might be low. The overall condition of fishes is often evaluated with the coefficient of condition (K), a length-weight relationship expressing the relative corpulence of fish as calculated by K = weight (g) x 100 / length (cm) (Bennett 1972). High condition factors are usually equated with high food intake, good potential for growth, and generally healthy conditions; low condition factors generally indicate insufficient food intake and/or possible environmental stress. Coefficients of condition were calculated for eight species collected from both the thermal and nonthermal creeks in large enough numbers for analysis. Most of the fishes in the thermal creek category were from Beaver Dam Creek because the catch from Four Mile Creek was so low. Calculations were based on total fish length as opposed to standard length.

Mean coefficients of condition in the thermal creeks were 1.18 for the spotted sucker, 1.75 for the redear sunfish, 0.78 for the channel catfish, 1.08 for the flat bullhead, 1.15 for the largemouth bass, 0.97 for the gizzard shad, 1.91 for the bluegill, and 1.55 for the redbreast sunfish (Table 4-21). Mean condition factors in the nonthermal creeks were 1.11 for the spotted sucker, 1.89 for the redear sunfish, 1.05 for the channel catfish, 1.22 for the flat bullhead, 1.19 for the largemouth bass, 1.14 for the gizzard shad, 1.67 for the bluegill, and 1.67 for the redbreast sunfish. Gizzard shad and channel catfish exhibited significantly ($p \leq 0.05$) lower condition in the thermal creeks (Table 4-21); in contrast, bluegill exhibited significantly higher ($p \leq 0.05$) condition in the thermal creeks than in the nonthermal creeks. None of the fishes exhibited obvious external differences in disease or parasitism between the thermal and nonthermal habitats.

The preceding comparisons indicate that gizzard shad and channel catfish overwintering in the thermal creeks during 1985/1986 suffered reduced condition. Lower condition in the thermal creeks may be related to increased metabolic rates, hence greater food demand in relation to supply. Marcy (1976) reported that catfish overwintering in a heated power plant discharge canal exhibited reduced condition and growth. Gibbons et al. (1978) indicated that largemouth bass occupying heated areas in Par Pond exhibited lower condition (K) than largemouth bass in cooler portions of the reservoir, presumably because of increased metabolic rates at higher temperatures.

4.4 TEMPERATURE AND FISH OCCURRENCE

The relationship between elevated temperatures and the distribution of adult and juvenile fishes was illustrated by plotting

Table 4-21. Mean (± 1 standard error) coefficient of condition (K) for selected species of fish in thermal and nonthermal creeks on the Savannah River Plant. November 1984 - August 1985.

Species	Thermal Creeks[a]			Nonthermal Creeks[b]			T-test for K
	Mean K	Mean length (cm)	N	Mean K	Mean length (cm)	N	
gizzard shad	0.97 (0.05)	32.6 (0.7)	19	1.14 (0.05)	36.0 (1.4)	14	2.30*
spotted sucker	1.18 (0.01)	30.3 (2.8)	14	1.11 (0.03)	35.8 (2.6)	56	1.82
flat bullhead	1.08 (0.07)	22.5 (0.6)	13	1.22 (0.06)	23.5 (0.4)	84	1.55
channel catfish	0.78 (0.02)	35.6 (2.4)	20	1.05 (0.08)	45.0 (4.0)	11	3.24*
redbreast sunfish	1.55 (0.06)	15.5 (1.0)	38	1.67 (0.05)	16.7 (0.8)	35	1.11
bluegill sunfish	1.91 (0.05)	17.0 (1.1)	7	1.67 (0.07)	15.7 (1.2)	15	2.14*
redear sunfish	1.75 (0.07)	21.8 (0.7)	12	1.89 (0.14)	22.2 (1.4)	6	1.00
largemouth bass	1.15 (0.06)	26.8 (3.1)	27	1.19 (0.04)	31.5 (4.1)	26	0.65

NOTE: K3 and K4 were used to compute the data presented in this table.

*Significant at $p \leq 0.05$.

[a]Four Mile Creek and Beaver Dam Creek.
[b]Steel Creek and Lower Three Runs Creek.

electrofisning CPUE and related parameters against temperature. All data used in this analysis were collected from tne sample station, in the mouth of Four Mile Creek. Use of data from only this station, rather than from several different stations, permitted comparisons between catch rates at different temperatures without introducing the confounding effects of habitat differences between stations.

Data from the Four Mile Creek mouth were collected on 74 sample dates encompassing three years of study and two sampling programs (quarterly and overwintering). From one to three contiguous 100 m zones were sampled on each sampling date. Three zones were sampled on 37 dates, two zones on eight dates, and one zone on 29 dates. CPUE was calculated for every sampling date individually. When more than one zone was sampled on a given date, tne CPUE values for each zone were averaged together to give a single mean value for the date. Unlike CPUE, species number and Shannon-Weaver species diversity (H') were only calculated for dates on which three zones were sampled. Dates on which one or two zones were sampled were excluded because the number of species captured may have been directly proportional to the area sampled (Odum 1971).

CPUE in the mouth of Four Mile Creek was highly variable at temperatures below approximately 30°C, ranging from 0.0 - 8.0 fish/100 m (Figure 4-11). While fairly high CPUEs (up to 5.5 fish/100 m) occurred at temperatures from 30 - 35°C, the percentage of zero catches (60%) was considerably higher than the per-

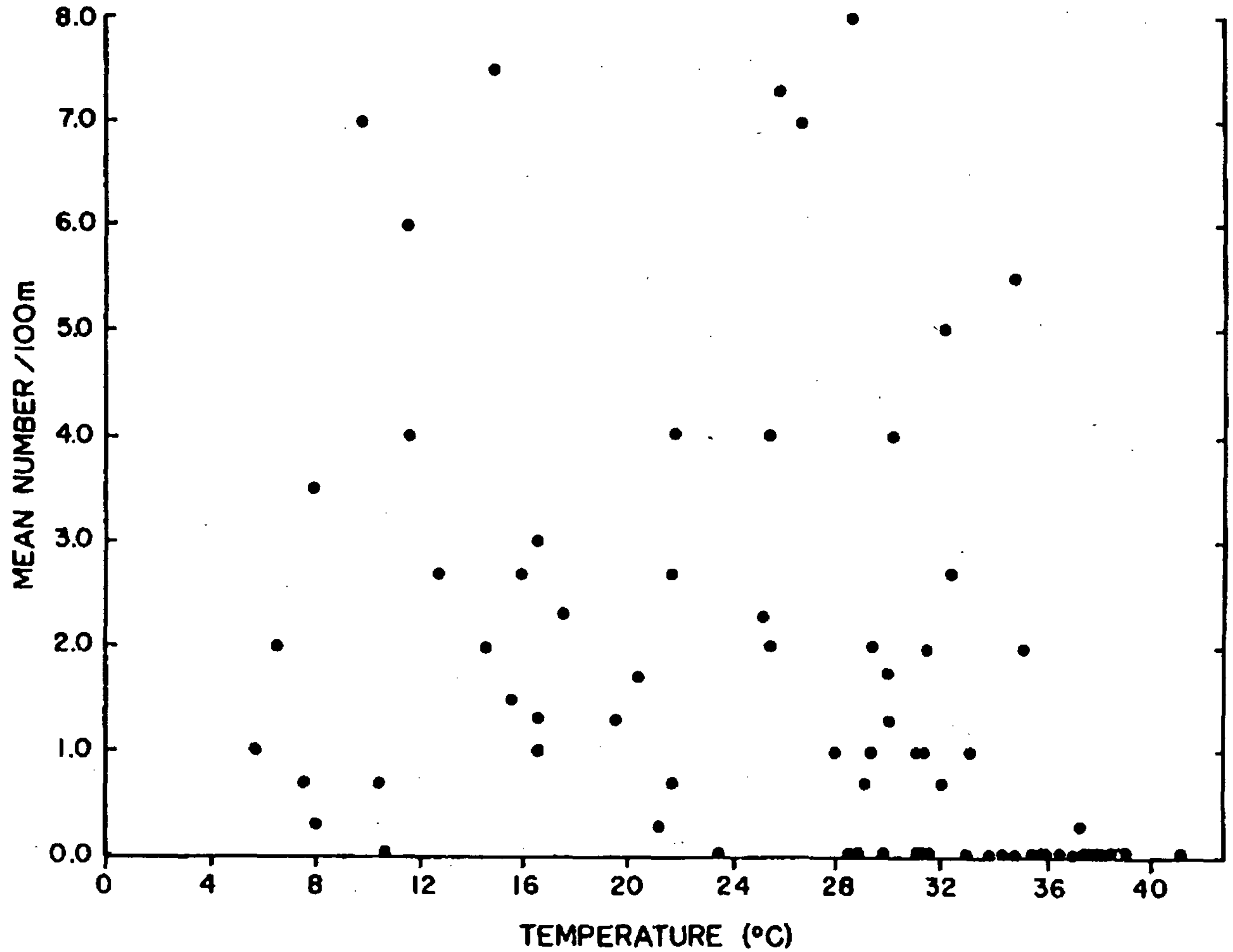

Figure 4-11. Mean number of fish/100 m collected by electrofishing at different temperatures in the mouth of Four Mile Creek (FGRPT82, FGRPT83, FGRPT84, FGRPT3). November 1984 - August 1985.

centage of zero catches at temperatures below 30°C (10.5%). At temperatures above 35°C, CPUE was generally 0.0 fish/100 m. These data indicate that 35°C is the upper temperature limit for the fishes that occur in Four Mile Creek. Temperatures between 30 and 35°C appear able to support relatively large numbers of at least some species. The comparatively large number of zero catches in this range may be related to temperature fluctuations in Four Mile Creek. Occasional temperatures in excess of 35°C near the time of sampling may have temporarily driven fish from the mouth of Four Mile Creek, even though temperatures were slightly below 35°C at the time of sampling.

The taxa most abundant at temperatures approaching 35°C were sunfishes, largemouth bass, gar, and shad (Dorosoma spp., Figure 4-12). Centrarchids (sunfish and bass) were particularly dominant at high temperatures, and most centrarchid species collected at relatively low temperatures were also collected at temperatures near 35°C. In addition to largemouth bass, these included the spotted sunfish, warmouth, redbreast sunfish, redear sunfish, and bluespotted sunfish (Figure 4-13). Bluegill were not collected at temperatures above 30°C, although this may have been due more to chance than to temperature tolerance, since reported temperature preferenda for bluegill range as high as 32.3°C (Fry and Pearson 1952, cited in Brown 1974).

Shannon-Weaver diversity and species richness are often used to evaluate stress in biological communities (Odum 1971). These parameters were calculated for the sample dates on which three

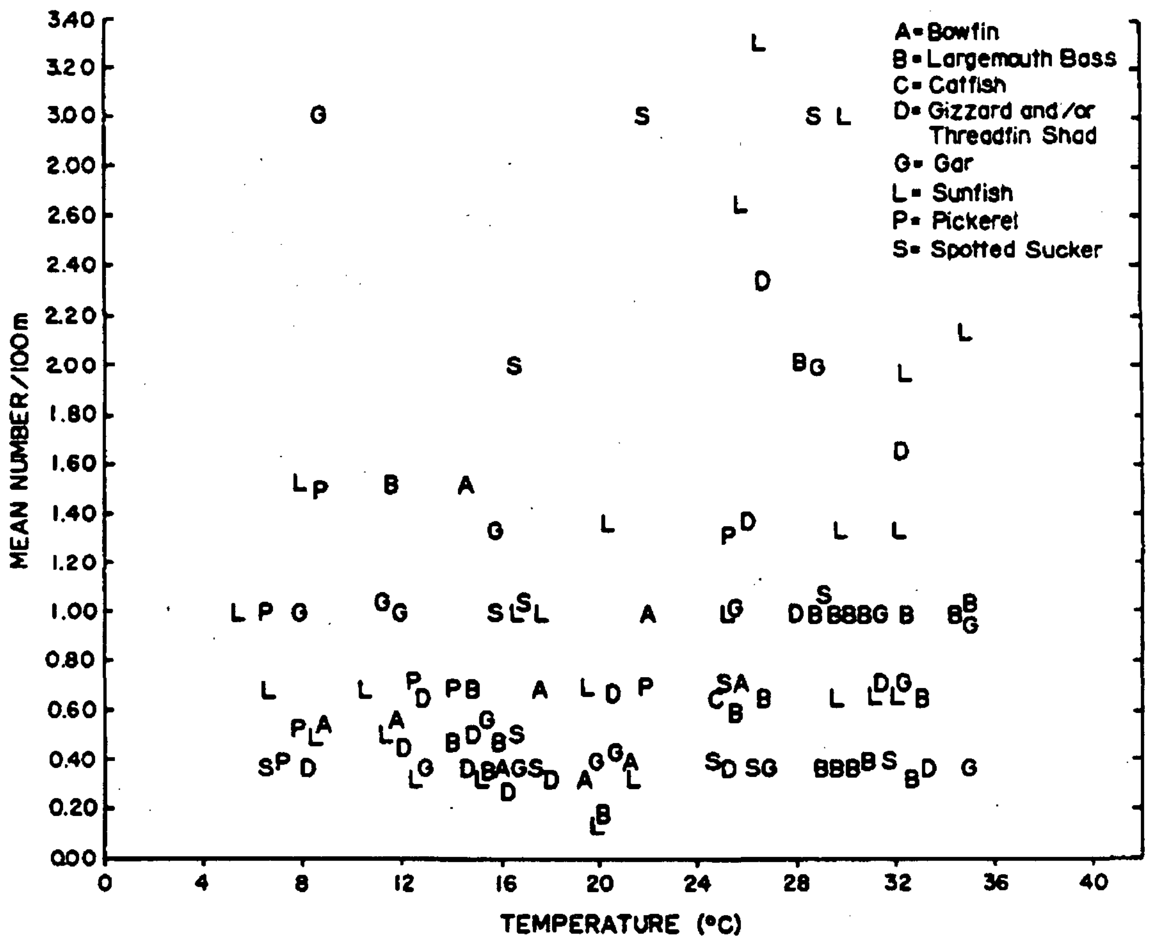

Figure 4-12. Mean number of fishes/100 m for common species collected by electrofishing at different temperatures (°C) in the mouth of Four Mile Creek (FGRPT82, FGRPT83, FGRPT84, FGRPT3). November 1984 - August 1985.

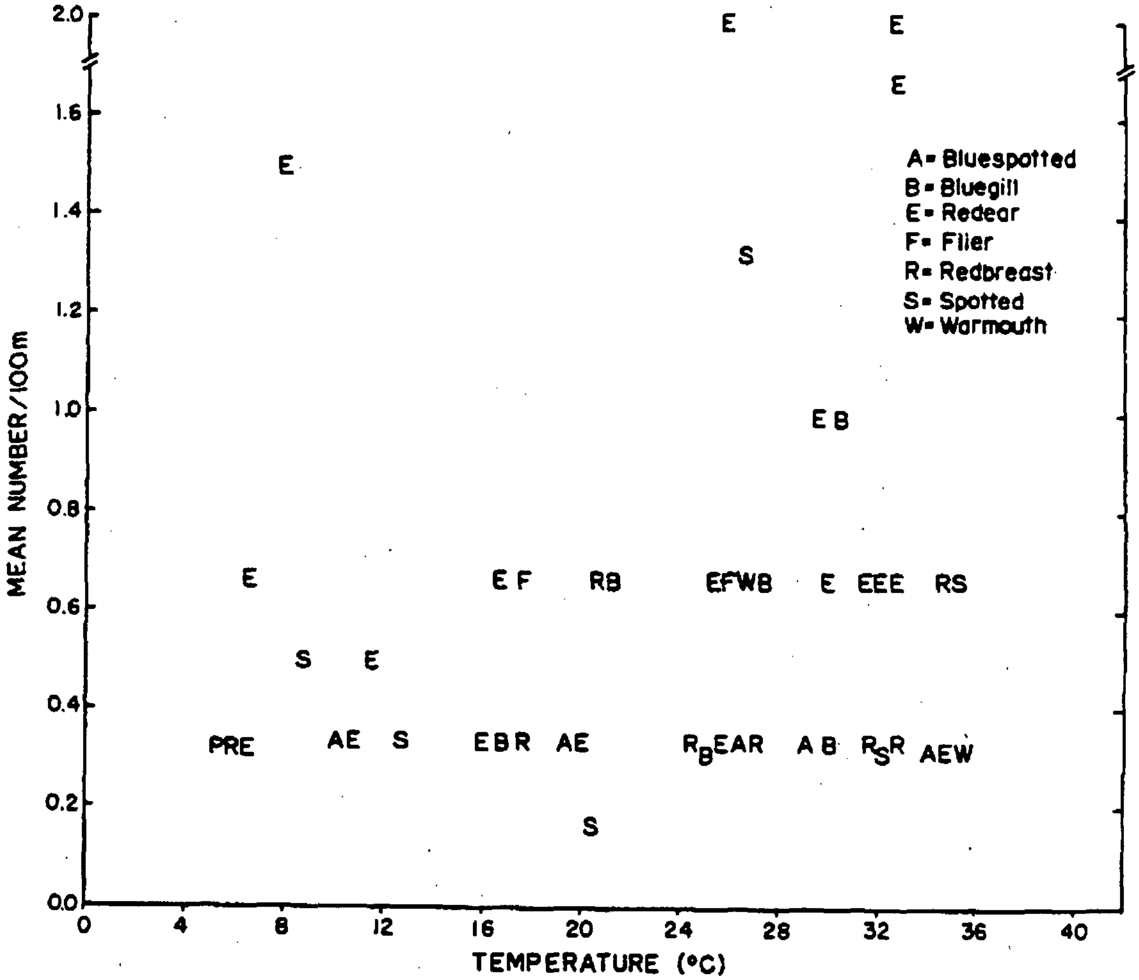

Figure 4-13. Mean number of sunfish/100 m collected by electrofishing at different temperatures in the mouth of Four Mile Creek (FGRPT82, FGRPT83, FGRPT84, FGRPT3). November 1984 - August 1985.

zones were sampled. As with CPUE, both parameters were highly variable and unrelated to temperature at temperatures below 35°C and zero at temperatures above 35°C (Figures 4-14 and 4-15).

The 35°C upper temperature limit established for adult and juvenile fishes in Four Mile Creek corresponds with the 35°C upper temperature limit previously established for ichthyoplankton in the SRP creeks and swamps (Paller et al. 1986). However, ichthyoplankton catch rates were depressed at temperatures between approximately 27 and 35°C, with some taxa absent from this temperature range and most others reduced in abundance. As with the adult fishes, centrarchids were the most abundant identifiable ichthyoplankton at temperatures approaching 35°C. These data suggest that temperatures in the 30 - 35°C range are able to support a relatively diverse community of adult fishes, but lower temperatures may be required for the reproduction of some species, particularly non-centrarchids. Results very similar to those observed in Four Mile Creek were reported by Marcy (1976) for fishes in the heated discharge canal of a nuclear power plant on the Connecticut River. Marcy (1976) found that the majority of the fishes left the canal when the water temperature reached approximately 35°C, but returned immediately after as little as a one-degree drop in temperature. Gammon (1971) also found the same critical temperature and temperature response among the more thermally tolerant fishes in the Wabash River.

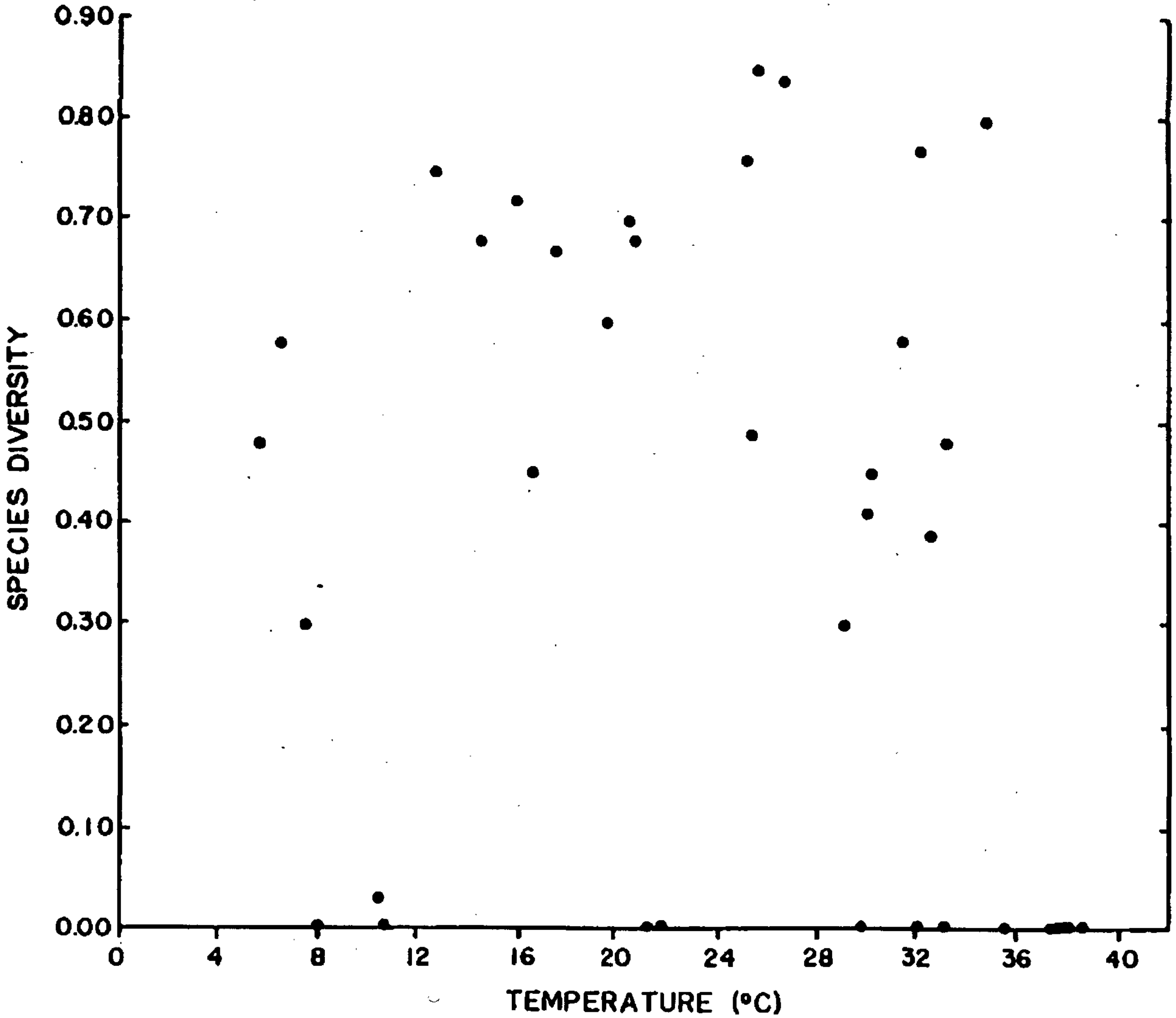

Figure 4-14. Shannon-Weaver species diversity for fishes collected by electrofishing at different temperatures in the mouth of Four Mile Creek (FGPRT82, FGPRT83, FGPRT84, GFPRT3). November 1984 - August 1985.

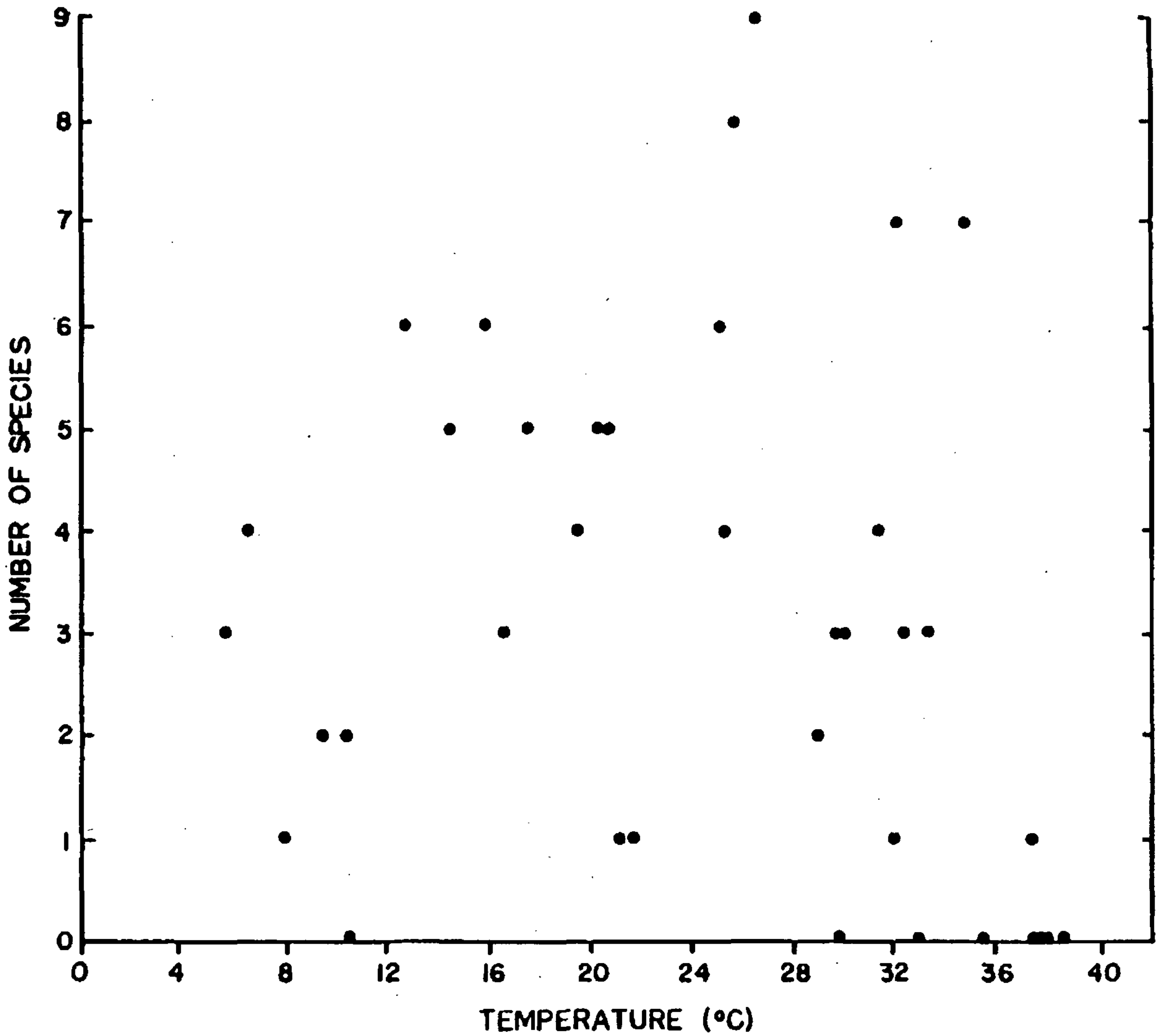

Figure 4-15. Species richness for fishes collected by electrofishing at different temperatures in the mouth of Four Mile Creek (FGRPT82, FGRPT83, FGRPT84, FGRPT3). November 1984 - August 1985.

4.5 IMPINGEMENT

The impingement section of this study was designed to provide estimates of the fish lost from the Savannah River fish community through impingement on the SRP cooling water intake screens. The rates of impingement were influenced by a variety of environmental and biological factors including water level (dependent on rainfall and discharge from upstream dams), volume of water pumped into the reactors (based on number of pumps and amounts required), water temperatures in the intake canals, and the species of fishes present in the canals (and related densities based on reproductive cycles).

The first impingement data were collected from March through August 1982 on a biweekly collection schedule that represented 12 sampling dates. After this series of collections, data were randomly collected from September 1983 through September 1985. During the course of the entire study, sampling was performed on 314 dates, with collections of 12, 98, 107, and 97 samples in 1982, 1982 - 1983, 1983 - 1984, and 1984 - 1985, respectively. The results of the September 1984 through September 1985 collections are presented in this report.

4.5.1 Species Composition

Between September 1984 and September 1985 (97 sampling dates), a total of 745 fish, representing 33 species, were collected from the SRP intake screens (Table 4-22). This number was similar to the 35 species collected by McFarlane et al. (1978),

Table 4-22. Total number and relative abundance of fish species impinged at 1G, 3G, and 5G pumphouses. September 1984 - September 1985.

Taxa	Total	Percent Abundance
bowfin	1	0.13
American eel	5	0.67
blueback herring	40	5.37
hickory shad	48	6.44
gizzard shad	136	18.26
threadfin shad	175	23.49
unidentified Clupeidae	1	0.13
redfin pickerel	13	1.74
chain pickerel	4	0.54
eastern silvery minnow	1	0.13
golden shiner	2	0.27
spottail shiner	24	3.22
Notropis spp.	4	0.54
unidentified Cyprinidae	4	0.54
spotted sucker	16	2.15
silver redhorse	1	0.13
white catfish	28	3.76
flat bullhead	13	1.74
channel catfish	11	1.48
Noturus sp.	1	0.13
unidentified Ictaluridae	13	1.74
Atlantic needlefish	1	0.13
flier	28	3.76
redbreast sunfish	22	2.95
pumpkinseed	2	0.27
warmouth	13	1.74
bluegill	47	6.31
dollar sunfish	1	0.13
redear sunfish	6	0.81
spotted sunfish	13	1.74
mud sunfish	2	0.27
Lepomis sp.	2	0.27
largemouth bass	16	2.15
black crappie	18	2.42
tesselated darter	1	0.13
yellow perch	7	0.94
blackbanded darter	1	0.13
hogchoker	23	3.09
unknown	1	0.13
Total	745	99.97

higher than the 22 species collected in 1982 by ECS (ECS 1983), and lower than the 48 species collected in 1982/1983 (Paller et al. 1984) or 50 species collected in 1983/1984 (Paller and Osteen 1985). The collection of fewer species could be attributed to river levels that were lower during the 1984/1985 spawning seasons than during the previous two spawning seasons.

The majority of the fish collected were in the shad and herring family (53.7%) or the sunfish family (22.8%; Table 4-22). Families with lesser numbers were catfish (8.9%), minnow (4.7%), hogchocker (3.1%), and pickerel (2.3%). The combined values of the remaining families represent less than 5% of the total collection. As in the 1983 - 1984 collection, threadfin shad was the most abundant species, representing 23.5% of the 1984 - 1985 total. Other species with values of over 5% of the total fish impinged were gizzard shad (18.3%), hickory shad (6.4%), bluegill (6.3%), and blueback herring (5.4%). In contrast with the previous two annual collections, the two dominant families reversed positions in this study. That is, while sunfish and shad/herring were the first and second most numerous groups impinged in the 1982 - 1983 and 1983 - 1984 studies, their rankings were reversed in the 1984 - 1985 study. Several factors probably influenced this change, but the most notable was that the canals were dredged during the 1984 - 1985 season, resulting in fewer submerged macrophytes. These macrophyte beds were excellent sources of cover and food for many species of sunfish (Paller et al. 1986).

4.5.2 Seasonal Trends

Generally, the number of fish impinged was lowest during the fall and spring and highest in the winter and summer (Figures 4-16 and 4-17; Table 4-23). The high numbers of fish impinged in the winter were correlated with river level. Correlation between elevated river level and impingement was noted by ECS (1983) and Paller et al. (1984), who found higher numbers of fish impinged when river levels were high and the spawning season at its peak. The relatively large numbers of fish impinged in the summer of 1985 were not associated with elevated river levels and could be related to the presence of large schools of shad in the intake canals. The predominant species removed from the screens at the time were fishes in the shad and herring family.

4.5.3 Relative Rates at Intake Canals

Comparisons of the relative impingement rates at the 1G, 3G, and 5G intakes were made by standardizing the number of impinged fish to a unit volume. The volumes of water pumped at 1G and 3G pumphouses were similar, ranging from 0.36 to 1.1 x 10^6 m^3/day at 1G pumphouse and 0.51 to 1.3 x 10^6 m^3/day at 3G pumphouse. The 5G pumphouse pumped approximately 0.19 x 10^6 m^3/day (Winona Specht, pers. comm.). The impingment rates for the three pumphouses were not comparable to each other or to past impingement rates. The mean impingement rates for 1G, 3G, and 5G were 7.0, 3.0, and 2.3 fish/10^6 m^3, respectively (Table 4-24). These rates were much lower than those reported in the past with the exception of the mean number of fish impinged in the 1G canal in 1982, which was

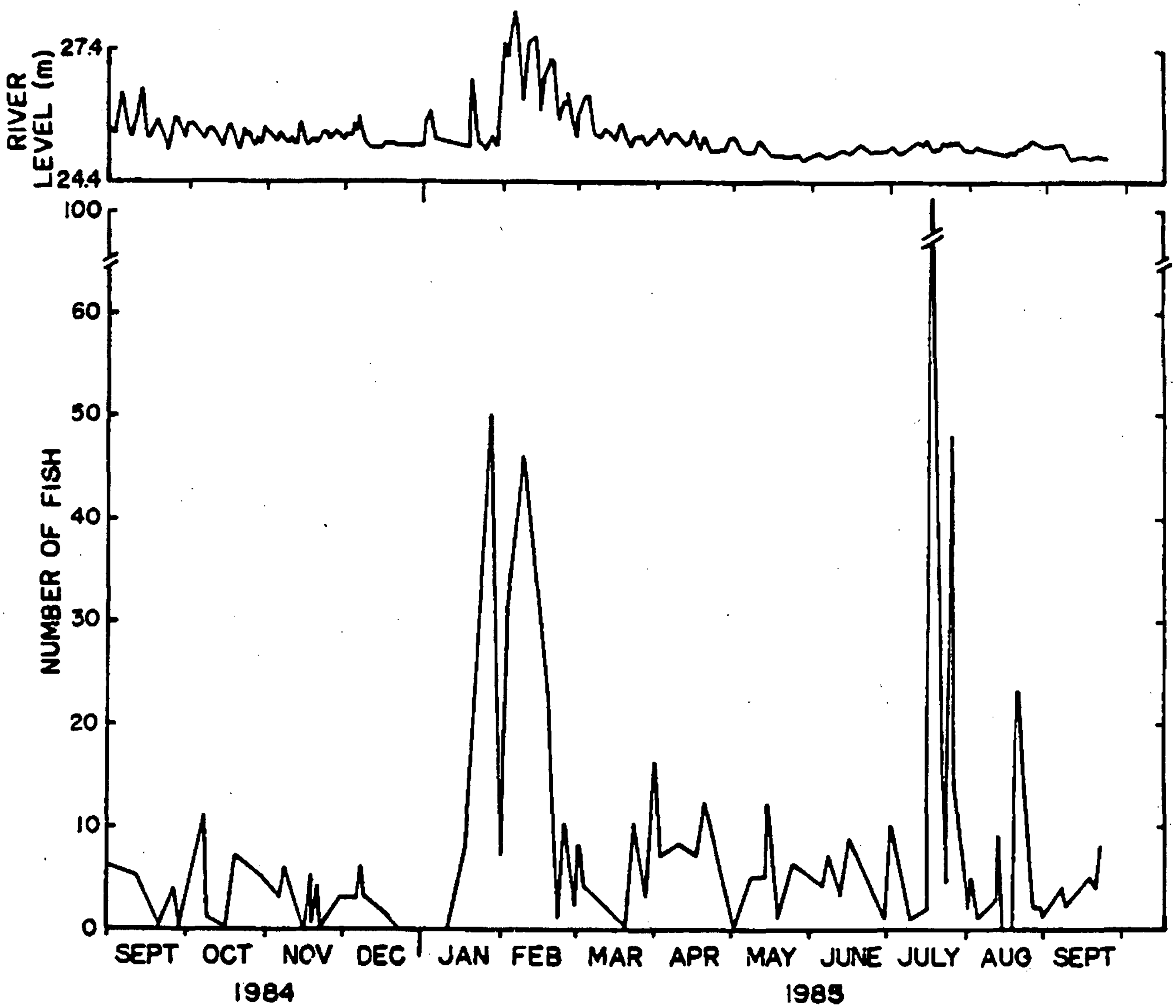

Figure 4-16. Number of fish impinged daily by the SRP pumphouses in relation to Savannah River levels. September 1984 - September 1985.

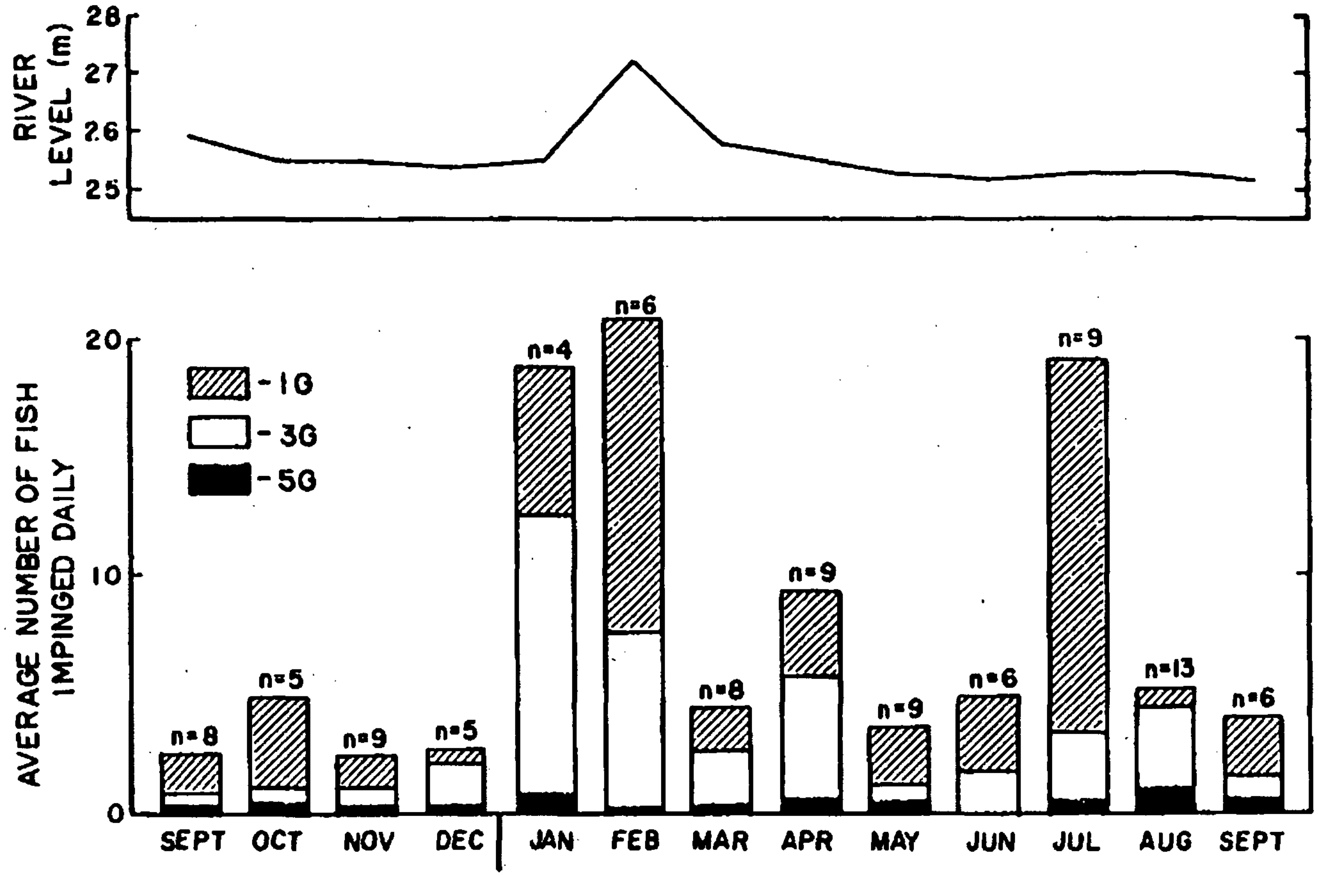

Figure 4-17. Average number of fish impinged daily at the 1G, 3G, and 5G pumphouses, and mean river levels. September 1984 - September 1985.

Table 4-23. Number and total weight (g) of fish impinged at 1G, 3G, and 5G pumphouses on 97 sampling dates. September 1984 - September 1985.

Month		1G		3G		5G		Total	
		No.	Wt.(g)	No.	Wt.(g)	No.	Wt.(g)	No.	Wt.(g)
1984									
September	(8)[a]	14	923	4	124	2	216	20	1263
October	(5)	19	655	3	1026	2	8	24	1689
November	(9)	13	1323	6	129	2	31	21	1483
December	(5)	3	66	9	479	1	14	13	559
1985									
January	(4)	25	1491	47	426	3	8	75	1925
February	(6)	80	4608	44	1787	1	4	125	6399
March	(8)	14	849	18	702	2	461	34	2012
April	(9)	33	4361	45	3410	5	535	83	8306
May	(9)	12	1028	22	1735	4	1173	38	3936
June	(6)	19	4109	10	2228	0	0	29	6337
July	(9)	158	1219	28	5539	5	44	191	6802
August	(13)	12	358	43	1311	13	54	68	1723
September	(6)	15	1477	6	358	3	967	24	2802
Total		4.3	231.6	2.9	198.5	0.4	36.2	7.7	466.4

[a]Number of sampling dates per month.

Table 4-24. Impingment rates of fishes (no. fish/10^6 m^3 of water pumped) at 1G, 3G and 5G pump-houses. September 1984 - September 1985.

Month	1G	3G	5G
1984			
September (8)[a]	2.0	0.5	1.3
October (5)	6.6	0.6	2.1
November (9)	2.2	1.1	1.2
December (5)	0.4	1.8	1.1
1985			
January (4)	7.0	10.3	3.9
February (6)	13.0	7.0	0.9
March (8)	2.0	2.2	1.3
April (9)	4.2	5.0	2.9
May (9)	1.6	2.1	2.3
June (6)	3.7	1.8	0.0
July (9)	39.9	3.8	2.9
August (13)	1.9	3.5	5.3
September (6)	4.4	1.7	2.6
Mean[b]	7.0	3.0	2.3

[a]Number of sampling dates per month.
[b]Mean is based on data from 97 sampling dates.

4.3 fish/10^6 m^3 of water (Paller et al. 1984). The differences among the three canals noted for the 1984 - 1985 study were probably due to increases in habitat variability caused by dredging and the occasional impingement of schools of fish. Paller and Osteen (1985) noted that the differences among pumphouse impingement rates were inflated by the impingement of schools of fish in relatively small volumes of water.

4.5.4 <u>Susceptibility of Fishes to Impingement</u>

The number of fish impinged daily ranged from 0 to 99 and averaged 7.7 fish/day. This value was less than the 19 fish/day collected in 1982 (ECS 1983), the 37 fish/day collected in 1982 - 1983 (Paller et al. 1984), the 18 fish/day collected in 1983 - 1984 (Paller and Osteen 1985), and approximately the same as the 7 fish/day collected by McFarlane et al. (1978). On the days when fish were impinged, the total weight/day of impinged fish ranged from 1 g to 2844 g and averaged 466.4 g/day.

The relative abundances of the fishes impinged at the 1G, 3G, and 5G pumphouses were compared with the relative abundance of the fishes sampled by electrofishing the areas near the pumphouses (Figure 4-18). These data indicate that species abundance and susceptibility are not closely associated and that the most abundant fishes do not necessarily appear in large numbers on the intake screens. In the 1984 - 1985 collections at the 1G canal sites, bluegill (39.1%), redbreast (24.2%), and yellow perch (11.7%) were the most abundant species in the electrofishing collections, while gizzard shad (29.4%), threadfin shad (20.1%),

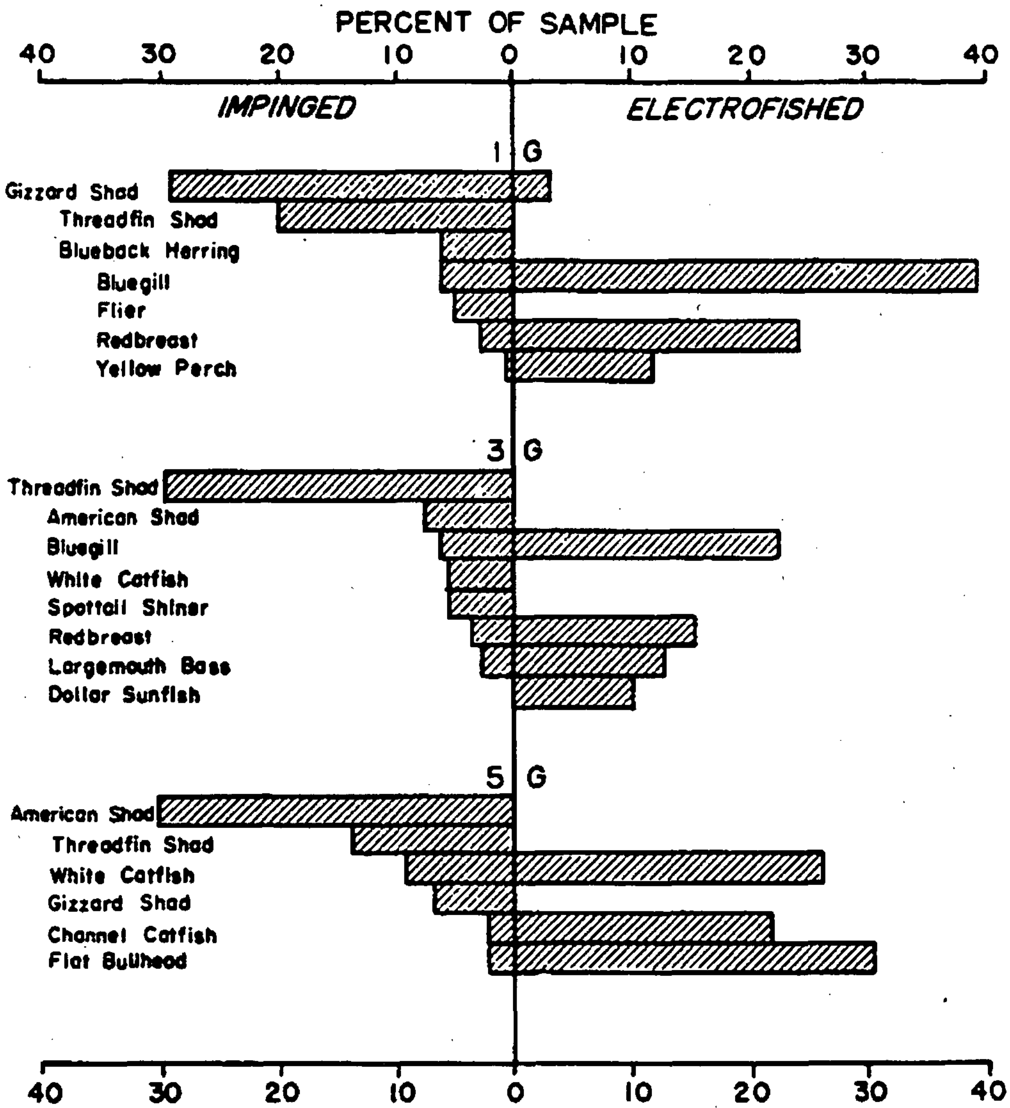

Figure 4-18.. Percent composition for selected species of fish impinged at the 1G, 3G, and 5G pumphouses and those collected by electrofishing in the vicinity of the pumphouses. September 1984 - September 1985.

blueback herring (6.5%), bluegill (6.5%), and flier (5.0%) were the most common species collected from the intake screens. In this case, the most abundant species collected via electrofishing, bluegill, represented only a small percentage of the total species impinged. In the 3G canal, bluegill (22.4%), redbreast sunfish (15.4%), largemouth bass (12.6%), and dollar sunfish (9.8%) were the predominant taxa in electrofishing samples. Threadfin shad (29.8%), American shad (7.7%), bluegill (6.3%), white catfish (6.0%), and spottail shiners (5.6%) were most commonly collected from the intake screens. As in the 1G canal, bluegill were most abundant in electrofishing collections, but were relatively unimportant in the impingement samples. At the 5G pumphouse, flat bullhead (30.4%), white catfish (26.1%), and channel catfish (21.7%) were the most abundant taxa in the electrofishing samples, while American shad (30.2%), threadfin shad (14.0%), white catfish (9.3%), and gizzard shad (7.0%) were the most numerous taxa on impingement screens. Based on these data, the three most abundant species captured during electrofishing (flat bullhead, white catfish, and channel catfish) were not the most numerous on the intake screens. Since the 5G canal is short, it would be expected that more riverine fishes would be impinged. The dissimilarity between the abundant taxa collected via electrofishing and those removed from the intake screens has been observed in other Savannah River studies (McFarlane et al. 1978; Paller et al. 1984; Paller and Osteen 1985).

A total of 745 fish representing 33 species were collected from intake screens during the 97 random dates sampled. Over the course of the 1984 - 1985 impingement study, the average number and weight (g) of fish impinged per day were 7.7 and 466.4, respectively. The two most numerous groups of fishes removed from the screens were shad/herring and sunfish, both of which were predominant in winter and summer. The 1G canal had the highest impingement rates, with 4.3 fish/day and 7.0 fish/10^6 m^3 of water. The numbers and weights of fish impinged during the 1984 - 1985 study period were significantly lower than those impinged in the previous two years of study. The most notable differences can probably be attributed to river level and habitat. The river levels were lower in the spawning season of 1984 - 1985 than in the past two seasons, when a large number of fishes were impinged on the intake screens. The spawning habitats in the 1G, 3G, and 5G canals were altered in the 1984 - 1985 season by extensive dredging. The removal of aquatic macrophyte beds was probably responsible for the lower numbers of fishes, especially sunfish, in the canal communities.

5.0 SUMMARY

A study of the juvenile and adult fish community in streams draining the SRP and in the Savannah River in the area of the SRP was conducted between September 1984 and September 1985. The study included sample stations in the Savannah River, the SRP intake canals, and the major onsite creeks. Most sites were sampled quarterly; however, a limited number were also sampled weekly during the winter to determine if fish congregated in thermal areas when normal water temperatures were low. The major objectives of this study were to examine the abundance and distribution of fishes near the Savannah River Plant in relation to thermal discharges into the river, creeks, and floodplain swamps and to determine the rate of impingement of adult and juvenile fishes on the intake screens at the SRP pumphouses.

Approximately 10,000 fish were collected by electrofishing and hoop netting during the November 1984 - August 1985 sampling period. The most abundant fishes (excluding minnows) taken by electrofishing were the redbreast sunfish (41.6%), spotted sucker (8.8%), spotted sunfish (8.2%), largemouth bass (5.7%), bluegill (5.6%), and American eel (5.4%). The most abundant fishes taken by hoop netting were the flat bullhead (38.0%), channel catfish (11.9%), bluegill (9.4%), white catfish (7.9%), black crappie (6.5%), and redbreast sunfish (5.5%).

To evaluate habitat preference, the study area was divided into intake canals, thermal river, nonthermal river, nonthermal creek, and thermal creeks. The thermal creeks included highly thermal Four Mile Creek, moderately thermal Beaver Dam Creek, and refuge areas in Pen Branch. The thermal river consisted of the South Carolina side of the river transect just below Beaver Dam Creek (RM 152.0) and of the one just below Four Mile Creek (RM 150.4). Dominant species in the intake canals were the bluegill, redbreast sunfish, and black crappie. Dominant species in the nonthermal river were the redbreast sunfish, spotted sunfish, spotted sucker, largemouth bass, channel catfish, white catfish, and flat bullhead. Dominant species in the nonthermal creeks were fairly similar to river species except that the catfishes were not as well represented. The thermal river and creek habitats differed from the nonthermal habitats in having higher percentages (although often lower numbers) of channel catfish, white catfish, largemouth bass, and coastal shiner and a lower percentage of flat bullhead. Exceptions occurred in Pen Branch refuge areas and portions of Four Mile Creek, where mosquitofish were the dominant, and sometimes only, species present.

Fish collected by electrofishing were used to estimate catch per unit effort as the number of fish/100 m of shoreline. Sample stations in Pen Branch were not included in these calculations, since they were difficult to sample quantitatively. CPUE averaged 3.8 fish/100 m during November, 1.6 fish/100 m during February, 4.4 fish/100 m during May, and 7.2 fish/100 m during August. The relatively low average CPUE during February was probably the result of high water levels that enabled fish to move out of the river and creeks and into the flooded swamp.

Electrofishing CPUE was highly variable at most sample stations, but was generally 0.0 fish/100 m in the segment of Four Mile Creek receiving reactor discharge. The only exception was in August, when C-Reactor was down and temperatures in Four Mile Creek were ambient. At this time, CPUE in Four Mile Creek was within the range of that in the other creeks. CPUE in moderately thermal Beaver Dam Creek was variable and exhibited no obvious relationship to temperature. CPUE in the thermal river habitats directly downstream from the mouths of the thermal creeks never exhibited unusual reduction.

Hoop netting catch per unit effort was expressed as number of fish collected per net day. In general, hoop netting CPUE was highly variable and exhibited no consistent habitat- or temperature-related patterns. The only exception was Four Mile Creek, where CPUE was consistently low (0.0 - 0.3 fish/net day). CPUE in Beaver Dam Creek was somewhat higher (0.0 - 0.7 fish/net day) and basically comparable with that in the nonthermal creeks. There was no evidence of reduced CPUE in the thermal river habitat.

Concentrated sampling in the thermal creeks (and appropriate control creeks) during the overwintering program suggested that redear sunfish, channel catfish, longnose gar, black crappie, and gizzard shad congregated in moderately heated areas. The American eel, spotted sucker, and flat bullhead avoided the thermal habitats. Fish appeared to congregate to the greatest extent in the thermal river habitat, which was heated only 2 - 3°C above ambient. However, there was slight evidence of congregation in Beaver Dam Creek, which was approximately 7°C above ambient. Fish avoided Four Mile Creek, where temperatures were very warm, occasionally exceeding 35°C.

The relationship between fish distribution and temperature was examined using data collected from Four Mile Creek over a three-year period. CPUE was unrelated to temperature at temperatures under 30°C, variable with an increased proportion of no fish in a sample at temperatures between 30 and 35°C, and zero at temperatures above 35°C. Sunfishes, largemouth bass, gar, and gizzard shad were the dominant species in the 30-35°C range. Shannon-Weaver diversity and species number were unrelated to temperature at temperatures below 35°C, but zero at higher temperatures.

An average of 7.7 fish weighing a total of 466.4 g were impinged daily on the SRP intake screens during the 1984/1985 impingement study. The most commonly impinged fishes were shad/herring and sunfishes. The 1G canal had the highest impingement rate, with 4.3 fish/day. Impingement rates were lower during the 1984/1985 sampling period than during earlier years, probably because fish were less abundant in the intake canals due to low river levels and habitat alterations caused by dredging.

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APPENDIX 1

Appendix 1

Common and scientific names of adult fishes collected in the Savannah River November 1982 - August 1985

Common name	Scientific name
longnose gar	*L. osseus*
Florida gar	*L. platyrhincus*
bowfin	*Amia calva*
American eel	*Anguilla rostrata*
unidentified clupeid	Clupeidae
unidentified herring or shad	*Alosa* sp.
blueback herring	*Alosa aestivalis*
American shad	*A. sapidissima*
gizzard shad	*Dorosoma cepedianum*
threadfin shad	*D. petenese*
mountain mullet	*Agonostomus monticola*
eastern mudminnow	*Umbra pygmaea*
unidentified pickerel	*Esox* spp.
redfin pickerel	*Esox americanus americanus*
chain pickerel	*E. niger*
unidentified minnow	Cyprinidae
common carp	*Cyprinus carpio*
eastern silvery minnow	*Hybognathus regius*
rosyface chub	*Hybopsis rubrifrons*
bluehead chub	*Nocomis leptocephalus*
golden shiner	*Notemigonus crysoleucas*
shiners	*Notropis* spp.
Ohoopee shiner	*Notropis leedsi*
ironcolor shiner	*N. chalybaeus*
dusky shiner	*N. cummingsae*
pugnose minnow	*N. emiliae*
spottail shiner	*N. hudsonius*
sailfin shiner	*N. hypselopterus*
bannerfin shiner	*N. leedsi*
yellowfin shiner	*N. lutipinnis*
taillight shiner	*N. maculatus*
whitefin shiner	*N. nivens*
coastal shiner	*N. petersoni*
unidentified carpsucker	*Carpiodes* spp.
quillback carpsucker	*Carpiodes cyprinus*
unidentified chubsucker	*Erimyson* spp.
creek chubsucker	*E. sucetta*
spotted sucker	*Minytrmea melanops*
unidentified redhorse	*Moxostoma* spp.
silver redhorse	*Moxostoma anisurum*
unidentified catfish	*Ictalurus* spp.
snail bullhead	*Icthalurus brunnens*
white catfish	*I. catus*
yellow bullhead	*I. natalis*

Appendix 1 (continued)

Common and scientific names of adult fishes collected in the Savannah River November 1982 - August 1985

Common name	Scientific name
brown bullhead	I. nebulosus
flat bullhead	I. platycephalus
channel catfish	I. punctatus
unidentified madtom	Noturus spp.
tadpole madtom	Noturus gyrinus
margined madtom	N. insignis
speckled madtom	N. leptacanthus
pirate perch	Aphredoderus sayanus
Atlantic needlefish	Strongylura marina
lined topminnow	Fundulus lineolatus
golden topminnow	F. chrysotus
starhead topminnow	F. notti
mosquitofish	Gambusia affinis
brook silverside	Labidesthes sicculus
striped bass	Morone saxatilis
unidentified sunfish	Centrarchidae
mud sunfish	Acantharchus pomotis
flier	Centrarchus macropterus
banded pygmy sunfish	Elassoma zonatum
bluespotted sunfish	Enneacanthus gloriosus
unidentified sunfish	Lepomis spp.
redbreast sunfish	Lepomis auritus
green sunfish	L. cyanellus
pumpkinseed	L. gibbosus
warmouth	L. gulosus
bluegill	L. macrochirus
dollar sunfish	L. marginatus
redear sunfish	L. microlophus
spotted sunfish	L. punctatus
redeye bass	Micropterus coosae
largemouth bass	M. salmoides
unidentified crappie	Pomoxis spp.
white crappie	Pomoxis annularis
black crappie	P. nigromaculatus
unidentified darter	Etheostoma spp.
sawcheek darter	Etheostoma serriferum
Savannah darter	E. fricksium
swamp darter	E. fusiforme
tessellated darter	E. olmstedi
yellow perch	Perca flavescens
blackbanded darter	Percina nigrofasciata
striped mullet	Mugil cephalus
hogchoker	Trinectes maculatus
river goby	Awaous tajasica

APPENDIX 2

Appendix 2 contains listings of computer programs that are referenced in the figures and tables of this report. This appendix is for documentation only and has not been distributed with the report.

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6. Fish collected by electrofishing were used to estimate catch per unit effort as the number of fish/100 m of shoreline. CPUE averaged 3.8 fish/100 m during November, 1.6 fish/100 m during February, 4.4 fish/100 m during May, and 7.2 fish/100 m during August. The relatively low average CPUE during February was probably the result of high water levels that enabled fish to move out of the river and creeks and into the flooded swamp.

7. Electrofishing CPUE was highly variable at most sample stations, but generally 0.0 fish/100 m were collected in the segment of Four Mile Creek receiving reactor discharge. The only exception was in August, when C-Reactor was down and temperatures in Four Mile Creek were ambient. At this time, CPUE in Four Mile Creek was within the range of that in the other creeks. CPUE in moderately thermal Beaver Dam Creek was variable and exhibited no obvious relationship to temperature. CPUE in the thermal river habitats directly downstream from the mouths of the thermal creeks never exhibited unusual reductions.

8. Hoop netting catch per unit effort was expressed as number of fish collected per net day. In general, hoop netting CPUE was highly variable and exhibited no consistent habitat- or temperature-related patterns. The only exception was Four Mile Creek, where CPUE was consistently low (0.0 - 0.3

The thermal river sample stations were generally 2 - 3°C warmer than the nonthermal river sample stations (Figure 4-8). Electrofishing catch rates in the thermal river habitat were highly variable, but almost always higher than the catch rates in the nonthermal river habitat (Figure 4-8). The mean electrofishing catch rate over all overwintering sample dates was 4.6 fish/100 m at the thermal river sample stations, compared with 1.8 fish/100 m at the nonthermal river sample stations (Table 4-19). Higher catch rates at the thermal river sample stations than at the nonthermal river sample stations were also observed during the winter of 1984/1985 (Paller and Osteen 1985).

In summary, the 1985/1986 overwintering electrofishing data suggests some congregation of fishes in the mildly heated reaches of the Savannah River just below the thermal creeks but no overall aggregation in mildly thermal Beaver Dam Creek. In contrast, most fishes avoided Four Mile Creek, which was often heated to temperatures in excess of 35°C. Responses to thermal habitats varied among species, with some species attracted to thermal areas and others avoiding them. Except for less aggregation in the thermal creeks during the winter of 1985/1986, these findings are fairly similar to those of the 1984/1985 over-wintering programs.

4.3.2.2 Hoop Netting Catch per Unit Effort

Hoop netting CPUE was more variable than electrofishing CPUE. Because of this high variability, the data from the two thermal creeks (Four Mile Creek and Beaver Dam Creek) were averaged

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TITLE Effects of Thermal Discharges on the Distribution and Abundance of Adult Fishes in the Savannah River and Selected Tributaries. Annual Report November, 1984-August, 1985. (ECS-SR-28)

DIVISION Environmental Sciences Division

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A. TECHNICAL CONTENT

Authorized by: √ J. C. Corey *JC Corey* (RESEARCH MANAGER OR DEPARTMENT SUPERINTENDENT) 1/22/87 DATE

B. CLASSIFICATION

Reviewed by: √ J. C. Corey *JC Corey* (AUTHORIZED DERIVATIVE CLASSIFIER) 1/22/87 DATE

C. J. Banick *CJ Banick* (AED CLASSIFICATION OFFICER) 1/15/87 DATE

Authority for Classification Determination CG-DAR-1, Topic 2.2 GUIDE NO. AND TOPIC NO.(S)

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DOE F 1332.15 (6-86)

OMB C... No. 1910-...

DOE AND MAJOR CONTRACTOR RECOMMENDATIONS FOR ANNOUNCEMENT AND DISTRIBUTION OF DOCUMENTS

239128

See instructions on Reverse Side

1. DOE Report No.	2. DOE Contract No.	3. Distribution Category No.
DPST-86-799 (ECS-SR-28)	DE-AC09-76SR00001	UC-11

4. Title "EFFECTS OF THERMAL DISCHARGES ON THE DISTRIBUTION AND ABUNDANCE OF ADULT FISHES IN THE SAVANNAH RIVER AND SELECTED TRIBUTARIES. ANNUAL REPORT. NOVEMBER 1984 - AUGUST 1985", By M. H. Paller, and B. M. Saul

5. Type of Document ("x" one)
- ☒ a. Scientific and technical report
- ☐ b. Conference paper: Title of conference ______ Date of conference ______

Exact location of conference ______ Sponsoring organization ______
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C. J. Banick, Classification Officer & Patent Reviewer		FTS 239-2606
Organization: Information Services (SSD)	Signature: C J Banick	Date 7/31/87

OSR 14-357
(Rev 10-86)

SAVANNAH RIVER DOCUMENT APPROVAL SHEET

(See SRP Procedures Manual Item 101)

Document Number DPST-86-799

UC or C Number

1. DESCRIPTION OF DOCUMENT (to be completed by author)

TITLE Effects of Thermal Discharges on the Distribution & Abundance of Adult Fishes in the SR - Selected ... Annual Report

AUTHOR(S) PHONE NO.

TYPE: ☐ INTERNAL DOCUMENT ☐ EXTERNAL DOCUMENT
☐ DP Report
☐ Paper (see below)
☐ Other

Additional Information for External Papers

PAPER FOR: Presentation Only ____ Publication Only ____ Both ____

MEETING NAME ____

CITY ____ DATES ____

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CLASSIFICATION (circle one for each)

Overall	S	C	UCNI	U
Abstract	S	C	UCNI	U
Title	S	C	UCNI	U
Cover Letter	S	C	UCNI	U

CLASSIFICATION GUIDE TOPICS ____

PATENT CONSIDERATIONS
Possible Novel Features ____
Closest Prior Art ____

APPROVED BY AED PATENT & CLASSIFICATION OFFICER ____ DATE ____

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1. DOE Report No. DPST-86-799 (ECS-SR-28)
2. DOE Contract No. DE-AC09-76SR00001
3. Distribution Category No. UC-11

4. "EFFECTS OF THERMAL DISCHARGES ON THE DISTRIBUTION AND ABUNDANCE OF ADULT FISHES IN THE SAVANNAH RIVER AND SELECTED TRIBUTARIES. ANNUAL REPORT. NOVEMBER 1984 - AUGUST 1985", By M. H. Paller, and B. M. Saul

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C. J. Banick, Classification Officer & Patent Reviewer

Phone FTS 239- 606

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Date 7/31/87

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CC: W. F. Perrin, DOE-SR (2)
J. S. Roberts, 703-A
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D. B. Moore-J. B. Gladden, 773-42A 5215
File: (DPST-86-799)
(ECS-SR-28)

September 24, 1987

239128

Mr. J. R. Powell, Technical Information Officer
U. S. Department of Energy
Savannah River Operations Office
Aiken, SC 29801

Dear Mr. Powell:

REQUEST FOR APPROVAL TO RELEASE SCIENTIFIC/TECHNICAL INFORMATION

The attached document is submitted for approval for external release. Please complete Part II of this letter and return the letter to the undersigned, by: ASAP 10/6/87 Patent clearance is requested and received via direct communication between DOE Patent Counsel and AED Patent Reviewer. The document has ~~not~~ been reviewed for classification and UCNI. The document is ~~classified~~/unclassified and contains no UCNI. (Strike words that do not apply.)

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C. J. Banick

I. DETAILS OF REQUEST FOR RELEASE

DPST-86-799 (ECS-SR-28), "EFFECTS OF THERMAL DISCHARGES ON THE DISTRIBUTION AND ABUNDANCE OF ADULT FISHES IN THE SAVANNAH RIVER AND SELECTED TRIBUTARIES. ANNUAL REPORT. NOVEMBER 1984 - AUGUST 1985", By M. H. Paller and B. M. Saul.

This is a support document for the Thermal Mitigation EIS. The document will be sent to (1) the Aiken Reading Room and (2) OSTI for distribution to the General Public.

Technical questions pertaining to the contents of the document should be addressed to the author(s) or

J. C. Corey, Research Manager
Environmental Sciences
Savannah River Laboratory

Questions concerning processing of this document should be addressed to the AED Classification Officer & Patent Reviewer at Extension 5-2606.

II. DOE-SR ACTION

DATE RECEIVED BY TIO 9-29-87

___Approved as written
___Remarks

___Not approved as written, ___revise and resubmit to DOE
X Approved upon completion of changes marked on document

J R Powell
J. R. Powell, Technical Information Officer, DOE-SR

Date: 10/23/87