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COMPREHENSIVE COOLING WATER STUDY FINAL REPORT

VOLUME V
AQUATIC ECOLOGY

SAVANNAH RIVER PLANT

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ABSTRACT

The Comprehensive Cooling Water Study (CCWS) was initiated in 1983 to evaluate the environmental effects of the intake and release of cooling water on the structure and function of aquatic ecosystems at the Savannah River Plant. The initial report (Gladden et al., 1985) described the results from the first year of the study. This document is the final report and concludes the program. The report comprises eight volumes. The first is a summary of environmental effects. The other seven volumes address water quality, radionuclide and heavy metal transport, wetlands, aquatic ecology, Federally endangered species, ecology of Par Pond, and waterfowl.

FOREWORD

This study was initiated in response to a commitment by the U.S. Department of Energy (DOE) Savannah River Plant Operations Office to the U.S. Senate Armed Services Committee and the State of South Carolina. The study was a joint effort undertaken by DOE, Du Pont, and the Savannah River Ecology Laboratory of the University of Georgia.

The broad scope of this project and size of the report necessitated that it be subdivided into smaller, coherent subject areas. The resulting document contains eight volumes:

Volume Number	DP Number	
I	1739-1	Summary of Environmental Effects
II	1739-2	Water Quality
III	1739-3	Radionuclide and Heavy Metal Transport
IV	1739-4	Wetlands
V	1739-5	Aquatic Ecology
VI	1739-6	Federally Endangered Species
VII	1739-7	Ecology of Par Pond
VIII	1739-8	Waterfowl

Only Volume I is being generally distributed. Readers desiring to obtain additional volumes may do so by writing to the National Technical Information Service.

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V. AQUATIC ECOLOGY

VOLUME SUMMARY

This report documents the results of the Aquatic Ecology Program of the Comprehensive Cooling Water Study (CCWS). The purpose of the Aquatic Ecology Program was to determine the environmental impacts of cooling water intake and release on the biological communities of SRP streams and swamps and the Savannah River, and the significance of these impacts on the SRP environment.

Lower Food Chain

The lower food chain studies were conducted over a two year period, from September 1983 to September 1984, and from October 1984 to September 1985, and included sampling of the SRP thermal, nonthermal, and post-thermal streams and swamps, as well as the Savannah River. Stream structure and habitat, primary production, organic matter processing and transport, and macroinvertebrates were studied either monthly or quarterly.

The major objective of the lower food chain studies was to determine the thermal impact of cooling water discharges on the structure and dynamics of nonvertebrate communities in surface water systems at the SRP (excluding Par Pond which is reported in Volume VII of the CCWS Final Report) and in the Savannah River. The lower food chain studies were designed to investigate the mechanisms and processes which regulate and influence this important part of the aquatic environment in order to address this objective.

The nonthermal streams included Upper Three Runs Creek, Lower Three Runs Creek, Meyers Branch, and the nonthermal portions of Four Mile Creek and Pen Branch. These nonthermal streams served as reference streams against which thermal and post-thermal streams of similar size could be compared to assess impacts. Water temperatures in these reference streams varied seasonally, but usually remained below 33°C. Stream structure was dominated by logs and sticks, but macrophytes and trailing vegetation were abundant at some of the larger nonthermal sites, where stream structure was most diverse. There were no obvious and consistent seasonal trends in stream structure parameters at most sites. In the nonthermal streams, the energy base was primarily allochthonous and leaf litter input was high. Leaves that fell into the stream were colonized by microbes and rapidly broken down by macroinvertebrate shredders. The seston had a high percentage of organic matter. Often the canopy provided by the stream-side trees was complete and dense; as a result, periphyton and macrophyte biomass were low, especially in the summer when light was most limiting. There were no significant differences in periphyton biomass (on a unit area basis) between large and small reference streams. Most of the reference streams failed to indicate any significant seasonal changes in macrophyte biomass. The periphyton that did occur was dominated by green algae and diatoms. The macroinvertebrate communities were diverse (56 to 70 taxa) and included pollution-sensitive taxa.

Steel Creek, a post-thermal stream, still shows some effects from reactor effluents, primarily related to the damage to its riparian zone. During this study, vegetation along the Steel Creek channel consisted of small trees and shrubs. There was less wood in the channel than in the nonthermal reference streams, and most structure was provided by less permanent features, such as sticks and macrophytes. The energy sources in Steel Creek varied between sites. Litter inputs were low at the upstream sites because of the lack of stream-side trees, while the downstream sites had litter inputs equivalent to the nonthermal streams. Leaves decomposed faster in Steel Creek than in the reference streams presumably due to the abundance of macroinvertebrate shredders in Steel Creek. Leaf weight loss was higher in Steel Creek compared to nonthermal reference streams, but the differences were not significantly different for any leaf species. At the upstream Steel Creek sites, there was a high concentration of suspended solids with low percent organic content. In general, the higher current velocity of Steel Creek and the lack of retention structures resulted in a higher inorganic silt load. Autochthonous energy sources were more important in Steel Creek than in the shaded reference streams. Periphyton biomass were generally high, and one Steel Creek station had a high macrophyte biomass. Macroinvertebrate densities, taxa richness, and biomass of functional groups were similar to those of the reference streams, indicating a substantial post-thermal recovery of the macroinvertebrate community.

The thermal streams which received reactor effluents were Four Mile Creek and Pen Branch. Their water temperatures varied with season, reactor operation, and proximity to the effluent outfall, but exceeded 50°C at some sampling stations during reactor operations. Stumps and logs were more abundant in the thermal streams than in the reference streams. Debris was also abundant, but trailing roots and macrophytes were scarce. The thermal streams had temperatures that excluded many plants and animals when the reactors were operating. Over a sixteen month period, decomposition of sycamore and sweetgum leaves in these streams was significantly lower compared to nonthermal and post-thermal streams, due to the absence of macroinvertebrate shredders. The total suspended solids (TSS) loads were higher than in the reference streams, but the organic content of the particulates was very low. Periphyton biomass was low at the hottest stream sites, while at cooler thermal sites biomass was high and was dominated by blue-green algae. Macroinvertebrate populations had low biomass and low densities except for a few tolerant forms such as oligochaetes, nematodes, and some chironomids. When the reactors were not operating, the streams were rapidly colonized by macroinvertebrates and algae, including forms other than blue-greens. The taxa richness, density, and biomass of many macroinvertebrates which had been absent or present in low numbers while the reactor was operating increased in Four Mile Creek during the summer of 1985 following shutdown of C Reactor in June. Organisms with short generation times, multiple generations per year, high growth rates and relatively high vagility (such as chironomid midges and heptageneiid mayflies) were abundant on the samplers in Four Mile Creek during the first three months of reactor outage. Other taxa would be expected to reinvade the stream if reactor outage was of sufficiently long duration.

Beaver Dam Creek receives heated effluent from a coal-fired power plant in D Area. As a result, the creek had moderately elevated temperatures (usually <35°C), increased discharge, and inputs of coal ash effluent. Stream characteristics in Beaver Dam Creek varied considerably from the headwaters to the mouth. The upstream stations had abundant woody debris and trailing vegetation, but turbidity and high current velocity limited the growth of macrophytes. Farther downstream, a slough area had low velocity, and abundant macrophyte beds. At the stations downstream from the slough, large logs were abundant and high current velocity and turbidity precluded macrophyte growth. Litterfall and periphyton production varied with percent canopy. Litterfall at the upstream station was high, and instream primary production was low. Farther downstream, where the canopy was more open, periphyton biomass was high. In the slough area, macrophyte biomass was high and litter inputs were low. Particulate matter (especially the large size fractions) imported from upstream settled out in the low velocity, luxuriantly vegetated slough area, contributing greatly to the retentiveness of the ecosystem. Although macroinvertebrate density in much of Beaver Dam Creek was comparable to reference stream densities, macroinvertebrate biomass was lower. Taxa richness was also relatively low, except in the slough area, were growth of macrophytes probably enhanced macroinvertebrate production.

The SRP deltas are areas that have suffered extensive tree loss due to increased water temperatures and sedimentation caused by reactor effluents. The post-thermal Steel Creek Delta had high macrophyte and periphyton biomass. Litterfall was lower than in the forested swamp areas. The TSS concentrations were low, although the organic matter percentages were higher than in some of the streams sampled. Macroinvertebrate taxa richness, biomass, and densities were high. The abundant macrophytes in the Steel Creek Delta exerted a major influence on the macroinvertebrate community by providing habitat, substrate for periphyton growth, and detritus.

In the thermal deltas of Four Mile Creek and Pen Branch, high water temperatures excluded macrophytes in the channels at some sites, and where aquatic plants did occur they did not form extensive beds as they did in the Steel Creek Delta. Without macrophytes, the organic matter retention characteristics, habitat, and energy base were very different from those of the Steel Creek Delta. Wood was abundant in both thermal deltas. Slow current velocities allowed deposition of particulate matter, especially evident in the Four Mile Creek Delta, where TSS concentrations and the size of particles in suspension decreased from the upstream to the downstream end of the delta. The energy base for the food chain in the thermal deltas included particulate organic matter transported from upstream and autochthonous production of blue-green algae. Litter inputs were low. Macroinvertebrate diversities were low when the reactors were operating. The communities were dominated by thermally-tolerant taxa such as oligochaetes, chironomids, and nematodes. Soft substrates in these thermal deltas may provide some protection for taxa which are able to burrow into the bottom. With C Reactor shutdown in June 1984, densities and biomass of invertebrates increased rapidly, in Four Mile Creek Delta during the following summer. Organisms with shorter life cycles and high reproductive potential (e.g., chironomids) were observed to recolonize the delta areas more quickly than invertebrates which have longer generation times (e.g., caddisflies and stoneflies). Since K Reactor operated almost continuously during 1984-1985, there was little opportunity to study recovery time in Pen Branch.

The effects of SRP operations on the Savannah River swamp included thermal effects, increased discharge, and sedimentation. The Pen Branch swamp resembled a natural swamp forest. Its canopy was dense, resulting in a high litterfall rate and low primary production. In comparison, the Steel Creek swamp had a more open canopy, lower litterfall rate, and higher macrophyte and periphyton biomass than the Pen Branch swamp. The TSS concentrations were low and the percentage of organic matter in the seston was high in both swamps. Both swamp systems retained particulate matter from upstream. Both systems had high macroinvertebrate biomass, density, and taxa richness.

Macroinvertebrates and periphyton samples were collected at ten Savannah River stations in the vicinity of the SRP (river miles 128.9 to 157.3). The results showed no impact from SRP thermal effluents, with the exception of periphyton biomass, which was higher immediately downstream of Four Mile Creek during the winter. However, annual mean periphyton biomass generally did not differ among river transects, and was generally higher than at the SRP stream sites. The macroinvertebrate communities consisted primarily of true flies, mayflies, caddisflies, stoneflies, and beetles. Neither the multiplate sampling nor the drift sampling of macroinvertebrates showed significant differences among river stations. Functional group densities and the taxonomic composition of macroinvertebrate communities were similar among the river stations. Most differences in invertebrate densities and biomass were attributable to season, with highest values in October, lowest values in winter and relative high densities in summer. These trends were consistent over both years of the study. The relatively greater importance of collector-filterers in the Savannah River as compared to the creek mouths was probably attributable to the stronger currents in the river.

Adult Fish and Ichthyoplankton

A study of the juvenile and adult fish community in streams draining the SRP and in the Savannah River in the vicinity of the SRP was conducted over a two-year period, from September 1983 to September 1984, and from September 1984 to September 1985. Most stations were sampled quarterly but a few stations were also sampled weekly during the winter of both sampling years to determine if fish congregated in the thermal areas of the creeks and river when ambient river temperatures were relatively low.

The major objectives of this study were to examine the abundance and distribution of fishes near the SRP 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 of the three SRP pumphouses.

Approximately 12,160 adult and juvenile fishes representing 68 species were collected by electrofishing and hoopnetting at 19 sample stations in the SRP study area in the 1983-1984 sampling year. The most abundant fishes (excluding minnows) taken by electrofishing were the 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%). The most abundant fishes taken by hoopnetting were the flat bullhead (29.2%), channel catfish (21.0%), redbreast sunfish (9.7%), white catfish (9.0%), black crappie (6.8%), longnose gar (5.6%), and bluegill (5.2%). Shiners (Notropis spp.) were the most abundant small fish collected, accounting for 88.9% of all minnows and other small fish.

Approximately 10,000 adult and juvenile fishes were collected by electrofishing and hoopnetting in the 1984-1985 sampling year. 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 hoopnetting 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%). In comparing total numbers and relative abundance estimates between the 1983-1984 and 1984-1985 sampling years, it should be noted that 15 new electrofishing sample stations were added in 1985 to characterize the fish communities in the channels and swamps of major SRP creeks, and that the sampling intensity were reduced from that of the 1983-1984 study.

To evaluate habitat preferences, the study area was divided into four habitats in the 1983-1984 sampling year: intake canals, the river, nonthermal creek stations, and thermal creeks. The nonthermal creeks were Upper Three Runs, Lower Three Runs, and Steel Creek. The thermal creeks included those in relatively hot Four Mile Creek, those in moderately hot Beaver Dam Creek, and the refuge areas in Pen Branch (the only locations where Pen Branch was sampled). The dominant species in the intake canals were the bluegill, black crappie, and chain pickerel. Redbreast sunfish, spotted sucker, channel catfish, and flat bullhead were dominant in the river and nonthermal creeks. In the thermal creeks, redbreast sunfish, largemouth bass, redear sunfish, channel catfish, and gar were the dominant species.

Species numbers in the thermal creeks exhibited a seasonal cycle, with the greatest numbers occurring in the winter and spring, and the lowest numbers occurring in the summer and fall when temperatures became excessive (particularly in Four Mile Creek). Species numbers exhibited a different pattern in the non-thermal creeks, peaking in the spring and dropping in the winter.

To evaluate habitat preferences in the 1984-1985 sampling year, the study area was divided into five habitats. The habitat designations were the same as 1983-1984 except that the river habitat was designated nonthermal or thermal, with the South Carolina side of the river at the transects immediately downstream from Four Mile Creek and Beaver Dam Creek constituting the thermal river habitat. In 1984-1985, the dominant species in the intake canals were the bluegill, redbreast sunfish, and black crappie. Bluegill and black crappie comprised a greater percentage of the total catch in the intake canals than the river or creeks, possibly reflecting a preference for quieter water. As in 1984, the weight of fish captured in intake canals was relatively low. The red-breast sunfish, spotted sunfish, spotted sucker, largemouth bass, bluegill, flat bullhead, and channel catfish were the dominant species at the nonthermal river sites. The relative composition of the dominant species in the nonthermal creeks was similar to that in the river, except that the species richness was greater in the river. In general, the fish communities in the river were more diverse than those in other habitats, due, presumably to greater habitat diversity (Paller & Osteen, 1985). The thermal river and creek habitats differed from the nonthermal habitats in that they had a higher percentage (although often lower numbers) of channel catfish, white catfish, largemouth bass, and coastal shiner and a lower percentage of flat bullhead. Exceptions occurred in the 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 (CPUE) or the number of fish/100 m of shoreline. The CPUE at stations in the Savannah River in 1983-1984 ranged from 1.0 to 10.8 fish/100 m during November, 0.3 to 2.6 fish/100 m during January, 0.7 to 10.2 fish/100 m during June, and 0.2 to 3.4 fish/ 100 m during August. The low CPUEs in January and August were probably due to relatively high water levels that not only permitted fish to disperse through the swamps, but also made sampling more difficult.

In 1983-1984, the CPUE in the intake canals was higher than in the other habitats, averaging 5.3 fish/100 m over the entire sampling period, compared to 2.7 fish/100 m in the river, 3.4 fish/100 m in the nonthermal creeks, and 1.3 fish/100 m in the thermal creeks. The comparatively high catches from the intake canals were probably attributable to the presence of large numbers of bluegill, chain pickerel, and other taxa in the extensive macrophyte beds in the canals. During 1985, these beds did not develop to nearly the same extent due to dredging activities.

The CPUE was consistently low (mean of 1.1 fish/100 m) in thermally influenced Four Mile Creek in 1983-1984. Higher catch rates only occurred when temperatures were low. Electrofishing catch rates (1.6 fish/100 m) in moderately thermal Beaver Dam Creek were only slightly lower than those in the nonthermal creeks.

Combining all sample stations in 1984-1985, the CPUE averaged 3.8 fish/100 m during November, 1.5 fish/100 m during February, 4.1 fish/100 m during May, and 7.2 fish/100 m during August.

In 1984-1985, the CPUE in the nonthermal creeks was higher than in the other habitats, averaging 6.3 fish/100 m over the entire sampling period, compared to 5.6 fish/100 m in the intake canals, 4.0 fish/100 m in the thermal and nonthermal river, and 1.8 fish/100 m in the thermal creeks. Generally, the CPUE in Four Mile Creek was zero fish/100 m. The only exception was in August 1985 when C Reactor was shut down and creek temperatures subsequently dropped. Then, the CPUE in Four Mile Creek was similar to the CPUE for the other creeks. The CPUE in moderately thermal Beaver Dam Creek was variable and exhibited no obvious relationship to temperature. The CPUE was highly variable at most of the other sampling stations.

Fish collected by hoopnetting were also used to estimate the CPUE (number of fish/net day). For both 1983-1984 and 1984-1985, the hoopnetting CPUE was highly variable, ranging from zero to 2.5 fish/net day, but the observed seasonal trends were similar to those observed with electrofishing. The only consistent indication of thermal impacts on the hoopnetting CPUE was in Four Mile Creek, where the CPUE ranged from zero to 0.5 fish/net day for both 1983-1984 and 1984-1985.

In the overwintering study it was found that some species congregated in the thermal habitats during the winter months and some did not. In the 1983-1984 and 1984-1985 study years, the species that did congregate in the thermal habitats significantly more than in the nonthermal habitats were the redbreast sunfish, channel catfish, longnose, and spotted gar, white catfish, and gizzard shad. Fish appeared to congregate to the greatest extent in the thermal river habitat that was heated only 2 to 3°C above ambient temperatures. In 1984-1985, fish avoided Four Mile Creek, where temperatures occasionally exceeded 35°C. Species that did not congregate in the thermal habitats during the winter (and may have avoided the thermal areas) were the spotted sucker, flat bullhead, and American eel. CPUE for all species combined was approximately twice as high in the thermal habitats as in the nonthermal habitats during the winter, which indicates an overall attraction to the thermal areas during the winter. Based on ratios of CPUE in thermal and nonthermal habitats, three major overwintering trends emerged from the 1984 study. Spotted suckers and flat bullheads strongly avoided thermal creeks during summer and weakly avoided them in winter. Channel and white catfish avoided thermal creeks in summer, but congregated in them in winter. Redear sunfish and longnose gar did not avoid thermal creeks in summer and congregated in them in winter. Considering all species combined, there appeared to be an overall attraction to thermal streams in winter. With the exception of gizzard shad and channel catfish, species which congregated in thermal streams in winter did not exhibit reduced condition (based on a coefficient of condition). Lower condition for these two species in the thermal creeks may be related to increased metabolic rates, and hence greater food demand in relation to supply.

A total of 1,938 fish representing 50 species were collected from intake screens during the 1983-1984 impingement study. The majority of the fish impinged were sunfish, gizzard shad, and threadfin shad. The highest impingement rates occurred in May and December. The 3G intake canal had the highest impingement rate of 9.5 fish/day while the 1G intake canal had the highest number impinged by volume of water pumped ($8.9/10^6$ m^3). Results indicated that species varied considerably in susceptibility to impingement, and the most abundant species were not necessarily the most frequently impinged.

A total of 745 fish representing 33 species were collected from intake screens during the 1984-1985 impingement study. The same taxa predominated in 1985 as in 1983-1984 (the shad/herring the sunfishes). The 1G intake canal had the highest impingement rate of 0.9 fish/day. The river levels were lower in the spawning season of 1985 than in 1984 when greater numbers of fishes were impinged on the intake screens. In addition, the spawning habitats in the 1G, 3G, and 5G canals were altered in the 1984-1985 season by extensive dredging. From both the 1983-1984 and 1984-1985 impingement studies, the data indicated that species abundance in the canals and susceptibility to impingement were not closely associated, and that the most abundant fishes did not necessarily appear in large numbers on the intake screens.

Weekly ichthyoplankton collections were made in the SRP creeks and swamp from February through July in 1984 and 1985. The creeks that were sampled included Upper Three Runs, Beaver Dam Creek, Four Mile Creek, Pen Branch, Steel Creek, Meyers Branch, and Lower Three Runs. In 1984, 3,708 fish larvae and 448 fish eggs were collected. The dominant taxa were sunfishes and bass (centrarchids; 38.8%), minnows (13.8%), darters (12.0%), spotted suckers (7.0%), and brook silverside (4.0%). The most common identifiable eggs were those of blueback herring. The three significant anadromous species in the SRP study area (blueback herring, American shad, and striped bass) were found in varying densities in the mouth of Steel Creek, but in relatively low densities in the other locations within the study area. The period of maximum spawning for most of the species in the creeks and swamps was April through May.

In 1985, 1,109 fish larvae and 710 fish eggs were collected in the SRP creeks and swamp. The most abundant larvae were darters (31.3%), centrarchids (16.9%), minnows (15.0%), spotted suckers (19.7%), and brook silversides (9.9%). The most common identifiable eggs were those of blueback herring and American shad. Relative composition of the ichthyoplankton was very similar over the two years of the study. However, there were some distinct differences. For example, American shad was five times more abundant in 1985.

Ichthyoplankton densities were highly variable at all locations throughout the study period. In the Steel Creek system, high ichthyoplankton densities were observed in the post-thermal Steel Creek swamp and in the creek mouth, with especially high densities in 1985 in the creek mouths. Ichthyoplankton densities were considerably lower in the nonthermal swamp adjacent to the post-thermal area and, in 1984, lowest in the sections of Steel Creek upstream from the swamp. During 1984 and 1985, the dominant taxa in the upper reaches of Steel Creek were minnows and darters; in the Steel Creek swamp the species composition was more diverse but was dominated by centrarchids, minnows, and darters. American shad, blueback herring, and darters predominated in the creek mouths. Most of the spawning in Steel Creek occurred between temperatures of approximately 17 to 25°C.

Ichthyoplankton were generally absent from the mid-reaches of Four Mile Creek and Pen Branch (below the reactor outfall) and in the delta, both of which were characterized by high water temperatures due to reactor discharges. During periods of river flooding, when temperatures at Four Mile Creek swamp and mouth were cooler, ichthyoplankton were collected. The collection of large numbers of eggs on a single day in May 1984 when C Reactor was down indicates that fish will move into the thermal creeks to spawn during reactor outages as soon as water temperatures become tolerable. Higher ichthyoplankton densities were observed in the cooler swamps of Four Mile Creek and Pen Branch. Beaver Dam Creek exhibited no evidence of thermal impact. Ichthyoplankton densities were low to moderate throughout the creek. In Four Mile Creek, centrarchids, brook silverside, and blueback herring were the dominant taxa in 1984 and minnows, centrarchids, carp, and darters were the dominant taxa in 1985. In Pen Branch, minnows and darters were the dominant taxa during both years. In Beaver Dam Creek, centrarchids, crappie, darters, and gizzard and threadfin shad were the dominant taxa in 1984 while blueback herring was the dominant taxa in 1985.

In both nonthermal Meyers Branch and Upper Three Runs, ichthyoplankton densities were low. Ichthyoplankton densities in Lower Three Runs were low in the downstream reaches of the creek and extremely high (averaging approximately 620/1,000 m^3 during 1984 and 1985) in the upstream reach just downstream from the tailwaters of Par Pond. The high densities in the tailwaters were probably due to ichthyoplankton transported over the spillway from Par Pond as well as spawning in the Par Pond tailwaters. In Meyers Branch, darters and centrarchids were the dominant taxa during both years. In Upper Three Runs, spotted suckers and crappie were the dominant taxa during 1984, and spotted suckers and darters were the dominant taxa during 1985. In Lower Three Runs, centrarchids, crappie, and darters were the dominant taxa in 1984, while brook silverside, darters, centrarchids, and crappie were the dominant taxa in 1985.

In the 1985 sample period, ichthyoplankton densities were again highly variable. The mean density values in Four Mile Creek and Pen Branch, the two streams receiving reactor effluent, were much lower than in the nonthermal creeks.

Analyses of the 1985 data revealed that most species in SRP waters spawn at temperatures from 12 to 26°C. Ichthyoplankton densities decreased above 26°C and ichthyoplankton were largely absent at temperatures above 35°C.

The anadromous species, American shad and blueback herring, were collected primarily in the creek mouths, which indicated the importance of the creek mouths in the life cycles of these species. They were particularly well-represented in the mouth of Steel Creek during both years of the study. The numbers of American shad and blueback herring collected from the creek mouths were much higher during 1985, when the Savannah River levels remained below flood stage. During 1984, when the floodplain was inundated during the spring, spawning could take place in the floodplain.

In 1985, fish larvae were collected from different habitats in Steel Creek (macrophyte beds, open water habitats, and the interface between the macrophyte beds and open water) to compare relative densities between these microhabitats. Larvae were collected in the greatest abundance in the macrophyte beds, indicating these vegetated areas are important to the reproduction and early life stages of many fishes in the SRP streams and swamps.

Diel samples taken in the Steel Creek swamp showed that larval densities in the open channels were approximately 18 times higher during the night than during the day. Larvae entering the open channels at night probably came from the macrophyte beds where larvae were concentrated in large numbers. These results indicate that the potential for entrainment of larvae via cooling water intake is higher at night, at least in areas with macrophyte beds.

In 1984, weekly ichthyoplankton collections were made at a total of 62 stations including transects in the Savannah River upstream and downstream from the SRP, as well as adjacent to the SRP, and in the mouth of 28 associated tributaries from Augusta to Savannah, GA. In 1985, weekly ichthyoplankton collections were taken from a reduced study area: ichthyoplankton was collected from the mouth of only 17 associated tributaries, with a total of 45 stations sampled. The primary objective of the 1985 study was to assess spawning activity and ichthyoplankton distribution in the Savannah River in relation to the influence of the SRP. The sampling program for 1984 and 1985 focused on the effects of thermal discharges and the entrainment of ichthyoplankton in river water removed for SRP reactor operations. The evaluation of ichthyoplankton production in Steel Creek was emphasized in this study.

A total of 24,289 fish larvae and 4,756 fish eggs were collected from February through July 1984. The dominant taxa collected were the Clupeidae, which included the anadromous American shad, blueback herring, nonanadromous threadfin shad, and the gizzard shad. Other taxa collected in abundance were sunfish, crappie, and minnow. American shad and striped bass were the dominant eggs collected in 1984.

A total of 19,926 fish larvae and 15,749 fish eggs were collected from February through July 1985. The dominant taxa collected were gizzard and threadfin shad, centrarchids, and spotted sucker. American shad were the dominant eggs collected in 1985. Large numbers of American shad and blueback herring were collected from the lower reaches of Steel Creek, indicating that the lower reaches of Steel Creek were an important spawning area for these anadromous species. These results are consistent with those from the creek and swamp study.

Of the major streams draining the SRP, Steel Creek transported the greatest number of fish eggs and larvae (53.0 million) to the Savannah River in 1984. Three large streams located downriver from the SRP, Briar Creek, Lake Parachuchia, and Coleman Lake (the latter two were not sampled in 1985) exceeded ichthyoplankton transport from Steel Creek (142.7 million, 102.4 million, and 95.9 million, respectively). In 1984, Steel Creek increased the ichthyoplankton densities of the Savannah River immediately downstream of the creek by 15%.

The 1985 sampling program did not include any stations downstream of River Mile 89.3, thereby eliminating five creeks that contributed large numbers of ichthyoplankton to the river in 1984. In 1985, Steel Creek transported more fish eggs and larvae to the Savannah River than any of the other creeks sampled (5.2 million), followed by Beaver Dam Creek (4.3 million). In May, June, and July, when temperatures in the mouth of Beaver Dam Creek often exceeded 30°C, ichthyoplankton densities were usually low compared to the other creeks. Overall, numbers of ichthyoplankton transported from Steel Creek and other major contributors decreased substantially in 1985, possibly due to decreased creek discharges and reduced spawning. Results of the sampling in the mouth of Four Mile Creek during both years indicates that fish move rapidly into thermal creek mouths to spawn when the reactors are down. The abundance of blueback herring eggs in the mouths of Beaver Dam and Four Mile Creeks may be attributable to dislodging of eggs from spawning areas by strong currents.

Spawning trends and ichthyoplankton densities in the five oxbows sampled during 1984 and 1985 were generally comparable to those in the river. The only exception was an oxbow at RM 100.2 which consistently had much higher densities than the river. During 1984 and 1985, gizzard and threadfin shad were the dominant ichthyoplankton in the oxbows.

Shortnose sturgeon, a federally listed endangered species, have been collected in small numbers in the Savannah River; nine sturgeon larvae were collected during 1984 and seven were collected in 1985. Of the 16 larvae, four were provisionally identified as shortnose sturgeon, and the remainder as Atlantic sturgeon.

During 1984, an estimated 23.4 million ichthyoplankters (eggs and larvae) were entrained, which was 8.5% of the total ichthyoplankton that were transported past the SRP. Of these, 17.6 million were larvae and 5.8 million were eggs. In 1984, 8.3% of the total susceptible ichthyoplankton was entrained (Paller et al., 1985). During 1985, an estimated 25.9 million ichthyoplankters were entrained. Total number of larvae entrained (10.9 million) was low compared to 1984 and prior years of sampling. Low numbers of larvae in 1985 may be attributable to the lack of Savannah River flooding during the spring, thereby precluding spawning in floodplain habitats. American shad and striped bass eggs dominated the ichthyoplankton samples during both years of the study. This total represented approximately 12.1% of the total ichthyoplankton that drifted past the SRP pumphouses.

While a substantial fraction of the Savannah River ichthyoplankton are entrained at the SRP cooling water intake structures, there appears to be no effect on the fishery of the river. Impacts may be mitigated by the fact that all of the species entrained have numerous spawning sites in the Savannah River and the fact that ichthyoplankton have high rates of natural mortalities. There has been no evidence to indicate that numbers of American shad or striped bass ichthyoplankton in the Savannah River have decreased during the CCWS or during previous years studied.

V.1 INTRODUCTION

The Comprehensive Cooling Water Study (CCWS) was initiated in October 1983 to evaluate the environmental impacts associated with the intake and release of cooling water from Savannah River Plant (SRP) operations. The CCWS was initiated in response to a commitment by the Department of Energy Savannah River Operations (DOE-SR) to the U.S. Armed Services Committee and the State of South Carolina. The study is a joint effort of DOE-SR, E. I. du Pont de Nemours and Company (Savannah River Laboratory), and the University of Georgia (Savannah River Ecology Laboratory).

One of the major program elements of the CCWS is the Aquatic Ecology Program, which is summarized in this volume, "Volume V--Aquatic Ecology, Comprehensive Cooling Water Study Final Report." This volume includes a summary of existing data reports that were generated during the CCWS from 1983 to 1985. Results of some previously initiated studies and long-term monitoring programs are also included. For an historical perspective on the life histories and distributions of semi-aquatic vertebrates on the SRP, see Gibbons et al., 1986.

The overall objective of the Aquatic Ecology Program was to assess the effects of cooling water intake and releases on the structure and dynamics of the biological communities of the SRP streams and swamp, and the Savannah River. To address this objective integrated studies of primary producer populations, organic matter, macroinvertebrates, and fish populations were conducted.

The specific objectives of the Aquatic Ecology Program (excluding Par Pond, which is reported on in Volume VII of this report) can be summarized as follows:

- Determine thermal impacts of cooling water discharges on the structure and dynamics of lower food chain (i.e., nonvertebrate) communities including periphyton, macrophytes, and macroinvertebrates;

- Assess fish spawning and location of nursery grounds on the SRP;

- Determine the relative importance of SRP streams to spawning fish, as compared to other Savannah River tributaries;

- Determine rates of ichthyoplankton entrainment and impingement of adult fishes at the cooling water intakes and assess the impacts of impingement and entrainment losses on the Savannah River fish community; and,

- Determine thermal plume effects on anadromous and resident fishes, including overwintering effects in the SRP swamp.

V.1.1 Report Structure

Chapter V.2 of this volume provides a general description of the surface water systems located on the SRP site or in its vicinity. Chapter V.3 is a report of the lower food chain studies conducted in the onsite streams and swamp and in the Savannah River. It includes studies of physical characteristics and stream structure, primary producers (algae and macrophytes), organic matter, and macroinvertebrates. Chapter V.4 reports on the studies of the fish populations in the Savannah River and the SRP onsite streams and swamp.

V.2 STUDY AREA

The SRP occupies a 778 km^2 (77,800 ha) site on the Upper Coastal Plain in Aiken, Barnwell, and Allendale counties, South Carolina (Figure V-2.1). The SRP is bordered on the southwest by the Savannah River for 27 km.

Five main drainage basins are located on the SRP (Figure V-2.2). Upper Three Runs Creek is a relatively unperturbed blackwater stream in the northwestern portion of the SRP. Beaver Dam Creek and Four Mile Creek receive thermal inputs from two different sources: Beaver Dam Creek receives thermal effluent from a coal-fired power plant and Four Mile Creek receives once-through cooling water from C Reactor. The Pen Branch system is also thermally perturbed. It receives once-through cooling water from K Reactor. The Steel Creek-Meyers Branch system consists of a post-thermal stream (Steel Creek) and its tributary (Meyers Branch), which has never received heated water. Lower Three Runs is located in the southeastern portion of the SRP. The upper reaches of Lower Three Runs stream are impounded to form a 1,012 ha cooling water reservoir for P Reactor.

Four Mile, Beaver Dam, Pen Branch, and Steel Creeks flow into a contiguous 30.2 km^2 (3,020 ha) river floodplain swamp which drains into the Savannah River. The swamp is separated from the main flow of the Savannah River by a natural levee along the river bank. Water moves through the swamp in a shallow sheet flow with well-defined channels where streams enter the upper side of the swamp, and exits through natural breaks in the levee. Throughout most of the year, water levels are maintained in the swamp by flow from the creeks. Periodically (usually during winter and spring), the Savannah River floods and spills over the levee that separates it from the swamp. When the river floods into the swamp, the flow in the creeks is reversed and many physiochemical features of the swamp are substantially altered.

The water used to cool the SRP reactors and to provide cooling water to the D-Area power plant is withdrawn from the Savannah River at three pumphouses located at River Miles (RM) 157.1, 155.3, and 155.2. The withdrawal rate of river water by the SRP varies from an estimate of 8.5 m^3/sec to 26.0 m^3/sec, depending on the number of reactors operating and the corresponding reactor power levels. After the cooling water flows through the reactor heat exchangers, the heated water is discharged to the river via one of the onsite streams or discharged into Par Pond via a series of canals and precooling ponds.

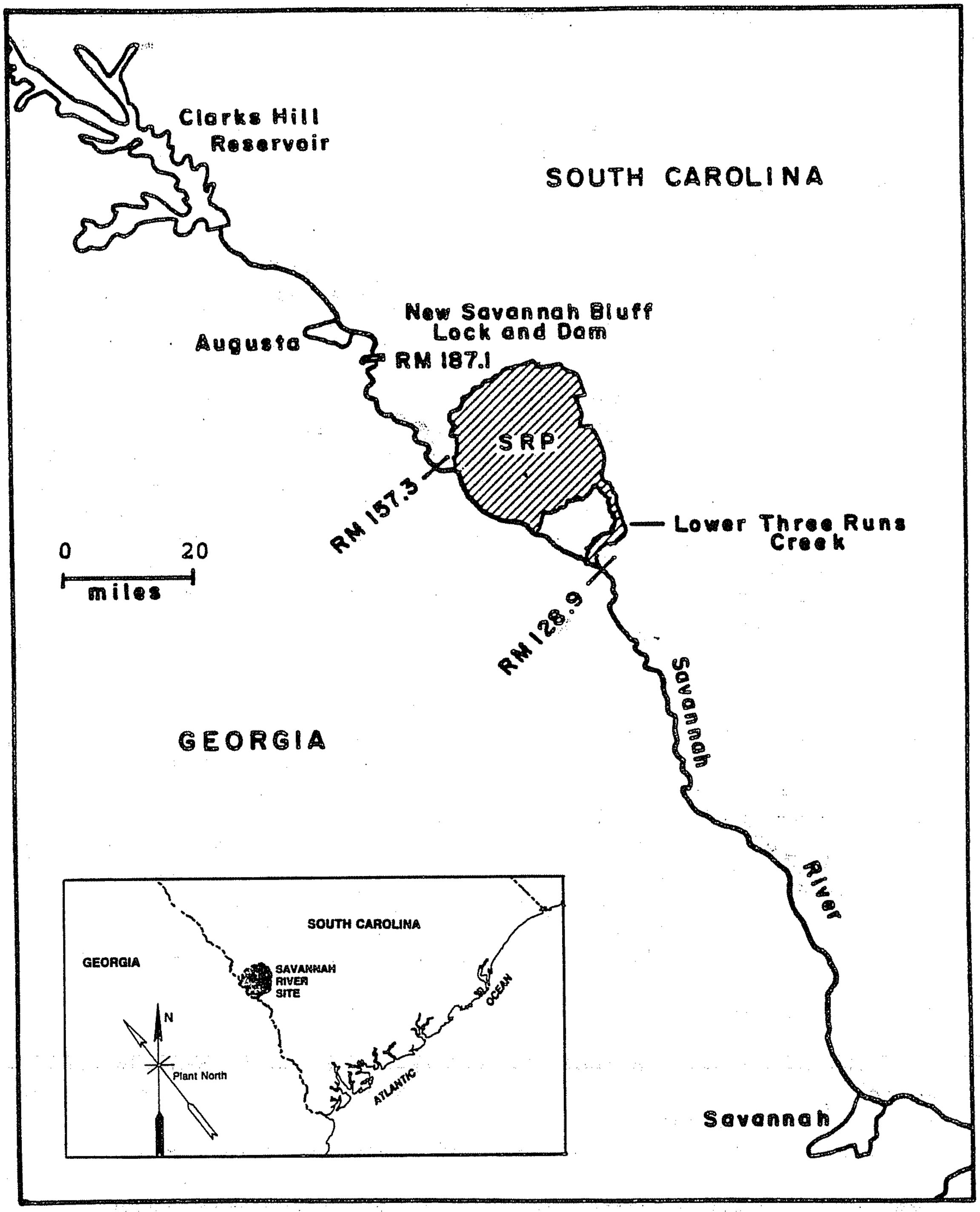


FIGURE V-2.1. A Map of the Savannah River from Clarks Hill Reservoir to Savannah, Georgia

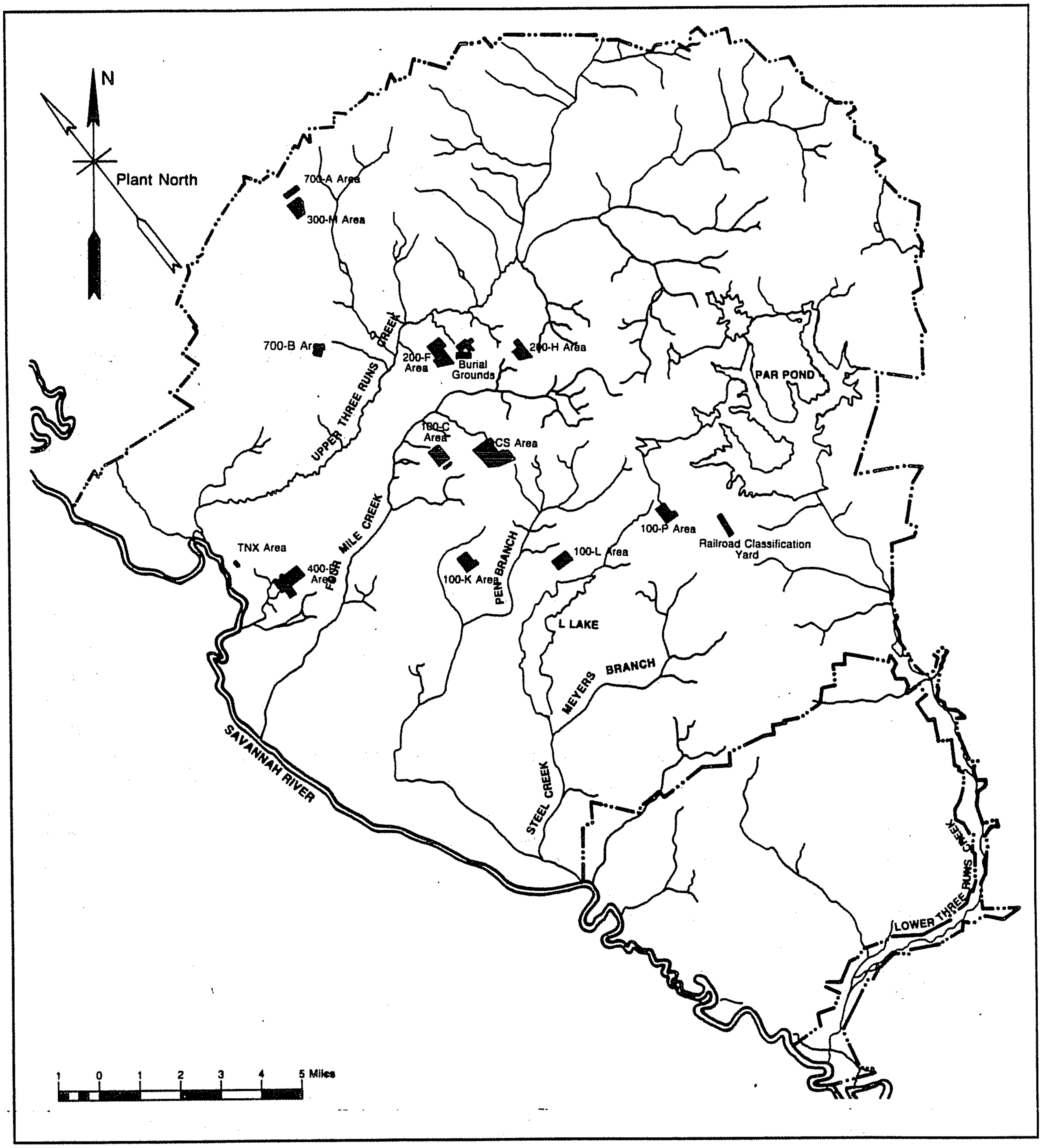


FIGURE V-2.2. The Savannah River Plantsite

V.2.1 Streams and Swamps of the SRP

Five tributaries originate in or pass through the SRP before flowing into the Savannah River: Upper Three Runs, Beaver Dam, Four Mile, Steel, and Lower Three Runs Creeks. A sixth stream, Pen Branch, does not flow directly into the Savannah River but joins Steel Creek in the floodplain swamp. During the CCWS sampling period, Four Mile Creek, and Pen Branch received thermal effluents from C and K Reactors. Beaver Dam Creek received thermal and industrial effluents from the D-Area power plant. Lower Three Runs received effluents from Par Pond at near ambient temperatures. Steel Creek received thermal effluent from L Reactor until 1968, when the reactor was put on standby. Since then, Steel Creek has been undergoing post-thermal recovery. Each of the five tributaries are described below.

V.2.1.1 Upper Three Runs Creek

Upper Three Runs is a large, cool (annual maximum of 26.1°C), blackwater stream located in the northern part of the SRP. It drains an area of approximately 5,266 km^2, and has an average discharge of 9.3 m^3/sec at the mouth of the creek. Upper Three Runs Creek is approximately 40 km long, with a lower 28 km located within the boundaries of the SRP. Upper Three Runs receives more water from underground sources (the Tuscaloosa aquifer) than the other SRP streams and as such, has low conductivity, hardness, and pH values. Upper Three Runs is the only major tributary of the SRP that has never received thermal discharges. Above its confluence with Tims Branch, Upper Three Runs is relatively unimpacted. Industrial effluents have been discharged into Tims Branch in the past, resulting in some heavy metal contamination. Since late 1985, the stream has been receiving effluents containing higher than background levels of nitrates from SRP operations in M Area (Specht et al., 1987).

V.2.1.2 Beaver Dam Creek

Before SRP operations, Beaver Dam Creek probably had only intermittent and/or very low flow. In 1952, Beaver Dam Creek began receiving heated effluent from a heavy water (D_2O) production facility and a coal-fired power plant. Since 1964 it has received effluent only from the D-Area power plant. Temperatures in Beaver Dam Creek typically average 1 to 8°C above ambient, and the average discharge is 4.7 m^3/sec at the mouth of the creek.

Beaver Dam Creek which is approximately 6 km long and drains an area of approximately 2.2 km^2, originates at the effluent outfall canal from D Area, and flows south, parallel to Four Mile

Creek, to the Savannah River. These two creeks are in close proximity and there is some mixing of their discharges in the Savannah River floodplain swamp. Beaver Dam Creek is deep, narrow, and channelized in its headwaters and near its mouth, and opens into a slough-like channel in its midreaches (Firth et al., 1986).

V.2.1.3 Four Mile Creek

Four Mile Creek is about 24 km long and drains an area of approximately 89 km^2. In its headwaters, Four Mile Creek is a small blackwater stream that is relatively unimpacted by SRP operations. The water chemistry in the headwater area of the creek is very similar to that of Upper Three Runs Creek, with the exception of nitrate concentrations, which are an order of magnitude higher than Upper Three Runs Creek. These elevated nitrate concentrations are probably the result of groundwater transport and outcropping from the F- and H-Area seepage basins (SREL, 1986). Downstream from C Reactor, heated Savannah River water (as hot as 70°C) is discharged into Four Mile Creek via Castor Creek, resulting in water temperatures in excess of 60°C in Four Mile Creek just downstream of its confluence with Castor Creek. In its lower reaches, Four Mile Creek broadens and flows through a delta that has been formed by the deposition of sediments. Although most of the flow through the delta is in one main channel, the delta has numerous standing dead trees, logs, stumps, and cypress trees which provide structure and reduce the water velocity in some areas. Downstream of the delta, the creek flows in one main channel and the majority of the flow (2.65 m^3/sec) discharges into the Savannah River at RM 152.1, while a small portion of the creek flows west and enters Beaver Dam Creek. Water temperatures at the mouth of the creek are as much as 20°C above ambient. When the Savannah River floods, water from Four Mile Creek flows along the northern boundary of the floodplain swamp and mixes with Steel Creek and Pen Branch instead of flowing directly into the river. When this occurs, stream temperatures at the mouth of Four Mile Creek and the water quality of the creek tends to be more similar to the Savannah River than to other creeks whose flows originate onsite.

V.2.1.4 Pen Branch

Pen Branch drains an area of 91 km^2 and is approximately 16 km long. In its headwaters, Pen Branch is a largely unperturbed blackwater stream, similar to the headwater reaches of Four Mile Creek. Above the confluence with Indian Grave Branch, discharge is approximately 0.1 m^3/sec. Thermal effluent from K Reactor joins Pen Branch via Indian Grave Branch, and accounts for over 90% of the stream volume (approximately 11.4 m^3/sec total discharge). As with Four Mile Creek, the reactor cooling water originates from the

Savannah River and changes the water quality as well as the temperature and flow regimes in Pen Branch (Firth et al., 1986). Pen Branch discharges into the Savannah River floodplain swamp rather than flowing directly into the Savannah River. Where it discharges into the swamp, it has formed a delta. Temperatures in the delta typically range from 25 to 40°C above ambient. The flow from Pen Branch spreads over the delta and continues through the swamp as shallow sheet flow until entering the lower reaches of Steel Creek and discharging into the Savannah River. When the Savannah River inundates the floodplain swamp, the flow from Pen Branch flows along the northern border of the swamp and crosses the Steel Creek Delta. When the Savannah River is not flooding, the Pen Branch flow enters the Steel Creek channel downstream from the swamp. By the time Pen Branch discharges into Steel Creek, its temperature is near ambient, due to dilution and cooling in the swamp.

V.2.1.5 Steel Creek-Meyers Branch

The headwaters of Steel Creek originate near P Reactor, and the stream flows approximately 16 km before reaching its delta. Meyers Branch flows approximately 10 km before entering Steel Creek. The total area drained by the Steel Creek-Meyers Branch system is 91 km^2, and natural discharge upstream of SRP Road B is approximately 1.0 m^3/sec. In 1954, Steel Creek began receiving thermal effluents from P and L Reactors. By 1961, a total of 24 m^3/sec of thermal effluent was being released by both reactors into Steel Creek. Another 0.4 m^3/sec of nonthermal effluent enters the creek from P Area. In 1963, P-Reactor effluent was diverted to Par Pond, and in 1968, L Reactor was put on standby. From 1968 until early 1985, Steel Creek was recovering from the impacts of SRP operations. In 1985, L Lake was constructed in Steel Creek. This is an impoundment designed to receive and cool heated effluent from L Reactor, which was brought back online in October 1985 (Firth et al., 1986). Land clearing and construction operations began in early 1985, and the dam was completed in late summer 1985. The studies in this report were completed before L Reactor was restarted and therefore do not reflect any subsequent impacts that L Lake may have had on Steel Creek. However, during the summer of 1985, Steel Creek was impacted by siltation from L-Lake construction activities. Discussions of Steel Creek in this report only include conditions before the restart of L Reactor.

During the time when Steel Creek was receiving thermal discharge and increased flow, an extensive delta developed where the creek entered the Savannah River floodplain swamp. The delta is drained by numerous braided channels that eventually coalesce and continue for approximately 1.6 km before entering the Savannah River. The average discharge of Steel Creek is 17.0 m^3/sec at the creek mouth.

Meyers Branch is a major tributary of Steel Creek. Meyers Branch is a small blackwater stream that has remained relatively unperturbed by SRP operations. The confluence of Steel Creek and Meyers Branch is located just upstream from the Savannah River floodplain swamp.

V.2.1.6 Lower Three Runs

Lower Three Runs is a large blackwater creek (mean discharge 1.6 m^3/sec) with a 1,012 ha mainstream impoundment in its headwaters. The impoundment, Par Pond, is used as a source of cooling waters for P Reactor. SRP operations cause very large discharge fluctuations just downstream from the dam at Par Pond, but groundwater and tributary inputs are sufficient to dampen these fluctuations farther downstream (Firth et al., 1986). During the period from October 1984 to September 1985, the discharge below Par Pond at SRP Road B (Station 42) ranged from 0.04 to 1.39 m^3/sec, with a mean of 0.56 m^3/sec. Temperatures of water released from Par Pond into Lower Three Runs are near ambient. Water temperature below Par Pond at SRP Road B (Station 42) ranged from 8.5°C in February 1985 to 32.2°C in June 1985, and the mean temperature during the period from 1973 to 1982 was 20.3°C, approximately 2°C higher than the mean for other nonthermal streams (Gladden et al., 1985). The total area drained by Lower Three Runs Creek is 490 km^2.

V.4.2.2 Savannah River

The Savannah River watershed includes western South Carolina and 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 (including the SRP region), it is broad with extensive floodplain swamps and numerous tributaries. The substrate consists of various combinations of silt, sand, and clay.

The U.S. Army Corps of Engineers regulates water flow in the Savannah River by means of three large reservoirs (Clarks Hill, Hartwell, and Russell), as well as by locks and dams. Besides being affected by the reservoirs, the river is influenced by dredging, sewage discharge, and industry. In general, the river water is well oxygenated, low in chemical and biochemical oxygen demand (Dukes, 1984) and slightly acidic.

The SRP has five nuclear reactors, two currently on standby, and a coal-fired power station. Two of the operating 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.

Cooling water pumped from the Savannah River for the power station returns to the river through Beaver Dam Creek. Thermal effluents discharged into these creeks flow through a floodplain swamp before re-entering the Savannah River through breaks in a natural levee which separates the swamp from the river. The third operating reactor utilizes a large, man-made cooling pond and requires only pond makeup water from the Savannah River. Prior to being placed on standby in 1968, a fourth reactor discharged cooling water into Steel Creek, which flows into the Savannah River near the southern boundary of the SRP.

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 water levels are low, the thermal creeks discharge directly into the river, producing plumes that follow the South Carolina shore. Thermal infrared surveys taken in August 1982, indicate that during mid-summer the plume from Four Mile Creek may be more than 10°C above ambient at the egress from the swamp to the river (Bristow & Doak, 1983). These surveys also indicate that the plume dissipates rather quickly due to dilution by the much larger Savannah River. The August infrared survey indicated that the temperature of the Four Mile Creek plume had dropped to approximately 2°C above ambient at 400 m from the discharge point. During colder months, however, the 2°C isotherm extends farther downstream because of the greatest temperature difference between the creek and river waters.

When the Savannah River is high enough to inundate the SRP floodplain swamp, there are no thermal plumes in the river. Under flood conditions, the creeks discharge into the flooded swamp and the water is channelled downstream along the upland bank of the swamp by the river overflow. Dilution and cooling occur in the floodplain swamp before the SRP effluent is discharged into the main channel (Shines & Tinney, 1983).

V.3 LOWER FOOD CHAIN

V.3.1 Introduction

This chapter summarizes the CCWS two-year study of the lower food chain communities of the SRP aquatic systems, including onsite streams and swamps and the adjacent reach of the Savannah River. It includes studies of stream structure and habitat, primary producers, organic matter, and macroinvertebrates. The lower food chain communities of Par Pond are discussed separately in Volume VII.

The CCWS was initiated in October 1983. The first year lower food chain sampling program was conducted through September 1984. The second year sampling program ran from October 1984 through September 1985. All material in this chapter, including literature citations, is taken from the following reports:

<u>1983-1984</u>

Gladden et al., 1985 (summary)
Kondratieff and Kondratieff, 1985a
Kondratieff and Kondratieff, 1985b
Hauer, 1985
O'Hop et al., 1985

<u>1984-1985</u>

Firth et al., 1986
Bott et al., 1986
O'Hop et al., 1986

The 1984-1985 study was much more extensive than that of the previous year; thereafter, the bulk of this chapter was taken from Firth et al. (1986). The following discussion of the lower food chain is abstracted from the introductions by Firth et al. (1986) and Gladden et al. (1985).

V.3.1.1 Energy Sources and Pathways

Food webs are pathways by which energy moves through the biological components of ecosystems. The source of energy-rich organic matter, and the way it moves through the ecosystem, are both important in determining the structure and functions of the invertebrate community. There are two major sources of organic matter that are important to the stream's food web. "Autochthonous" organic matter is produced a stream ecosystem by primary producers such as algae and macrophytes. "Allochthonous" organic matter is produced outside the stream ecosystem (e.g., leaf litter) and enters the system from the adjacent landscape.

Physical characteristics such as channel size, velocity, substrate, and canopy cover are important in determining whether the energy input is predominantly allochthonous or autochthonous. Small, closed canopy streams in deciduous forests are usually too shaded for much algal or macrophyte production. As a result, they depend on allochthonous organic matter inputs (occurring primarily during autumnal leaf drop) as their main energy source. Typically, as a stream increases in size it becomes wider, and the canopy extends over less of the water surface. Because there is less leaf litterfall and more light available to the primary producers in the stream, autochthonous production becomes more important in intermediate stream reaches. River food webs, like those of small streams, are strongly dependent on allochthonous energy inputs, but while streams depend on leaf litter from the adjacent watershed, rivers depend on organic matter carried in from upstream reaches. Autochthonous productivity in rivers is usually limited by depth and turbidity, unstable substrate, and discharge fluctuations. Swamps generally have lower current velocities than streams, which allows more aquatic vegetation growth, given enough light and nutrients (Kitchens et al., 1974). Swamp forest trees, aquatic submerged and emergent macrophytes, and their epiphytes all contribute to the autochthonous energy in swamps. Allochthonous organic matter enters swamps primarily through groundwater outcroppings, tributary streams, and river flooding.

Between its introduction into a system and its final respiration to carbon dioxide (CO_2), organic matter follows an intricate decomposition pathway and supports a complex food web. An understanding of the stream system depends upon an understanding of the various components in the breakdown of organic matter and the transport of energy between those components. Figure V-3.1 is a diagram of the typical interrelationships among the important energy flow components of a stream system.

V.3.1.2 Stream Structure

The physical structure of a stream channel, including logs, roots, debris piles, trailing terrestrial vegetation, and plant beds, plays two important roles in aquatic ecosystem function. First, it provides habitat (shelter, and in some cases, food) for fish and invertebrates, and second, it is important in retention of organic matter and control of sediment erosion. Physical structures in a stream act as retention devices, helping to hold organic matter in place, thereby reducing losses to downstream reaches.

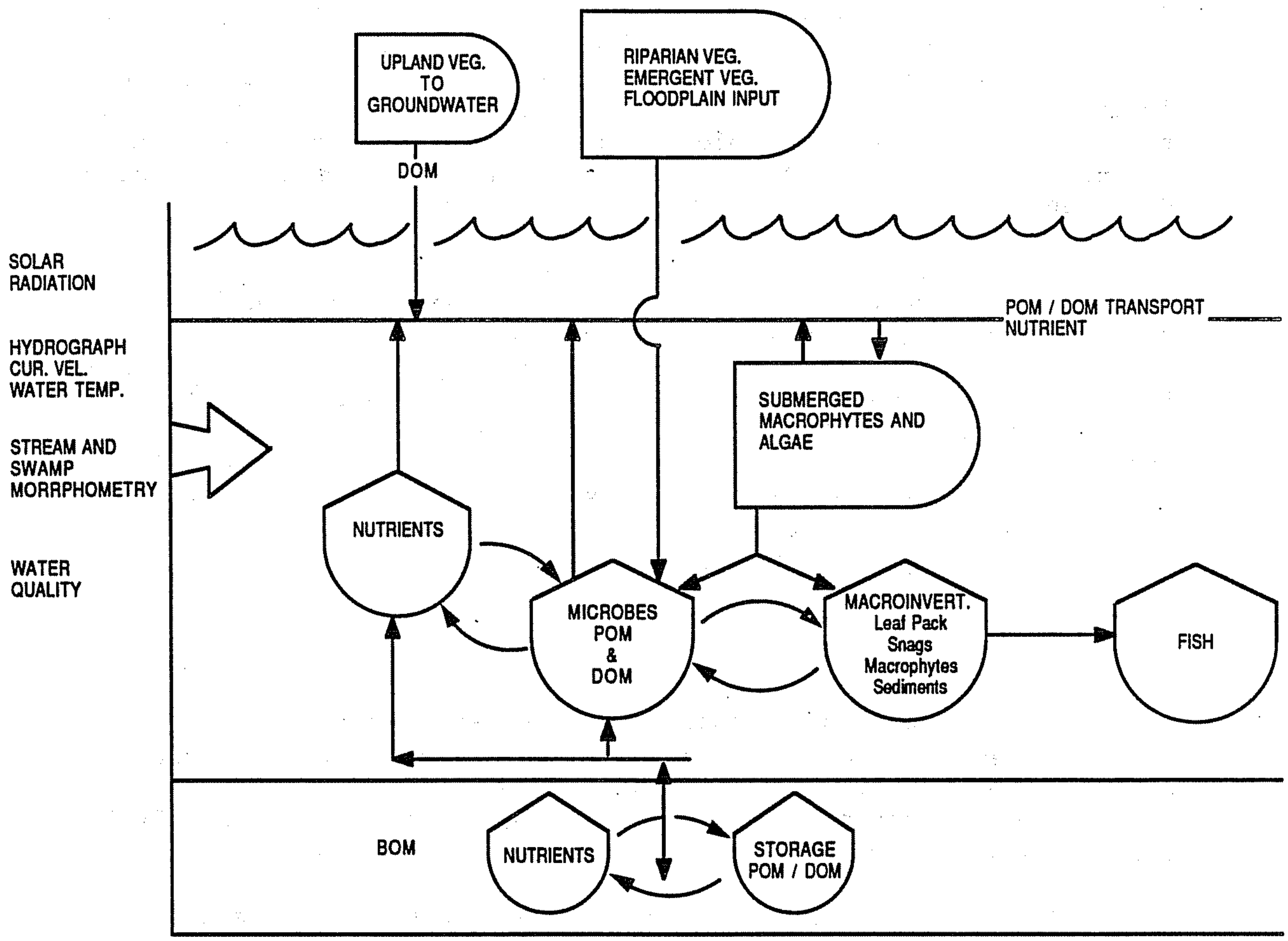


FIGURE V-3.1. Diagram Flow Model of the Interrelationships of Various Important Components of a Stream or Wetland Ecosystem: POM = Particulate Organic Matter; DOM = Dissolved Organic Matter; BOM = Benthic Organic Matter.

V.3.1.3 Primary Producers

Autotrophy by periphyton and aquatic vascular plants plays a fundamental role in many aquatic food webs. Periphyton has been defined as the assemblage of organisms attached to submerged materials in water, and includes diatoms, algae, fungi, bacteria, protozoa, and metazoa (Hynes, 1970; Weber, 1973). Some authors include only the photosynthetic microflora in their definition of periphyton. Periphyton colonize nearly all submerged substrates including vascular plants (epiphytic periphyton) and are an easily digested, high quality food for macroinvertebrates.

Aquatic vascular plants, or macrophytes, are usually consumed after death or senescence. Vascular plant tissue is more difficult to digest and assimilate by consumers than periphyton. However, the food value of macrophytes is enhanced by periphyton colonization. Macrophytes release significant amounts of nutrients (Carpenter, 1980) and organic compounds (Godshalk & Wetzel, 1976) both during growth and after senescence. These compounds help to support an active epiphyte community which is not only a good food source, but also helps to break down the recalcitrant (difficult to decompose) macrophyte detritus.

V.3.1.4 Organic Matter

Much of the energy available to stream organisms is in the form of detrital organic matter originating from allochthonous sources or from dead aquatic plants. This nonliving organic matter serves an important role in streams because it is available throughout the year, including periods of low primary productivity.

Most of the organic matter transported in a stream is dissolved organic matter (DOM; Hobbie and Likens, 1973) and is largely unavailable to macroinvertebrates as a direct food source. However, it may be indirectly available by microbial uptake or by conversion into particulate organic matter (POM) through flocculation. Other sources of POM include leaves, feces of macroinvertebrates, dead animal tissue, sloughed algae, and decomposed macrophytes. Physical and biological processing breaks large organic particles into fine particulate organic matter (FPOM), an important food source of macroinvertebrates.

The particulate matter carried by a stream includes both organic and inorganic particles. Often an organic film clings to an inorganic particle, so it is impossible to categorize individual particles as one or the other. In this report, the term "seston" is used to describe the material carried in suspension by the stream, including both organic and inorganic material. It is also referred to as total suspended solids (TSS). The percent organic matter content is an indicator of the quality of the seston as a food source. Seston with a high percent organic matter is generally a good food source, while seston with a low percent organic matter indicates that much of the seston is comprised of inorganic sediment particles. Particle size distribution of the seston can be an indication of the amount of organic matter processing that is going on in a stream or one of its reaches.

V.3.1.5 Macroinvertebrates

Macroinvertebrates are integral components of the food webs of freshwater stream systems. In this study, macroinvertebrates have been defined as those stream invertebrates retained by a 600 μ sieve (Firth et al., 1986). As consumers and as prey, they are important to the structure and function of aquatic ecosystems (Hynes, 1970; Cummins, 1974; Cummins and Klug, 1979). Because macroinvertebrates are often the initial consumers of autotrophs or allochthonous organic matter, they provide a vital link between primary food sources and higher trophic levels such as fish. The recognition of the importance of macroinvertebrates has provided the impetus for much research and has been responsible for the use of aquatic macroinvertebrates as indicators of water quality (Weber, 1973). The abundance, types of species, and diversity of aquatic macroinvertebrates are usually indicative of the long-term conditions of a stream reach because of the relatively long life cycles (often several weeks to a year) and sedentary nature of many macroinvertebrate species (Taylor & Roff, 1982). The above considerations, in conjunction with the relative ease of taxonomic identification (as compared to the meiofauna and microfauna), establishes the macroinvertebrates as the key biotic component for environmental impact assessment. The 600 μ sieve used in processing the macroinvertebrate samples is small enough to retain virtually all adult macroinvertebrate taxa and most of the macroinvertebrate life-stages, ensuring adequate sampling of the macroinvertebrate component.

Some of the factors that affect the community composition, diversity, and abundance of aquatic macroinvertebrates are temperature, current velocity, water quality, available food, and substrate.

Some aquatic macroinvertebrates are specific in their diets, but most are opportunistic generalists. Variability among macroinvertebrate groups occurs more in the method of food aquisition than in the type of food eaten. A classification based on the functional mechanisms of food acquisition rather than species-specific and location-specific diet was developed by Cummins (1973). This approach focuses on ecosystem processes and allows comparisons of ecosystems within a stream and between geographical regions (Hauer, 1985).

V.3.1.6 Stress Effects

Stress usually involves an interference with the normal structure or function of a system. The manner in which an ecosystem responds to stress is often characterized by: (1) resistance, which is the ability of an ecosystem to minimize its response to a disturbance; and (2) resilience, which is the rapidity with which an ecosystem recovers once the disturbance has ceased (Webster et al., 1975; Webster et al., 1983). Although streams typically have a low resistance to disturbances, they generally are considered to be resilient to temporary disturbances because of their flow-through nature, strong interactions with surrounding ecosystems, and rapid recolonization by most stream inhabitants. However, stream disturbances are often accompanied by disturbances to the nonresilient riparian zone bordering the stream. Damage to the riparian zone can have repercussions on the stream for decades (Kondratieff and Kondratieff, 1985b; Gurtz and Wallace, 1984).

Several of the lotic systems studied in this project were stressed by heated discharges, large flow fluctuations, watershed deforestation, siltation, and various industrial effluents. Some of these stresses have been affecting the streams and swamp for many years; others are relatively recent. Steel Creek was affected by heated effluent until 1968. Since then, it has been essentially undisturbed until recent construction activities for L Lake. It is a good example of a stream in a state of recovery after a severe thermal disturbance.

The effects of heated discharges range from thermal enhancement at slightly elevated temperatures (Dahlberg and Conyers, 1974; Naiman, 1976) to substantial shifts in community composition and diversity at high temperatures (Howell and Gentry, 1974; Rodgers, 1980; Patrick, 1974). At high, but not lethal temperatures, a few tolerant forms may become extremely abundant as the more sensitive species disappear and competition for resources decreases.

Aquatic macrophytes are absent in extremely hot temperatures, (Sharitz et al., 1974; Kondratieff and Kondratieff, 1985b) but the biomass of several macrophyte species peaks at moderately elevated temperatures (Sharitz & Gibbons, 1981). Algal community composition and diversity are affected by temperature. There is often a shift from diatoms and green algal species in cool waters to blue-green algal species in heated waters (Patrick, 1974).

The effects of thermal discharges on macroinvertebrate communities have been well documented (e.g., Hutchison, 1976; Ward and Stanford, 1982). Organisms cannot survive water temperatures above a critical maxima, (generally 35°C or less) which varies with species, age, and acclimation of the organism. Below this threshold, the effects are more complex. Increased water temperatures may affect emergence patterns, development and maturation, and the number of generations per year (Sweeney and Vannote, 1978; Wise, 1980; Rodgers, 1980; Parkin and Stahl, 1981; Elliott, 1984). Generally, the invertebrate community composition changes to favor thermally tolerant species and species richness may be significantly reduced in thermally disturbed areas (Benda and Proffitt, 1974; Howell and Gentry, 1974; Ferguson and Fox, 1978; Kondratieff and Kondratieff, 1985a, 1985b). The tolerant macroinvertebrate taxa that respond positively to increased water temperatures include oligochaetes, nematodes, gastropods, and chironomid midges (Vincent, 1967; Ferguson and Fox, 1978; Kondratieff & Kondratieff, 1985a, 1985b; Laybourn, 1979; Nichols, 1981; Rasmussen, 1982; Wood, 1982).

Associated with the SRP heated water discharges are changes in discharge rates. Because they are concurrent, the effects of increased temperature and increased discharge are impossible to separate. Discharge rates affect the physical structure of the stream channel and the associated development of aquatic vegetation. Large fluctuations in discharge cause sediment scour and deposition, both of which are disruptive to the stream bed and associated flora, thereby reducing the amount of macroinvertebrate habitat and potentially affecting the entire food chain.

V.3.2 Study Sites

During the CCWS lower food chain study, stations on the onsite streams and swamp, and the Savannah River were sampled for various lower food chain parameters. During the first year (October 1983 to September 1984), eight stream sites, six delta sites, ten river transects, two intake canals, and five creek mouth sites were included, for a total of 31 sites. The following year (October 1984 to September 1985), the study was expanded to include 52 sites, including all but two of the first-year sites. Table V-3.1 shows station numbers, location, years sampled, and thermal regime. In order to facilitate referral to earlier reports, the station numbers used in this report are the same as those used in the preliminary reports. Because station numbers were not consistent across years, first-year station numbers (streams and swamps) are preceded by "1983-1984," and second-year station numbers by "1984-1985." The first-year river and creek mouth stations were identified by the river mile (RM) numbers. For example, the river station downstream from Lower Three Runs Creek was called 1983-1984 Transect 128.9 (RM 128.9). The station at the mouth of Beaver Dam Creek was called 1983-1984 Creek 152.1 (RM 152.1). The 16 thermal sites included five on Beaver Dam Creek (BD), eight on Four Mile Creek (FM and FMD) and three on Pen Branch (PB and PBD) (Table V-3.1).

TABLE V-3.1

CCWS Lower Food Chain Sampling Station Numbers, Location, and Thermal Regime

Station Number	Sampled 1983-1984	Sampled 1984-1985	Location	Thermal Regime
1		X	UTR	n
2		X	UTR	n
3	X	X	UTRM	n
4	X	X	SR	n
5	X	X	BD	t
6		X	BD	t
7		X	BD	t
8		X	BD	t
9	X	X	BDM	t
10	X	X	SR	n
11	X	X	SR	n
12		X	FM	n
13		X	FM	t
13A	X		FM	t
14	X	X	FMD	t
14H	X		FMD	t
15	X	X	FMD	t
16		X	FMD	t
17		X	FMD	t
18	X	X	FMM	t
19	X	X	SR	n
20		X	PB	n
21	X	X	PB	t
22	X	X	PBD	t
23	X	X	PBD	t
24		X	PBS	n
25	X	X	SR	n
26	X	X	SC	n
27		X	SC	n
28	X	X	SC	n
29	X	X	SC	n
30		X	SCD	n
31		X	SCD	n
32		X	SCD	n
33	X	X	SCD	n
34		X	SCS	n
35	X	X	SCS	n
36		X	SC	n

TABLE V-3.1, Contd

Station Number	Sampled 1983-1984	1984-1985	Location	Thermal Regime
37	X	X	SCM	n
38	X	X	SR	n
39	X	X	MB	n
40	X	X	MB	n
41	X	X	SR	n
42		X	LTR	n
43		X	LTR	n
44		X	LTR	n
45	X	X	LTRM	n
46	X	X	SR	n
47	X	X	SR	n
48		X	SR	n
49	X	X	SR	n
53		X	LTR	n
1G	X	X	Intake Canal 1G	n
3G	X	X	Intake Canal 3G	n
Total	32	52		

Key to Abbreviations

n	Nonthermal
t	Thermal
SR	Savannah River
UTR	Upper Three Runs Creek
UTRM	Upper Three Runs Creek mouth
BD	Beaver Dam Creek
BDM	Beaver Dam Creek mouth
FM	Four Mile Creek
FMM	Four Mile Creek mouth
FMD	Four Mile Delta
PB	Pen Branch Creek
PBD	Pen Branch Delta
PBS	Pen Branch Swamp
SC	Steel Creek
SCM	Steel Creek mouth
SCD	Steel Creek Delta
SCS	Steel Creek Swamp
MB	Meyers Branch Creek
LTR	Lower Three Runs Creek
LTRM	Lower Three Runs Creek mouth

Figure V-3.2 is a map showing the locations of all the sites. Table V-3.2 shows which parameters were sampled at each site during each year. Appendix V-1 includes complete descriptions and location information for all the sites.

V.3.2.1 Upper Three Runs Creek

Upper Three Runs Creek is a large, cool, blackwater stream. Above its confluence with Tims Branch, there is little effect from SRP operations. Tims Branch, which enters Upper Three Runs Creek at Road C, has been contaminated by heavy metals in the past, and is currently receiving high levels of nitrates from plant operations in M Area (Specht et al., 1987). The nitrate concentrations in Tims Branch during the period from November 1983 to August 1985 ranged from 0.004 to 0.293 mg NO_3-N/L (SREL, 1986), and the mean concentration of nitrates + nitrites during the period from 1973 to 1982 was 0.186 mg N/L (Gladden et al., 1985). The only Upper Three Runs station sampled both years was located approximately 200 m upstream from the mouth (Station 3). Two stations were added the second year: 1984-1985 Station 1 was upstream from the confluence with Tims Branch; 1984-1985 Station 2 was located midway between Stations 1 and 3. The two upstream sites had poorly developed floodplains, steep banks, and nearly complete canopies. The site at the creek mouth had a partial canopy and its floodplain was inundated periodically when the river flooded.

V.3.2.2 Beaver Dam Creek

Beaver Dam Creek is a deep, narrow stream, channelized in the upper reaches by high flows. Prior to SRP operations, Beaver Dam Creek probably had only intermittent flow (Jacobsen, 1972). It currently receives heated cooling water effluent from a coal-fired power plant, effluents from coal ash settling basins and a coal pile leachate basin, and effluents from various D-Area facilities. These effluents are discharged into a common discharge canal which forms the headwaters of Beaver Dam Creek. The effluent flow is dominated by the power plant cooling water releases and to a lesser extent by fly ash basin effluent. The remaining effluent discharges are characterized by low and sporadic flows. The effluent is not nearly as hot as reactor effluent and the temperature of Beaver Dam Creek is rarely elevated above 35°C. Therefore, Beaver Dam is considered a moderately thermal stream. Until 1982, a heavy water plant process facility in D Area discharged process cooling water into Beaver Dam Creek. Discharge from D Area presently does not exceed 2.55 m^3/sec, while prior to 1982, discharges up to 3.7 m^3/sec were recorded (Miller, 1984; Duke, 1984).

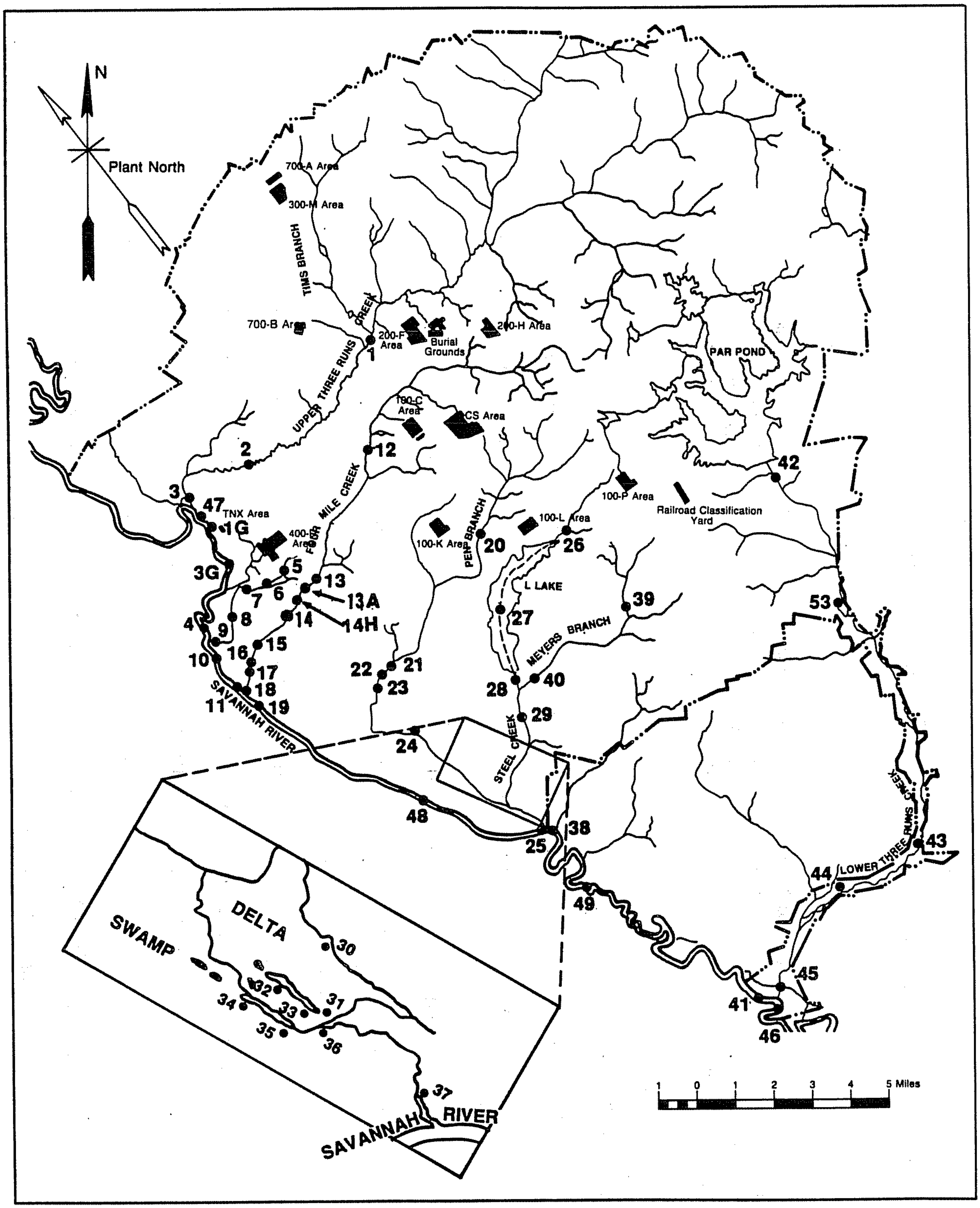


FIGURE V-3.2. Map of Savannah River Plant Study Area Showing 1984-1985 Station Numbers and Locations.

TABLE V-3.2

Study Program Elements at Each Station and Frequency of Sampling

Key:

n	Nonthermal	BD	Beaver Dam Creek	PBD	Pen Branch Delta	SCS	Steel Creek Swamp
t	Thermal	FM	Four Mile Creek	PBS	Pen Branch Swamp	MB	Meyers Branch Creek
SR	Savannah River	FMD	Four Mile Delta	SC	Steel Creek	LTR	Lower Three Runs Creek
UTR	Upper Three Runs Creek	PB	Pen Branch Creek	SCD	Steel Creek Delta	1G,3G	Intake Canals
						CM	Creek Mouth

o sampled during 1983-1984
+ sampled during 1984-1985

Physical measurements: Temperature - measured at all 1984-1985 stations; frequency varied from weekly to monthly.

Volume discharge (DISCH) - measured quarterly at all 1984-1985 stations; estimated monthly from permanent depth gauges after April 1985.

Current Velocity (CV) - measured quarterly at all 1984-1985 stations, monthly after April 1985.

Channel morphometry (MORPH) - measured once at all sites, quarterly at DISCH sites.

Stream structure: Channel mapping (MAP) - quarterly.

Primary producers: Periphyton biomass (B-PERI) - quarterly during October 1983 - September 1984, monthly during October 1984 - September 1985.

Periphyton taxonomy (TAX-PERI) - periphyton samples were collected and sent to Stroud Water Research Laboratory for analysis quarterly.

Macrophyte (aquatic vascular plant) sampling (B-AVP) - quarterly.

Organic matter: Airborne litter (LITTER) - monthly except weekly for six weeks during maximum leaf fall (1984-1985 only).

Seston (SESTON) - quarterly during October 1983 - September 1984; monthly during October 1984 - September 1985.

Mass transport (MASS-TR) - monthly.

TABLE V-3.2, Contd

Leaf decomposition (LEAF-DC).

Particulate organic matter (POM) - intervals varied from bi-weekly to quarterly.

Dissolved organic matter (DOM) - intervals varied from bi-weekly to quarterly.

Macroinvertebrates: Hester Dendy multiplate samplers (HESTERS) - monthly.

Snag (MI-SNAG) - monthly during December 1983 - May 1984.

Drift (DRIFT) - quarterly.

Leafbag substrates (MI-LEAVES) - quarterly.

Sampling of macrophyte beds (MI-AVP) - quarterly.

Sampling of sediments (MI-SED) - monthly during 1983 - 1984 only.

Station	Location	Thermal Regime	DISCH/ CV	MORPH	MAP	B-PERI	TAX-PERI	B-AVP	LITTER	SESTON	MASS-TR	HESTERS	DRIFT	MI-LEAVES	MI-AVP	MI-SED	MI-SNAG	POM/ DOM	LEAF-DC
1	UTR	n	+	+	+	+	+	+	+	+	+	+	+	+					
2	UTR	n	+	+					+										
3	UTR-CM	n	+	+		o+	o			+	+	o+	o+	+				o	
5	BD	t	+	+		o	+		+			o+	+	o+		o	o		o
6	BD	t		+		+				+		+	+	+					
7	BD	t	+	+	+		+	+	+			+	+	+					
8	BD	t	+	+		+	+			+	+	+	+	+	+				
9	BD-CM	t	+	+		o+	o			+	+	o+	o+	+				o	
12	FM	n	+	+					+			+	+	+					
13	FM	t	+	+					+										
13A	FM	t				o				o		o		o		o	o		o
14	FMD	t	+	+	+	+	+	+		o+	+	o+	+	o+		o	o		o
14H	FMD	t								o									
15	FMD	t	+	+	+	+		+	+	+	+	+	+	+					

TABLE V-3.2, Contd

Station	Location	Thermal Regime	DISCH/ CV	MORPH	MAP	B-PERI	TAX-PERI	B-AVP	LITTER	SESTON	MASS-TR	HESTERS	DRIFT	MI-LEAVES	MI-AVP	MI-SED	MI-SNAG	POM/ DOM	LEAF-DC
16	FMD	t										+	+	+					
17	FMD	t		+		+	+		+	+		+	+	+					
18	FM-CM	t	+	+		o+	o			o+	+	o+	o+	+				o	
20	PB	n	+	+		+			+	+	+	+	+	+					
21	PB	t	+	+	+	o+		+	+	+	+	o+	+	o+		o	o	o	o
22	PBD	t	+	+	+	+	+	o+	+	o+	+	+	+	o+	o+		o		o
23	PBD	t		+				o		o		o+	+	o+	o+		o		o
24	PBS	n	+	+	+	+	+	+	+	+	+	+	+	+					
26	SC	n	+	+	+	o+	+	+	+	o+	+	o+	+	o+		o	o		o
27	SC	n	+	+	+	+	+	+	+	+	+	+	+	+					
28	SC	n	+	+	+	o+		+	+	o+	+	o+	+	+			o	o	o
29	SC	n	+	+	+	+	+	+	+	o+	+	+	+	+				o	
36	SC	n	+	+		+	+		+	+	+								
37	SC-CM	n	+			o+	o		+			o+	o+	+				o	
30	SCD	n										+	+	+	+				
31	SCD	n		+		+	+			+		+	+	+	+				
32	SCD	n		+		+						+	+	+	+				
33	SCD	n	+	+	+	+		o+	+	o+	+	o+	+	o+	o+		o	o	o
34	SCS	n	+	+	+	+	+	+	+			+	+	+	+				
35	SCS	n	+	+	+	+		o+	+	o+		o+	+	o+	o+		o		o
39	MB	n	+	+	+	o+	+	+	+	o+	+	o+	+	o+		o	o		o
40	MB	n	+	+	+	o+	+	+	+	o+	+	o+	+	o+		o	o		o
42	LTR	n	+	+	+	+	+	+	+	+	+	+	+	+					
53	LTR	n	+	+	+	+		+	+	+	+								
43	LTR	n	+	+	+	+		+		+		+	+	+					
44	LTR	n				+	+		+	+									
45	LTR-CM	n		+		+				+		+	+	+					
1G													o+					o	
3G													o+						
4	SR	n				o+	o					o+	o+						
10	SR	n				o+	o					o+	o+						
11	SR	n				o+	o					o+	o+						
19	SR	n				o+	o					o+	o+						
25	SR	n				o+	o+			+		o+	o+						

TABLE V-3.2, Contd

Station	Location	Thermal Regime	DISCH/CV	MORPH	MAP	B-PERI	TAX-PERI	B-AVP	LITTER	SESTON	MASS-TR	HESTERS	DRIFT	MI-LEAVES	MI-AVP	MI-SED	MI-SNAG	POM/DOM	LEAF-DC
38	SR	n				o+	o+			+		o+	o+					o	
41	SR	n				o+	o					o+	o+					o	
46	SR	n				o+	o					o+	o+						
47	SR	n				o	o					o	o+					o	
48	SR	n											+						
49	SR	n				o	o					o	o+						

Source: Firth et al., 1986.

Five stations, distinct in physical and riparian characteristics, were established on Beaver Dam Creek. The station at the effluent outfall (1984-1985 Station 5) was sampled during both years of study. It was located where the stream was deep and channelized, the canopy was dense, and the water was gray and turbid, due to inputs of coal ash effluent. The stream at Station 6 had little canopy, and flowed through a shallow floodplain covered by semi-aquatic emergent macrophytes. Station 7 was located in a wide slough-like area with a lower current velocity and more macrophytes than any other site on this creek. The canopy at Station 7 was restricted to the edges of the channel. The channel at Station 8 was deep and narrow, with an open canopy. The station at the creek mouth (Station 9) was sampled both years. It had a deeply incised channel with steep banks and a nearly complete canopy.

V.3.2.3 Four Mile Creek

The headwaters of Four Mile Creek exhibit minimal impact from SRP operations. The average flow of Four Mile Creek upstream of any plant discharge is about 0.015 m^3/sec and is increased by effluents and drainage from 200-F, 200-H, and the Central Shops Area to about 0.6 m^3/sec just upstream of the confluence with the C-Reactor discharges. In the nonthermal headwater reaches, median summer water temperatures were 24.3 to 25°C, and the winter medians were 9.0 to 10.7°C. The pH in the nonthermal reaches was slightly below neutrality, being the lowest in the fall and the highest in the winter. Median dissolved oxygen concentrations just downstream from the swampy headwater pool were 6.4 mg/L and 7.15 mg/L just upstream of the confluence with Castor Creek. However, concentrations of nitrate-nitrogen just upstream of the C-Reactor effluent discharge are an order of magnitude greater than other onsite stream locations, due to the outcropping of nitrates from shallow groundwaters adjacent to the F- and H-Area seepage basins.

Below Castor Creek, thermal effluent from C Reactor comprises greater than 90% of the discharge volume of Four Mile Creek. Since the thermal effluent is Savannah River water, the chemical makeup and nutrient levels in this reach of the creek are similar to those of the river. Below Castor Creek, Four Mile Creek is a large, deep, thermal (up to 50°C) stream that spreads out over what was once the floodplain. The Four Mile Creek Delta was originally a cypress-tupelo gum (<u>Taxodium distichum-Nyssa aquatica</u>) swamp prior to SRP operations. However, inundation by reactor thermal effluent killed many of the floodplain trees so that a canopy no longer exists in the delta. Presently, low velocity channels or sheet flow carry the water through the open canopy delta. Some of this water flows into the contiguous swamp, some evaporates, and some coalesces into a stream channel that flows swiftly into the Savannah River.

Seven sampling stations were located on Four Mile Creek. Station 12 was located in the cool, shaded headwater reaches of the creek, above the reactor effluent outfall, but below the SRP F- and H-Area seepage basins. The stream at Station 13 was swift, deep, and hot, and was similar to the site for the Station 13a sampled in 1983-1984. Stations 14 15, 16, and 17 were numbered in order moving downstream across the delta. A thermal gradient existed from Stations 14 to 17. The site at Station 18 was sampled both years and was located approximately 10 m upstream of the creek mouth, as is the case for creek mouth sites on other streams. When this site is flooded by river water, the direction of the flow is sometimes reversed (Gladden et al., 1985; also see Section V.2.1.3). When such flow reversals are coincident with the operation of C Reactor, temperatures at the mouth of Four Mile Creek remain near ambient.

Although Four Mile Creek is referred to in this report as a thermal stream, it did not receive thermal effluent from June 1985 through the end of this study (September 1985) because C Reactor was taken off-line for maintenance.

V.3.2.4 Pen Branch

Upstream from its delta, Pen Branch is very similar to Upper Four Mile Creek. Pen Branch has an undisturbed, relatively shallow headwater reach upstream of its confluence with Indian Grave Branch, with flows normally ranging up to 1.0 m^3/sec. Downstream from the K-Reactor discharge (via Indian Grave Branch) the creek is deep and swift-flowing (representative flow 11.4 m^3/sec) as a result of the influence of heated effluent. Like Four Mile Creek, Pen Branch has no canopy in its delta. However, the deltas of the two creeks differ in several ways. The water in the Pen Branch Delta follows many small, shallow channels and sheet flow is confined to the near-channel areas. Thus, there are extensive areas of side pools and channels where semi-aquatic vegetation can grow without being in direct contact with the hot water. Pen Branch does not coalesce to form a main channel as does Four Mile Creek. Instead, the gradually cooling water enters a swamp forest. This swamp is contiguous to the Steel Creek swamp described in the next section. Pen Branch water eventually joins the Savannah River by way of Steel Creek.

There were five sampling stations on the Pen Branch system. One site, Station 20, was located in the cool headwater area. The water at Station 21 downstream from the effluent outfall was deep, swift, and very hot. The site at Station 22 was in one of the small channels in the open delta, and Station 23 was on a similar small channel, but in an area of partial canopy. The sites at Stations 21, 22, and 23 were sampled both years; Station 24 was in the dense swamp forest.

V.3.2.5 Steel Creek-Meyers Branch

Steel Creek received reactor effluent from 1954 until 1968 when L Reactor was put on standby. Steel Creek was recovering from impacts of SRP operations until early 1985, when land clearing and construction of L Lake began. By October, the reservoir was filled, and shortly thereafter, L Reactor was brought back on-line, discharging its effluent directly into the reservior.

In this report, Steel Creek is referred to as post-thermal and an assessment of its recovery is a major objective of this study. However, during the summer of 1985, effects due to construction activities were evident. This study does not continue beyond the startup of L Reactor. The following are preconstruction descriptions of the Steel Creek stations.

The site at Station 26, which was sampled both years, was located in a small, channelized stream area; Station 27 was located in a similar area downstream. Both had steep, well-defined banks, and dense shrubs and small trees in the riparian zone. The creek at Station 28, upstream from the confluence with Meyers Branch, consisted of several shallow channels braided through a thinly wooded floodplain. At Station 29, the stream was wide and shallow with well-defined islands and a partial canopy.

Meyers Branch is a major tributary to Steel Creek and is relatively undisturbed by SRP operations. The two Meyers Branch stations were sampled both years. The channel at Station 39 was well defined, with fairly steep banks, a complete canopy, and a substrate of gravel and sand. At Station 40, the substrate was composed of sand and organic mud; the canopy was complete but not dense. The floodplain of cypress and red maple (Acer rubrum) was inundated or wet a major portion of the year.

Six sites were located in the low gradient Steel Creek Delta swamp. The sites at Stations 30, 31, 32, and 33 were located in the open canopy delta. The channels at these sites had sand substrates and beds of submerged macrophytes, edged by beds of emergent macrophytes. Channels at Stations 30 and 32 were shallow and had low current velocities, while channels at Stations 31 and 33 were relatively deep and had higher current velocities. The site at Station 33 was sampled both years. Two sites were located in the swamp forest south of the delta. They had deep main channels with shallow sheet flow through the cypress-tupelo gum forest. The site at Station 34, located in an area of partial canopy, was densely colonized by submerged macrophytes, while Station 35 had fewer macrophyte beds and a denser canopy.

Nearly all of the water from the Steel Creek Delta swamp coalesces into one main channel that flows into the Savannah River. Two stations were located on this channel downstream from the delta. The site for Station 36 was located at its origin just downstream from the delta. The site for Station 37, sampled both years, was located at the creek mouth. Both sites had a large discharge volume, swift flow, partial canopy, and a substrate of clay and sand.

V.3.2.6 Lower Three Runs Creek

Lower Three Runs Creek is a large blackwater stream with a 1012 ha impoundment (Par Pond) at its headwaters. Cooling water for P Reactor is cycled through Par Pond, but is at near ambient temperature when it reaches the creek. Savannah River Plant operations cause very large discharge fluctuations (0.04-1.39 m^3/sec at Station 42) just downstream from the dam, but groundwater and tributary inputs dampen these fluctuations farther downstream (1.72-4.38 m^3/sec at Station 43).

Five stations were sampled during the second year of the study. The site for Station 42 was located downstream from the impoundment, where the channel was well-defined, with deeply incised, steep banks, and a nearly complete, but not dense, canopy of mature bottomland hardwoods. The site for Station 43 had a nearly complete canopy and sandy substrate. In February 1985, Station 53 was substituted for Station 43 because it was judged that a site more intermediate in location was desirable between Stations 42 and 44 for certain parameters and biotic features being monitored (Firth et al., 1986). The two stations were similar in morphometry, substrate, and discharge.

The site for Station 44 was located in a well-defined channel through a regularly inundated floodplain. Its canopy was complete and dense. The site for Station 45, located in the creek mouth, was in an incised channel with steep banks. The canopy at Station 45 was complete, but not dense. This was the only Lower Three Runs station that was sampled both years of the study.

V.3.2.7 Savannah River

The Savannah River was sampled for two years, upstream and downstream from the creek mouths, with the exception of Upper Three Runs Creek. The sites for Station 4 and Station 10 were located upstream and downstream from Beaver Dam Creek; Station 11 and Station 19 were at Four Mile Creek; Station 25 and Station 28 were located at Steel Creek; and Station 41 and Station 46 were located at Lower Three Runs Creek. Station 48 was located downstream from

Four Mile Creek at RM 145.7. Two additional river sites were sampled during the first year. One was located upstream from Upper Three Runs Creek at RM 157.3 (Station 47), and the other was located midway between Steel Creek and Lower Three Runs at RM 137.7. Intake canals 1G and 3G were sampled both years.

V.3.3 Physical Measurements

V.3.3.1 Introduction

During the first year of the CCWS, water temperature was measured at the seven stream sites, four of the five delta sites, and at the swamp site (Kondratieff & Kondratieff, 1985a; 1985b).

During the second year of the CCWS, water temperature was measured at all sites, and current velocity, volume discharge, and channel dimensions were measured at selected mapped sites (Table V-3.2). This section summarizes Sections 3.1 and 4.1 of ECS-SR-26, Lotic Aquatic Ecosystems of the Savannah River Plant: Impact Evaluation, Habitat Analyses and the Lower Food Chain Commuities (Firth et al., 1986) which describes the methods and results of the aquatic ecology component of the CCWS for the 1984-1985 study year.

V.3.3.2 Materials and Methods

During the first year of the CCWS, water temperature was measured using a combination of the following techniques: continuous recording Ryan thermographs (Model J), hand-held thermometers, and Hydrolab meters (Kondratieff & Kondratieff, 1985a; 1985b). Water temperature was monitored using a combination of the following techniques: hand-held long stem thermometers, max-min thermometers, and continuous recording thermographs (Ryan Model J and Hydrolab Model 2001). Continuous recording thermographs were deployed at Stations 7 and 9 (Beaver Dam Creek), 14, 17, and 18 (Four Mile Creek), 22-24 (Pen Branch), 26-29, 34-35, and 37 (Steel Creek), 40 (Meyers Branch), and 45 (Lower Three Runs Creek). During each site visit, water temperature was taken with a long stem thermometer. The max-min thermometer was also read and reset. Continuous recording thermographs were replaced as necessary. Gaps in the continuous data exist due to pulling the thermographs for data retrieval or repair. All temperature data were recorded in waterproof field notebooks that were returned to the laboratory. At regular intervals, data were recorded in a permanent lab notebook. Field thermometers were initially checked for accuracy against precision-grade long-stem thermometers. Ryan thermographs were calibrated at the factory prior to deployment in the field and the calibration verified before use to ensure accuracy to within 1°C. Readings were not taken from max-min thermometers when it was noted that the mercury bulb was out of the water, the mercury had separated, or the magnetic bars were imbedded in the mercury column. For the latter two cases, the thermometers were replaced with working ones.

Current velocity and volume discharge were determined quarterly beginning in January 1985 for one to three transects (depending on within-station variability) at 29 stations. Current velocities were measured at intervals across the transect using an electromagnetic water current meter Water current meters were calibrated by the manufacturer, and calibration was checked before each use. Intervals used were 0.5 m for channels $< = 7$ m wide, and 1 m for wider channels. Beginning in April 1985, at selected sites, discharge was calculated from water levels recorded at semi-permanent depth gauges. Current velocity was measured at 50 cm below the water surface if the stream was $> = 1$ m, or 0.25 to 0.50 times the depth if the depth was < 1 m. Depth was measured at the same intervals using a meter stick or calibrated rod. Volume discharge (m^3/sec) was calculated as follows:

$$\text{Discharge } (m^3/\text{sec}) = \sum_{i}^{n} \left[\text{cross sectional area } i \ (m^2) \times \text{current velocity } i \ (m/\text{sec})\right]$$

Mean current velocities, mean widths, mean depths, and total cross-sectional area were also determined for each transect at each station.

V.3.3.3 Results and Discussion

V.3.3.3.1 Temperature

During the period from November 1983 to May 1984, temperatures in the nonthermal creeks and Beaver Dam Creek gradually increased through the spring, with relatively small weekly ranges. Although Four Mile Creek temperatures were elevated during January, C Reactor experienced an extended outage from early February through late March, so the early spring water temperatures were ambient. Pen Branch temperatures were more variable, oscillating from near ambient (10-15°C) to thermal (25-35°C) over two to three week intervals. During the period from June to September 1984, the nonthermal creek sites (Stations 26, 28, 33, 35, 39, and 40) had gradual temperature increases through the summer. Beaver Dam Creek (Station 5) also had a fairly constant thermal regime which was slightly elevated above ambient. The other thermal creek sites (Stations 13A, 14, 21, 22, and 23) experienced wide temperature fluctuations as C and K Reactors cycled up and down at irregular intervals.

Water temperatures in the SRP creeks varied due to season and influences within each drainage basin (especially SRP operations). Table V-3.3 presents monthly maximum and minimum temperatures recorded at all 1984-1985 stations by all methods. Table V-3.4 presents monthly average temperatures for 1984-1985 sites where continuous recorders were deployed. Gaps in the continuous record were filled, wherever possible, by estimating average daily water temperatures using linear regression techniques (Firth et al., 1986). Estimates were derived when (1) water temperatures at the station with missing values were highly correlated with those of another station (preferably in the same drainage system), (2) the station used for the estimation was monitored during the interval not measured at the station in question, and (3) both stations were monitored with continuous recorders for their periods of record. No attempt was made to estimate monthly maximum and minimum water temperatures at any site. Usually the behavior of water temperature was linear over a restricted range, and therefore, temperatures within these ranges could be used for deriving regression estimates. These criteria served to maintain the validity of the estimated data even though estimates were made for a substantial portion of the study period at many stations.

Water temperatures at stations receiving thermal effluents were subdivided into periods corresponding to days when heated waters were discharged and days when no discharges occurred. This often improved correlations of water temperature between stations. Average daily water temperatures could not be estimated for Stations 7 and 9 (Beaver Dam Creek), 14, 17, and 18 (Four Mile Creek), or 22, 23, and 24 (Pen Branch; Table V-3.3) for some intervals. No suitable, highly correlated measurements were available from other stations along these water courses to allow estimation of water temperatures during some of the nonmonitored intervals at these sites. The blank entries, and footnotes to Table V-3.4 identify the extent and duration of data gaps.

Water temperatures at stations not affected by thermal discharges were lowest in January and highest in July (Tables V-3.3 and V-3.4). Maximum water temperatures were usually below 30°C from October 1984 to May 1985, and below 33°C from June to September 1985.

Average daily water temperatures in streams receiving heated water discharges varied with season, plant operating schedules, and proximity to the effluent outfall. The sites at Four Mile Creek Station 14 and Pen Branch Station 22 (the stations located closest to discharge points) showed the highest average monthly temperatures (Table V-3.4). Water temperatures at Four Mile Creek Stations 17 and 18, and Pen Branch Station 23, located farther downstream, were lower, but monthly averages remained elevated. The amount of cooling between upstream and downstream stations varied seasonally, with the largest reduction in temperature occurring in the winter.

TABLE V-3.3

Monthly Minimum and Maximum Temperature (°C) Recorded at all 1984-1985 Stations (October 1984-September 1985). Data are from Max-Min Thermometers, Long-Stem Thermometer and Continuous Recording Thermographs.

	1984			1985								
Station	October	November	December	January	February	March	April	May	June	July	August	September
Upper Three Runs												
1n	15.6-21.1	9.5-21.1	10.6-14.4	8.3-17.2	6.7-8.9	10.6-17.2	10.6-20.0	14.4-22.2	20.0-23.3	2.10-23.3	19.0-*	16.0-22.2
2n	18.0-20.0††	10.5-19.5†	11.5**	7.0**	-	-	13.3-20.0	17.8-21.1	-	21.1-25.6	21.5-21.7†	21.0-23.3†
3n	17.0-18.5†	11.0-15.5†	11.5-12.0†	9.0-17.0†	8.0-14.0†	14.0-16.0†	12.2-20.0	17.5-22.0†	16.7-25.6	21.1-26.1	18.9-24.4	17.0-23.5†
Savannah River												
4n	21.0-23.0†	7.8-26.7	12.0-14.0†	15.0**	8.0-9.0†	12.5-14.0**	14.0-23.3	18.5-31.1	24.0†	21.1-26.1	22.0-22.8†	20.0-28.9
Beaver Dam Creek												
5t	18.5-32.0	15.0-32.2	24.5**	11.1-21.1	10.0-17.3	22.2-24.4	15.6-23.9	26.7-31.7	27.8-33.0	27.0-33.0	23.9-28.5	28.0**
6t	25.0-31.0	17.2-30.0	10.0-24.0	12.2-26.7	8.3-22.0	18.3-25.6	16.7-28.9	22.8-32.2	27.8-36.7	25.0-33.3	25.6-32.2	23.9-29.4
7t	25.0-28.0	15.5-21.1	15.0-22.2**	5.0-16.0	-	14.0-26.7	18.5-27.7	20.5-30.0	23.7-33.5	26.4-33.0	27.0-32.5	24.6-31.1
8t	24.0-28.0	12.2-28.9	11.1-22.2	12.2-23.9	6.7-35.0	7.8-27.8	19.4-27.2	22.2-31.1	26.7-33.3	24.4-32.2	25.6-31.1	22.2-32.2
9t	17.8-28.4	15.9-23.7	14.6-25.1	10.1-26.0	6.2-22.7	19.0-25.0	21.0-26.1	24.0-30.0	30.6-34.0	27.5-28.5†	27.0-28.9†	23.3-28.9
Savannah River												
10n	21.0-23.0†	15.0-18.0	9.5-14.0†	12.0-16.0†	8.0††	14.0-14.0†	15.0-15.0†	19.0-22.5†	24.5-25.0†	23.0-24.0†	23.0-23.5†	21.0-24.5†
11n	21.5-24.0†	15.0-18.0†	12.0-14.0†	11.0-16.0†	9.0††	12.5-13.5†	14.5-14.5†	18.5-21.0†	24.0-24.5	23.5-27.5†	23.5-24.5†	24.0††
Four Mile Creek												
12n	16.7-25.6	7.8-25.0	6.1-16.7	4.4-25.0	1.1-17.8	5.6-20.0	4.4-23.3	15.6-26.7	21.1-24.4	20.0-31.1	21.1-28.9	23.0††
13t	23.5-56.0†	22.0-51.0	49.0-55.0	49.5††	-	-	-	17.8-54.4	-	-	24.0††	24.0††
14t	20.6-45.3	14.9-47.0	16.0-45.0	8.9-47.8	5.6-48.9	15.0-45.6	11.1-49.0	18.5-50.0	40.0-51.7	22.8-*	22.0-33.3	17.8-33.3
15t	19.0-*	14.4-37.8	14.4-37.2	25.6-35.0	6.7-36.7	12.2-38.9	16.7-40.0	18.3-44.4	34.4-45.6	21.1-*	-	17.8-33.3
16t	21.0-39.0	15.6-40.5	15.0-34.4	28.9-38.9	* -40.0	6.7-40.0	16.7-41.1	18.9-45.0	36.7-46.1	24.4-*	-	18.9-33.3
17t	21.0-30.5	13.3-36.6	14.8-37.2	26.1-35.0	6.1-36.1	15.5-38.8	* -40.0	18.3-44.4	32.5-47.5	24.6-33.6	24.8-34.5	19.5-39.0
18t	20.0-22.0†	17.0-35.2	14.9-36.0	22.6-35.7	11.2-35.9	10.0-38.4	* -40.5	17.8-43.3	33.5-45.0	21.1-31.0	22.9-31.3	18.7-32.2
Savannah River												
19t	21.5-24.0	18.0-18.0†	14.0-17.0†	12.0-18.5†	11.0-14.0†	16.5-17.0†	17.5-17.5†	20.0-24.0†	26.5††	22.5-24.0†	24.0-24.0†	21.0-24.5†

* Data anomaly.
** N = 1
† N = 2
†† N = 3

Source: Firth et al., 1986.

TABLE V-3.3, Contd

Station	1984 October	November	December	1985 January	February	March	April	May	June	July	August	September
20n	15.5-21.0	7.2-22.2	5.6-15.0	5.6-16.7	3.3-17.2	12.8-18.3	8.9-22.2	14.4-26.1	18.9-26.5	20.6-25.6	21.1-25.0	17.0-23.5†
21t	23.3->60.0	* -50.0	6.7-38.9	6.7E-53.3	4.4-51.1	12.2-52.8	12.8-54.5	16.7-54.4	21.7-60.0	15.0-54.4	21.1-57.2	22.2-54.4
22t	17.9-45.9	* -42.8	6.1-40.7	7.8-41.0	4.4-38.8	5.6-42.2	13.3-43.3	17.2-43.3	20.6-47.8	20.3-45.5	20.5-45.5	16.9-46.6
23t	20.0-*	5.6-41.1	-	5.6-37.8	4.4-36.6	12.8-39.4	12.2-41.1	17.8-43.8	20.7-44.2	21.1-43.7	23.9-44.4	17.0-35.9
24n	20.0**	6.1-27.2†	5.6-17.8	3.3-25.6	3.3-22.8	12.4-27.4	11.7-28.0	18.2-29.1	22.0-31.7	18.9-31.4	23.0-30.8	18.5-31.1
Savannah River												
25n	21.0-22.0†	16.0-24.4	12.0-15.7	10.5-15.5†	7.5-9.5†	12.0-13.0†	10.0-17.8	17.8-21.0	23.3-25.0	21.7-27.8	23.5-24.0†	21.0-26.7
Steel Creek												
26n	17.8-26.7	3.3-26.7	4.4-20.6	5.6-*	7.2-13.3	15.5-21.1	15.6-26.1	14.4-24.1	17.0-26.7	18.8-24.5	18.2-23.6	17.0-24.0
27n	21.0-25.6	9.0-27.8	13.5-19.4	12.0-18.0†	8.0-15.0	14.4-20.0	12.2-25.6	16.7-25.6	21.1-29.4	21.6-33.3	19.5-30.6	23.3-31.7
28n	16.7-30.5	9.4-25.0	8.2-21.1	4.7-18.3	5.6-15.6	6.7-21.1	10.6-23.3	21.1-26.7	18.5-30.6	19.9-34.4	20.6-30.7	17.5-28.5
29n	13.0-30.0	8.5-23.8	4.4-18.9	1.5-18.0	2.2-16.9	8.5-19.4	12.2-25.0	12.9-27.2	18.3-30.0	22.2-29.8	22.2-28.9	16.6-29.4
30n	27.0**	12.2**	-	-	4.0**	-	20.0**	21.0-34.0†	22.8**	*	29.0**	27.0**
31n	18.0-26.0	10.0-* ††	9.0-*	3.3-20.6	0.0-18.9	3.9-21.1	11.7-25.6	16.7-26.7	21.1-31.7	14.2-31.7	23.0-28.9	11.1-28.3
32n	17.0-24.0	11.0-26.7	9.0-17.0††	2.0-18.5††	6.0-9.5†	16.5-20.0†	10.0-27.8	15.8-27.8	18.9-30.6	21.7-33.3	24.0-30.0	10.0-35.6
33n	20.0-26.0	6.7-25.0	5.0-18.3	3.3-20.6	0.0-18.9	7.8-20.0	10.6-23.9	17.2-26.7	21.1-31.7	21.1-28.3	22.2-26.2	14.4-26.6
34n	16.7-26.6	6.6-27.8	1.1-18.9	3.3-20.0	0.0-20.6	9.3-24.1	9.4-24.1	16.8-25.0	21.1-27.8	21.1-28.3	22.2-26.2	14.4-26.2
35n	14.6-24.6	6.7-24.4	1.7-16.1	4.4-21.7	0.0-18.9	0.0-18.9	9.6-21.3	10.6-22.8	20.7-28.9	21.8-27.8	21.7-26.7	17.8-31.7
36n	19.5-22.0	11.0-24.4	5.6-17.8	6.5-18.0	8.0-10.5	0.5-20.0	11.1-22.2	17.5-26.7	22.2-31.1	19.4-26.7	23.3-28.3	17.2-30.6
37n	14.1-25.6	5.7-25.6	5.0-16.0	5.0-17.8	7.5-10.5†	6.7-23.0	11.7-26.2	16.7-26.7	18.9-31.1	16.7-27.8	16.7-27.2	17.0-28.9
Meyers Branch												
39n	15.5-26.0	8.0-22.8	5.6-16.1	6.1-18.9	6.5-17.8	3.9-18.9	7.8-25.6	16.7-26.1	17.8-30.0	20.0-29.4	21.0-27.8	17.5-27.5
40n	11.0-23.3	5.5-23.3	3.9-17.2	3.3-17.8	1.1-17.8	3.3-21.4	7.2-23.3	12.7-23.3	16.5-24.0	18.0-26.7	17.2-26.7	13.7-26.7
Savannah River												
38n	21.1-22.0†	16.0-27.8	10.0-15.0†	8.5-16.0†	7.0-9.5†	14.0-14.5†	17.5-19.0†	19.0-22.0†	23.5-26.0†	23.0-24.0†	23.5-24.0	20.0-25.3†
41n	21.0-23.0†	16.0-20.0†	11.5-12.0†	10.0-15.5†	8.0-9.5†	12.0-17.5†	16.0-17.0†	18.0-21.5†	25.0**	21.0-23.0†	23.5-24.0†	21.0**

* Data anomaly.
** N = 1
† N = 2
†† N = 3

Source: Firth et al., 1986.

TABLE V-3.3, Contd

Station	1984 October	November	December	1985 January	February	March	April	May	June	July	August	September
Lower Three Runs												
42n	14.0-23.0	16.7-26.7	12.8-18.9	8.9-19.4	8.5-21.7	9.4-20.0	15.6-25.6	15.0-25.6	22.2-32.2	26.7-31.7	22.0-31.3	21.1-30.6
53n	-	-	-	-	9.0-15.5†	6.7-15.6	12.2-21.1	17.2-21.7	17.2-27.2	18.3-27.2	22.2-27.8	18.9-27.8
43n	17.0-22.2	8.5-21.7	7.0-13.5	6.7-13.9	4.0**	9.3**	16.5**	19.0**	19.5**	-	23.0**	19.5**
44n	8.3-22.2	8.9-22.2	6.0-13.5	6.7-17.8	7.0-12.5	14.0-18.3	11.1-21.1	13.3-21.7	20.0-24.0	22.8-27.8	20.0-25.6	17.8-28.3
45n	14.3-21.4	5.2-17.0	5.0-12.1	4.9-15.5	4.9-14.6	9.8-21.0	11.7-23.9	15.6-23.9	20.4-25.7	18.9-26.1	20.8-24.8	17.1-26.1
Savannah River												
46n	20.5-23.0†	16.0-19.0†	10.5-15.0†	9.5-15.5†	9.5††	12.0-17.5†	16.0-17.0†	18.0-21.0†	23.5-25.5†	21.0-23.0†	24.0-24.0†	21.0-25.0†

* Data anomaly (a suspect reading due to equipment malfunction).
** N = 1
† N = 2
†† N = 3
- = No data

Source: Firth et al., 1986.

TABLE V-3.4

Monthly Average Water Temperatures (°C) Recorded at Stations in Streams Draining the Savannah River Plant (data from Ryan recording thermometers and Hydrolab recording thermometers) (October 1984 - September 1985)

	1984			1985							
Station	October	November	December	January	February	March	April	May	June	July	August	September
Beaver Dam Creek												
7t							22.9	26.5	28.6	29.6	29.4	27.1
9t	25.4[a]	20.6[a]	21.4	16.9[b]	14.0							
Four Mile Creek												
14t	31.2	36.6	40.9	37.4	36.2							
17t		33.1[c]	34.0[c]	30.9[c]	27.7[c]	31.9[c]	38.3[c]	39.2[c]	37.6	29.0	27.8[c]	24.9[c]
18t		30.9	31.7	28.8	23.6[d]	29.7	35.8	36.8	34.8[e]	27.3[e]	26.9	25.1[e]
Pen Branch												
22t	34.0	19.2	28.0	24.4				36.8	32.4	37.2[f]		24.1
23t	32.8[g]	21.9[g]	28.4[g]	25.8[g]				35.0[g]	32.6[g]	34.3		24.8
24n	23.6[h]	15.6[i]	15.2[i]	13.1[i]		19.7[i]	22.7[h]	24.6[i]	27.1	28.4[h]	27.9	25.7
Steel Creek												
26n									20.7	21.8	21.4	21.4
28n	20.7[j]	14.8	13.3	10.0[j,k]	11.7[j,k]	18.1[l]	21.0[l]	22.4[j,l]	23.7[j]	26.1	24.8	22.3[k]
29n	20.9[m,n,o]	14.5[m]	13.0[m]	9.1[m,n]	11.7[o,p]	17.5[p]	19.9[n,p]	21.8[n]	24.2[m,n,o]	26.2[m]	25.5[m]	22.8[o]
34n	20.0[q,r]	12.4[q]	12.0[s]	7.9[s,t,u]	10.4[r,u]	16.3	19.5[q]	21.7[s]	24.5[r,s]	25.1[s]	25.0	22.6[s]
35n	19.5	11.4[v,w]	10.8[w,x]	6.5[x,y]	8.2[w,y]	15.0[w]	18.0[w]	20.3[w,y]	23.6[x]	24.2	23.7[w]	21.3[w,x]
37n	18.4[z,aa]	10.9[aa]	11.0	7.2[z]	9.1[z]	15.6[z]	19.3	21.4	23.9[z]	24.8	24.4	22.2[z,ab]
Meyers Branch												
40n	17.1[ac]	10.6	10.2[ac]	7.5[ac]	8.6[ac]	13.0[ac]	16.5	18.7[ac]	20.7[ac]	21.5	21.2	19.7[ac]
Lower Three Runs												
45n	18.5[ad]	9.4[ad]	8.8	5.9[ae]	7.4	13.7	17.8	19.9	23.0[ae]	23.6[ae]	23.1	20.6[af]

Note: Superscripts refer to the linear regression equations found on the following pages.

TABLE V-3.4, Contd

Note: The following linear regression equations (model y = a + bx) were used to estimate average daily water temperatures on dates with missing temperature values.

Note	Stations Estimated (y)	Stations From (x)	Slope	Intercept	r^2	n	se*	Comments
a	9	40	0.920	10.995	0.925	84	1.130	Dates: 29 Oct 84 - 7 Nov 84
b	9	37	0.698	13.276	0.883	134	1.568	Dates: 15-17 Jan 85
c	17	18	1.059	0.397	0.963	50	1.295	Dates: 8 Nov 84 - 5 Feb 85; 21 Feb 85 - 12 Mar 85; 14 Mar 85 - 23 May 85; 22 Aug 85 - 11 Sep 85
d	18	9	1.147	7.975	0.635	77	2.525	C-Reactor operating; Dates: 24-25, 28-29 Oct 84; 6, 11-20 Feb 85
e	18	17	0.910	0.751	0.963	50	1.200	Dates: 8 Jun 85 - 12 July 85 18-20 Sep 85
f	22	23	1.099	-2.275	0.811	75	3.353	Dates: 28-31 July 85
g	23	22	0.733	7.884	0.811	75	2.749	Dates: 1-16 Oct 84; 19 Oct 84 - 16 Jan 85; 13-14 May 85; 5-6 June 85
h	24	35	0.897	6.131	0.858	90	1.586	Dates: 1-31 Oct 84; 16 Apr 85; 15-17 July 85
i	24	34	0.999	3.209	0.864	171	1.375	Dates: 1 Nov 84 - 16 Jan 85; 1-7 Mar 85; 23-27 May 85
j	28	37	0.801	5.237	0.950	190	1.268	Dates: 18-25 Oct 84; 11-14 Jan 85; 14-28 Feb 85; 24 May 85 - 14 Jun 85; 11 Sep 85
k	28	29	0.925	1.409	0.988	91	0.747	Dates: 25 Jan 85 - 13 Feb 85; 12-30 Sep 85
l	28	34	0.827	4.580	0.970	84	1.119	Dates: 1 Mar 85 - 8 Apr 85; 11 Apr 85 - 23 May 85;
m	29	28	1.067	-1.253	0.988	91	0.802	Dates: 1-17 Oct 84; 26 Oct 84 - 13 Nov 84; 14 Dec 84 - 3 Jan 85; 15-24 Jan 85; 14 June 85 - 18 Jul 85; 7-10 Aug 85
n	29	37	0.832	4.709	0.958	138	1.251	Dates: 18-20 Oct 84; 13-14 Jan 85; 9-10 Apr 85; 24 May 85 - 3 June 85; 14 June 85
o	29	45	0.893	4.608	0.959	163	1.380	Dates: 21-25 Oct 84; 14-21 Feb 85; 4-13 June 85; 11 Sep 85

* Standard error of estimate.

TABLE V-3.4, Contd

Note	Stations: Estimated (y)	From (x)	Slope	Intercept	r^2	n	se*	Comments
p	29	34	0.846	3.667	0.952	170	1.058	Dates: 22 Feb 85 - 8 Apr 85
q	34	40	1.202	-0.581	0.979	161	0.864	Dates: 1-17 Oct 84; 25 Oct 84 - 13 Nov 84; 9-10 Apr 85
r	34	45	0.898	4.039	0.925	179	1.548	Dates: 18-24 Oct 84; 14-21 Feb 85; 4-13 June 85
s	34	37	0.937	1.860	0.985	150	0.742	Dates: 14 Dec 84 - 17 Jan 85; 24 May 85 - 3 June 85; 14 June 85 - 17 Jul 85; 10-11 Sep 85
t	34	28	1.173	-4.780	0.970	84	1.333	Dates: 18-24 Jan 85
u	34	29	1.126	-3.152	0.952	170	1.220	Dates: 25 Jan 85 - 13 Feb 85
v	35	40	1.130	-0.173	0.935	136	0.982	Dates: 1-13 Nov 84
w	35	34	1.000	-1.342	0.964	64	0.853	Dates: 14 Nov 84 - 13 Dec 84; 22 Feb 85 - 14 Mar 85; 24 Apr 85 - 23 May 85; 13 Aug 85 - 9 Sep 85; 12-30 Sep 85
x	35	37	0.954	0.525	0.911	128	1.082	Dates: 14 Dec 84 - 17 Jan 85; 18-19 June 85; 10-11 Sep 85
y	35	45	1.113	-1.596	0.935	113	0.971	Dates: 18 Jan 85 - 21 Feb 85; 24 May 85 - 17 June 85
z	37	45	0.941	1.917	0.863	274	1.065	Temperatures ≥13°C at Station 45
	37	45	1.452	-1.620	0.968	68	0.587	Temperatures ≥13°C at Station 45 Dates: 21-27 Oct 84; 18 Jan 85 - 13 Mar 85; 4-13 June 85; 16-18 Sep 85
aa	37	28	1.185	-5.295	0.950	190	1.542	Dates: 28 Oct 84 - 8 Nov 84
ab	37	34	1.051	-1.663	0.985	150	0.786	Dates: 19-30 Sep 85
ac	40	45	0.784	2.865	0.961	223	0.889	Dates: 18-24 Oct 84; 22 Dec 84 - 16 Jan 85; 18 Jan 85 - 13 Mar 85; 29 May 85 - 14 June 85; 10-11 Sep 85
ad	45	40	1.227	-2.841	0.961	223	1.112	Dates: 28 Oct 84 - 8 Nov 84
ae	45	37	0.918	1.114	0.863	274	1.052	Temperatures ≥13°C at Station 45
	45	37	0.667	1.330	0.968	68	0.398	Temperatures <13°C at Station 45 Dates: 17 Jan 85; 18 Jun 85 - 15 Jul 85
af	45	29	1.075	-4.305	0.959	163	1.514	Dates: 19-30 Sep 85

* Standard error of estimate.

Source: Firth et al., 1986

During the months when C Reactor was operating (October 1984 to June 1985), maximum temperatures in Four Mile Creek surpassed 35°C, a threshold often considered to be near the lethal maximum for most macroinvertebrates (Parkin and Stahl, 1981; Durrett and Pearson, 1975; Miller et al., 1976). Temperatures reached or exceeded 50°C every month at Station 13. At Station 18, located at the mouth of Four Mile Creek, maximum temperatures exceeded 40°C from April to June (Table V-3.3).

Water temperatures in Pen Branch fluctuated widely due to the operating schedule of K Reactor. Often, stream temperatures at Station 22 increased as much as 15°C within a day after reactor startup (Firth et al., 1986). Because monthly temperature averages include periods of reactor shutdown, they do not reflect the magnitude of the thermal impact on the stream system. Maximum temperatures may be better indicators of the environmental stress. During all months of the study, except February, maximum temperatures at Station 22 exceeded 40°C (Table V-3.3). The site at Station 23, located downstream, was often several degrees cooler than Station 22. However, during November 1984 and April through August 1985, it too had maximum temperatures in excess of 40°C (Table V-3.3).

The maximum temperatures at Station 24, located in the Pen Branch swamp, did not exceed 32°C over the year; however, its average monthly temperatures are consistently higher than other delta/swamp stations, such as Steel Creek swamp Stations 34 and 35 (Table V-3.4). Differences were greatest (5.2 and 6.6°C) in January and smallest (2.6 and 3.5°C) in June. The discharge from K Reactor cools before reaching Pen Branch Station 24, under most conditions (Bristow and Doak, 1983; Scott et al., in press), and thermal effluents did not affect this site during this study (Firth et al., 1986). Maximum temperatures at Station 24 did not exceed 32°C during the sampling year (Table V-3.3). The temperature elevation at Station 24 may have been caused instead by solar insolation in the sparsely canopied upstream area and may, therefore, be an indirect effect of the thermal effluent (which killed trees in this area) (Firth et al., 1986). Although elevated temperatures (5-10°C higher than ambient) have been recorded during flooding of the Savannah River (Shines & Tinney, 1983), no such effects were observed during the 1984-1985 study year.

Water temperatures in Beaver Dam Creek were somewhat elevated throughout the year due to heated water discharge from a coal-fired electricity generating plant, but rarely exceeded 35°C (Table V-3.3).

V.3.3.3.2 Volume Discharge

The volume discharge measurements for the 1984-1985 stations are presented in Table V-3.5. There is enormous variability in the discharge of the SRP creeks; consequently, average discharges based upon periodic sampling may not be meaningful data. In this report, streams are referred to as large or small, based mainly on average discharge. The large nonthermal streams included Upper Three Runs Creek (Stations 1-3), three sites on Steel Creek (Stations 29, 36, and 37), and Lower Three Runs Creek (Stations 42, 43, and 53). The small nonthermal creeks were Four Mile Creek and Pen Branch upstream from their reactor effluent outfalls (Stations 12 and 20, respectively), three sites on Steel Creek (Stations 26, 27, and 28), and both Meyers Branch sites (Stations 39 and 40). The cutoff point between small and large streams was 1.05 m^3/sec. The only exception to this criterion were the three Lower Three Runs Creek sites. They were classified as large streams because they were quite wide (maximum widths of each > = 9.6 m).

All of the thermal streams were considered large. When the reactors were operating, Four Mile Creek and Pen Branch were considerably larger than Beaver Dam Creek and the reference streams. In general, the delta channels had lower volume discharges than the swamp channels.

V.3.3.3.3 Current Velocity

The ranges of mean current velocities for large and small nonthermal streams were similar (Table V-3.6). Velocities were generally higher in the thermal streams than in the nonthermal streams, with the highest velocities occurring in Four Mile Creek. In Beaver Dam Creek, there was an upstream area (Stations 5 and 6) with swift currents (0.30 and 0.50 m^3/sec, respectively), a slow moving (current velocity 0.22 m^3/sec) slough area (Station 7), and a second area (Stations 8 and 9) with swift currents (0.52 and 0.39 m^3/sec, respectively) downstream. Delta and swamp areas generally had low current velocities due to their lower gradients (Firth et al., 1986).

V.3.3.3.4 Channel Morphometry

Mean stream depths are presented in Table V-3.7. The thermal stream sites were generally deep. Three of the stations on Beaver Dam Creek had mean depths greater than 1 m. The mean depth reported in Table V-3.7 for Four Mile Creek Station 13 was measured when the reactor was not in operation. During reactor operation, the stream would be deeper (Firth et al., 1986). Channel depth at the delta sites was a function of location, flow rates, and number

TABLE V-3.5

Minimum, Maximum, Mean, Coefficient of Variation (CV) and N (number of items the measurements were taken) are Given for Volume Discharge (m^3/sec) (October 1984-September 1985)

Station	Location/ Thermal Regime	Minimum Measured Discharge	Maximum Measured Discharge	Mean	CV	N
1	UTR-n	2.91	5.75	4.74	25.2	5
2	UTR-n	4.66	4.96	4.81	4.4	2
3	UTR-n	3.02	12.15	6.26	66.0	4
5	BD-t	1.38	2.32	1.79	24.9	4
7	BD-t	2.30	3.90	2.76	24.3	5
8	BD-t	2.73	4.62	3.43	25.2	4
9	BD-t	2.43	5.46	4.44	31.2	4
12	FM-n	0.11	0.51	0.29	53.7	5
13	FM-t	2.59*	8.73**	5.66	76.7	2
14†	FMD-t	0.05*	0.69**	0.51	53.1	5
15†	FMD-t	1.12**	2.95**	2.32	37.2	4
18	FM-t	1.20*	4.88**	2.65	59.5	4
20	PB-n	0.04	0.16	0.11	49.7	5
21†	PB-t	1.14*	1.71*	1.39	26.3	3
21††	PB-t	18.97**	21.15**	20.06	7.7	2
22†	PBD-t	0.04*	0.21**	0.12	71.2	5
24†	PBS-n	0.35	1.48	0.82	56.4	5
26	SC-n	0.07	0.33	0.26	41.3	5
27	SC-n	0.59	1.01	0.87	18.6	5
28†	SC-n	0.10	0.31	0.22	40.1	4
28††	SC-n	0.36	0.56	0.46	30.7	2
29	SC-n	0.73	1.22	1.03	18.0	5
33†	SCD-n	0.32	1.17	0.80	42.4	5
34†	SCS-n	0.49	0.64	0.55	11.4	5
35†	SCS-n	0.73	2.58	1.75	41.8	5
36	SC-n	8.72	12.04	10.38	22.6	2
37	SC-n	11.68	12.35	12.02	3.9	2
39	MB-n	0.03	0.14	0.07	59.4	5
40	MB-n	0.20	0.42	0.33	33.3	5
42	LTR-n	0.04¶	1.39	0.56	112.8	4
43	LTR-n	1.72	4.38	2.67	44.9	5
53	LTR-n	0.61	1.42	0.88	42.5	4

Note: n = nonthermal, t = thermal

* Reactor was down during measurement.
** Reactor was up during measurement.
† Measurements made on the mapped channel only; not representative of entire stream or delta discharge.
†† Measurements made across entire stream system.
¶ Par Pond discharge was very low during measurement.

Source: Firth et al., 1986.

TABLE V-3.6

Mean, Coefficient of Variation (CV), N (number of station averages used to compute mean), and n (number of individual measurements used to compute N station averages) are Given for Current Velocity (m/sec) (October 1984-September 1985)

Station	Location/ Thermal Regime	Mean Current Velocity (m/sec)	CV	N	Σn
1	UTR-n	0.41	10.7	5	125
2	UTR-n	0.31	7.6	2	30
3	UTR-n	0.27	37.0	3	69
5	BD-t	0.30	38.8	3	35
6*	BD-t	0.50	22.6	6	-
7	BD-t	0.22	12.1	3	26
8	BD-t	0.52	4.9	2	21
9	BD-t	0.39	45.2	2	32
12	FM-n	0.30	31.1	4	31
13	FM-t	0.67	53.2	2	20
14	FMD-t	0.28	21.2	5	59
15	FMD-t	0.23	16.9	3	27
16*	FMD-t	0.31	46.0	4	-
17*	FMD-t	0.26	37.3	6	-
18	FM-t	0.41	97.2	2	26
20	PB-n	0.14	38.5	4	31
21	PB-t	0.63	72.9	4	61
22	PBD-t	0.13	26.3	5	37
23*	PBD-t	0.04	93.8	5	-
24	PBS-n	0.14	14.2	3	32
25*	SR-n	0.64	27.4	8	-
26	SC-n	0.25	37.5	5	43
27	SC-n	0.42	9.8	5	53
28	SC-n	0.30	25.5	6	58
29	SC-n	0.29	22.7	5	85
30*	SCD-n	0.0	0.0	1	-
31*	SCD-n	0.31	74.5	10	-
32*	SCD-n	0.18	82.2	3	-

Note: n = nonthermal, t = thermal

* Mean current velocity at these sites was computed from N individual measurements taken near the channel center on N dates. Means from these data will generally be higher than those computed from measurements taken across the entire stream channel because the slower-moving water near the channel edges is not included in the analysis.

Source: Firth et al., 1986.

TABLE V-3.6, Contd

Station	Location/ Thermal Regime	Mean Current Velocity (m/sec)	CV	N	Σn
33	SCD-n	0.16	28.2	4	27
34	SCS-n	0.11	37.5	3	23
35	SCS-n	0.18	24.5	4	38
36	SC-n	0.41	5.0	2	23
37	SC-n	0.61	0.0	1	15
38*	SR-n	0.41	56.9	9	-
39	MB-n	0.13	53.1	5	34
40	MB-n	0.17	9.7	5	56
42	LTR-n	0.12	57.4	2	22
43	LTR-n	0.18	42.2	4	84
44*	LTR-n	0.17	24.7	5	-
45*	LTR-n	0.28	25.7	6	-
53	LTR-n	0.12	12.9	2	25

Note: Station averages were computed from many current velocity measurements taken at uniform intervals across the stream channel at the time discharge was being measured.

Source: Firth et al., 1986.

TABLE V-3.7

Mean N (number of station averages* used to compute mean), and n (number of individual measurements used to compute N station averages) are given for stream depth and SS depth (water depth at stream shore) (October 1984–September 1985)

Station	Location/ Thermal Regime	Stream Depth (m)			SS Depth (m)		
		Mean	N	n	Mean	N	Σn
1	UTR-n	0.66	6	145	0.22	6	12
2	UTR-n	0.81	2	32	0.0	2	4
3	UTR-n	0.90	5	118	0.04	5	10
5	BD-t	0.88	3	39	0.12	3	6
7	BD-t	1.37	3	27	0.54	3	6
8	BD-t	1.15	6	67	0.38	6	12
9	BD-t	1.11	6	101	0.0	6	12
12	FM-n	0.30	3	26	0.13	3	6
13†,††	FM-t	0.59	2	22	0.01	2	4
14**	FMD-t	0.30	8	114	0.05	7	14
15**	FMD-t	1.39	3	27	1.05	3	6
18	FM-t	0.72	4	52	0.06	4	8
20	PB-t	0.16	8	90	0.04	7	14
21**	PB-t	0.36	3	52	0.06	3	6
21†	PB-n	0.95	3	64	0.46	3	6
22**	PBD-t	0.16	8	75	0.09	7	14
24**	PBS-n	1.16	3	35	0.69	3	6
26	SC-n	0.19	6	61	0.04	6	12
27	SC-n	0.34	5	58	0.20	5	10
28**	SC-n	0.15	4	35	0.07	4	8
28†	SC-n	0.28	2	29	0.04	2	4
29	SC-n	0.36	8	140	0.19	8	16
33**	SCD-n	1.10	7	62	0.89	7	14
34**	SCS-n	0.77	3	26	0.63	3	6
35**	SCS-n	0.95	4	42	0.54	4	8
36	SC-n	1.90	2	25	0.39	2	4
37	SC-n	1.66	6	97	0.74	6	12
39	MB-n	0.12	6	48	0.02	6	12
40	MB-n	0.28	6	72	0.07	6	12
42	LTR-n	0.27	3	36	0.03	3	6
43	LTR-n	0.98	4	88	0.23	4	8
53	LTR-n	0.48	3	41	0.0	3	6

* Station averages for stream depth were computed from many depth measurements taken at uniform intervals across the stream channel (or at the two banks for SS depths) at the time discharge was being measured. The mean of these station averages is presented in the above table.

** Measurements made on mapped channel or a single channel only.

† Measurements made across entire channel system.

†† Measurements made while reactor was down.

Source: Firth et al., 1986.

of channels (Firth et al., 1986). Generally, the Four Mile Creek Delta channels were fairly deep; the Pen Branch Delta site was shallow. Swamp channels were deeper than delta channels in most cases (Table V-3.7).

Stream width is important because it affects the percent canopy cover, which in turn affects the primary productivity of a stream. In a forested watershed, a narrow stream will have a complete canopy, and the growth of macrophytes and periphyton may be limited by available light. In wider streams there may be open areas in the canopy, resulting in increased primary production (Vannote et al., 1980).

Mean stream widths at the small nonthermal stream sites ranged from 3.4 m to 5.4 m (Table V-3.8). The sites with undisturbed riparian zones had complete canopies; however, the Steel Creek sites that had suffered tree loss as a result of past SRP operations had a sparse canopy cover (Firth et al., 1986). In the large nonthermal streams, mean widths ranged from 8.9 m to 22.5 m. Several of the large nonthermal streams had mature forests of large trees on their floodplains and nearly complete canopies (Firth et al., 1986).

Beaver Dam Creek was narrow except in the slough area and near the mouth (Table V-3.8). The thermal reactor streams were very wide. The delta and swamp sites were generally narrow to moderately wide (<10 m). Canopy cover was not determined by channel width at these sites but by the presence or absence of trees. Sites that had received reactor effluents had open canopies due to extensive tree kills (Firth et al., 1986).

V.3.4 Stream Structure

V.3.4.1 Introduction

The volume and size distribution of wood stored in a stream reflect past and current stream and riparian characteristics and give an indication of the stream's retention ability and available habitat. Events that affect stored wood include deforestation, siltation, abnormally high discharges, and bank erosion (Firth et al., 1986).

The abundance of logs, sticks, stumps, debris, and vegetation is important in determining the type and productivity of animal communities living in a stream. In addition to providing fish and invertebrate habitats, these structures enhance the efficiency of a stream reach by retaining organic matter long enough for processing to take place (Bilby & Likens, 1980).

TABLE V-3.8

Mean, Coefficient of Variation (CV) and N (number of measurements) are Given for Channel Width (m) and Channel Cross Section Area (m^2) (October 1984-September 1985)

Station	Location/ Thermal Regime	Channel Width (m)			Channel Cross Section Area (m^2)		
		Mean	CV	N	Mean	CV	N
1	UTR-n	15.7	7.4	6	9.54	38.9	6
2	UTR-n	14.3	2.0	2	12.52	5.0	2
3	UTR-n	22.5	13.7	5	22.63	92.4	5
5	BD-t	5.0	0.0	3	4.14	26.1	3
6†	BD-t	4.5	15.7	2	-	-	-
7	BD-t	8.0	12.5	3	10.19	5.7	3
8	BD-t	5.1	3.5	6	6.15	20.3	6
9	BD-t	7.8	2.9	6	9.22	10.7	6
12	FM-n	3.6	31.5	4	0.62	73.0	2
13**	FM-t	15.0	9.0	2	8.48	44.4	2
14*	FMD-t	4.8	37.6	8	1.67	53.8	8
15*	FMD-t	8.0	12.5	3	11.42	10.1	3
16*,†	FMD-t	8.0	17.6	2	-	-	-
17*,†	FMD-t	8.5	24.9	2	-	-	-
18	FM-t	7.3	41.9	4	6.83	66.1	4
20	PB-n	3.9	17.7	8	0.66	37.7	8
21*	PB-t	8.0	5.2	3	3.07	15.4	3
21**	PB-t	16.8	6.7	3	16.32	3.1	3
22*	PBD-t	4.2	14.2	8	0.66	49.6	8
23*,†	PBD-t	4.0	14.2	2	-	-	-
24*	PBS-n	5.3	28.6	3	6.66	53.3	3
26	SC-n	4.6	13.7	6	0.93	15.1	6
27	SC-n	5.2	19.0	5	1.83	18.5	5
28*	SC-n	3.7	15.6	4	0.61	39.6	4
28**	SC-n	6.6	16.2	2	1.95	22.9	2
29	SC-n	8.9	19.2	8	3.35	39.7	8
30*,†	SCD-n	2.2	0.0	1	-	-	-
31*,†	SCD-n	2.3	15.7	2	-	-	-
32*,†	SCD-n	2.5	28.3	2	-	-	-
33*	SCD-n	4.6	17.2	7	5.31	43.8	7
34*	SCS-n	7.2	52.3	3	5.33	32.2	3
35*	SCS-n	7.3	12.1	4	7.41	19.6	4
36	SC-n	11.1	13.4	2	22.27	11.5	2
37	SC-n	15.0	3.8	6	25.37	51.4	6
39	MB-n	3.4	11.0	6	0.49	29.4	6
40	MB-n	5.4	14.8	6	1.66	33.4	6
42	LTR-n	9.4	52.9	3	0.87	68.5	3
43	LTR-n	12.4	18.3	4	12.41	14.5	4
44†	LTR-n	13.8	12.8	2	-	-	-
45†	LTR-n	12.0	23.6	2	-	-	-
53	LTR-n	12.4	5.7	3	6.24	7.1	3

* Measurements made on mapped channel or a single channel only.
** Measurements made across entire channel system.
† Cross section area not measured.

Source: Firth et al., 1986.

During both years of the CCWS, stream structure was examined through detailed mapping of selected sites. Stream channel mapping provided data on channel layout, stored wood, abundance and biomass of macrophyte, abundance of retention devices, and habitat. Observations provided additional information about habitat quality and the ability of the stream to retain organic matter.

V.3.4.2 Materials and Methods

During the first study year, only two sites were mapped: Station 40 on Meyers Branch and a site upstream from Station 28 on Steel Creek. These two sites were characterized by having ambient temperatures and a stream channel with few macrophytes, but with a well-developed floodplain that was regularly inundated. Detailed maps of 25 m sections of each creek were drawn. Wood, debris, and macrophyte beds were measured and drawn to scale.

The following year, 19 stations, which were considered representative of the habitats found on the SRP streams, were mapped quarterly (Table V-3.2). Five 25 m longitudinal reaches at each site were marked along a section of the stream channel considered representative of the particular site. In each 25 m reach, all material greater than or equal to 1 cm was measured and drawn to scale, in accurate positions, on a map of the stream reach. Area measurements were recorded for trailing terrestrial vegetation and leaf packs. Volume measurements were taken of roots, logs and sticks, stumps, cypress knees and trees in the channel, and macrophyte beds.

To compare sites and determine seasonal trends in abundance of stream structures, Duncan's Multiple Range Tests were run on all wood parameters, trailing vegetation, trailing roots, and debris area.

V.3.4.3 Results and Discussion

There were no obvious seasonal trends at most of the sites. Differences in wood abundance appeared to be random and may have involved movement of sticks into and out of the mapped reach as well as burial or uncovering of large wood on the bottom. At two delta sites (Stations 15 and 22) and two stream sites (Stations 26 and 43), trailing terrestrial vegetation was significantly ($p < 0.05$) more abundant in the spring and summer, but there were no seasonal differences at the other sites. Trailing roots were significantly ($p < 0.05$) more abundant in the summer at the three swamp sites (Stations 24, 34, and 35), and in the spring at one stream site (Station 26), but the other sites showed no seasonal differences. The only sites that had differences in the abundance of debris between seasons were Station 35 in the Steel Creek swamp, and Station 39 in Meyers Branch. At both sites, debris was more abundant in the winter (Firth et al., 1986).

V.3.4.3.1 Nonthermal Streams

Figures V-3.3 and V-3.4 show the Meyers Branch (Station 49) and Steel Creek (upstream from Station 28) maps that were drawn in the spring of 1984. There were abundant stream structures in Meyers Branch. The total volume of wood at the Meyers Branch site was considerably greater than the volume of wood at the Steel Creek site (Gladden et al., 1985). The abundant wood structures in Meyers Branch were available to act as retention devices, slowing the downstream movement of large particle organic matter (Gladden et al., 1985). Results of seston studies, described in Section V.3.6.3, substantiate that Meyers Branch was more retentive than Steel Creek.

Figures V-3.5 and V-3.6 show maps of sites on Meyers Branch (Station 39) and Steel Creek (Station 26), drawn in the fall of 1984. Although the sites were not the same as those mapped previously, the results were similar. The Meyers Branch site had a great deal of structure, consisting of large wood jams, debris (leaf and twig packs), isolated sticks and logs, and trailing vegetation. The shoreline was convoluted at irregular intervals, adding to the complexity of the habitat. The post-thermal Steel Creek site had less structure and most of the material was smaller in size (Firth et al., 1986).

Figure V-3.7 is a map of Station 42, on Lower Three Runs Creek. Like the Meyers Branch site, it had abundant organic material and a complex structure.

In general, most of the structure in the nonthermal reference streams was provided by wood; logs contributed the greatest volume (m^3/m^2; Table V-3.9) and sticks contributed the most density (number/m^2; Table V-3.10). Steel Creek had less wood volume in storage than the nonthermal reference streams (Table V-3.9), probably due to the loss of riparian trees during reactor operations (Firth et al., 1986). Sticks (Table V-3.10) and trailing roots (Table V-3.11) were more abundant at the Steel Creek sites. Trailing terrestrial vegetation was not important at most nonthermal sites (Table V-3.11). Debris was important at all sites (Table V-3.12). Aquatic macrophytes contributed little to stream structure at all the closed canopy sites (Table V-3.13). However, at two open canopy sites, one on Steel Creek and one on Lower Three Runs Creek, there was a moderately high macrophyte biomass (Firth et al., 1986).

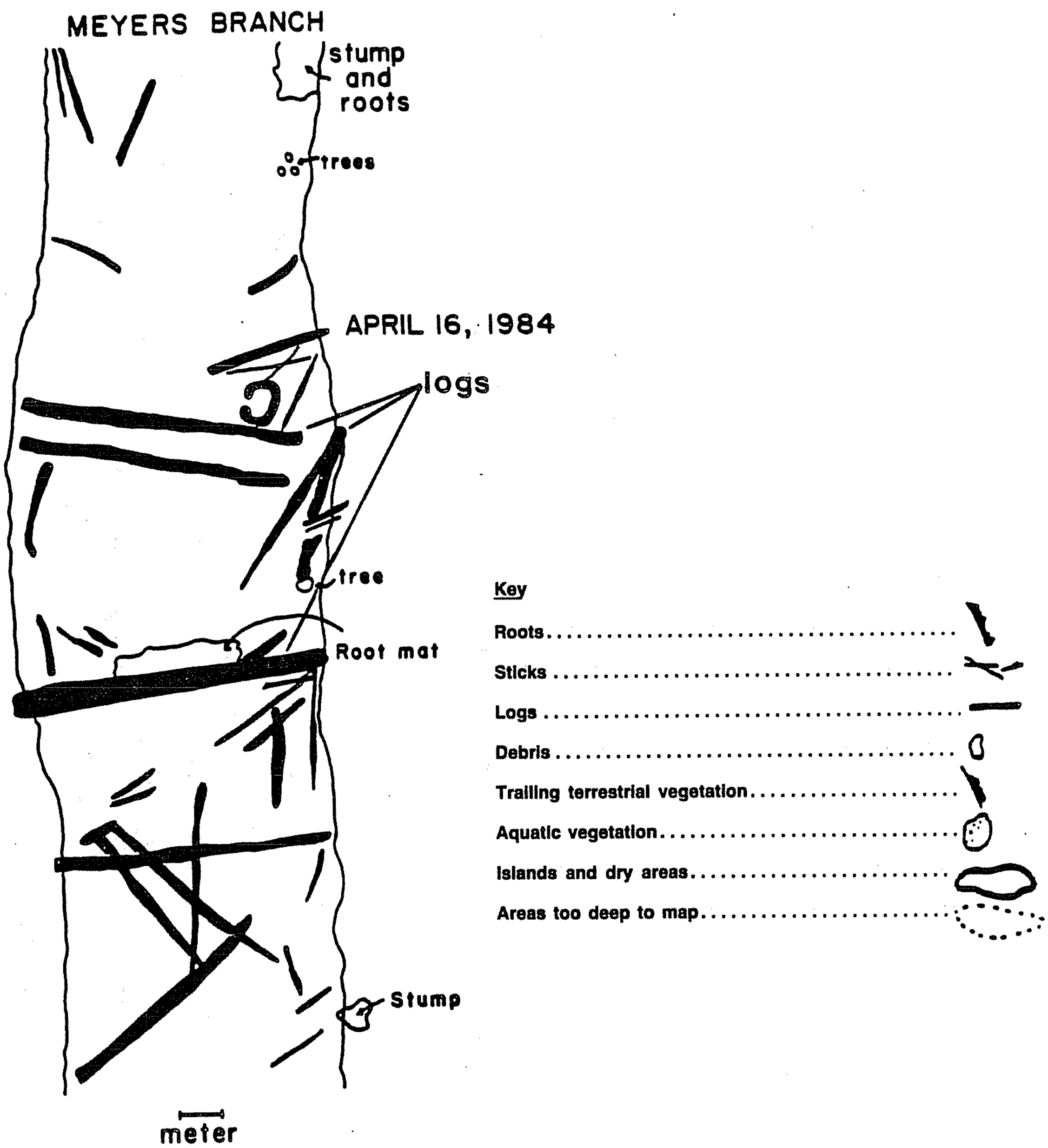


FIGURE V-3.3. Wood and Other Retentive Structures of a 25 m Reach of Meyers Branch (1983-1984 Station 12)
Source: Hauer, 1985.

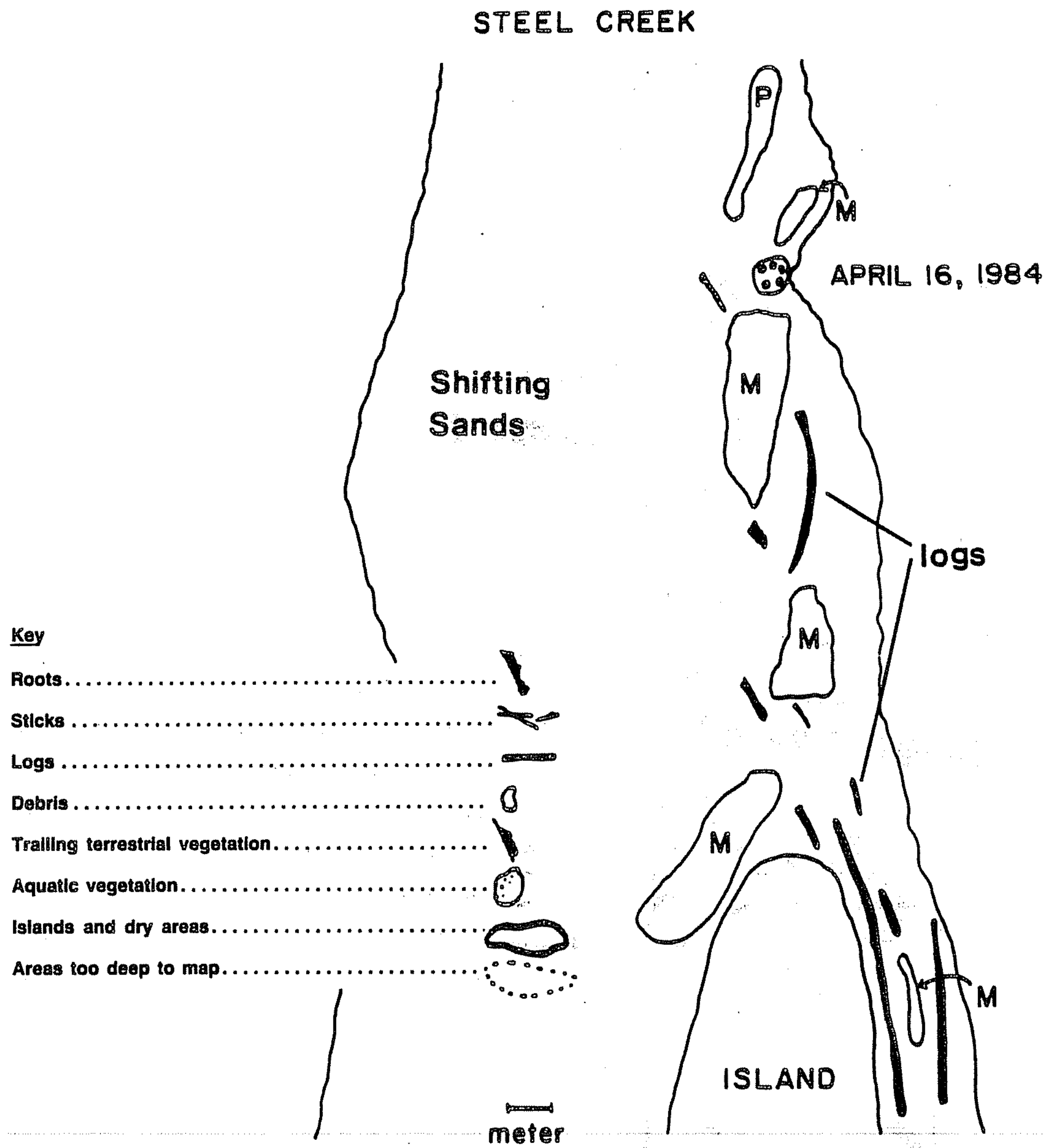


FIGURE V-3.4. Wood and Other Retentive Structures of a 25 m Reach of Steel Creek (above 1983-1984 Station 8) P = Polygonum spp.; M = Myriophyllum spp. Source: Hauer, 1985.

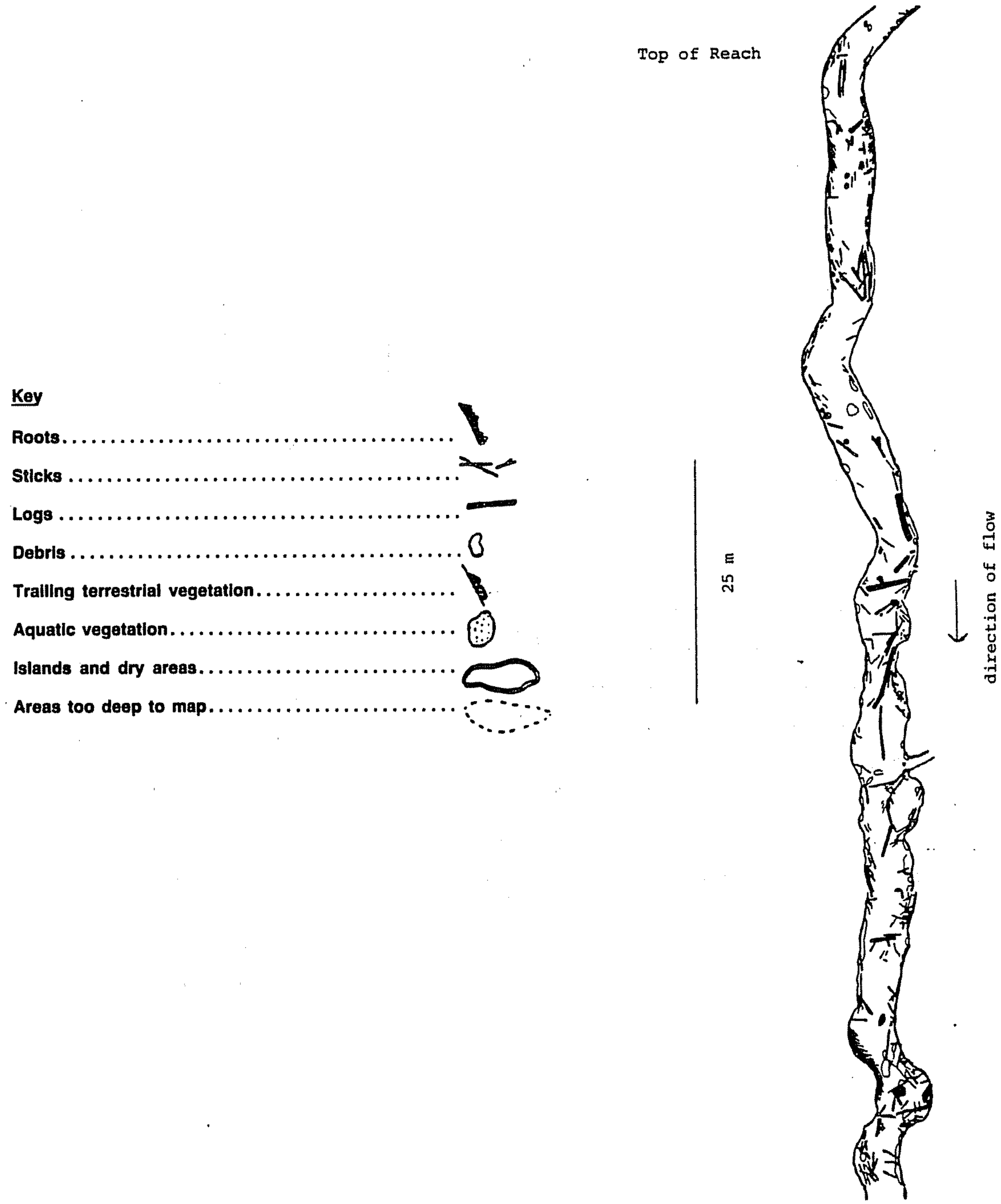


FIGURE V-3.5. Map of Stream Channel at 1984-1985 Station 39 on Meyers Branch (Fall 1984). Map Shows 120 m of the 125 m Mapped at this Site.
Source: Firth et al., 1986.

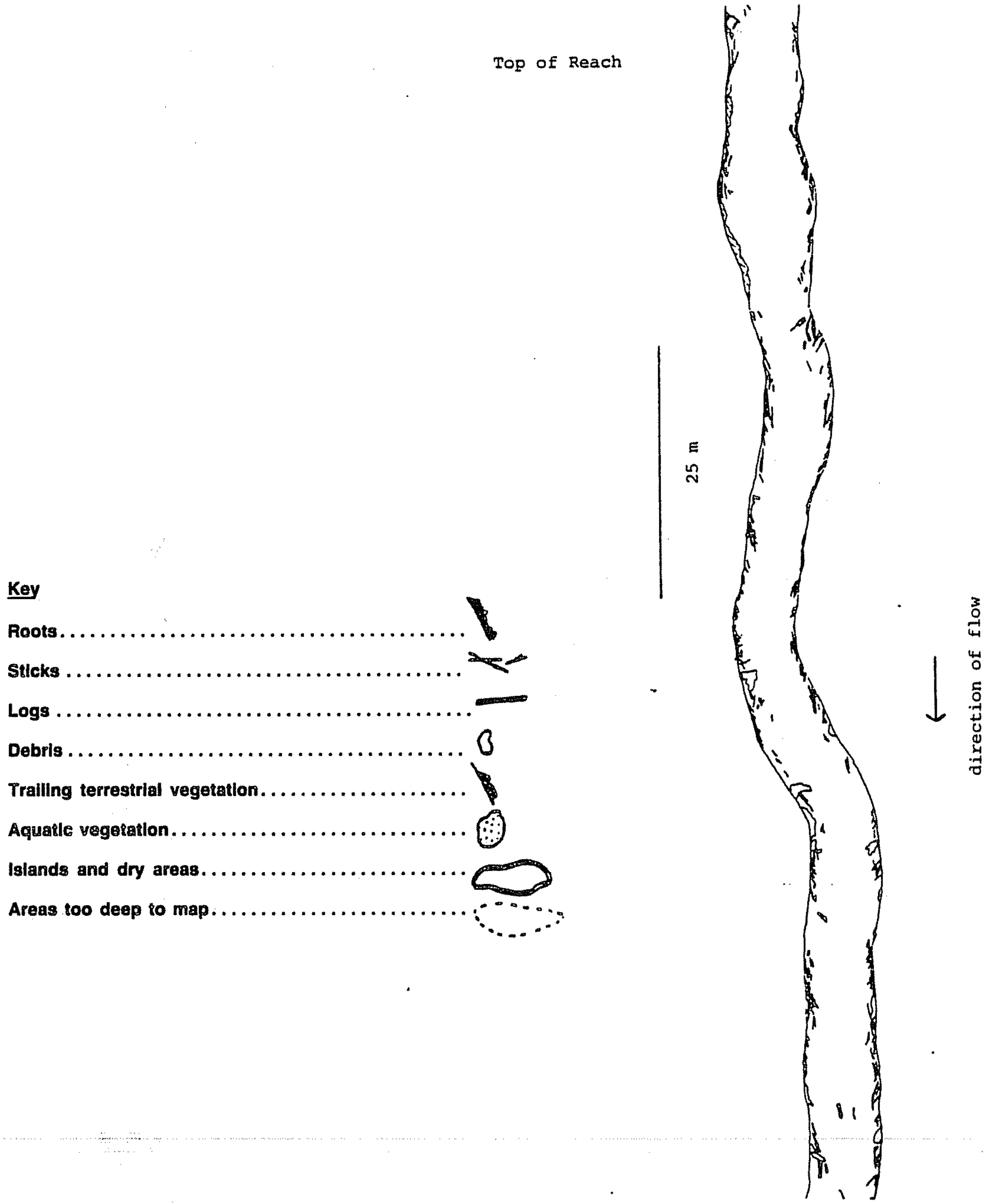


FIGURE V-3.6. Map of Stream Channel at 1984-1985 Station 26 on Steel Creek (Fall 1984). Map Shows 120 m of the 125 m Mapped at this Site.
Source: Firth et al., 1986.

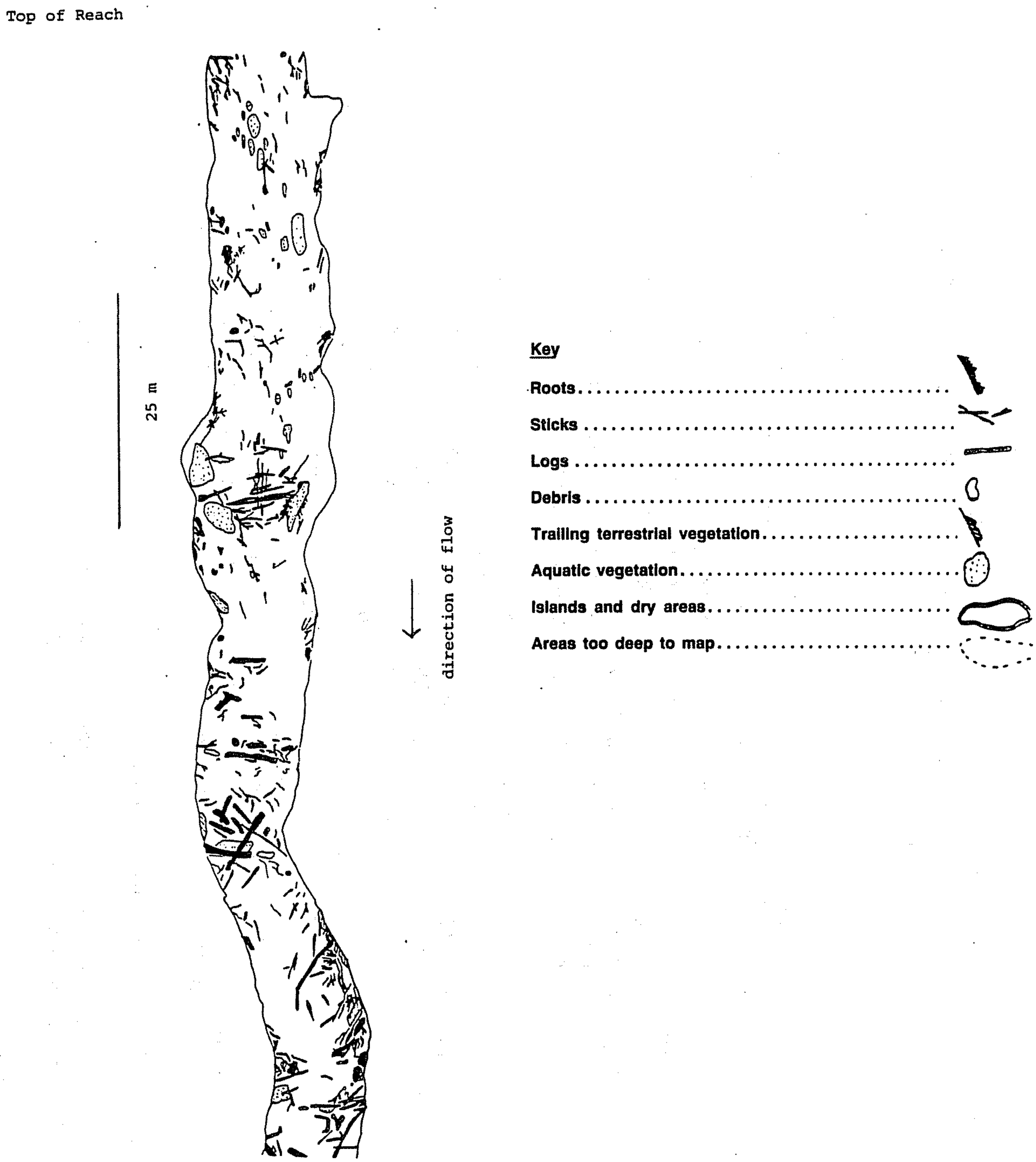


FIGURE V-3.7. Map of Stream Channel at 1984-1985 Station 42 on Lower Three Runs Creek (Fall 1984). Map Shows 120 m of the 125 m Mapped at this Site.
Source: Firth et al., 1986.

TABLE V-3.9

The Annual Mean N, and Standard Deviation (s) are Given for the Following Wood Volume Parameters at Each Mapped 1984-1985 Station: Total Wood Volume (m^3/m^2); Volume of Logs (>10 cm diameter; m^3/m^2); and Volume of Sticks (<10 cm diameter; m^3/m^2) (October 1984-September 1985)

Station	Location/ Thermal Regime	Total Wood Volume* (m^3/m^2)		Log Volume (m^3/m^2)		Stick Volume (m^3/m^2)		Percent Volume Due to Logs (m^3/m^2)		N**
		Mean	s	Mean	s	Mean	s	Mean	Standard Deviation	
1	UTR-n	0.0010	-	0.0007	0	0.0003	-	70.5	-	1
7	BD-t	0.0008	0.0009	0.0007	0.0009	<0.0001	0.0001	70.62	42.53	20
14	FMD-t	0.0046	0.0039	0.0044	0.0039	0.0005	0.0003	89.71	14.37	16
15	FMD-t	0.0074	0.0039	0.0071	0.0039	0.0002	0.0001	96.15	2.62	15
21	PB-t	0.0089	0.0071	0.0076	0.0071	0.0012	0.0006	77.67	12.59	12
22	PBD-t	0.0201	0.0205	0.0187	0.0206	0.0014	0.0010	87.44	9.57	7
24	PBS-n	0.0063	0.0073	0.0060	0.0074	0.0003	0.0009	75.92	37.92	20
26	SC-n	0.0114	0.0130	0.0086	0.0130	0.0027	0.0039	66.25	35.68	16
27	SC-n	0.0060	0.0019	0.0054	0.0019	0.0006	0.0004	88.76	7.50	9
28	SC-n	0.0038	0.0048	0.0030	0.0047	0.0008	0.0009	54.56	34.05	16
29	SC-n	0.0056	0.0031	0.0043	0.0025	0.0013	0.0021	78.98	22.01	12
33	SCD-n	0.0042	0.0040	0.0034	0.0040	0.0008	0.0017	75.56	39.57	20
34	SCS-n	0.0055	0.0059	0.0054	0.0059	0.0001	0.0001	81.51	34.41	20
35	SCS-n	0.0218	0.0365	0.0217	0.0365	0.0001	0.0001	93.50	22.11	20
39	MB-n	0.0193	0.0159	0.0140	0.0143	0.0052	0.0088	69.52	26.39	20
40	MB-n	0.0096	0.0099	0.0078	0.0100	0.0018	0.0028	78.88	23.16	20
42	LTR-n	0.0179	0.0206	0.0127	0.0179	0.0052	0.0137	70.09	30.85	20
53	LTR-n	0.0074	0.0076	0.0045	0.0080	0.0029	0.0036	55.65	37.35	9
43	LTR-n	0.0073	0.0074	0.0069	0.0072	0.0004	0.0011	90.85	13.52	20

Note: Abbreviations are listed in Table V-3.2.

* Totals are different from the sum of the components due to computer rounding error.
** Total number of 25 m reaches mapped during sampling year.

Source: Firth et al., 1986.

TABLE V-3.10

The Annual Mean N, and Standard Deviation (s) are Given for the Following Wood Volume Parameters at Each Mapped 1984-1985 Station: Total Wood Volume (No./m^2); Log Density (>10 cm diameter; No./m^2); and Stick Density (<10 cm diameter; No./m^2) (October 1984-September 1985)

Station	Location/ Thermal Regime	Total Wood Density (no./m^2) Mean	Total Wood Density s	Log Density (no./m^2) Mean	Log Density s	Stick Density (no./m^2) Mean	Stick Density s	Percent Density Due to Sticks (no./m^2) Mean	Percent Density Due to Sticks Standard Deviation	N**
1	UTR-n	0.0010	-	0.0007	0	0.0003	-	70.5	-	1
7	BD-t	0.0008	0.0009	0.0007	0.0009	<0.0001	0.0001	70.62	42.53	20
14	FMD-t	0.0046	0.0039	0.0044	0.0039	0.0005	0.0003	89.71	14.37	16
15	FMD-t	0.0074	0.0039	0.0071	0.0039	0.0002	0.0001	96.15	2.62	15
21	PB-t	0.0089	0.0071	0.0076	0.0071	0.0012	0.0006	77.67	12.59	12
22	PBD-t	0.0201	0.0205	0.0187	0.0206	0.0014	0.0010	87.44	9.57	7
24	PBS-n	0.0063	0.0073	0.0060	0.0074	0.0003	0.0009	75.92	37.92	20
26	SC-n	0.0114	0.0130	0.0086	0.0130	0.0027	0.0039	66.25	35.68	16
27	SC-n	0.0060	0.0019	0.0054	0.0019	0.0006	0.0004	88.76	7.50	9
28	SC-n	0.0038	0.0048	0.0030	0.0047	0.0008	0.0009	54.56	34.05	16
29	SC-n	0.0056	0.0031	0.0043	0.0025	0.0013	0.0021	78.98	22.01	12
33	SCD-n	0.0042	0.0040	0.0034	0.0040	0.0008	0.0017	75.56	39.57	20
34	SCS-n	0.0055	0.0059	0.0054	0.0059	0.0001	0.0001	81.51	34.41	20
35	SCS-n	0.0218	0.0365	0.0217	0.0365	0.0001	0.0001	93.50	22.11	20
39	MB-n	0.0193	0.0159	0.0140	0.0143	0.0052	0.0088	69.52	26.39	20
40	MB-n	0.0096	0.0099	0.0078	0.0100	0.0018	0.0028	78.88	23.16	20
42	LTR-n	0.0179	0.0206	0.0127	0.0179	0.0052	0.0137	70.09	30.85	20
53	LTR-n	0.0074	0.0076	0.0045	0.0080	0.0029	0.0036	55.65	37.35	9
43	LTR-n	0.0073	0.0074	0.0069	0.0072	0.0004	0.0011	90.85	13.52	20

Note: Abbreviations are listed in Table V-3.2.

* Totals are different from the sum of the components due to computer rounding error.
** Total number of 25 m reaches mapped during sampling year.

Source: Firth et al., 1986.

TABLE V-3.11

The Annual Mean N, and Standard Deviation are Given for the Following Parameters at Each Mapped 1984-1985 Station: Trailing Vegetation Area (m^2/m^2) and Trailing Root Volume (m^3/m^2) (October 1984-September 1985)

Station	Location/ Thermal Regime	Trailing Vegetation Area (m^2/m^2)		Trailing Root Volume (m^3/m^2)		N
		Mean	s	Mean	s	
1	UTR-n	0.0047	-	0	-	1
7	BD-t	0.0100	0.0175	0.0001	0.0004	20
14	FMD-t	0.0004	0.0219	0.0001	-	16
15	FMD-t	0.0117	0.0219	0.0001	0.0002	15
21	PB-t	0.0742	0.2007	0.0001	0.0003	12
22	PBD-t	0.0141	0.0212	0	0	7
24	PBS-n	0.0006	0.0026	0.0007	0.0016	20
26	SC-n	0.0129	0.0203	0.0147	0.0381	16
27	SC-n	0.0351	0.0334	0.0790	0.2148	9
28	SC-n	0.0411	0.0429	0.0003	0.0005	16
29	SC-n	0.0385	0.0587	0.0014	0.0022	12
33	SCD-n	0.0084	0.0327	<0.0001	<0.0001	20
34	SCS-n	0.0010	0.0034	0.0001	0.0002	20
35	SCS-n	0.0005	0.0013	0.0005	0.0013	20
39	MB-n	0.0045	0.0084	0.0093	0.0068	20
40	MB-n	0.0276	0.0553	0.0040	0.0061	20
42	LTR-n	0.0111	0.0261	0.0010	0.0025	20
53	LTR-n	0.0220	0.0287	0.0031	0.0044	9
43	LTR-n	0.1942	0.1147	0.0013	0.0024	20

Note: Abbreviations are listed in Table V-3.2.

Source: Firth et al., 1986.

TABLE V-3.12

The Annual Mean N, and Standard Deviation (s) are Given for Debris Area (m^2/m^2) at Each Mapped 1984-1985 Station (October 1984-September 1985)

Station	Location/ Thermal Regime	Debris Area (m^2/m^2) Mean	s	N
1	UTR-n	0.0093	-	1
7	BD-t	0.0013	0.0029	20
14	FMD-t	0.0007	0.0015	16
15	FMD-t	0.0002	0.0008	15
21	PB-t	0.0886	0.1125	12
22	PBD-t	0.0157	0.0256	7
24	PBS-n	0.0034	0.0051	20
26	SC-n	0.0137	0.0075	16
27	SC-n	0.0211	0.0271	9
28	SC-n	0.0132	0.0132	16
29	SC-n	0.0313	0.0405	12
33	SCD-n	0	-	20
34	SCS-n	0.0002	0.0008	20
35	SCS-n	0.0040	0.0075	20
39	MB-n	0.0399	0.0463	20
40	MB-n	0.0368	0.0453	20
42	LTR-n	0.0419	0.0526	20
53	LTR-n	0.0105	0.0106	9
43	LTR-n	0.0218	0.0176	20

Note: Abbreviations are listed in Table V-3.2.

Source: Firth et al., 1986.

TABLE V-3.13

Annual Mean N, and Standard Deviation (s) are Presented for the Following Vegetation Parameters on a per m^2 Basis at Each Mapped 1984-1985 Station: Aquatic Vascular Plant (AVP) Area (m^2/m^2); AVP Volume (m^3/m^2); AVP Biomass (g/m^2) and AVP Percent Cover (October 1984-September 1985)

Station	Location/ Thermal Regime	AVP Area		AVP Volume		AVP Biomass		Percent Cover		N
		Mean	s	Mean	s	Mean	s	Mean	s	
1	UTR-n	0.0245	-	0.0030	-	3.326	-	2.449	-	1
7	BD-t	0.1167	0.0692	0.0242	0.0192	17.68	12.07	12.16	8.131	20
14	FMD-t	0.0010	0.0031	-	-	0.0047	0.0189	0.0189	0.3070	16
15	FMD-t	0.0127	0.0288	0.0055	0.0156	4.107	13.04	1.268	2.880	15
24	PBS-n	0.0002	0.0004	-	-	0.0288	0.0625	0.0162	0.0351	20
26	SC-n	0.0019	0.0049	-	-	-	-	0.1848	0.4960	16
27	SC-n	0.0001	0.0004	-	-	-	-	0.0122	0.0367	9
28	SC-n	0.0423	0.0675	0.0010	0.0015	16.75	28.83	4.026	6.736	16
29	SC-n	0.0002	0.0004	<0.0001	<0.0001	0.0855	0.1949	0.0202	0.0430	12
33	SCD-n	0.3958	0.1434	0.1807	0.1349	82.18	48.70	39.61	14.17	20
34	SCS-n	0.2786	0.2968	0.1196	0.1666	84.01	113.4	29.87	29.85	20
35	SCS-n	0.2331	0.3229	0.0832	0.1267	59.62	78.83	23.32	32.31	20
39	MB-n	0.0001	0.0002	<0.0001	<0.0001	0.0002	0.0007	0.0054	0.0167	20
40	MB-n	0.0009	0.0030	0.0002	0.0005	0.0111	0.0331	0.0916	0.2998	20
42	LTR-n	0.0335	0.0558	0.0017	0.0029	1.929	3.437	3.349	5.584	20
53	LTR-n	0.0000	-	0.0000	-	0.0000	-	0.0000	-	9
43	LTR-n	0.0060	0.0185	<0.0001	<0.0001	0.0284	0.1121	0.5429	1.834	20

Note: Abbreviations are listed in Table V-3.2.

Source: Firth et al., 1986.

V.3.4.3.2 Thermal Streams

Stream structure at the moderately thermal Beaver Dam Station 7 was dominated by aquatic vegetation; the mean macrophyte abundance was much higher than in the nonthermal streams (Table V-3.13). The abundance of trailing vegetation and roots was similar to the reference streams (Table V-3.11), while the total area occupied by debris was lower than in the reference streams (Table V-3.12). The apparently low wood volume (Table V-3.9) may be misleading. The depth and turbidity of the channel at Station 7 made it possible to map only the wood that was visible on the channel edges or near the water surface. Although the abundance of debris was low at this site, organic matter retention was probably high due to the dense macrophyte beds (Firth et al., 1986).

The structure at the other mapped thermal site (Pen Branch Station 21) was dominated by wood (Figure V-3.8). Cypress logs and stumps, presumably from the pre-SRP floodplain, were abundant. The decay process in the heated waters of Pen Branch may be slowed due to the absence or incapacitation of decomposer organisms (Firth et al., 1986). Aquatic vegetation was absent at the Pen Branch site (Table V-3.13). Retention of organic matter was probably low in Pen Branch due to periodic high discharges and the lack of aquatic plants and macroinvertebrates (Firth et al., 1986).

V.3.4.3.3 Deltas

Delta sites were depositional areas where the stream gradient decreased and the stream current velocity slowed. Complete loss of the swamp forest had occurred due to current or past discharges of heated effluents. Four delta sites were mapped: thermal Four Mile Creek Delta Stations 14 (Figure V-3.9) and 15 (Figure V-3.10), thermal Pen Branch Delta Station 22 (Figure V-3.11), and nonthermal Station 33 in the Steel Creek Delta (Figure V-3.12).

Stream structure and habitat were strongly influenced by thermal conditions at the delta sites. The Pen Branch Delta site had significantly greater wood density than the other delta sites (Table V-3.10). It was covered by a deep, dense, intricate network of logs and sticks in an organic mud matrix (Firth et al., 1986). Wood densities at the Four Mile Creek Delta sites, although lower than at the Pen Branch site, were greater than the density of the Steel Creek Delta site (Table V-3.10). Abundance of trailing vegetation was similar among the delta sites (Table V-3.11). Debris was most abundant in Pen Branch (Table V-3.12). Only the nonthermal Steel Creek Delta site had abundant macrophytes. The Four Mile Creek sites had only occasional plants, and aquatic vegetation was entirely absent at the Pen Branch site (Table V-3.13). The abundant plants at the Steel Creek Delta site provided excellent

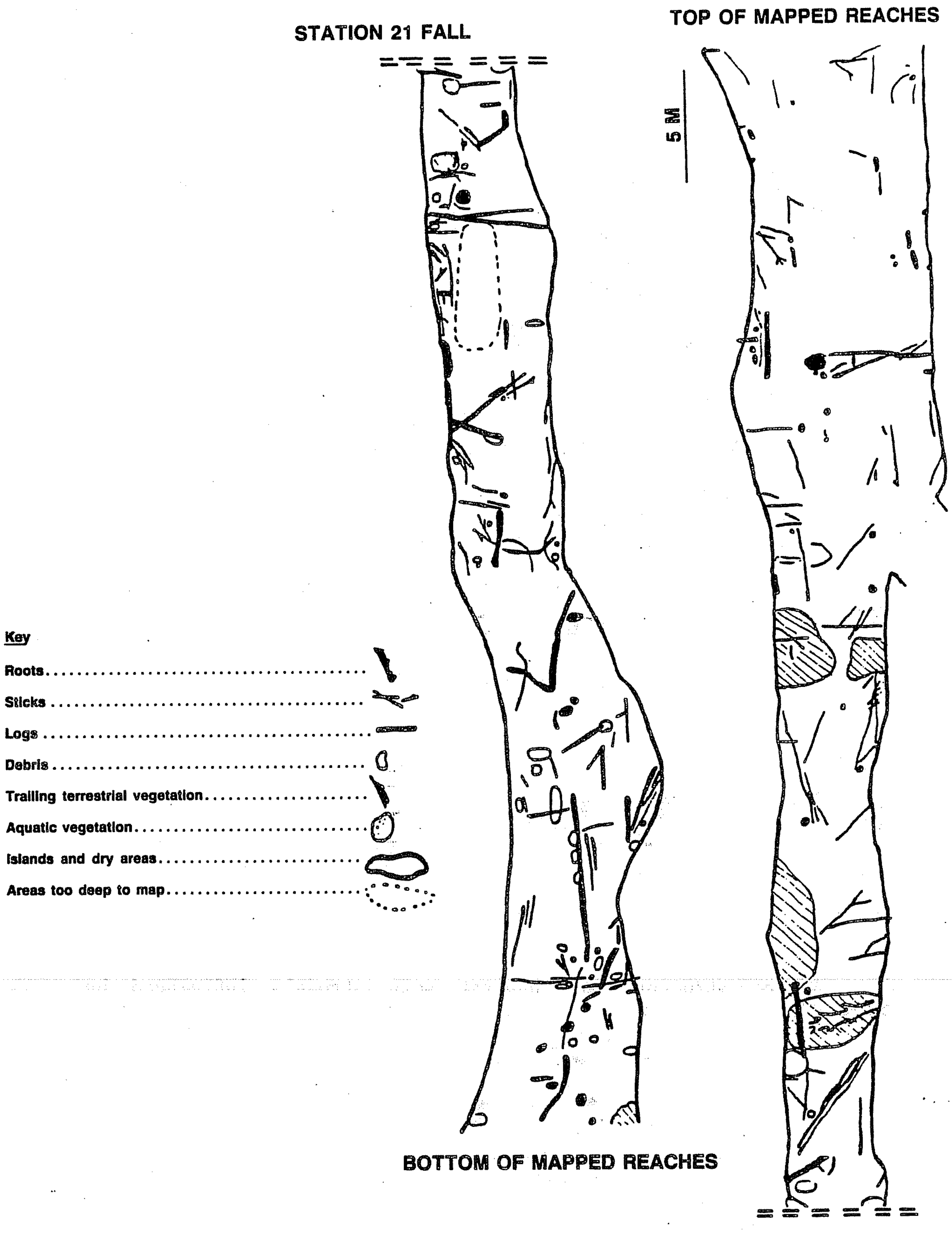


FIGURE V-3.8. Map of Stream Channel at Station 21 on Pen Branch (Fall 1984)

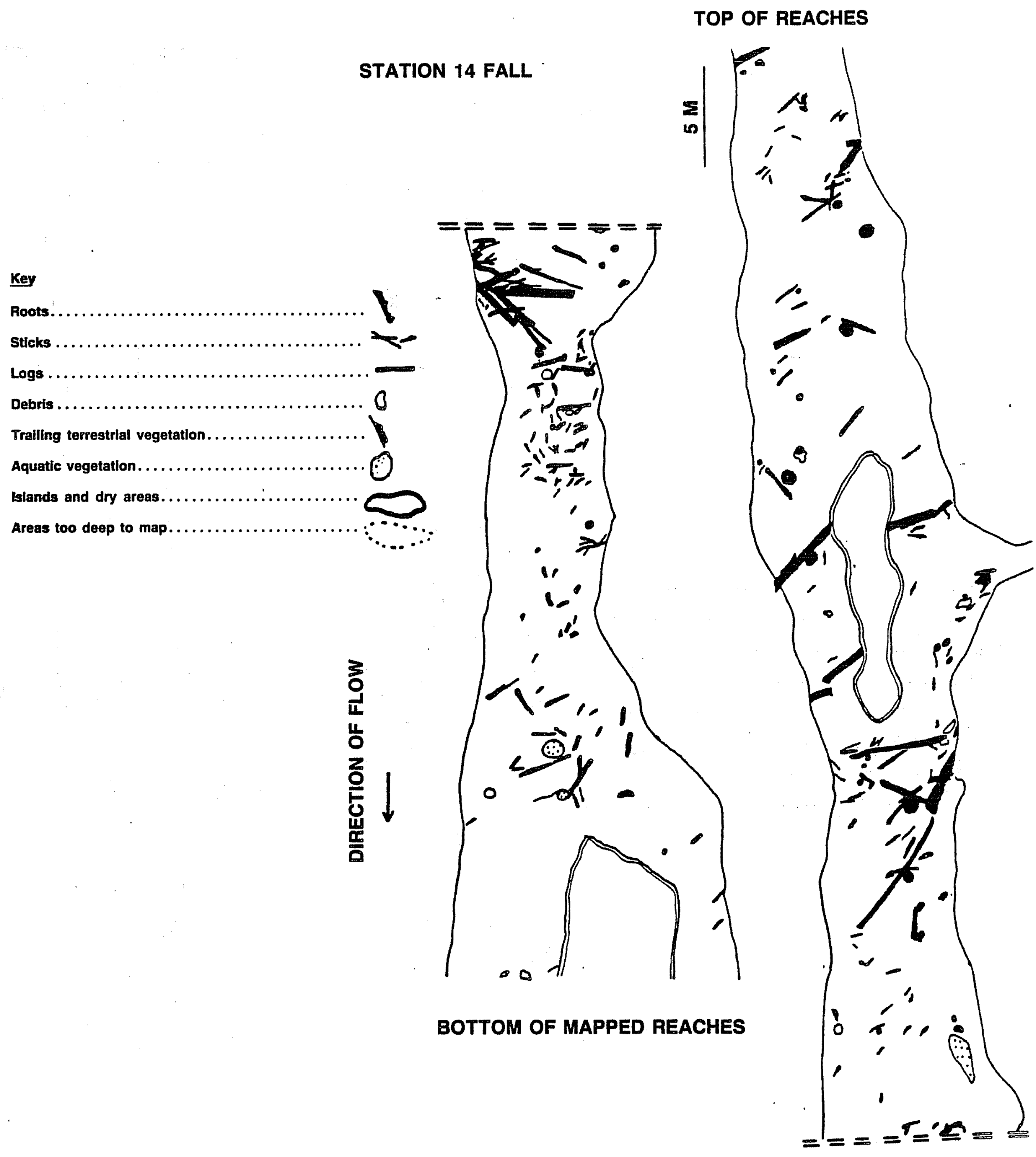


FIGURE V-3.9. Map of Stream Channel at Station 14 on Four Mile Creek (Fall 1984)

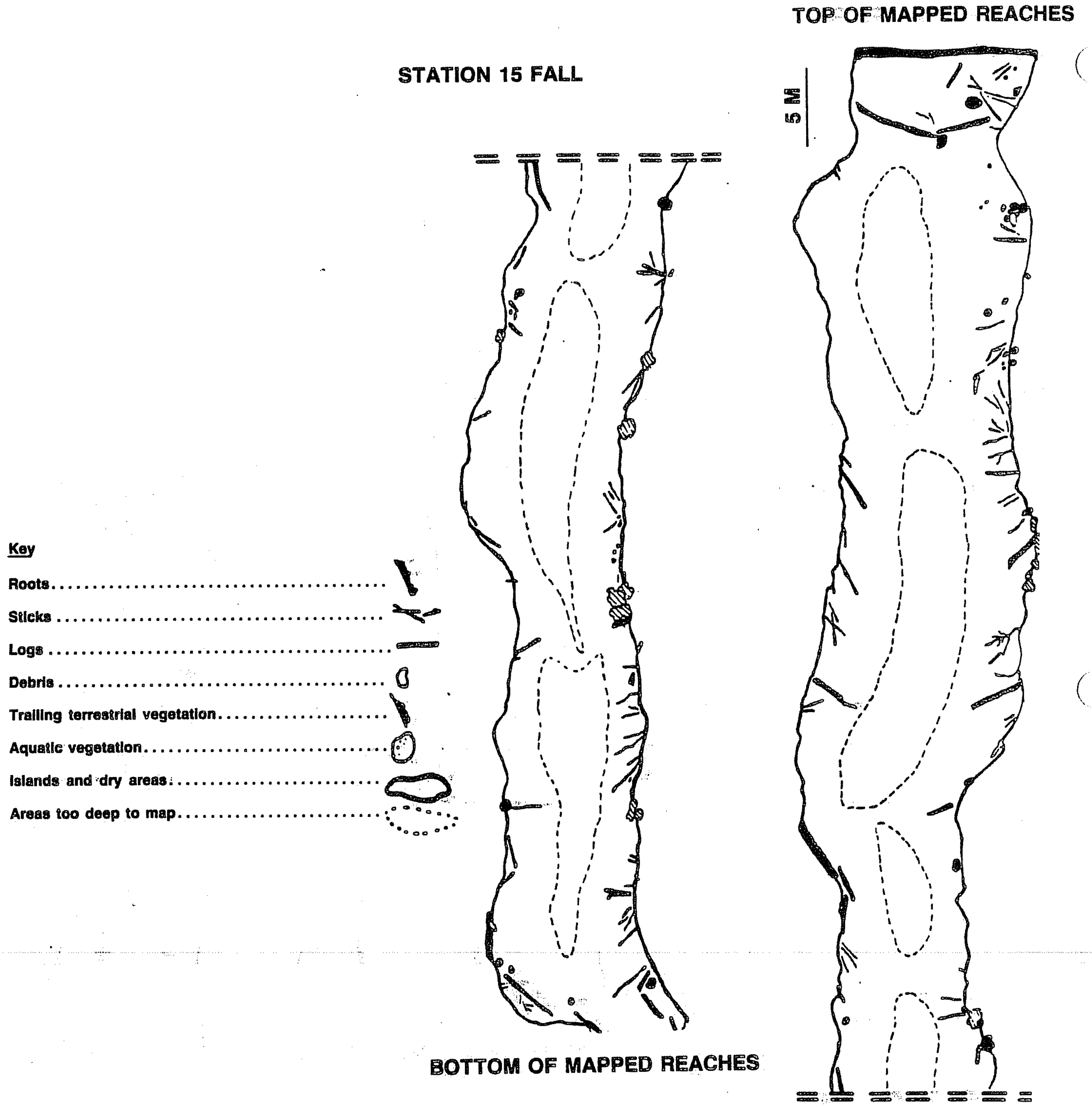


FIGURE V-3.10. Map of Stream Channel at Station 15 on Four Mile Creek (Fall 1984)

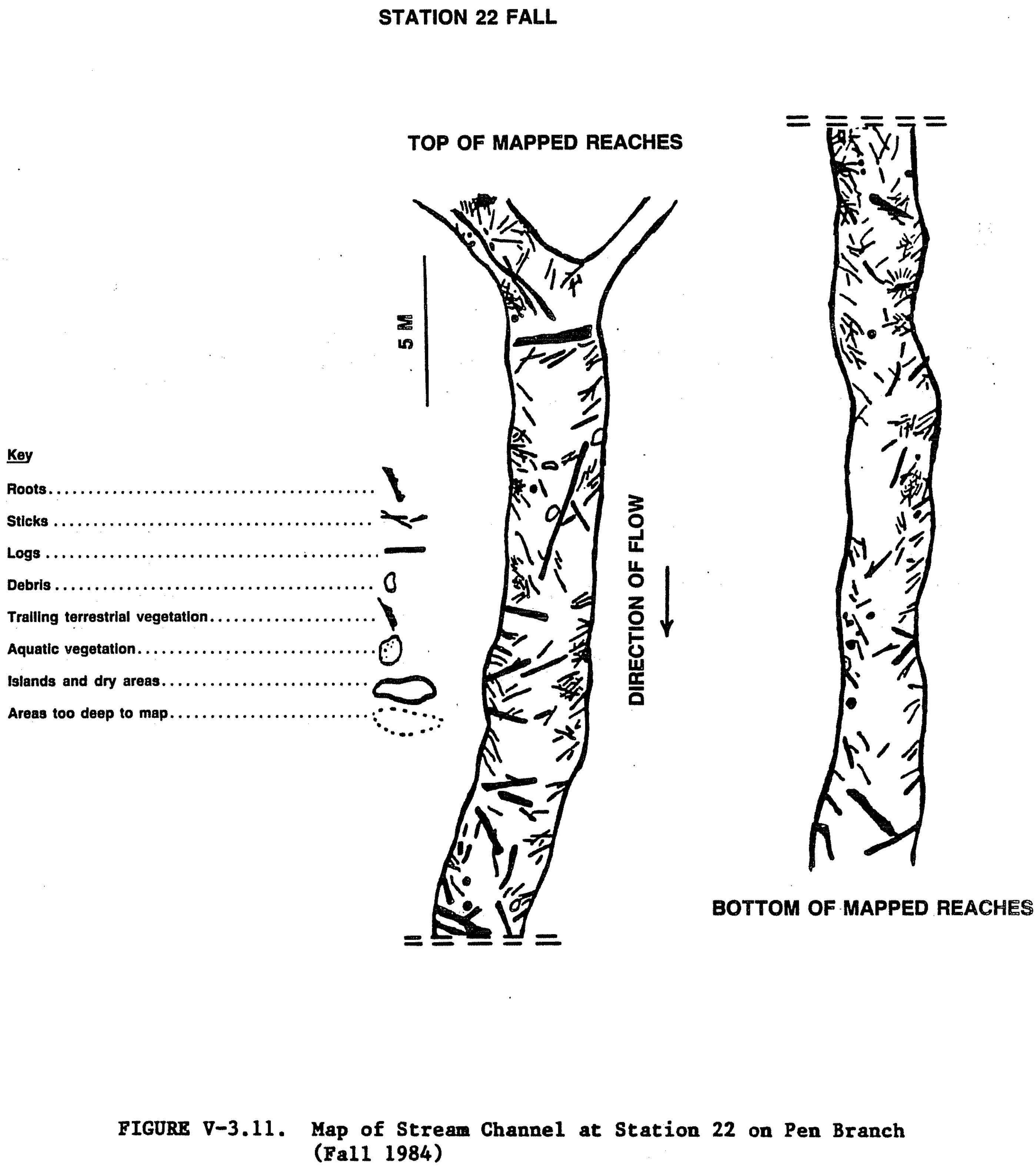


FIGURE V-3.11. Map of Stream Channel at Station 22 on Pen Branch (Fall 1984)

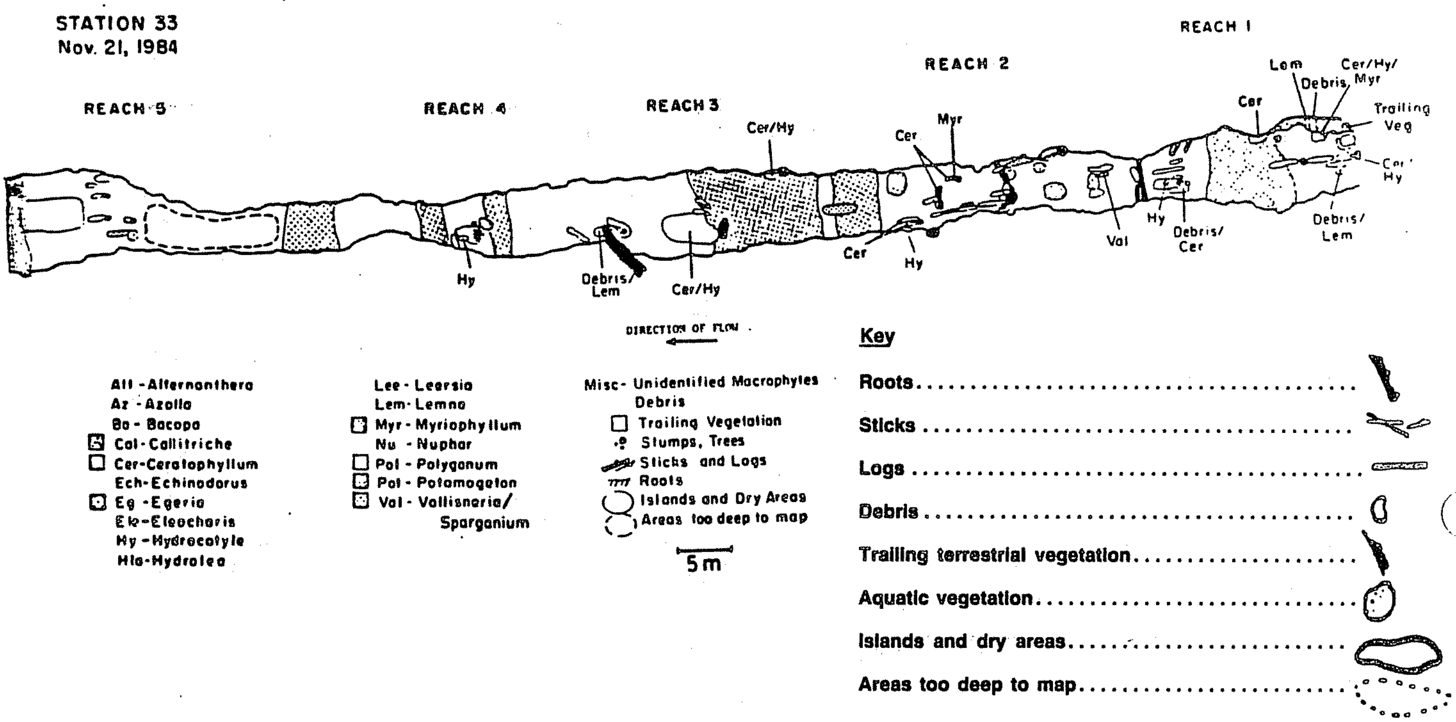


FIGURE V-3.12. Map of Stream Channel at Station 33 on Steel Creek (Fall 1984)

animal habitat and high organic matter retention. The thermal delta sites were less retentive. Because Pen Branch Delta had greater log and stick density and lower current velocity than Four Mile Creek Delta, it was probably the more retentive of the two thermal deltas (Firth et al., 1986).

V.3.4.3.4 Swamps

Three nonthermal swamp sites were mapped: Station 24 in the Pen Branch swamp (Figure V-3.13) and Stations 34 and 35 in the Steel Creek swamp (Figures V-3.14 and V-3.15). Structure in the two swamp systems was very different, and was influenced by the amount of canopy. In the more natural closed canopy Pen Branch swamp site, structure was provided mostly by wood, with a distribution of sticks and logs similar to many stream sites. Total density of wood was significantly higher than at the two Steel Creek swamp sites (Table V-3.10). However, total wood volume was significantly higher at Station 35, and did not differ significantly between Stations 24 and 34. Macrophytes were nearly absent at the Pen Branch swamp site (Table V-3.13). In the Steel Creek swamp, the partially open canopy allowed the development of extensive beds of macrophytes at both sites, which provided excellent habitat and probably increased the retentiveness of the system (Firth et al., 1986).

V.3.5 Primary Producers

V.3.5.1 Introduction

Primary producers (autotrophs) in lotic systems consist mainly of periphyton and macrophytes. Periphyton communities are composed of algae that are attached to submerged surfaces, such as rocks, plants, wood, and benthic sediments (Hynes, 1970). Nonphototrophic organisms, such as fungi and bacteria, are often included in a definition of periphyton and, in some analyses, cannot be separated from the phytosynthetic taxa. A broader term that includes the nonphotosynthetic microbes is "aufwuchs;" the terms periphyton and aufwuchs are often used interchangeably.

Some periphyton studies are done by random sampling of natural substrates. However, the difficulties and lack of experimental control in sampling natural substrates has led to the use of artificial substrates (e.g., glass slides) in research and monitoring studies (APHA, 1985). While the species assemblages and abundances of periphyton on artificial surfaces may not be representative of those on natural substrates (Hynes, 1970), artificial substrates do provide a uniform and quantifiable surface that periphyton can colonize. In the CCWS, both natural and artificial substrates were sampled in the periphyton studies.

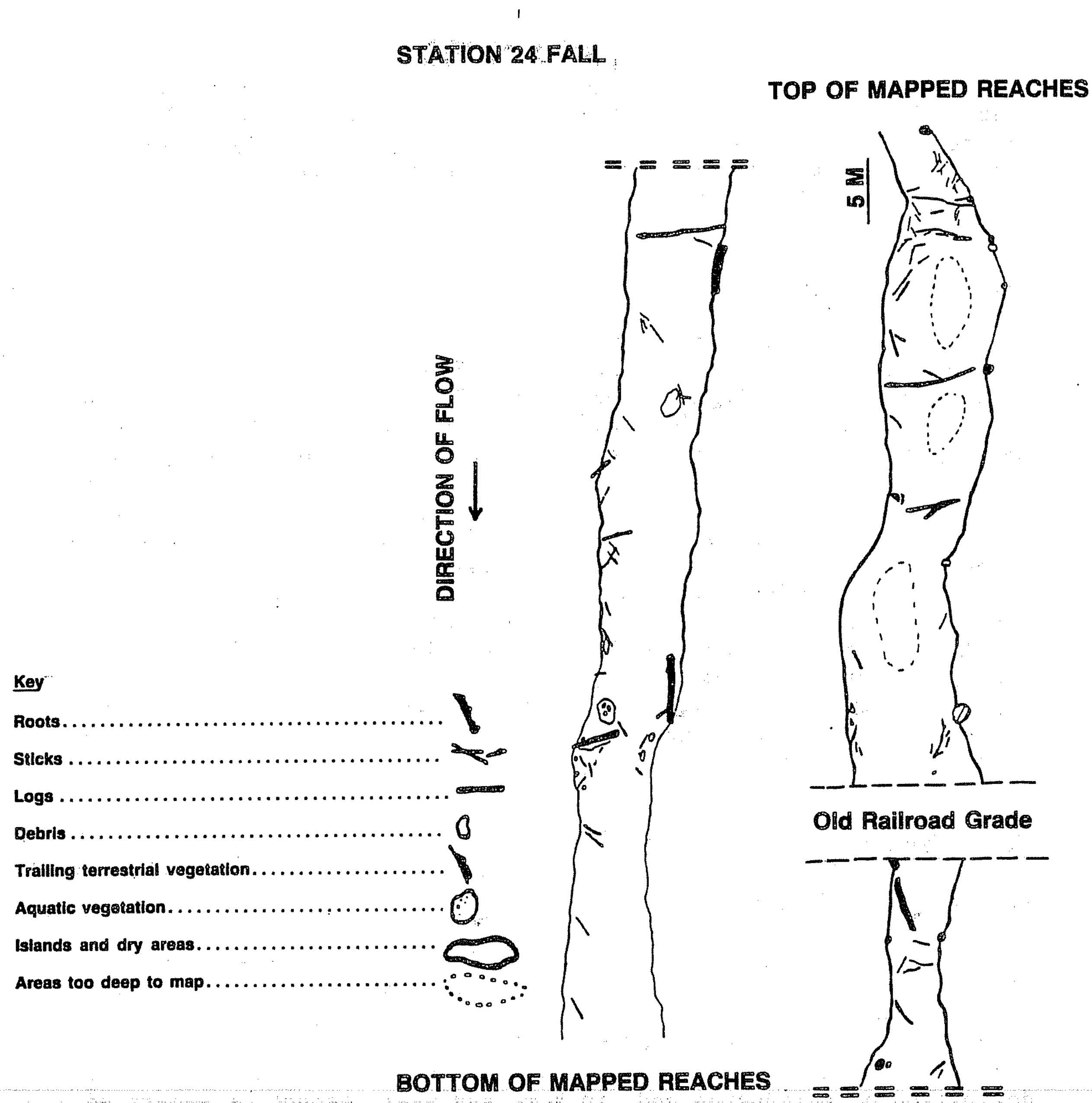


FIGURE V-3.13. Map of Stream Channel at Station 24 on Pen Branch (Fall 1984)

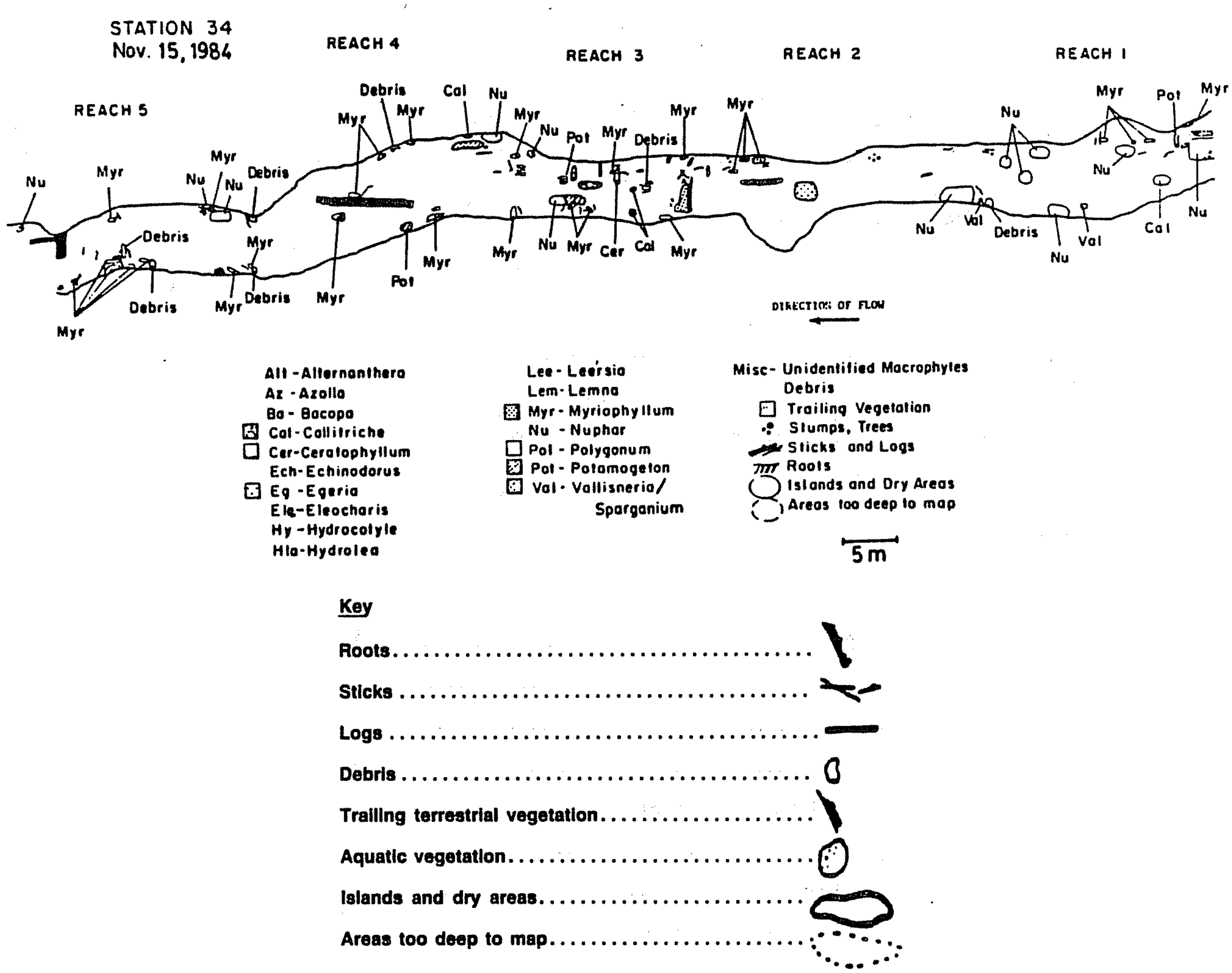


FIGURE V-3.14. Map of Stream Channel at Station 34 on Steel Creek (Fall 1984)

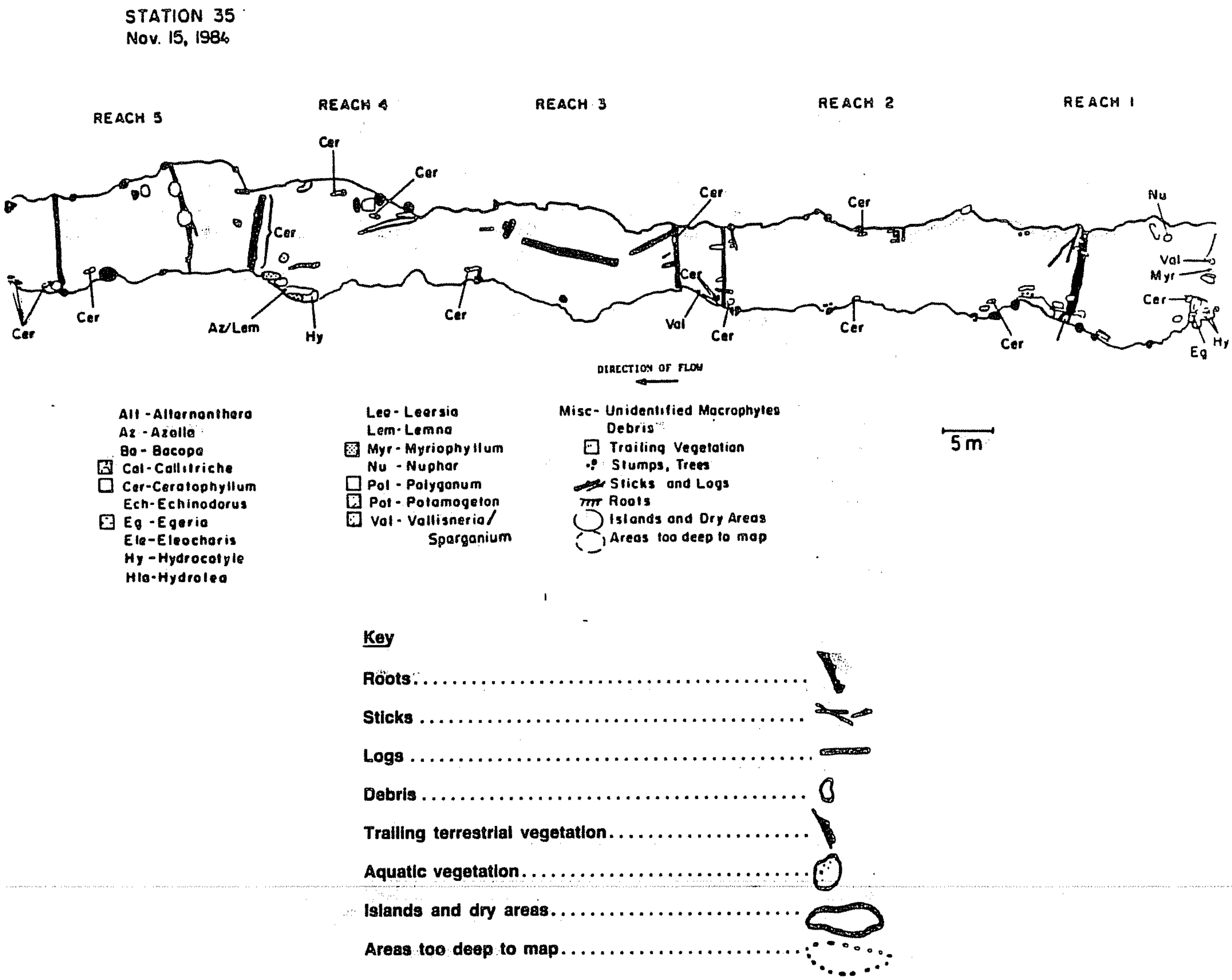


FIGURE V-3.15. Map of Stream Channel at Station 35 on Steel Creek (Fall 1984)

Analysis of periphyton communities can be accomplished through a variety of methods including: taxonomic identifications; chlorophyll analyses, from which the biomass of living photosynthetic taxa can be estimated; and ash-free dry weight (AFDW) analysis, which provides a measure of the organic portion (standing crop) of the living and dead material attached to submerged surfaces. All of these methods were used in the CCWS, as described below in Section V.3.5.2.

Macrophytes are aquatic vascular plants. The methods used in the CCWS to analyze macrophytes included: area or volume measurements of plant beds, taxonomic identification, and measurements of biomass or macrophyte standing crop, using AFDW. Both living and dead plant material were included in standing crop measurements.

Stream autotroph production is determined by a number of environmental factors which include substrate, light, nutrients, temperature, current velocity, and grazer activities (Hynes, 1970). Available light, which is often the limiting factor in stream autotrophic production, is affected by conditions such as season, latitude, percent canopy, and the depth or turbidity of the water. However, at the SRP, effects due to reactor operation and other industrial processes may supercede many of the natural environmental factors (Firth et al., 1986). Several of the streams sampled in this study exhibited effects of human activities. Some examples include altered discharge and flow, increased incident radiation due to riparian tree loss, increased nutrients, increased temperatures, altered water clarity, and altered sediment composition.

V.3.5.2 Materials and Methods

V.3.5.2.1 Periphyton

During the first year of the study, periphyton samples were collected from the stream sites, creek mouths, and river transects during three seasons (winter, spring, and summer).

From stream Stations 5, 13A, 14, 21, 26, 28, 39, and 40, fifteen random natural substrate samples were collected and analyzed for chlorophyll a, dry weight, and AFDW, to determine periphyton (living algal) biomass and organic standing crop (periphyton biomass plus associated nonliving organic matter) at each site (Kondratieff & Kondratieff, 1985b). Periphyton biomass was calculated from chlorophyll a concentrations (APHA, 1980) corrected for pheophytin (Lorenzen, 1967). Organic standing crop was estimated directly from AFDW using the method of Wallace et al. (1982). A list of species was compiled at all stations on a frequent basis through microscopic examination of natural substrates by trained taxonomists.

Periphytometers (Periphytometer II, Design Alliance, Inc.) were used to monitor periphyton in creek mouths and the Savannah River. Each periphytometer held eight glass slides oriented perpendicular to the flow of the water. The periphytometers were submerged just below the water surface and left for 30 days. The periphyton collected on the slides were analyzed for chlorophyll a, taxonomy, and AFDW in a manner similar to that for the natural substrates; APHA, 1980; Weber, 1973; Lorenzen, 1970).

The following year, artificial leaf substrates were used for periphyton colonization at 39 stations (see Table V-3.2). Sycamore (Plantanus occidentalis) leaves in plastic mesh bags were secured in the main current of stream channels for one week during each month of the study. Biomass was estimated from the chlorophyll a concentration (corrected for phaeophytin; APHA, 1980; Lorenzen, 1967) of acetone-extracts of ground leaf samples (Firth et al., 1986).

Detailed taxonomic analyses were carried out on samples taken quarterly during 1985 from selected sites (Table V-3.2). Slides from periphytometers and leaf packs that had been colonized approximately 30 days were shipped to the Academy of Natural Sciences of Philadelphia. There, the slides were microscopically examined to determine the relative abundance of species of algae. The samples were then processed for pigment analysis. Total algal biomass, diatom biomass, and blue-green algal biomass were estimated from pigment analyses of chlorophyll a, chlorophyll c, and phycocyanin, respectively (Bott et al., 1986). Total community biomass was estimated from AFDW, assuming most of the organic material was attributable to living algae.

V.3.5.2.2 Macrophytes

During 1983-1984, macrophyte samples were collected from each of the 12 stream and swamp sites to prepare a species list. Semi-aquatic and riparian vegetation was also qualitatively characterized, and included in the overall taxa list (Appendix V-3.2). For the biomass and standing crop determinations of aquatic macrophytes, only swamp and delta stations were sampled. The other stations were not characterized by macrophyte communities. At the delta sites (Stations 22 and 23), twenty 0.3 m^2 random samples were collected. The Stations 33 and 35 had extensive macrophyte growth. They were mapped to determine area and volume of the macrophyte beds, and were quantitatively sampled to determine biomass and macroinvertebrate standing crop using dry weight and AFDW analysis. Both living and dead macrophyte material was collected and weighed to determine the macrophyte standing crop. Macrophyte sampling occurred three times (winter, spring, and summer) during the 1983-1984 study year. River transects and creek mouths were not sampled for macrophytes during the first study year. The site at Station 33 was sampled both in the channel and in the adjacent smartweed (Polygonum) beds.

In 1984-1985, macrophyte beds in stream, delta, and swamp channels were measured at all mapped stations (Table V-3.2). Submerged macrophyte beds were measured to determine volume, while area of channel covered was determined for emergent macrophytes. Biomass was quantitatively determined for each species present at each site, by sampling in beds and subsequent dry weight and AFDW analysis (Firth et al., 1986). However, sampling was not conducted in the mapped channels themselves.

V.3.5.3 Results and Discussion

V.3.5.3.1 Periphyton

Periphyton biomass (based on chlorophyll concentrations) and benthic organic matter standing crop (from AFDW analysis) results for the stream stations sampled during the 1983-1984 study year are presented in Table V-3.14 and V-3.15, respectively. The periphyton biomass and standing crop for the Savannah River and tributary creek mouth stations are presented in Tables V-3.16 and V-3.17, respectively. The results for periphyton biomass for the stream stations sampled during the 1984-1985 study year are presented in Table V-3.18, whereas Table V-3.19 presents a summary of the biomass and algal-C for blue-green algae, algae, diatoms, and total algae for 20 selected stations sampled in 1984-1985.

Periphyton biomass was one to two orders of magnitude lower during 1984-1985 compared to 1983-1984. This large year-to-year difference is at least partly attributable to the different methodologies employed during the two years of the study (see Section V.3.5.2.1).

Results of the 1983-1984 sampling showed that periphyton communities differed at thermal and nonthermal sites. Green algae and diatoms characterized the nonthermal sites, while thick mats of blue-green algae were unevenly distributed at the thermal sites (Gladden et al., 1985). During winter sampling, periphyton biomass was highest at the thermal sites (Stations 13A, 14, and 21). Warm water temperatures during the winter months stimulated blue-green algal production in the thermal streams (Gladden et al., 1985). In the spring, mean periphyton biomass was highest at two of the thermal sites (Four Mile Creek Stations 13A and 14). Highly thermal Pen Branch Station 21 had a very low biomass, compared to the other thermal streams in the spring, probably resulting from disruption of the blue-green algal mat communities by discontinuous reactor operation. Periphyton biomass was lower at all sites in

TABLE V-3.14

Periphyton Biomass (g AFDW/m^2) at Each 1983-1984 Station During Winter, Spring, and Summer Sampling*

Location	Station	Mean (range)	n	Coefficient of Variation
		Winter		
BD-t	5**			
FM-t	13A	9.17 (0.0-26.14)	37	73.51
FM-t	14	13.26 (0.25-32.70)	42	83.92
PB-t	21	11.61 (1.87-29.80)	29	59.55
SC-n	26	1.94 (0.31-13.45)	40	170.90
SC-n	28	1.35 (0.01-4.30)	43	104.47
MB-n	39	3.59 (0.56-10.11)	45	66.58
MB-n	40	7.29 (0.94-17.48)	44	55.08
		Spring		
BD-t	5	1.48 (0.0-8.16)	44	174.59
FM-t	13A	14.42 (0.0-47.40)	45	96.59
FM-t	14	20.83 (0.53-38.18)	45	55.42
PB-t	21	3.81 (0.08-10.54)	45	71.44
SC-n	26	2.41 (0.05-17.51)	45	177.66
SC-n	28	0.56 (0.24-4.45)	43	111.18
MB-n	39	10.73 (0.13-40.42)	45	99.41
MB-n	40	9.22 (1.86-21.06)	45	54.73
		Summer		
BD-t	5	0.02 (0.00-0.15)	28	180.40
FM-t	13A	4.41 (0.24-16.24)	39	95.20
FM-t	14	2.24 (0.19-10.38)	43	102.30
PB-t	21	1.49 (0.18-5.75)	45	78.60
PBD-t	22	4.65 (0.33-11.49)	41	67.50
SC-n	26	0.32 (0.08-0.86)	45	45.80
SC-n	28	0.18 (0.01-0.41)	42	50.00
MB-n	39	0.17 (0.00-1.37)	36	154.90
MB-n	40	1.49 (0.36-6.27)	45	97.20

Note: Abbreviations are listed in Table V-3.2.

* Mean, range, number of samples (n) and coefficient of variation (CV) are given.
** Beaver Dam Creek was not sampled for biomass until spring.

Source: Gladden et al., 1985.

TABLE V-3.15

Organic Standing Crop (g AFDW/m^2) at Each 1983-1984 Station (Winter, Spring, and Summer 1984)

Location	Station	Mean (range)	n	Coefficient of Variation
		Winter		
BD-t	5	1063.5 (529.1-1586.5)	6	35.8
FM-t	13A	2346.7 (887.6-4976.6)	30	44.2
FM-t	14	653.0 (0.0-1771.3)	27	90.4
PB-t	21	1737.7 (765.6-3572.6)	30	39.4
SC-n	26	400.8 (0.0-3344.4)	28	193.8
SC-n	28	463.9 (0.0-2343.7)	30	128.8
MB-n	39	321.2 (17.0-1118.8)	16	97.8
MB-n	40	474.2 (0.0-1080.8)	28	62.2
		Spring		
BD-t	5	615.9 (0.0-1588.6)	30	73.2
FM-t	13A	1508.8 (122.6-3667.1)	30	63.0
FM-t	14	1298.2 (224.7-2978.1)	30	76.9
PB-t	21	2254.4 (224.2-4684.4)	30	66.5
SC-n	26	198.4 (60.5-810.1)	30	90.9
SC-n	28	67.1 (21.0-288.7)	30	74.4
MB-n	39	382.1 (18.0-2411.7)	30	159.9
MB-n	40	920.5 (135.6-2475.3)	30	72.3
		Summer		
BD-t	5	1339.8 (677.5-2430.8)	20	38.6
FM-t	13A	220.5 (41.9-963.7)	30	98.8
FM-t	14	895.5 (137.1-2655.9)	30	81.5
PB-t	21	1953.0 (1019.7-3797.7)	30	34.7
PBD-t	22	829.0 (343.2-1665.2)	28	37.9
SC-n	26	128.8 (14.0-1084.8)	30	155.2
SC-n*	28	98-327 (26.5-671.4)	28	52.7
MB-n	39	250.5 (32.0-722.5)	6**	113.7
MB-n	40	571.5 (44.0-2666.9)	30	113.3

* Values estimated from dry-weight data based on probable 0.3-1.0 percent organic content. Ash-free dry weight data not obtained due to very low organic content and insufficient sample size.

** The substrate at Station 11 consisted of gravel and cobble in a matrix of sand. Random samples of periphyton could be collected from the surfaces of these rocks for chlorophyll a analyses. However, cores suitable for AFDW analysis were frequently impossible to collect using the technique employed at other stations.

Note: Abbreviations are listed in Table V-3.1.

Source: Kondratieff and Kondratieff, 1985a; 1985b.

TABLE V-3.16

Periphyton Biomass (chlorophyll a mg/m^2) from the Savannah River and Tributary Creek Mouth Stations Sampled Monthly (October 1983 - September 1984)

River Station	Oct. Mean	Nov. Mean	Dec. Mean	Jan. Mean	Feb. Mean	Mar. Mean	Apr. Mean	May Mean	June Mean	July Mean	Aug. Mean	Sep. Mean	Annual Mean	Annual SE
46	13.1	18.0	6.1	15.9	0.9	4.6	23.9	30.9	8.3	102.0	-	31.6	23.21	8.88
41	8.9	29.2	20.5	2.3	0.8	39.4	46.4	54.2	36.7	51.0	23.2	43.1	29.64	5.60
49	15.3	19.1	0.3	6.3	0.3	1.7	18.0	2.1	46.7	44.7	4.6	4.0	13.59	4.95
38	24.1	17.8	3.5	0.9	0.7	32.8	15.5	34.6	63.7	55.4	65.9	11.6	27.21	7.13
25	18.4	32.0	2.0	3.9	0.5	43.7	42.2	14.2	16.4	9.2	16.0	17.3	17.98	4.36
19	21.7	9.6	43.7	28.0	2.3	21.5	15.3	29.3	28.7	42.0	16.8	15.1	22.83	3.54
11	13.0	10.7	34.2	2.4	0.3	0.2	0.8	-	33.2	51.2	16.4	8.3	15.52	5.36
10	15.5	18.1	-	4.7	0.5	0.1	27.0	-	23.5	89.4	6.2	10.0	19.50	8.75
4	15.9	10.3	1.0	8.1	0.8	0.4	41.5	21.4	34.3	66.6	41.9	16.1	21.52	6.22
47	12.1	8.9	0.1	-	-	-	-	-	-	-	-	-	7.03	4.39
All river stations													21.29	1.95
All river stations except 47												20.89	1.91	

Creek Mouth	Oct. Mean	Nov. Mean	Dec. Mean	Jan. Mean	Feb. Mean	Mar. Mean	Apr. Mean	May Mean	June Mean	July Mean	Aug. Mean	Sep. Mean	Annual Mean	Annual SE
45	15.2	5.1	9.0	14.9	12.2	72.2	37.9	13.8	19.9	9.1	49.3	7.9	22.21	6.17
37	1.7	4.3	8.4	6.8	4.8	42.4	7.3	24.5	29.5	106.5	14.9	17.0	22.34	8.79
18	1.1	3.6	7.8	41.2	16.7	42.9	10.8	93.0	4.5	2.3	16.7	1.9	20.21	8.16
9	9.4	0.6	4.4	12.0	25.1	51.5	10.4	62.5	36.7	11.9	29.5	21.9	22.99	5.78
3	5.3	3.2	0.2	0.6	8.8	45.7	11.5	-	19.2	38.2	72.2	18.2	20.28	7.20
All creek mouth stations													21.63	3.02
All creek mouth stations except 18													21.99	3.24

Source: O'Hop et al., 1985.

TABLE V-3.17

Periphyton Standing Crop (AFDW mg/m^2) from the Savannah River and Tributary Creek Mouth Stations Sampled Monthly (October 1983 - September 1984)

River Station	Oct. Mean	Nov. Mean	Dec. Mean	Jan. Mean	Feb. Mean	Mar. Mean	Apr. Mean	May Mean	June Mean	July Mean	Aug. Mean	Sep. Mean	Annual Mean	Annual SE
46	2997	1220	333	980	66	186	2573	2386	5066	4948	-	2137	2081.1	556.5
41	1755	1644	1900	233	75	2797	3680	4404	2564	2631	5460	3135	2524.8	472.0
49	2400	1800	164	393	83	235	3084	1000	2020	4840	-	1030	1549.9	467.9
38	1937	975	253	64	162	2122	1500	2110	4228	2935	4953	1686	1910.4	464.2
25	2740	1857	306	166	100	2551	2724	1164	1286	1906	1304	2508	1551.0	298.5
19	2673	224	1884	1506	226	1411	1604	3213	3204	6975	1460	4248	2385.7	565.9
11	1488	1066	1388	446	200	315	351	-	2948	6584	-	1362	1614.8	643.6
10	4064	1082	-	586	291	164	1406	-	2600	3504	3123	2486	1930.6	469.0
4	2644	1043	200	451	336	140	2995	400	3226	10655	-	1322	2128.4	966.6
47	3880	802	106	-	-	-	-	-	-	-	-	-	1596.0	1420.1
All river stations													1961.9	172.1
All river stations except 47													1972.8	174.8

Creek Mouth	Oct. Mean	Nov. Mean	Dec. Mean	Jan. Mean	Feb. Mean	Mar. Mean	Apr. Mean	May Mean	June Mean	July Mean	Aug. Mean	Sep. Mean	Annual Mean	Annual SE
45	1622	935	771	1313	657	3924	2468	911	1775	1735	1835	795	1561.8	279.7
37	248	533	557	417	433	2400	782	1460	1793	2428	1215	1528	1149.5	233.3
18	2064	922	620	2893	2453	2575	1080	5062	5629	5228	2226	2633	2782.1	508.8
9	1175	620	573	660	1800	2560	1031	4195	1386	1226	2091	1556	1572.8	380.5
3	3397	475	404	466	831	1657	1937	373	1053	2076	6523	2200	1782.7	531.2
All creek mouth stations													1769.8	22.7
All creek mouth stations except 18													1516.7	24.1

Source: O'Hop et al., 1985.

TABLE V-3.18

Periphyton Biomass (g AFDW m^2) Mean N, Standard Error, Coefficient of Variation (CV) and Minimum and Maximum Values are Presented for Each 1984-1985 Station Over All Months (October 1984-September 1985)

Station	Location/ Thermal Regime	Mean	N	Standard Error	CV	Minimum	Maximum
1	UTR-n	0.0848	72	0.0048	47.66	0.0314	0.2468
3	UTR-n	0.1010	71	0.0055	45.83	0.0353	0.2358
4	SR-n	0.2387	72	0.0373	132.5	0.0317	1.454
6	BD-t	0.1548	59	0.0393	195.2	0.0288	1.713
8	BD-t	0.1024	72	0.0101	83.35	0.0209	0.4330
9	BD-t	0.0586	72	0.0042	60.22	0.0145	0.2545
10	SR-n	0.2279	66	0.0438	156.1	0.0000	2.457
11	SR-n	0.2040	60	0.0259	98.31	0.0293	0.7491
14	FMD-t	0.2517	72	0.0347	116.8	0.0354	1.780
15	FMD-t	0.1030	48	0.0117	78.83	0.0104	0.4352
17	FMD-t	0.1191	54	0.0237	146.3	0.0334	1.222
18	FM-t	0.1368	71	0.0296	182.2	0.0121	1.713
19	SR-t	0.2797	72	0.0468	142.0	0.0380	1.597
20	PB-n	0.0683	70	0.0031	37.62	0.0220	0.1414
21	PB-t	0.1816	72	0.0315	147.2	0.0035	1.355
22	PBD-t	0.2338	72	0.0275	99.72	0.0055	1.223
24	PBS-n	0.0926	72	0.0067	61.28	0.0264	0.3096
25	SR-n	0.1980	72	0.0338	145.0	0.0251	1.388
26	SC-n	0.1509	72	0.0172	96.93	0.0429	0.8923
27	SC-n	0.1060	66	0.0085	64.89	0.0264	0.3812
28	SC-n	0.1390	66	0.0244	142.7	0.0087	1.487
29	SC-n	0.1304	72	0.0076	49.79	0.0372	0.4287
31	SCD-n	0.2360	72	0.0408	146.8	0.0220	2.911
32	SCD-n	0.1676	71	0.0135	68.12	0.0196	0.5013
33	SCD-n	0.2023	72	0.0160	66.98	0.0659	0.6390
34	SCS-n	0.1729	72	0.0175	86.06	0.0397	1.080
35	SCS-n	0.1904	72	0.0197	87.93	0.0342	0.8208
36	SC-n	0.1350	72	0.0122	76.47	0.0303	0.5068
37	SC-n	0.1000	71	0.0057	48.14	0.0381	0.2975
38	SR-n	0.1710	72	0.0294	145.9	0.0166	1.818
39	MB-n	0.0819	72	0.0035	35.83	0.0314	0.1564
40	MB-n	0.0761	66	0.0059	63.52	0.0259	0.3294
41	SR-n	0.1542	70	0.0161	87.51	0.0383	0.7761
42	LTR-n	0.1213	72	0.0076	53.50	0.0297	0.3305
53	LTR-n	0.0666	48	0.0068	70.29	0.0045	0.2809
43	LTR-n	0.1030	18	0.0088	36.06	0.0480	0.1695
44	LTR-n	0.0774	71	0.0041	44.99	0.0061	0.1504
45	LTR-n	0.1267	66	0.0269	148.4	0.0034	1.625

Note: Abbreviations are listed in Table V-3.2.

Source: Firth et al., 1986.

TABLE V-3.19

Summary of Blue-Green Algal Biomass-C, Percent Blue-Green Algal-C, Algal Biomass-C, Percent Algal-C, Diatom Biomass-C, Percent Diatom-C of Algal-C, and Summary of Total Biomass-C on Slide for Each Season (January - October 1985)

Station		µg Blue-Green-C/cm^2					Blue-Green-C/Algal-C As Percent				
		Spring	Summer	Autumn	Mean	S.D.	Spring	Summer	Autumn	Mean	S.D.
Post-Thermal and Non-Thermal Streams											
1	Upper Three Runs	5.10	-	-	5.10	-	3.30	-	-	3.30	-
25	Savannah River	-	-	-	-	-	-	-	-	-	-
26	Steel Creek	-	-	-	-	-	-	-	-	-	-
27	Steel Creek	-	-	-	-	-	-	-	-	-	-
29	Steel Creek	-	4.00	-	4.00	-	-	4.20	-	4.20	-
31	Steel Creek	-	5.40	-	5.40	-	-	-	-	-	-
34	Steel Creek	-	-	-	-	-	-	-	-	-	-
36	Steel Creek	-	-	-	-	-	-	-	-	-	-
38	Savannah River	-	0.00	-	0.00	-	-	0.00	-	0.00	-
39	Meyers Branch	-	-	-	-	-	-	-	-	-	-
40	Meyers Branch	-	-	-	-	-	-	-	-	-	-
42	Lower Three Runs	-	0.05	-	0.05	-	-	0.00	-	0.00	-
44	Lower Three Runs	-	-	-	-	-	-	-	-	-	-
	Mean	5.10	2.36				3.30	1.40			
	S.D.	-	2.76				2.42				
	N	1	4				1	3			
Thermal Streams											
5	Beaver Dam	-	-	-	-	-	-	-	-	-	-
7	Beaver Dam	-	-	-	-	-	-	-	-	-	-
8	Beaver Dam	-	5.20	-	5.20	-	-	54.70	-	54.70	-
14	Four Mile Dam	48.60	-	11.50	30.05	26.23	69.30	-	31.30	50.30	26.87
17	Four Mile Creek	-	-	-	-	-	-	-	-	-	-
22	Pen Branch	-	1.80	27.20	14.50	17.96	-	3.70	25.80	14.75	15.63
24	Pen Branch	-	-	-	-	-	-	-	-	-	-
	Mean	48.60	3.50	19.35			69.30	29.20	28.55		
	S.D.	2.40	11.10				36.06	3.89			
	N	1	2	2			1	2	2		

TABLE V-3.19, Contd

Station		µg Diatom-C/cm²					Diatom-C/Algal-C As Percent				
		Spring	Summer	Autumn	Mean	S.D.	Spring	Summer	Autumn	Mean	S.D.
Post-Thermal and Non-Thermal Streams											
1	Upper Three Runs	38.40	32.20	5.10	25.23	17.71	24.90	134.70	104.10	87.90	56.66
25	Savannah River	57.30	47.50	-	52.40	6.93	95.20	164.40	-	129.80	48.93
26	Steel Creek	34.90	50.20	6.50	30.53	22.17	51.90	100.40	83.30	78.53	24.60
27	Steel Creek	57.90	-	-	57.90	-	83.80	-	-	83.80	-
29	Steel Creek	53.70	50.20	23.25	42.38	16.66	91.90	52.50	74.05	72.82	19.73
31	Steel Creek	29.20	-	14.10	21.65	10.68	31.30	-	95.30	63.30	45.25
34	Steel Creek	10.20	-	7.75	8.98	1.73	73.00	-	58.80	65.90	10.04
36	Steel Creek	2.50	-	1.00	1.75	1.06	63.80	-	17.60	40.70	32.67
38	Savannah River	64.10	27.50	-	45.80	25.88	84.70	47.70	-	66.20	26.16
39	Meyers Branch	33.10	4.90	5.70	14.57	16.06	58.30	42.20	712.50	271.00	382.43
40	Meyers Branch	17.70	8.40	5.90	10.67	6.22	63.80	1400.00	245.80	569.87	724.65
42	Lower Three Runs	-	50.60	36.90	43.75	9.69	-	37.80	93.40	65.60	39.32
44	Lower Three Runs	18.80	2.00	-	10.40	11.88	102.20	125.00	-	113.60	16.12
	Mean	34.82	30.39	11.80			68.73	233.86	164.98		
	S.D.	20.23	20.73	11.43			24.53	439.73	214.46		
	N	12	9	9			12	9	9		
Thermal Streams											
5	Beaver Dam	8.57	9.80	3.50	7.29	3.34	81.60	408.30	76.10	188.67	190.23
7	Beaver Dam	33.30	-	27.10	30.20	4.36	111.50	-	86.90	99.20	17.39
8	Beaver Dam	52.40	16.50	11.60	26.83	22.28	86.60	173.40	610.00	290.00	280.51
14	Four Mile Dam	16.10	34.90	36.50	29.17	11.34	23.00	152.40	99.50	91.63	65.06
17	Four Mile Creek	-	-	-	-	-	-	-	-	-	-
22	Pen Branch	45.90	26.50	10.80	27.73	17.58	41.50	54.50	10.30	35.43	22.72
24	Pen Branch	16.90	0.20	5.90	7.67	8.49	96.40	100.00	125.50	107.30	15.86
	Mean	28.86	17.58	15.90			73.43	177.72	168.05		
	S.D.	17.79	13.63	13.02			34.00	136.92	219.89		
	N	6	5	6			6	5	6		

TABLE V-3.19, Contd

Station		μg Algal-C/cm² Spring	Summer	Autumn	Mean	S.D.	Algal-C/Total-C As Percent Spring	Summer	Autumn	Mean	S.D.
Post-Thermal and Non-Thermal Streams											
1	Upper Three Runs	154.30	23.90	4.90	61.03	81.3	75.10	98.40	11.10	61.53	45.20
25	Savannah River	60.20	28.90	-	44.55	22.1	70.10	60.30	-	65.20	6.93
26	Steel Creek	67.30	50.00	0.80	41.70	30.6	55.60	26.80	11.60	31.33	22.35
27	Steel Creek	69.20	-	-	69.20	-	63.80	-	-	63.80	-
29	Steel Creek	58.40	95.60	31.40	61.80	32.2	46.20	84.70	36.95	55.95	25.32
31	Steel Creek	93.00	-	14.80	53.90	55.3	79.50	-	42.30	60.90	26.30
34	Steel Creek	14.00	-	13.10	13.55	0.6	28.20	-	42.25	35.23	9.93
36	Steel Creek	3.80	-	5.80	4.80	1.4	45.20	-	44.60	44.90	0.42
38	Savannah River	75.60	57.70	-	66.65	12.6	82.60	37.50	-	60.15	21.89
39	Meyers Branch	56.70	11.60	0.80	23.03	29.6	40.10	31.40	2.40	24.63	19.74
40	Meyers Branch	35.50	0.60	2.40	12.83	19.6	56.00	1.10	6.30	21.13	30.31
42	Lower Three Runs	-	133.90	39.50	86.70	66.7	-	95.30	5.60	50.45	63.73
44	Lower Three Runs	18.40	1.60	-	10.00	11.8	61.20	4.20	-	32.70	40.31
	Mean	58.87	44.87	13.39			58.63	48.86	22.57		
	S.D.	40.41	45.17	13.46			16.70	37.45	18.30		
	N	12	9	9			12	9	9		
Thermal Streams											
5	Beaver Dam	10.50	2.40	4.60	5.83	4.1	55.30	10.30	7.40	24.33	26.86
7	Beaver Dam	29.80	-	31.20	30.50	0.9	90.40	-	34.30	62.35	39.67
8	Beaver Dam	60.50	9.50	1.90	23.97	31.8	59.40	148.40	3.20	70.33	73.21
14	Four Mile Dam	70.20	22.90	36.70	43.27	24.3	85.60	105.50	146.80	112.63	21.22
17	Four Mile Creek	-	-	-	-	-	-	-	-	-	-
22	Pen Branch	110.70	48.60	105.30	88.20	34.4	71.40	276.10	34.80	127.43	130.04
24	Pen Branch	12.70	0.20	4.70	5.87	6.3	31.00	0.90	47.00	26.30	23.41
	Mean	49.07	16.72	30.73			65.72	108.24	45.58		
	S.D.	38.88	19.90	39.47			21.86	112.82	52.43		
	N	6	5	6			6	5	6		

TABLE V-3.19, Contd

Station		µg Total Biomass-C/cm² Spring	Summer	Autumn	Mean	S.D.
Post-Thermal and Non-Thermal Streams						
1	Upper Three Runs	205.50	24.30	44.00	91.27	99.42
25	Savannah River	85.00	47.90	-	66.45	26.23
26	Steel Creek	121.00	186.50	67.00	124.83	59.84
27	Steel Creek	108.50	-	-	108.50	-
29	Steel Creek	126.50	112.90	86.00	108.47	20.61
31	Steel Creek	117.00	27.20	35.00	59.73	49.75
34	Steel Creek	49.50	-	31.00	40.25	13.00
36	Steel Creek	8.50	-	13.00	10.75	3.18
38	Savannah River	91.50	153.90	-	122.70	44.12
39	Meyers Branch	141.50	36.90	33.00	70.47	61.55
40	Meyers Branch	63.50	54.50	38.00	52.00	12.93
42	Lower Three Runs	-	140.50	700.00	420.25	395.63
44	Lower Three Runs	30.50	37.70	-	33.85	5.44
	Mean	95.67	82.23	116.33		
	S.D.	53.58	60.29	219.92		
	N	12	10	9		
Thermal Streams						
5	Beaver Dam	19.00	23.40	62.00	34.80	23.66
7	Beaver Dam	33.00	-	91.00	62.00	41.01
8	Beaver Dam	102.00	6.10	59.00	55.70	48.04
14	Four Mile Dam	82.00	21.70	25.00	42.90	33.90
17	Four Mile Creek	-	-	-	-	-
22	Pen Branch	155.00	17.60	303.00	158.53	142.73
24	Pen Branch	41.00	23.50	10.00	24.83	15.54
	Mean	72.00	18.46	91.67		
	S.D.	51.34	7.31	107.45		
	N	6	5	6		

Source: Bott et al., 1986.

the summer compared to winter and spring (Table V-3.14). At reference sites (Stations 39 and 40), shading may have been a factor in the lower algal standing crop, while low standing crop at the thermal sites was probably attributable to summer temperatures that approached the upper limits of algal tolerance, as well as periodic senescence and sloughing of the mat-formers. Lowest biomass values were found in the mildly heated waters of Beaver Dam Creek (Station 1). Factors other than temperature appear to be adversely affecting periphyton growth in this creek (Evans and Giesy, 1984, as cited in Kondratieff and Kondratieff, 1985b). Biomass was also consistently low at Station 26 and 28 in post-thermal Steel Creek (Table V-3.14). Occasional pulses of unusually high discharge through the Steel Creek channel presumably due to P-Area effluents, probably washed periphyton free from the sand substrate, keeping standing crop low. Stations 26 and 28 also receive moderate shading from a partial canopy.

During all three seasons sampled, benthic organic standing crops (AFDW, including living and nonliving components) were generally higher at thermal sites than at nonthermal sites (Table V-4.15). The higher standing crops at most of the thermal sites resulted mainly from accumulated periphyton residues. Station 13A on upper Four Mile Creek was an exception to this rule. Standing crop at Station 13A decreased by more than an order of magnitude from winter to spring sampling. Possible causal factors include changes in stream morphometry leading to a release of stored organic detritus via flow changes and/or decreased algal production. Of the nonthermal sites, Meyers Branch Station 40 consistently had the highest standing crop, due most likely to retention of a substantial fraction of allochthonous inputs from the tree canopy that shades the site. Organic matter standing crops at the Meyers Branch sites increased from winter to spring, and subsequently decreased from spring to summer (Table V-3.15). In contrast, Steel Creek sites (Stations 26 and 28) showed decreased standing crops from winter to spring. Cold flow pumping tests at L Reactor between the sampling periods may have increased discharge enough to scour organic matter from the channel. Summer benthic organic standing crops at Steel Creek Stations 26 and 28 were generally similar to those collected in spring and were substantially lower than those collected during the winter.

The 1983-1984 creek mouth and river sampling with periphytometers showed some differences between transects, but there were no consistent differences that resulted from SRP effluents. Due to high variability among the samples and problems with maintaining the periphytometers, subtle and low-level results were difficult or impossible to detect. Periphyton biomass estimates (from chlorophyll *a* concentrations) (Table V-3.16) and organic standing crops (Table V-3.17) showed conspicuous seasonality, with summer highs and winter lows; however, the annual means did not differ significantly between the reference transects (i.e., those upriver of the creek mouths and not influenced by thermal discharges) and the transects downstream from the mouths of thermal streams. The cool season (October to March) mean standing crop of organic matter was significantly higher ($p < 0.05$) at the mouth of Four Mile Creek than at the mouths of the nonthermal streams (O'Hop et al., 1985).

Results from the 1984-1985 sampling of the nonthermal reference sites showed periphyton biomass, (from chlorophyll a concentrations), to be uniformly low (Table V-3.18). There were no significant differences ($p > 0.05$) in periphyton biomass between the large (nonthermal) reference streams (Upper and Lower Three Runs) and the small reference streams (Pen Branch headwaters and Meyers Branch).

Mean periphyton biomass at the Steel Creek sites was significantly greater ($p < 0.0001$) than at the reference sites (Table V-3.18). The factor most likely to be responsible for the greater biomass in Steel Creek was light. The partial canopies at the Steel Creek sites were not dense, and were open in some places. In contrast, the reference sites had complete, dense canopies in many places (Firth et al., 1986).

Construction of a dam across Steel Creek, starting in June 1985, created heavy silt loads at Stations 27, 28, and 29. A comparison of the periphyton biomass at those sites before and after the start of construction activities showed no differences at Stations 27 and 28, but showed significantly lower ($p < 0.0001$) biomass at Station 29 during construction (Firth et al., 1986).

The range of mean periphyton biomass at thermal stream Stations 6, 8, and 21 was 0.10 to 0.18 g/m^2 (Table V-3.18). Variations in periphyton biomass were higher at the thermal stream sites than at the nonthermal sites. For example, at Pen Branch Station 21, the biomass ranged over three orders of magnitude (0.0035 to 1.355 g/m^2). Because of the on and off cycles of K Reactor, water temperature and stream flow in Pen Branch varied widely over short periods of time. Periphyton biomass at Station 21 was significantly greater ($p < 0.0002$) when K Reactor was not operating (Firth et al., 1986).

In Beaver Dam Creek, variation of periphyton biomass was higher at the upstream site (Station 6), than at the downstream site (Station 8), although the annual means were not significantly different ($p > 0.05$; Table V-3.18) (Firth et al., 1986). The D-Area effluent canal, which forms the headwaters of Beaver Dam Creek, receives cooling water effluent, effluent from coal ash settling basins, effluent from a coal pile leachate basin, and effluents from various other D-Area facilities. These effluent outfalls are point-source discharges and are individually monitored under NPDES discharge permits. With the exception of some minor violations, these effluent outfalls consistently met NPDES permit standards during the study period. In view of the compliance with NPDES standards, it appears unlikely that the levels of pollutants released from D Area during the study period were sufficient to cause significant adverse impacts to the periphyton at Station 6. Fluctuations in the periphyton biomass in upper Beaver Dam Creek may be related to perturbations that occurred prior to the initiation of the study, or to habitat differences unrelated to the levels of pollutants in the various D-Area effluents.

Mean periphyton biomass at the Pen Branch Delta site (Station 22) was significantly greater ($p < 0.0118$) than at the Four Mile Delta sites at which periphyton biomass was measured (Stations 14, 15, and 17), probably the result of higher water temperatures at the Four Mile Delta sites (Firth et al., 1986).

During reactor operation, there was a gradient of decreasing temperatures proceeding downstream across the Four Mile Creek Delta from Station 14 to Station 17, but there were no significant differences ($p > 0.05$) in periphyton biomass between those sites (Firth et al., 1986). When C Reactor was not operating, Station 14 had higher biomass ($p < 0.0001$) than Station 17. Surprisingly, neither Station 14 nor Station 22 (Pen Branch Delta) had a significant difference in mean periphyton biomass between reactor operation and reactor shutdown. This apparent lack of a thermal effect may be attributed to the high variability in periphyton biomass at these sites (Firth et al., 1986), and the corresponding low power of the statistical tests utilized.

Periphyton biomass in the nonthermal Steel Creek Delta sites (Stations 31, 32, and 33) fell within the same range as the thermal delta sites (Table V-3.18). Mean periphyton biomass was greater at the nonthermal delta sites than at the Four Mile Creek Delta sites; however, it was not greater than at the Pen Branch Delta Station 22. Apparently, water temperature was not the only factor influencing periphyton production at the delta sites.

Mean periphyton biomass did not differ significantly ($p > 0.05$) between the closed canopy Steel Creek swamp sites nor between those swamp sites and the open canopy Steel Creek Delta sites (1984-1985 Stations 31-33) (Table V-3.18). Because the canopy at the Steel Creek swamp sites is not dense, light limitation was probably not an important factor in periphyton development (Firth et al., 1986). In comparison, the densely-canopied Pen Branch swamp Station 24 had a significantly lower periphyton biomass than Pen Branch Delta Station 22. There were no significant differences in the biomass at Pen Branch swamp Station 24 based on operating status of K Reactor, probably because K-Reactor effluent caused only a slight warming of the water at this station (Firth et al., 1986).

The creek mouth stations were grouped separately from the other creek stations because they were affected by river flooding in addition to upstream creek events. Periphyton biomass at the Beaver Dam Creek mouth site was lower than at any of the other creek mouth sites. This was probably due to light limitation by turbidity and the closed canopy (Firth et al., 1986).

The thermal station at the mouth of Four Mile Creek (Station 18) showed no significant difference in periphyton biomass between periods when C Reactor was operating or not operating. There were also no significant ($p > 0.05$) differences in periphyton biomass when Station 18 was compared with the nonthermal creek mouth stations (Stations 3, 37, and 45), despite the elevated temperatures at the Four Mile Creek mouth site (Firth et al., 1986).

Savannah River sites generally had higher periphyton biomass than the stream sites (Table V-3.18). The only river station that behaved uniquely was the site downstream from Four Mile Creek (Station 19). It had a significantly greater ($p < 0.0141$) periphyton biomass than the other river site (Firth et al., 1986).

The results of the detailed taxonomic analysis conducted quarterly at 20 selected stations during the 1984-1985 study year (Table V-3.19) showed identification of major groups of algae by pigment analysis agreed well with the microscopic taxonomic identification in 34 out of 36 samples (Bott et al., 1986). Differences between the thermal and non- or post-thermal streams in total biomass, algal biomass, or diatom biomass were not statistically significant, although there were significant differences ($p < 0.05$) between streams within a thermal class. These trends were most likely due to the wide ranges in thermal conditions for streams grouped in each thermal class. Blue-green algae, however, were present in appreciable densities only in the thermal streams. In the non- and post-thermal streams, significantly greater densities of total algal biomass and diatom biomass were found in the spring than in winter. In the thermal streams, seasonal effects were not apparent.

V.3.5.3.2 Macrophytes

Appendix V-3.2 lists all species of aquatic macrophytes found during the winter and spring of the 1983-1984 study, along with the semi-aquatic and riparian vascular plants characterizing each site. Species richness (number of taxa) was highest at post-thermal Station 28 (with partial canopy and well-developed floodplain) and nonthermal swamp Stations 33 and 35 (Table V-3.20). None of the thermal stream stations (Stations 13A, 14, and 21) had any macrophyte representation. Extensive beds of aquatic macrophytes were

TABLE V-3.20

Number of Macrophyte Taxa at Each 1983-1984 Sampling Station (November 1983-May 1984)

	Station												
	Mildly Thermal	Thermal Streams			Thermal Swamp		Post-thermal Stream		Post-thermal Swamp		Reference Stream		
	5	13A	14	21	22	23	26	28	33	35	39	40	
Total No. taxa	28	20	24	16	19	17	28	32	22	32	35	26	
Taxa growing in stream channel	4	0	0	0	8	4	1	2	9	12	6	2	
Taxa growing on floodplain	0	0	0	0	6	10	0	18	11	18	0	17	
Taxa growin in other riparian areas	24	20	24	16	5	3	27	12	2	2	29	7	
Channel + floodplain taxa	4	0	0	0	14	14	1	20	20	30	6	19	

Source: Gladden et al., 1985.

found only in the nonthermal delta and swamp sites (during both years) and (during the second year) in the slow moving slough area of Beaver Dam Creek (Station 7).

During winter sampling, most of the macrophyte standing crop collected at the Pen Branch Delta sites (Stations 22 and 23), and from the *Polygonum* beds in the Steel Creek Delta at Station 9 was dead. The material in the stream channels at Stations 33 and 35 was living, but not growing rapidly (Gladden et al., 1985).

In the winter, the thermal, open canopy areas (1983-1984 Station 22) supported a significantly greater ($p < 0.001$) macrophyte standing crop than the nonthermal, open canopy channel areas (Station 33; Table V-3.21), whereas in spring (when no macrophytes were found at Station 22) just the opposite was true. The thermal, closed canopy site (Station 23) had a significantly greater ($p < 0.001$) standing crop than the nonthermal closed canopy site (Station 35) in the winter, while in the spring, there were no significant ($p > 0.05$) differences between the two sites. During the winter, the relative composition of the macrophyte community at Stations 33 and 35 were quite different (Table V-3.22). The greatest difference was the absence of *Nuphar*, *Vallisneria* and *Callitriche* at 1983-1984 Station 9. Standing crops of *Hydrocotyle*, *Ceratophyllum* and *Myriophyllum* were 3 to 4 times greater at Station 33 compared to Station 35. Low temperatures associated with the flooding that occurred between the winter and spring sampling affected the Pen Branch Delta stations by retarding macrophyte growth resulting in low macrophyte biomass in spring (Table V-3.21). Macrophytes were absent from the open canopy Pen Branch Delta site (Station 22; Table V-3.21). Samples from the closed canopy Pen Branch site (Station 23) included sparse, but living macrophytes. However, macrophytes at post-thermal Steel Creek swamp Stations 33 and 35 were not affected by the flooding. The difference in response to the flooding may have been due to the difference in the species found in the two areas (Gladden et al., 1985). Species overlap between the two areas was less than 10 percent (Appendix V-3.2). In spring, there was greater similarity of taxa composition between Stations 33 and 35 compared to the winter (Table V-3.22). Of the seven taxa collected, only *Nuphar* was not present at both stations. The greatest difference between the two stations involved *Ceratophyllum*, which was by far the most important taxa at Station 33. At Station 35, *Ceratophyllum* was an important but secondary member of the assemblage. While *Callitriche* was by far the most abundant taxa at Station 35, its biomass at the station was actually lower than that at Station 33.

Unseasonal heavy rainfall during August 1984, just prior to the summer sampling resulted in very high levels of the Savannah River and extensive flooding of the Pen Branch and Steel Creek swamp. Macrophytes in the Pen Brandc Delta and swamp were decimated by the deep hot water that was forced from the channels

TABLE V-3.21

Macrophyte Standing Crop (g AFDW/m^2)* at Delta and Swamp 1983-1984 Stations During Winter, Spring, and Summer 1984. Mean, Standard Deviations (s), Coefficient of Variation (CV), and Number of Samples (n) are Given for Samples Collected January-September 1984.

	Station 22 PBD-t	23 PBD-t	33 SCS-n	33P** SCS-n	35 SCS-n
			Winter		
Mean	452.75	73.31	5.02	449.54	3.21
s	196.16	105.74	2.75	175.86	3.41
CV	43.4	144.2	19.93	39.12	106.03
n	20	20	32	15	41
			Spring		
Mean	***	13.63	115.60	229.47	31.27
s		17.37	69.16	81.22	23.13
CV		126.46	59.83	35.39	73.97
n		20	75	15	50
			Summer		
Mean	219.58	0.18	43.82	355.93	7.32
s	416.5	0.37	12.9	165.2	6.79
CV	189.7	206.4	29.5	46.4	92.7
n	20	20	68	15	94

Note: Abbreviations are listed in Table V-3.2.

* Includes living and dead herbaceous material.
** Station 9P was located in the *Polygonum* beds adjacent to the Station 9 channel.
*** Macrophyte beds were absent due to extensive spring flooding.

Source: Kondratieff and Kondratieff, 1985a; 1985b.

TABLE V-3.22

Biomass (g/m^2) and Percent of Total Biomass Contributed by Macrophyte Genera Collected at Stations 33 and 35 During Winter, Spring, and Summer Sampling (November 1983 - May 1984)

Season	Genus	Biomass (g/m^2) Station 33	Biomass (g/m^2) Station 35	% of Total Biomass Station 33	% of Total Biomass Station 35
Winter	*Hydrocotyle*	1.46	0.43	28.95	12.87
	Ceratophyllum	2.17	0.72	42.90	21.34
	Myriophyllum	1.42	0.31	28.14	9.41
	Nuphar	0.00	1.09	0.00	32.48
	Vallisneria	0.00	0.62	0.00	18.49
	Callitriche	0.00	0.16	0.00	4.80
	Potamogeton	0.00	0.00	0.00	0.00
Spring	*Hydrocotyle*	4.38	2.97	3.84	9.54
	Ceratophyllum	62.35	2.47	54.71	7.95
	Myriophyllum	4.06	0.27	3.56	0.87
	Nuphar	0.00	3.01	0.00	9.67
	Vallisneria	6.32	0.78	5.54	2.50
	Callitriche	27.81	20.50	24.41	65.87
	Potamogeton	9.03	1.12	7.93	3.58
Summer	*Hydrocotyle*	0.67	0.24	1.56	3.03
	Ceratophyllum	36.71	7.36	85.66	93.68
	Myriophyllum	1.35	0.20	3.16	2.50
	Nuphar	0.00	0.03	0.00	0.38
	Vallisneria	4.11	0.02	9.59	0.27

Source: Kondratieff and Kondratieff, 1985a.

into the thickly-vegetated low-lying areas for more than a week. At Station 22, only sparse "standing dead" vegetation thickly coated with blue-green algae was collected, while at closed canopy Station 23, an exceptionally small standing crop was collected. The late summer flooding also affected macrophytes in the Steel Creek swamp, with decreases of channel macrophytes at Stations 33 and 35 of one-third to one-half compared to spring. Polygonum, which occurred in extensive beds at Station 33 and usually reaches peak standing crop in summer, did not attain normal growth due to the effects of the flooding.

At both Stations 33 and 35, channel macrophyte biomass decreased significantly between spring and summer sampling. Macrophyte percent cover also decreased in the closed canopy swamp (Station 35) between spring and summer, but in the open canopy Station 33, percent cover increased significantly, due mainly to increased biomass and cover of Vallisneria (tapegrass), which was apparently only slightly affected by the unusual flooding (Table V-3.22). Except for Vallisneria, the relative composition of the submerged macrophyte community was similar at the two sites, with Ceratophyllum predominating.

The 1984-1985 macrophyte data were collected from channels at all the mapped sites (Table V-3.2), but not in the mapped channels themselves, as described in Section V.3.4. At each site, four vegetation parameters: area, volume, biomass, and percent cover, were measured for total and species-specific macrophyte development (Tables V-3.23 and V-3.24, respectively). All aquatic and semi-aquatic taxa occurring in the channels and floodplains were included in these tables.

The reference stream sites (Stations 1, 39, 40, 42, and 43) had few macrophytes. With the exception of Station 42, the seasonal means for the reference stream sites did not differ for any of the parameters measured. The site at Station 42, on Lower Three Runs Creek, was included as a reference stream site because it does not receive thermal effluent. However, it does receive Par Pond discharge which causes large discharge fluctuations. The site at Station 42 had significantly higher ($p < 0.05$) means for the vegetation parameters than the other reference sites. It was the only reference site that showed significant seasonal variations, with more abundant vegetation collected in the spring than in other seasons (Firth et al., 1986). At Station 42 there were at least seven aquatic vascular plant taxa. Potamogeton grew in moderate abundance in the spring (5.5 g/m^2), with nearly 11% cover. Ceratophyllum grew during winter, spring, and summer, but never exceeded 1% cover (Firth et al., 1986).

TABLE V-3.23

Annual Mean N, and Standard Deviation (s) are Presented for the Following Vegetation Parameters on a per m^2 Basis at Each Mapped 1984-1985 Station: Aquatic Vascular Plant (AVP) Area (m^2/m^2); AVP Volume (m^3/m^2); AVP Biomass (g/m^2) and AVP Percent Cover (October 1984-September 1985)

Station	Location/ Thermal Regime	AVP Area		AVP Volume		AVP Biomass		Percent Cover		N
		Mean	s	Mean	s	Mean	s	Mean	s	
1	UTR-n	0.0245	-	0.0030	-	3.326	-	2.449	-	1
7	BD-t	0.1167	0.0692	0.0242	0.0192	17.68	12.07	12.16	8.131	20
14	FMD-t	0.0010	0.0031	-	-	0.0047	0.0189	0.0189	0.3070	16
15	FMD-t	0.0127	0.0288	0.0055	0.0156	4.107	13.04	1.268	2.880	15
24	PBS-n	0.0002	0.0004	-	-	0.0288	0.0625	0.0162	0.0351	20
26	SC-n	0.0019	0.0049	-	-	-	-	0.1848	0.4960	16
27	SC-n	0.0001	0.0004	-	-	-	-	0.0122	0.0367	9
28	SC-n	0.0423	0.0675	0.0010	0.0015	16.75	28.83	4.026	6.736	16
29	SC-n	0.0002	0.0004	<0.0001	<0.0001	0.0855	0.1949	0.0202	0.0430	12
33	SCD-n	0.3958	0.1434	0.1807	0.1349	82.18	48.70	39.61	14.17	20
34	SCS-n	0.2786	0.2968	0.1196	0.1666	84.01	113.4	29.87	29.85	20
35	SCS-n	0.2331	0.3229	0.0832	0.1267	59.62	78.83	23.32	32.31	20
39	MB-n	0.0001	0.0002	<0.0001	<0.0001	0.0002	0.0007	0.0054	0.0167	20
40	MB-n	0.0009	0.0030	0.0002	0.0005	0.0111	0.0331	0.0916	0.2998	20
42	LTR-n	0.0335	0.0558	0.0017	0.0029	1.929	3.437	3.349	5.584	20
53	LTR-n	0.0000	-	0.0000	-	0.0000	-	0.0000	-	9
43	LTR-n	0.0060	0.0185	<0.0001	<0.0001	0.0284	0.1121	0.5429	1.834	20

Note: Abbreviations are listed in Table V-3.2.

Source: Firth et al., 1986.

TABLE V-3.24

The Annual Mean, Number of Reaches Mapped During Year (N) and Standard Deviation (s) are Given for the Following Plant Taxa Parameters: Area (m^2/m^2); Volume (m^3/m^2); Biomass (g/m^2); Percent Cover (percent of mapped area covered by species in question) (October 1984-September 1985)

List of Species Abbreviations:

ALT *Alternanthera philoxeroides*
AZ *Azolla caroliniana*
BA *Bacopa* sp.
CAL *Callitriche heterophytlla*
CER *Ceratophyllum demersum*
EG *Egeria densa*
GRAS Unidentified grass (Poaceae)
HLA *Hydrolea quadrivalvis*
HY *Hydrocotyle ranunculoides*
LEE *Leersia* sp.
LEM *Lemna* spp. (and occasional *Spirodela* fronds)
LUD *Ludwigia* sp.
MISC Unidentified
MYR *Myriophyllum spicatum*
NU *Nuphar luteum*
POL *Polygonum* spp.
POT *Potamogeton pusillus*
VAL *Vallisneria americana* (and/or *Sparangium* sp.)

Species	Area Mean	Area s	Volume Mean	Volume s	Biomass Mean	Biomass s	Percent Cover Mean	Percent Cover s	N
					Station 1 (UTR-n)				
BA	0.0017	-	0.0003	-	-	-	0.1690	-	1
POT	0.0228	-	0.0027	-	3.326	-	2.280	-	1
					Station 7 (BD-t)				
ALT	0.0133	0.0310	0.0015	0.0035	1.437	3.269	1.333	3.097	20
CAL	0.0008	0.0015	0.0002	0.0003	0.0905	0.1731	0.1048	0.1905	20
CER	0.0849	0.0464	0.0220	0.0167	11.62	9.322	8.824	6.067	20
HY	0.0001	0.0002	<0.0001	<0.0001	0.0015	0.0058	0.0062	0.2444	20
LEE	0.0026	0.0063	0.0002	0.0007	0.3085	0.7610	0.2643	0.6326	20
LEM	0.0038	0.0062	-	-	0.5661	1.113	0.4621	0.7724	20
MISC	0.0033	0.0060	-	-	-	-	0.3305	0.6017	20
POL	0.0078	0.0161	-	-	3.486	7.210	0.8340	1.696	20

Source: Firth et al., 1986.

TABLE V-3.24, Contd

Species	Area Mean	Area s	Volume Mean	Volume s	Biomass Mean	Biomass s	Percent Cover Mean	Percent Cover s	N
					Station 14 (FMD-t)				
GRAS	0.0010	0.0031	-	-	-	-	0.0956	0.3077	16
LEM	<0.0001	0.0001	-	-	0.0047	0.0189	0.0026	0.0105	16
					Station 15 (FMD-t)				
ALT	<0.0001	0.0001	0.0008	0.0030	1.766	6.841	0.0039	0.0152	15
CER	0.0126	0.0287	0.0047	0.0127	2.340	6.327	1.264	2.866	15
LEM	<0.0001	<0.0001	-	-	0.0003	0.0011	0.0001	0.0005	15
					Station 21 (PB-t) No vegetation in channel				
					Station 22 (PBD-t) No vegetation in channel				
					Station 24 (PBS-n)				
LEM	0.0002	0.0004	-	-	0.0288	0.0625	0.0162	0.0351	20
					Station 26 (SC-n)				
MISC	0.0019	0.0049	-	-	-	-	0.1848	0.4960	16
					Station 27 (SC-n)				
MISC	0.0001	0.0004	-	-	-	-	0.0122	0.0367	9
					Station 28 (SC-n)				
ALT	0.0012	0.0041	0.0001	0.0004	0.2847	0.9330	0.1235	0.4130	16
BA	0.0001	0.0002	<0.0001	<0.0001	0.0010	0.0041	0.0063	0.0250	16
LUD	0.0001	0.0004	0.0001	0.0003	0.0334	0.1335	0.0102	0.0408	16
MISC	0.0003	0.0012	-	-	-	-	0.0308	0.1233	16
MYR	0.0063	0.0108	0.0008	0.0012	0.9620	2.258	0.4261	0.6815	16
POL	0.0341	0.0631	-	-	15.30	28.33	3.406	6.304	16
POT	0.0002	0.0008	<0.0001	0.0001	0.0240	0.0930	0.0230	0.0806	16

Source: Firth et al., 1986.

TABLE V-3.24, Contd

Species	Area Mean	Area s	Volume Mean	Volume s	Biomass Mean	Biomass s	Percent Cover Mean	Percent Cover s	N
				Station 29 (SC-n)					
MISC	<0.0001	0.0001	-	-	-	-	0.0016	0.0055	12
POL	0.0002	0.0004	-	-	0.0837	0.1957	0.0186	0.0434	12
				Station 33 (SCD-n)					
AZ	0.0010	0.0038	0	0	0.1706	0.6763	0.0955	0.3785	20
CAL	0.0065	0.0139	0.0025	0.0073	1.306	3.769	0.8090	1.576	20
CER	0.0965	0.0561	0.0502	0.0295	62.24	38.38	9.649	5.611	20
HLA	0.0014	0.0050	-	-	0.3548	2.669	0.1445	0.4958	20
HY	0.0023	0.0057	0.0007	0.0021	0.9281	2.669	0.2296	0.5698	20
LEM	0.0028	0.0074	-	-	0.0858	0.1419	0.2802	0.7396	20
MYR	0.0248	0.0407	0.0132	0.0232	8.941	14.06	2.346	4.093	20
POL	0.0011	0.0030	-	-	0.4941	1.334	0.1103	0.2971	20
VAL	0.2594	0.1572	0.1140	0.1201	7.665	8.016	0.1103	0.2971	20
				Station 34 (SCS-n)					
CAL	0.1391	0.2398	0.0726	0.1287	37.50	66.99	13.91	23.98	20
CER	0.0329	0.0396	0.0133	0.0187	16.73	23.14	3.287	3.956	20
HY	0.0002	0.0010	0.0001	0.0005	0.1478	0.6430	0.0234	0.0980	20
LEM	0.0092	0.0273	-	-	0.2646	0.5258	0.9217	2.732	20
MYR	0.0111	0.0314	0.0031	0.0087	2.921	8.884	3.112	10.08	20
NU	0.0167	0.0269	0.0056	0.0103	0.1712	0.3243	1.668	2.692	20
POT	0.0607	0.0728	0.0214	0.0384	25.85	47.13	6.073	7.278	20
VAL	0.0087	0.0243	0.0034	0.0094	0.2251	0.6058	0.8746	2.433	20
				Station 35 (SCS-n)					
AZ	0.0002	0.0007	-	-	0.0278	0.1241	0.0155	0.0693	20
CAL	0.1682	0.3223	0.0575	0.1214	29.81	62.93	16.82	32.24	20
CER	0.0381	0.0453	0.0185	0.0260	23.02	34.41	3.804	4.535	20
DG	0.0049	0.0083	0.0020	0.0041	1.846	3.428	0.4878	0.8311	20
HY	0.0006	0.0013	0.0001	0.0001	0.2961	1.147	0.0583	0.1255	20

Source: Firth et al., 1986.

TABLE V-3.24, Contd

Species	Area Mean	Area s	Volume Mean	Volume s	Biomass Mean	Biomass s	Percent Cover Mean	Percent Cover s	N
				Station 35 (SCS-n)					
LEM	0.0056	0.0108	-	-	0.2057	0.5313	0.5594	1.077	20
MISC	0.0001	0.0002	-	-	-	-	0.0056	0.0218	20
MYR	0.0013	0.0028	0.0006	0.0017	0.5947	1.748	0.1256	0.2772	20
NU	0.0040	0.0095	0.0010	0.0029	0.0048	0.1343	0.4016	0.9544	20
POT	0.0089	0.0161	0.0031	0.0054	3.750	6.615	0.8943	1.608	20
VAL	0.0014	0.0032	0.0004	0.0012	0.0268	0.0764	0.1445	0.3255	20
				Station 39 (MB-n)					
MISC	<0.0001	0.0001	-	-	-	-	0.0030	0.0134	20
VAL	<0.0001	0.0001	<0.0001	<0.0001	0.0002	0.0007	0.0024	0.0107	20
				Station 40 (MB-n)					
NU	0.0001	0.0003	<0.0001	0.0001	0.0003	0.0014	0.0076	0.0338	20
VAL	0.0008	0.0030	0.0002	0.0005	0.0108	0.0332	0.0840	0.3002	20
				Station 42 (LTR-n)					
CAL	0.0002	0.0008	<0.0001	<0.0001	0.0005	0.0021	0.0180	0.0805	20
CER	0.0025	0.0042	0.0003	0.0005	0.3474	0.5316	0.2540	0.4207	20
MISC	0.0022	0.0087	-	-	-	-	0.2226	0.8693	20
MYR	0.0003	0.0011	<0.0001	<0.0001	0.0068	0.0201	0.0343	0.1148	20
POL	0.0004	0.0016	-	-	0.1890	0.7137	0.0420	0.1580	20
POT	0.0270	0.0558	0.0011	0.0028	1.369	3.373	2.696	5.578	20
VAL	0.0008	0.0032	0.0003	0.0011	0.0159	0.0685	0.0818	0.3200	20
				Station 53 (LTR-n)					
				No vegetation in mapped channel					
				Station 43 (LTR-n)					
MISC	0.0049	0.0184	-	-	-	-	0.4851	1.839	20
NU	0.0011	0.0040	<0.0001	<0.0001	0.0284	0.1121	0.0578	0.1996	20

Source: Firth et al., 1986.

Macrophyte development at the Steel Creek sites was similar to that of the reference streams. There were no significant ($p > 0.05$) differences among three of the sites (Stations 26, 27, and 29). Similarly, there were no significant differences in vegetation parameters between seasons at these three sites ($p < 0.05$). The fourth site, Station 28, is a clear, shallow stream with a partial to open canopy. Its macrophyte development was significantly greater ($p < 0.05$) than the other Steel Creek sites. Mean biomass at Station 28 ranged from near 0 g/m^2 (fall 1984) to 52 g/m^2 (summer 1985) and mean percent cover reached a maximum of 12% in summer 1985. When the Steel Creek sites were compared as a group to the pooled reference sites, plant biomass was greater at the Steel Creek sites; however, area, volume, and percent cover were not significantly different.

The Station 28 had at least seven aquatic plant taxa, but only water milfoil (Myriophyllum) and smartweed (Polygonum) grew in any abundance. Pondweed (Potamogeton) grew in moderate abundance there. The other nonthermal stations had zero to two taxa per site.

The two mapped (and representative) thermal stream sites were Station 21 on Pen Branch and Station 7 on Beaver Dam Creek. The Pen Branch site was hot enough to exclude macrophytes from the channel. Mildly thermal Station 7 had extensive beds of macrophytes along the channel. In Beaver Dam Creek, spring and summer means for plant area, volume, and percent cover were significantly greater ($p < 0.0001$) than fall and winter means for these parameters. Vegetation characteristics resembled those in the main channels of the Steel Creek Delta stations described below (Firth et al., 1986).

At least eight macrophyte taxa were found at Beaver Dam Station 7. The bottom of the channel was not densely colonized because of the water turbidity (Firth et al., 1986), apparently attributable to source water (i.e., the Savannah River) contributions, the velocity regime (Newman et al., 1985), effluents from D Area. The plant growth started in the slow current and shallow bank areas and spread toward the channel center as the growing season progressed. The dominant vegetation during winter and spring was emergent Polygonum growing in mats. By summer, alligator weed (Alternanthera) and an aquatic grass (Paspalum repens) had completely replaced Polygonum along the channel edge. Coontail (Ceratophyllum) grew along the channel edges throughout the year.

The open canopy delta sites fell into three groups: the thermal Pen Branch Delta (Station 22), which had no aquatic vegetation in the channels; the thermal Four Mile Delta (Stations 14 and 15), which had some vegetation but had a mean cover of less than two percent; and the nonthermal Steel Creek Delta (Station 33), which had extensive macrophyte beds in and along the channels, with a mean cover of 40 percent. The Steel Creek Delta macrophyte production was generally greatest in the spring. Means for all the vegetation parameters were significantly greater ($p < 0.001$) in the Steel Creek Delta than in the Four Mile Creek Delta, Pen Branch Delta, or Beaver Dam Creek (Station 7).

The thermal delta sites (Stations 14, 15, and 22) all had no more than three macrophyte taxa, and had very low biomass and percent cover. In contrast, the Steel Creek Delta (Station 33) had abundant macrophytes, and a wide variety of taxa. In the Steel Creek Delta channels, Ceratophyllum had the highest annual mean biomass and remained dominant throughout the year. Myriophyllum and water celery (Sparganium) also had a relatively high annual biomass. During the fall and spring, Myriophyllum and Vallisneria were approximately equal in importance at Station 33, but in winter the relative importance of Myriophyllum increased while Vallisneria remained about the same in relative importance (Firth et al., 1986).

Differences in macrophyte development at the swamp stations were due to differences in the percent canopy at the different sites. The Pen Branch swamp site (Station 24) was completely shaded, while the Steel Creek sites (Stations 34 and 35) had partial canopies (Firth et al., 1986). Aquatic vegetation in the Pen Branch swamp was sparse, but was most abundant in the winter and spring. The two Steel Creek swamp sites (Stations 34 and 35) had abundant macrophyte taxa, eight of which were found at both stations. At both of the Steel Creek swamp stations, water starwort (Callitriche) had the highest mean biomass and highest mean percent cover. Other important taxa at both stations were Ceratophyllum and Potamogeton. At Station 34, different taxa dominated the assemblage each season (Firth et al., 1986). Myriophyllum was dominant during the fall, whereas Potomogeton was dominant during the winter. Callitriche was dominant during the spring, and Ceratophyllum was dominant during the summer. At Station 35, the fall, winter, and spring assemblages were dominated by Ceratophyllum, with Callitriche dominating the spring assemblage. The greatest macrophyte development occurred in spring at both Steel Creek swamp sites. The means for all the vegetation parameters were significantly lower ($p < 0.05$) in the Pen Branch swamp than in the Steel Creek swamp. The Steel Creek swamp sites did not differ from each other.

V.3.6 Organic Matter

V.3.6.1 Introduction

Since invertebrate communities in SRP streams depend, to a substantial degree, on detrital organic matter as a food base, effects of thermal discharges on organic matter transport and processing rates can have profound effects on invertebrate community structure and functioning. Organic matter can originate from autochthonous production (i.e., through the death of macrophytes or the sloughing of periphyton) or can be imported to the aquatic ecosystem from the landscape. In the aquatic ecosystem, this organic material is repeatedly processed and reduced in size by physical and biological means.

Thermal effluents can alter organic matter dynamics in SRP streams both directly and indirectly. High current velocities associated with thermal discharges result in accelerated transport of detrital material out of the ecosystem, and can also increase the rate of physical processing of organic material. Greatly elevated temperatures will slow or stop microbial decomposition of organic matter, rendering it a lower quality food source for invertebrates. Severe thermal conditions can result in the destruction of riparian vegetation and swamp forests, leading to a more open canopy, increased autochthonous production of organic matter, and decreased allochthonous organic inputs from the landscape. The increased current regime and lack of riparian vegetation can lead to a reduction in stream habitat structure, which can further reduce the retention capacity of the stream for organic matter.

Organic matter transport and processing in the SRP streams and swamps were investigated during both years of the CCWS. The focus of the organic matter studies was to facilitate understanding of: (1) the transport dynamics, storage, and retention of organic matter; (2) the processing of leaf material that enters the streams and habitats of the SRP; and (3) how these factors are influenced by current or previous reactor operations at the SRP (Hauer, 1985).

During 1983-1984, there were four components of the organic matter study. The first component was an investigation of suspended particulates in transport (seston), benthic organic matter (storage), and in-stream wood (retention devices) along selected reaches of Steel Creek and its major tributary, Meyers Branch, to compare organic matter dynamics at a post-thermal stream and an unaltered stream in order to assess the degree of recovery of Steel Creek. In the second component, particulate organic matter (POM) dynamics were studied in the thermal sections of Four Mile Creek during reactor operation and reactor shutdown. The study provided data on downstream changes in organic matter dynamics in a thermal stream as well as the relationship of organic matter transport to reactor operating status. Input and output dynamics of POM in the SRP floodplain swamp were investigated in the third component, with sampling sites located on all four streams entering the swamp (i.e., Beaver Dam Creek, Four Mile Creek, Pen Branch, and Steel Creek), as well as on Upper Three Runs Creek. Leaf decomposition rates for three dominant bottomland tree species under different temperature conditions were studied in the final component of the 1983-1984 study. Sites on Meyers Branch served as reference sites for the stations on the post-thermal and thermal streams.

During the following year (1984-1985), there were two organic matter studies. The first used litter collections to determine the amount of allochthonous organic matter entering stream ecosystems from riparian sources. The second was a study of the quantity, size distribution, and organic matter content of particulate matter in transport in the SRP streams.

V.3.6.2 Materials and Methods

V.3.6.2.1 1983-1984 Studies

All procedures are detailed by Hauer (1985). To assess the status of post-thermal Steel Creek, seston samples were collected quarterly from Steel Creek and Meyers Branch stations. Triplicate 25 L water samples were collected from the streams. Water samples were passed through a series of sieves: 2,000, 500, 125, 75, 45, and 20 μm mesh nitex. Material collected on each sieve and the water that passed through the 20 μm sieve, were analyzed to determine dry weight and AFDW. Dry weight is the total weight of the particulate matter, or total suspended solids (TSS), and AFDW is the weight of the organic portion. During spring 1984, benthic organic matter samples were collected across transects from Meyers Branch Station 40 and Steel Creek Station 28 (see Table V-3.1) using a 5 cm diameter coring device to a depth of 30 cm. Percent organic matter of core samples were determined by dry weight/AFDW analysis.

To assess the effects of thermal discharge in Four Mile Creek, seston samples were collected upstream and downstream of the Four Mile Creek Delta (5 stations total) during full reactor power and during a reactor outage in order to determine the effect of reactor operation on seston transport. Seston fractionation and analysis were identical to that used in the Steel Creek study.

Water samples were also collected every 4 hours during each sampling period for determination of diel changes in total POM and DOM. Water samples were taken in 1 L, acid washed, Nalgene bottles and placed on ice. Samples were returned to the laboratory at the end of the 24-hour sampling period for further preparation and analysis. Two 50 mL subsamples were filtered onto a pre-fired (500°C) Whatman GF/F glass-fiber filter. The filter-plus filtered material was then placed into a pre-fired 10 mL ampule and 10 mL of carbon-free water added. Two 10 mL subsamples of the filtrate were put into separate pre-fired ampules. The ampules containing the filter and particulates were the POM samples and the ampules containing the filtrate water were the DOM samples. Potassium persulfate (0.2 g) and 10% phosphoric acid (0.25 mL) were added to each ampule. Water samples in each ampule were then purged with O_2 for 5 minutes. With purging still in progress, each ampule was sealed with a flame. Standards were made using dextrose. Ampules were autoclaved for 1 hour to oxidize organic carbon to CO_2. Samples and standards were then shipped to the University of Montana Biological Station for analysis. Results are reported in mg L^{-1} of elemental carbon.

Statistical analyses were conducted to test for differences in total POM and inorganic seston between stations and status of reactor operation.

The floodplain swamp input-output study was conducted at 12 stations, selected to obtain data from the major inputs and outputs of the swamp (Four Mile Creek, Beaver Dam Creek, Pen Branch, and Steel Creek) and at locations within the swamp and the river. Stations were also located on Upper Three Runs Creek and in the intake canal for reference (Figure V-3.16). Water samples were collected in 1 L Nalgene bottles and returned to the laboratory for sample preparation. Total POM and DOM samples were prepared and analyzed according to modified procedures after Menzel and Vaccaro (1964) within 24 hours of collection. Total suspended solids (TSS) sample water was filtered onto an acid washed, dried, and weighed Gelman AC glass fiber filter. The filter plus particulate material was then dried a minimum of 48 hours at 100°C, then finally weighed (to nearest 0.00001 g). The TSS value was calculated as final filter weight minus prefiltration filter weight. Biweekly sampling for total POM and DOM was initiated in February 1983 and was conducted through March 1984.

Material in the stream channel at each of the above sites was mapped as described in Section V.3.4.2.

Decomposition of sycamore (<u>Platanus occidentalis</u>), sweetgum (<u>Liquidambar styraciflua</u>) and bald cypress (<u>Taxodium distichum</u>) leaves were studied. Sycamore and sweetgum are common trees in the bottomland hardwood forests bordering the Savannah River swamp. Along with tupelo gum, bald cypress dominates in the Savannah River swamp where standing water is present almost year round. The leaves were collected immediately after abscission, air-dried, put into leaf packs, weighed, and then placed into large mesh plastic

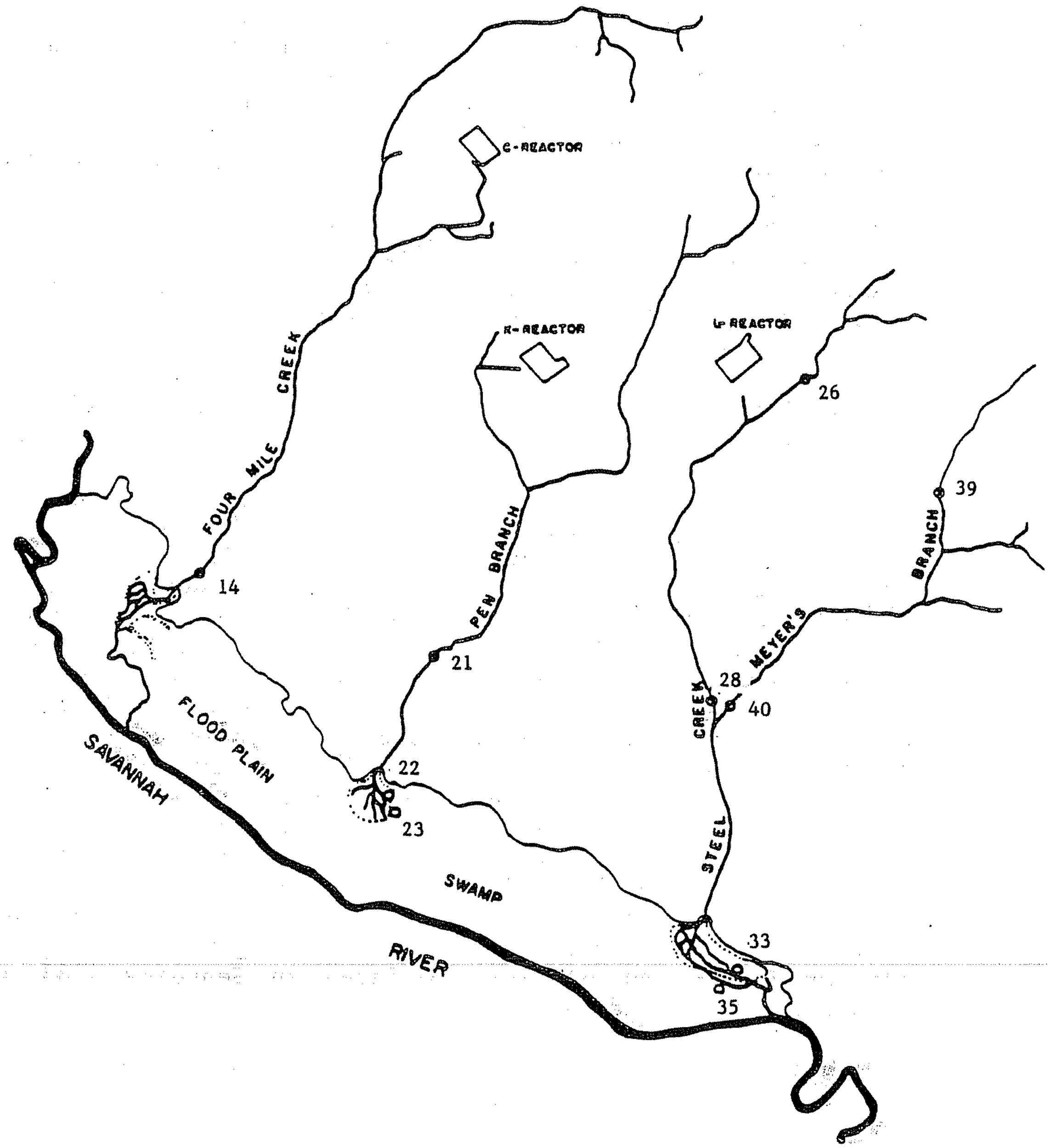


FIGURE V-3.16. Location of Sampling Stations for Leaf Decomposition Studies

bags. Six sets of bags (each set with one bag of each species) were placed at regular intervals along five transects at each of the 1983-1984 sampling sites. One set of bags from each site was retrieved after 24 hours, and after 1, 2, 4, 8, and 16 weeks. The retrieved leaf packs were rinsed to remove silt and macroinvertebrates, then air-dried. The initial and final weights were determined, and the percent of sample remaining was calculated for each leaf pack.

V.3.6.2.2 1984-1985 Studies

Leaf litter was collected weekly during the fall season and monthly during the rest of the year at 25 sites (Table V-3.2). Three litter traps measuring 26 cm by 33.5 cm were placed at each station, one close to each bank and the third in the center of the channel. The litter samples that were collected were air-dried and weighed. The weights of the litter samples were averaged by month for each station (g/m^2/month). Litterfall was also expressed as grams per linear reach of stream per month (Firth et al., 1986).

Water samples from 31 stations (Table V-3.2) were analyzed to determine the quantity, size distribution, and organic content of the particulate matter in transport. The whole water (unfractioned) sample was filtered through a 0.45 μm sieve. Dry weight and AFDW of the filtered material was determined. The weight of the material in the whole water sample was expressed per volume and included all particles greater than or equal to 0.45 μm in size. For the size fraction analysis, the samples were divided into fine (0.45-25 μm), medium (25-100 μm), and large (>100 μm) fractions by using a series of sieves. Each fraction was measured to determine dry weight and AFDW.

V.3.6.3 Results and Discussion

V.3.6.3.1 1983-1984 Particulate Matter Studies

Comparisons of the quantity and organic content of particulate matter in transport and the quantity of benthic organic matter in post-thermal Steel Creek and undisturbed Meyers Branch can be used to provide insight into the degree of recovery of Steel Creek from the effects of thermal discharges. Differences between the two surface water bodies would be expected, since the riparian vegetation of Steel Creek below the reactor outfall has not yet recovered, and structure in the two streams was also quite different. If Steel Creek were less retentive than Meyers Branch, it should be reflected in higher (organic and inorganic) seston loadings suggested by lower standing crops of benthic organic matter.

Data from sites on the Steel Creek system indicated that Steel Creek remains considerably altered from its natural state. The headwaters of Steel Creek and Meyers Branch (above their confluence) are of approximately equal watershed size and drain areas of similar geomorphology (Hauer, 1985). However, past operations of P and L Reactors affected Steel Creek and, although at the time of this study Steel Creek had not received heated effluent since 1968, differences in organic matter dynamics between the two creeks were still evident.

As reported in Section V.3.4.3.1, Meyers Branch had a large quantity of fallen trees, sticks, and root mats, while Steel Creek had very little wood and debris in the channel. In Meyers Branch, the total concentration of organic and inorganic material in transport was low throughout the year (Tables V-3.25 through V-3.28). The upper Meyers Branch site (Station 39) varied little in TSS concentrations between seasons, with total dry weights ranging from about 1.7 mg/L in winter 1983 to 3 mg/L in spring 1984. Concentrations of organic matter ranged from 0.87 mg/L in winter 1983 to 1.54 mg/L in fall 1983. Percent organic matter at Stations 39 and 40 was low and varied within relatively narrow ranges over the four seasons (0.447 - 0.475 mg/L and 0.386 - 0.460 mg/L, respectively). At both sites, percent organic matter decreased consistently during the study (highest in fall 1983 and lowest in summer 1984). The lower Meyers Branch site (Station 40) generally had about twice the TSS concentration of the upper site, with a range of about 2 mg/L in winter 1983 to about 6 mg/L during the other three seasons. Trends for organic material were similar across stations, with lowest concentrations (0.88 mg/L) in winter 1983, and concentrations of 2.4-2.8 mg/L during the other three seasons. The material in transport at both sites had a high organic content. The smallest size fractions made up most of the particulate matter. Because comparatively little material was in the larger size fractions, most of the large particulate material must have been retained within the stream reaches. Retention of large particulate seston suggests that leaves entering the stream were incorporated into leaf packs or deposited in areas of low current velocity where they decomposed (Gladden et al., 1985).

The concentrations of particulate matter in transport in Steel Creek (Stations 26 and 28) were considerably higher than in Meyers Branch. Concentrations of TSS at Stations 26 and 28 ranged from 5.0 and 9.9 mg/L (winter 1983) to 76.5 mg/L (fall 1983) and 19.2 mg/L (spring 1984). The very high TSS concentrations at Station 26 during all seasons except winter was due mainly to increased concentrations in the size classes 75-2000 μ, a trend not seen at other sites. Concentrations of particulate organic matter at Stations 26 and 28 showed similar seasonal trends as TSS, with concentrations ranging from 1.0 mg/L and 2.0 mg/L (winter 1983) to 5.7 mg/L (fall 1983) and 5.0 mg/L (spring 1984). Stations 26 and 28 (in that order) had consistently the lowest percent organic

TABLE V-3.25

Seston Dry Weight and Ash-Free Dry Weight in Meyers Branch, Steel Creek, and Steel Creek Swamp (September 1983)

	Dry Weight (mg/L)					
Station No.	39	40	26	28	5	6
Particle Size, μ	Upper Meyers Branch	Lower Meyers Branch	Upper Steel Creek	Lower Steel Creek	Steel Creek at Cypress Bridge	Steel Creek Swamp
<0.45	1.717	2.054	5.576	4.478	3.976	0.790
<20-0.45	0.184	0.490	0.431	2.667	2.674	0.113
<45-20	0.363	0.839	2.698	4.290	2.550	0.139
<75-45	0.366	0.903	2.805	1.659	1.251	0.168
<125-75	0.213	0.984	16.425	1.126	1.054	0.130
<500-125	0.051	0.353	44.978	0.175	0.217	0.064
<2000-500	0.032	0.377	3.612	0.516	0.976	0.043
Total	2.926	6.000	76.525	14.911	12.698	1.447
	Ash Free Dry Weight (mg/L)					
<0.45	1.008	1.047	1.060	0.992	2.072	0.294
<20-0.45	0.074	0.179	0.126	0.510	0.895	0.041
<45-20	0.139	0.321	0.521	0.868	0.644	0.059
<75-45	0.148	0.345	0.297	0.365	0.389	0.076
<125-75	0.096	0.411	0.257	0.391	0.278	0.058
<500-125	0.038	0.101	0.113	0.117	0.070	0.035
<2000-500	0.032	0.353	3.353	0.439	0.696	0.038
Total	1.535	2.757	5.694	3.682	5.317	0.601

Source: Gladden et al., 1985.

TABLE V-3.26

Seston Dry Weight and Ash-Free Dry Weight in Meyers Branch, Steel Creek, and Steel Creek Swamp (December 1983)

	Dry Weight (mg/L)					
Station No.	39	40	26	28	5	6
Particle Size, μ	Upper Meyers Branch	Lower Meyers Branch	Upper Steel Creek	Lower Steel Creek	Steel Creek at Cypress Bridge	Steel Creek Swamp
<0.45	1.440	1.055	3.715	7.300	3.17	0.024
<20-0.45	0.040	0.095	0.313	0.394	0.072	0.027
<45-20	0.091	0.204	0.349	0.651	0.092	0.024
<75-45	0.050	0.188	0.270	0.380	0.086	0.008
<125-75	0.083	0.333	0.276	0.907	0.114	0.005
<500-125	0.026	0.064	0.046	0.174	0.029	0.001
<2000-500	0.017	0.084	0.000	0.072	0.088	0.832
Total	1.747	2.023	4.969	9.878	3.651	0.921
	Ash Free Dry Weight (mg/L)					
<0.45	0.755	0.535	0.746	1.530	0.767	0.316
<20-0.45	0.016	0.022	0.050	0.060	0.024	<0.001
<45-20	0.039	0.056	0.058	0.083	0.029	0.002
<75-45	0.010	0.055	0.048	0.054	0.024	0.003
<125-75	0.030	0.127	0.054	0.193	0.035	0.014
<500-125	0.005	0.021	0.017	0.053	0.016	0.027
<2000-500	0.010	0.059	0.000	0.033	0.075	0.023
Total	0.865	0.875	0.973	2.006	0.970	0.386

Note: The particulate matter in transport in Steel Creek was considerably greater than in Meyers Branch. A comparison of the upstream Steel Creek site with the upstream Meyers Branch site shows that during the April, June, and September samplings, the TSS at the Steel Creek site was more than ten times that of the Meyers Branch. There was less difference between the two downstream sites, but Steel Creek TSS was at least twice that of the Meyers Branch during all four seasons.

Source: Gladden et al., 1985.

TABLE V-3.27

Seston Dry Weight and Ash-Free Dry Weight in Meyers Branch, Steel Creek, and Steel Creek Swamp (April 1984)

			Dry Weight (mg/L)			
Station No.	39	40	26	28	5	6
Particle Size, μ	Upper Meyers Branch	Lower Meyers Branch	Upper Steel Creek	Lower Steel Creek	Steel Creek at Cypress Bridge	Steel Creek Swamp
<0.45	1.367	1.932	4.162	8.010	5.14	0.903
<20-0.45	0.416	0.852	2.051	2.994	1.513	0.104
<45-20	0.428	0.952	2.951	1.998	2.324	0.145
<75-45	0.393	0.814	5.768	2.506	1.156	0.168
<125-75	0.360	1.003	22.580	2.810	0.964	0.156
<500-125	0.051	0.519	0.866	0.368	0.136	0.059
<2000-500	0.0	0.051	1.409	0.460	0.620	0.031
Total	3.015	6.123	39.787	19.146	11.853	1.566
			Ash Free Dry Weight (mg/L)			
<0.45	0.927	0.926	0.838	2.854	1.24	0.232
<20-0.45	0.132	0.328	0.339	0.575	0.364	0.046
<45-20	0.152	0.322	0.342	0.375	0.638	0.063
<75-45	0.136	0.310	0.327	0.308	0.341	0.082
<125-75	0.103	0.434	0.499	0.313	0.248	0.090
<500-125	0.012	0.233	0.245	0.205	0.070	0.038
<2000-500	0.0	0.031	1.175	0.396	0.580	0.030
Total	1.462	2.585	3.765	5.026	3.481	0.581

Source: Gladden et al., 1985.

TABLE V-3.28

Seston Dry Weight and Ash-Free Dry Weight in Meyers Branch, Steel Creek, and Steel Creek Swamp (June 1984)

			Dry Weight (mg/L)			
Station No.	39	40	26	28	5	6
Particle Size, µ	Upper Meyers Branch	Lower Meyers Branch	Upper Steel Creek	Lower Steel Creek	Steel Creek at Cypress Bridge	Steel Creek Swamp
<0.45	1.832	1.459	6.281	4.078	4.425	0.661
<20-0.45	0.076	0.607	0.773	0.854	0.774	0.003
<45-20	0.177	0.993	1.435	1.372	1.910	0.006
<75-45	0.329	0.902	2.212	1.617	0.710	0.011
<125-75	0.086	1.813	7.862	1.448	2.669	0.026
<500-125	0.052	0.381	0.269	0.419	0.271	0.031
<2000-500	0.0	0.080	1.454	1.156	0.796	0.031
Total	1.140	2.409	3.740	3.074	3.842	0.423
			Ash Free Dry Weight (mg/L)			
<0.45	0.963	0.992	1.089	1.306	1.840	0.338
<20-0.45	0.022	0.230	0.150	0.157	0.214	0.002
<45-20	0.070	0.374	0.230	0.245	0.508	0.004
<75-45	0.048	0.324	0.182	0.176	0.208	0.008
<125-75	0.016	0.296	0.744	0.270	0.304	0.017
<500-125	0.020	0.139	0.088	0.087	0.102	0.030
<2000-500	0.0	0.054	1.257	0.833	0.666	0.024
Total	1.140	2.409	3.740	3.074	3.842	0.423

Source: Gladden et al., 1985.

matter, which ranged from 0.74-0.196 mg/L and 0.203-0.281 mg/L, respectively. At Station 26, concentrations of POM were inversely related to concentrations of TSS. Compared to other stations sampled, Station 26 was atypical in that the largest size class (500-2000 μ) dominated during most seasons (except winter).

A comparison of the upstream Steel Creek site with the upstream Meyers Branch site shows that during the April, June, and September samplings, the TSS at the Steel Creek site was more than ten times that of the Meyers Branch site. There was less difference between the two downstream sites, but Steel Creek TSS was at least twice that of the downstream Meyers Branch site during all four seasons. These results indicated that Steel Creek was substantially more erosive than Meyers Branch. The particulate matter in Steel Creek had a high concentration of organic matter (POM) in the large size fractions, and a high inorganic content in the intermediate size classes. The high inorganic transport and the large size fractions of POM in Steel Creek indicated poor retention and a significant downstream movement of organic matter (Gladden et al., 1985).

Concentrations of both TSS (dry weight) and POM (ash-free dry weight) were consistently lowest at the Steel Creek swamp sites (Tables V-3.25 to V-3.28), with order of magnitude or near order of magnitude differences compared to Steel Creek at Cypress Bridge apparent during all seasons except winter (when there were 3 to 4 fold differences). Percent organic matter values in the Steel Creek swamp were similar in range to those in Meyers Branch (0.371-0.550 mg/L), but showed different seasonal trends (lowest in spring and highest in summer).

Sediment cores taken from Steel Creek (Station 28) and Meyers Branch (Station 40) revealed substantial differences in the quantity of organic matter within the sediments of the two streams (Figures V-3.17 and V-3.18). Benthic sediment samples from Steel Creek generally had less than one percent organic matter content. The only exception was in the upstream Steel Creek transect where the stream had eroded one bank, exposing the organic floodplain sediment (Hauer, 1985). In contrast, cores taken in Meyers Branch had a considerably higher organic matter content, especially along the stream edge where the amount of organic matter ranged from 10 to 40 percent of the total weight of the cores. The small amount of organic matter stored in Steel Creek sediments reinforced the findings that Steel Creek was exporting more organic matter than other similar, but unimpacted creeks (i.e., Meyers Branch). The scarcity of large wood and debris in Steel Creek (see Figure V-3.4) may explain its low organic matter retention.

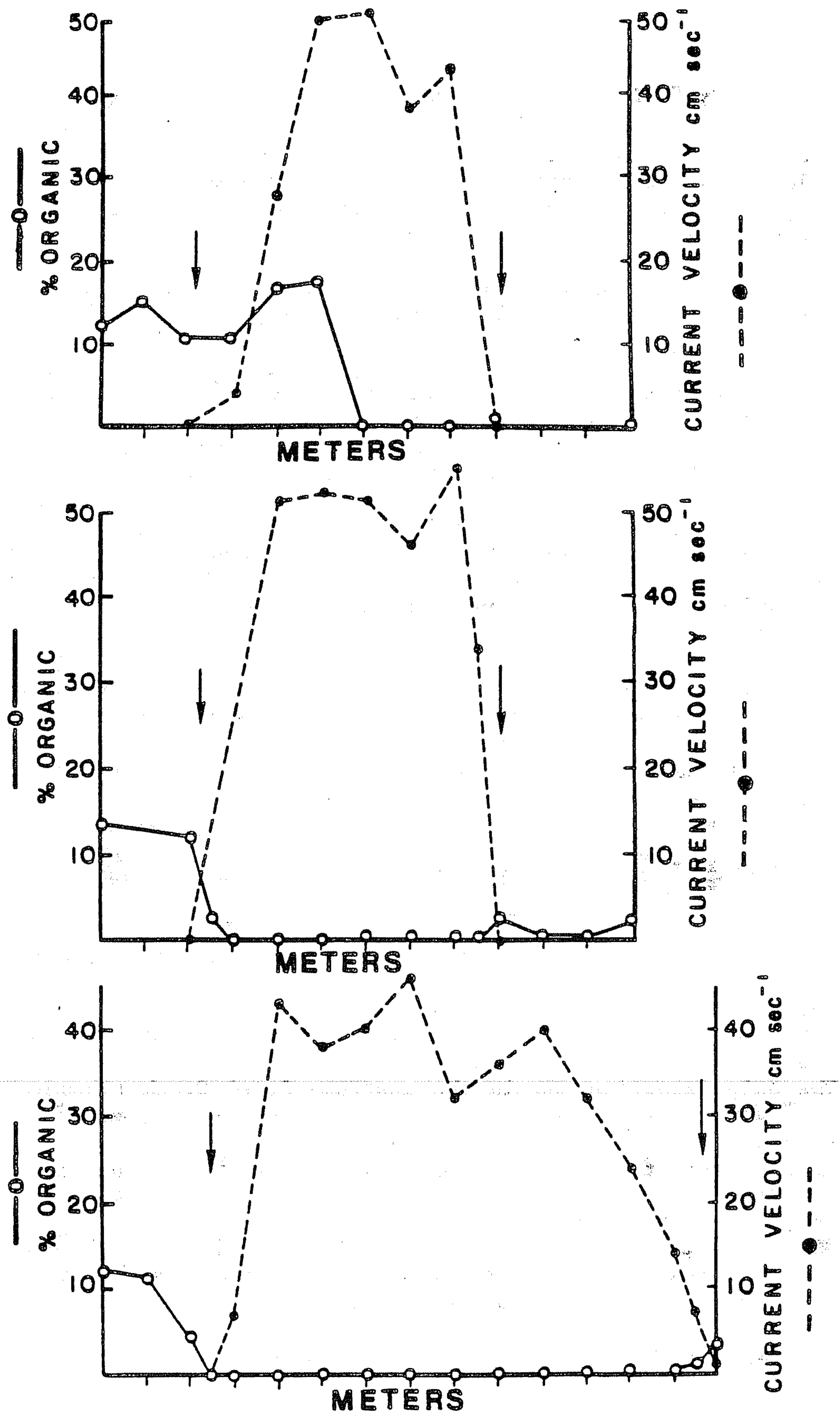


FIGURE V-3.17. Mean Percent Organic Matter (AFDW) and Current Velocity at 1 m Intervals Along Three Transects at Steel Creek Above 1983-1984 Station 28. Arrows Denote Stream Bank. Source: Hauer, 1985.

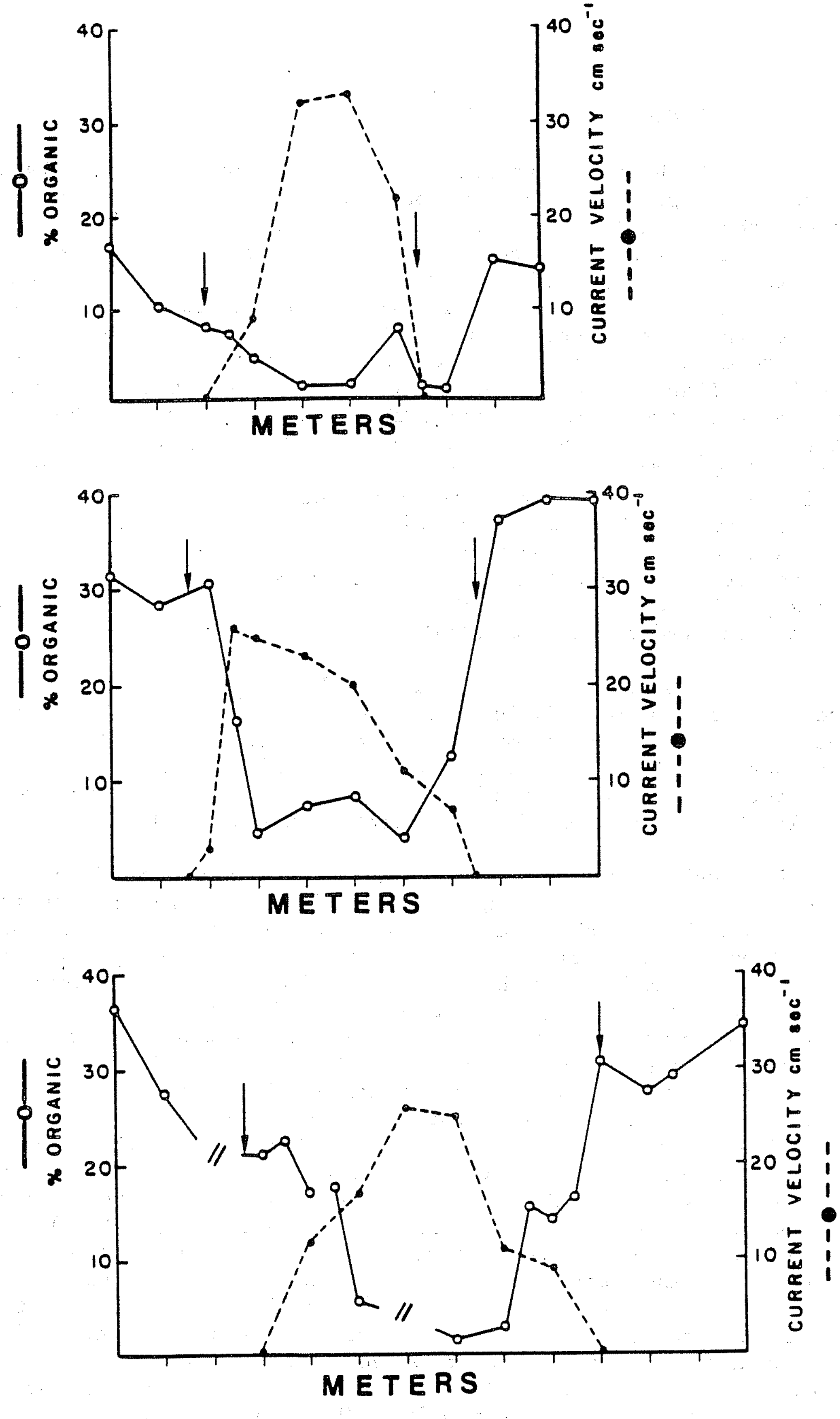


FIGURE V-3.18. Mean Percent Organic Matter (AFDW) and Current Velocity at 1 m Intervals Along Three Transects at Meyers Branch 1983-1984 Station 40. Arrows Denote Stream Bank. Source: Hauer, 1985.

V.3.6.3.2 1983-1984 Four Mile Creek Study

In SRP thermal streams, seston is important primarily as a source of organic matter for organisms in the downstream swamps rather than as a food source for instream consumers because temperatures are too high to support most consumers. Blue-green algae constitute the major part of the POM in the thermal streams. In the hottest areas, algae colonized surfaces outside the stream channel that were wetted by spray from turbulence. In cooler areas downstream, the algae colonized surfaces of snags, clay banks, and debris. Algal mats formed large clumps that were sloughed and transported downstream. Because the discharge rates in the thermal streams vary due to reactor operations, the algal communities were not stable. Thermally tolerant species that became established during long periods of reactor operation could not survive a prolonged reactor shutdown. Likewise, algal and insect communities that colonized the stream during reactor shutdown were lost when the reactor was restarted. Because there was not a stable invertebrate population to feed on the algae within the stream, most of it was transported downstream (Hauer, 1985).

In this study, Stations 13A, 14, 14H, 15, and 18 on Four Mile Creek were sampled during periods of cold flow (reactor not operating), early hot flow (immediately after reactor startup), and late hot flow (after several months of continuous operations). The concentration of the organic content (AFDW) and TSS (dry weight) (Tables V-3.29 and V-3.30) were quantified (Hauer, 1985).

Particulate organic matter concentrations ranged from 1.25 to 6.30 mg/L for all sampling stations and all sampling conditions (Table V-3.29), with lowest concentrations at Station 18 during cold flow and highest concentrations at Station 14H during early hot flow. Similar trends were seen for inorganic seston, with concentrations ranging from 1.28 to 15.94 mg/L (Table V-3.30). There were significantly lower ($p < 0.05$) concentrations of both POM and particulate inorganic material during cold flow than during either early or late hot flow. Station 14H was in a delta channel that had no water during periods of reactor shutdown. Apparently, the algal community that was established during the cold flow period was transported downstream along with inorganic sediment with the restart of the reactor. After several weeks of reactor operation, there was no significant difference ($p < 0.05$) in the concentrations of particulate organic and inorganic matter between Station 14H and Station 15. Station 18, located at the mouth of the creek, had significantly less ($p < 0.05$) POM in transport than any of the other sites. This was attributed to the deposition of particulates within the swamp (Hauer, 1985). The POM concentrations at Four Mile Creek Stations 13A and 14 during late hot flow in September 1983 (3.47 and 3.29 mg/L, respectively) were similar to those found at Station 28 in lower Steel Creek during the same month (see Table V-3.21).

TABLE V-3.29

Mean Ash-Free Dry Weights (mg/L) of Particulate Organic Matter for Each Size Fraction (µm) at Each Sampling Site on Four Mile Creek During Cold Flow, Early Hot Flow, and Late Hot Flow

	Fraction	Study Site* 13A	14	14H	15	18
C	2000	0.0224	0.1756	-	0.0588	0.0365
O	500	0.0449	0.0741	-	0.0452	0.0327
L	125	0.0641	0.1319	-	0.1613	0.0435
D	75	0.0624	0.0841	-	0.0891	0.0437
	45	0.0604	0.0824	-	0.0768	0.0487
	20	0.0436	0.0659	-	0.1236	0.0460
	.45	1.0076	1.1240	-	1.0030	0.9970
	Total	1.3054	1.7380	-	1.5578	1.2481
	n =	3	3	-	3	3
	C.V.	2.06	5.65	-	10.25	3.78
E	2000	0.0457	0.1187	0.3648	0.1248	0.0701
A	500	0.0765	0.3471	0.4542	0.0580	0.0680
R	125	0.1951	0.4197	1.2674	0.1344	0.1651
L	75	0.2085	0.2579	0.7990	0.2704	0.1396
Y	45	0.3853	0.3115	0.6136	0.2318	0.1608
	20	0.1927	0.1633	0.1880	0.0970	0.1092
H	.45	1.8933	1.4933	2.6100	2.6000	2.6670
O						
T	Total	2.9971	3.1115	6.2970	3.5164	3.3798
	n =	3	3	2	2	3
	C.V.	5.95	10.46	14.11	0.15	16.22
L	2000	0.0612	0.2148	0.5105	0.6895	0.3194
A	500	0.2024	0.4214	0.3645	0.1505	0.0798
T	125	0.5800	0.5824	0.3555	0.3125	0.1778
E	75	0.1100	0.2038	0.1425	0.7670	0.1518
	45	0.1328	0.2172	0.1680	0.1310	0.0914
H	20	0.1312	0.1196	0.1965	0.1800	0.0990
O	.45	2.0021	2.1322	1.8242	1.9962	1.1720
	Total	3.2197	3.8914	3.5617	4.2267	2.0912
	n =	2	2	2	2	2
	C.V.	3.42	3.29	11.67	1.36	8.77

* Station C was dewatered during cold flow.

Source: Hauer, 1985.

TABLE V-3.30

Mean Ash Weight (mg/L) of Particulate Matter for Each Size Fraction (µm) at Each Sampling Site on Four Mile Creek During Cold Flow, Early Hot Flow, and Late Hot Flow

		Study Site*				
	Fraction	13A	14	14H	15	18
C	2000	0.0000	0.0661	-	0.0029	0.0035
O	500	0.0163	0.0133	-	0.0119	0.0382
L	125	0.0672	0.1368	-	0.1575	0.0340
D	75	0.0721	0.0656	-	0.1049	0.0283
	45	0.1293	0.0449	-	0.1093	0.0352
	20	0.0796	0.0675	-	0.0731	0.0211
	.45	1.1930	2.0030	-	1.9940	1.1210
	Total	1.5575	2.3972	-	2.4536	1.2813
	n =	3	3	-	3	3
	C.V.	4.75	3.07	-	2.09	4.69
E	2000	0.0367	0.1247	0.4376	0.0822	0.0279
A	500	0.0707	0.4476	0.8490	0.0450	0.0680
R	125	0.3160	0.8516	4.2510	0.3038	0.1651
L	75	0.4099	0.5221	2.7230	0.3704	0.5300
Y	45	1.0244	0.6916	2.2094	0.5054	0.6939
	20	0.5628	0.4137	0.7048	0.1956	0.3731
H	.45	3.5733	2.0130	4.7700	1.6000	3.0000
O						
T	Total	5.9938	5.0643	15.9448	3.1024	4.8580
	n =	3	3	2	2	3
	C.V.	17.71	15.01	33.85	7.96	8.07
L	2000	0.0900	0.6380	0.5955	0.1210	0.0372
A	500	1.0728	0.7540	0.5105	0.0935	0.0280
T	125	1.4182	1.2308	0.5415	0.1930	0.4524
E	75	0.1920	0.2672	0.1385	0.0625	0.4508
	45	0.2702	0.2244	0.1440	0.0575	0.2210
H	20	0.3572	0.1458	0.1005	0.0605	0.1562
O	.45	3.0421	3.4918	3.0636	3.3263	3.1100
	Total	6.4425	6.7520	5.0941	3.9143	4.4556
	n =	2	2	2	2	2
	C.V.	10.50	21.78	0.34	2.73	4.45

* Station C was dewatered during cold flow.

Source: Hauer, 1985.

Figures V-3.19 through V-3.21 illustrate the particle size breakdown of the organic seston. The ultrafine (UPOM) size class made up the largest proportion of the POM at all sites and for all sampling periods. Station 14H, during early hot flow, was the only case where the ultrafine portion accounted for less than 50% of the total POM. During cold flow, UPOM accounted for more than 80% of the POM at Stations 13A and 18. The larger size classes were slightly more important at Stations 14 and 15. During early hot flow, the percentage of UPOM was greatest at Stations 15 and 18. Mean particle size at Stations 15 and 18 was highest under early hot flow, but showed no increase over cold flow during early hot flow. At Stations 13A, 14, and 14H, the larger size fraction represented a greater percentage than it did during cold flow. Mean particle size was higher under hot flow conditions at Stations 13A, 14, and 14H, and was substantially higher under early flow conditions at Stations 14 and 14H. The percentage of fine and large organic particulates increased moving downstream from Station 13A to Station 14H. All sites had similar size fraction compositions during late hot flow. In general, there was a greater proportion of larger sized POM materials during reactor operation than during reactor shutdown. The mean particle sizes are within the range found within the Steel Creek-Meyers Branch system (see Tables V-3.25 through V-3.28; Hauer, 1985).

Results of this study indicate that Four Mile Creek is profoundly affected by thermal discharges. Higher flows of heated water increase seston transport downstream. Periphyton are eroded and transported to the swamp ecosystem where they are deposited and become a rich food source to the thermally tolerant invertebrate species living there.

V.3.6.3.3 1983-1984 Swamp Study

Particulate organic matter import to and export from the Savannah River swamp were quantified in this study. Sampling stations were located on the tributary creeks, on the major outflow channels, and within the swamp itself (Stations 47, 16, 3, 13A, 21, 29, 35, 33, 37, 9, 18, and 38 in Figure V-3.16).

Figure V-3.22 presents the mean concentrations of POM found at the sampling sites. The arrows indicate the directional flow of water from input to output. The thermal tributary creeks (Four Mile and Pen Branch) imported more organic matter to the swamp than the nonthermal tributary creek (Steel Creek). The concentration of POM that entered the swamp by Four Mile Creek was very similar to the concentration exported from the swamp by the thermal creeks. Apparently, the swamp does not effectively filter POM from Four Mile Creek water due to the high discharge in Four Mile Creek and the short distance through the swamp that this water flows before joining the river (Hauer, 1985).

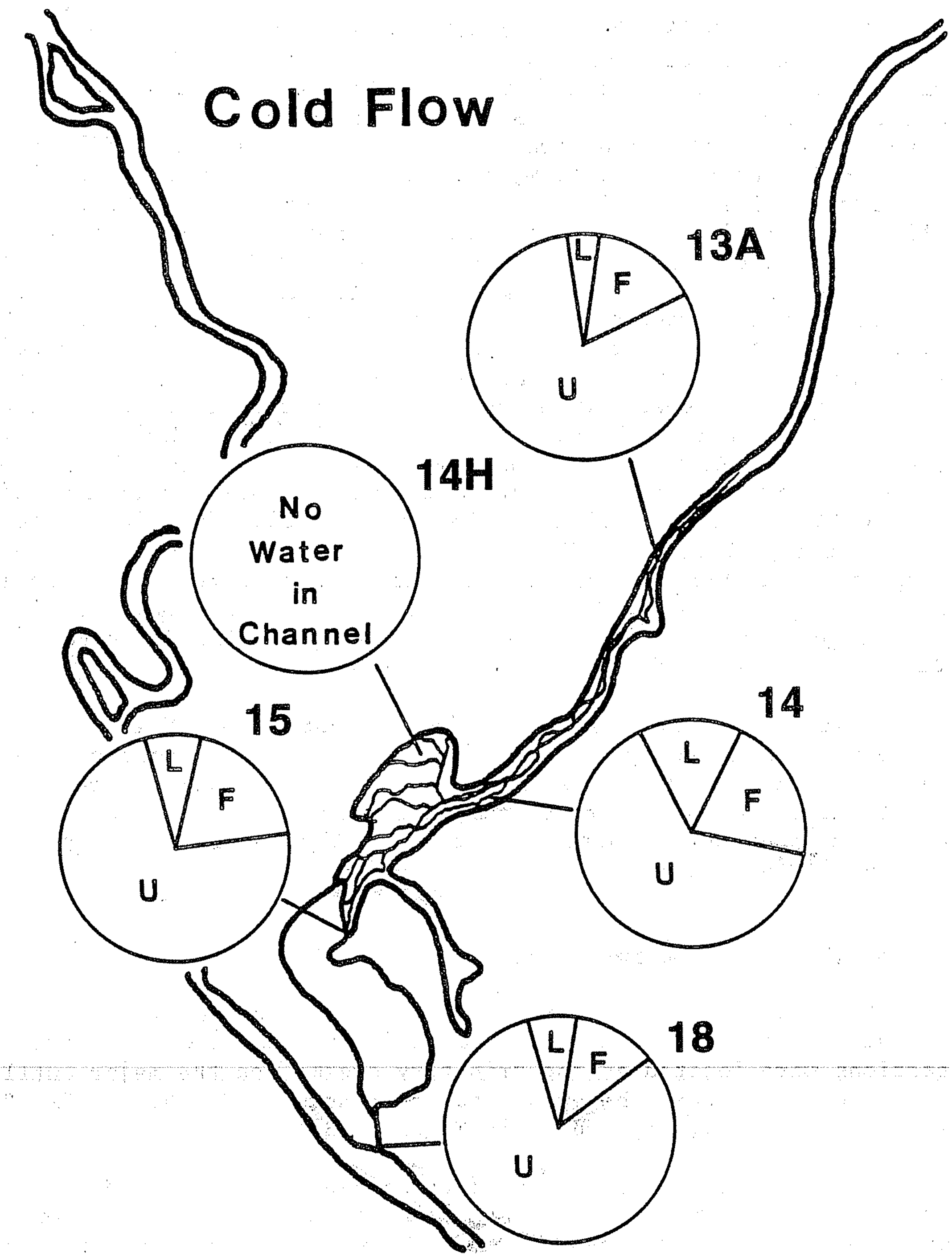


FIGURE V-3.19. Percent of Total AFDW in the Large (L, >500 μm), Fine (F, 500 >x> 45 μm), and Ultrafine (U, 45 >x> 0.45 μm) Size Classes of POM at Each Sampling Site During Cold Flow.
Source: Hauer, 1985.

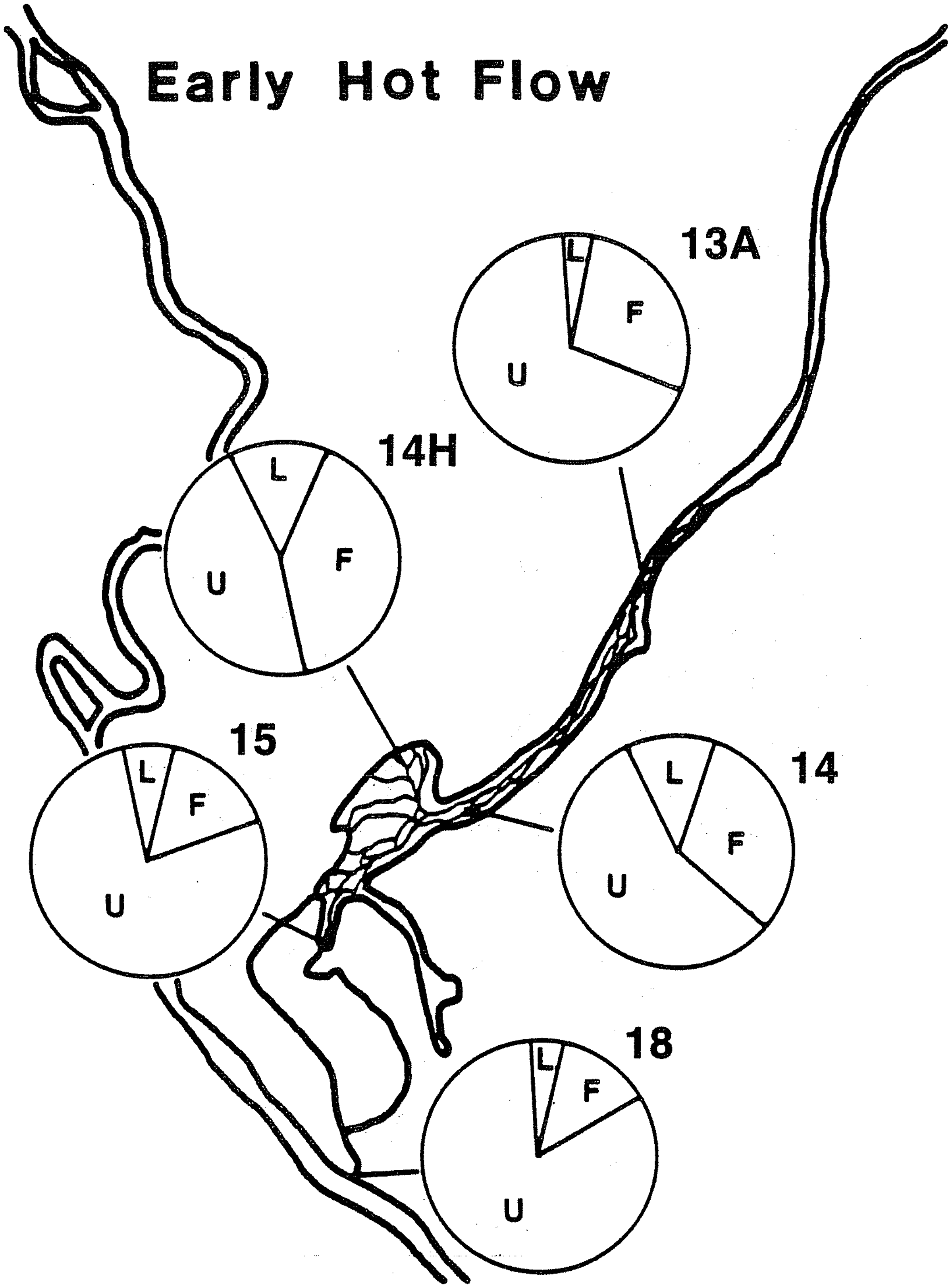


FIGURE V-3.20. Percent of Total AFDW in the Large (L, >599 µm), Fine (F, 500 >x> 45 µm), and Ultrafine (U, 45 >x> 0.45 µm) Size Classes of POM at Each Sampling Site During Early Hot Flow.
Source: Hauer, 1985.

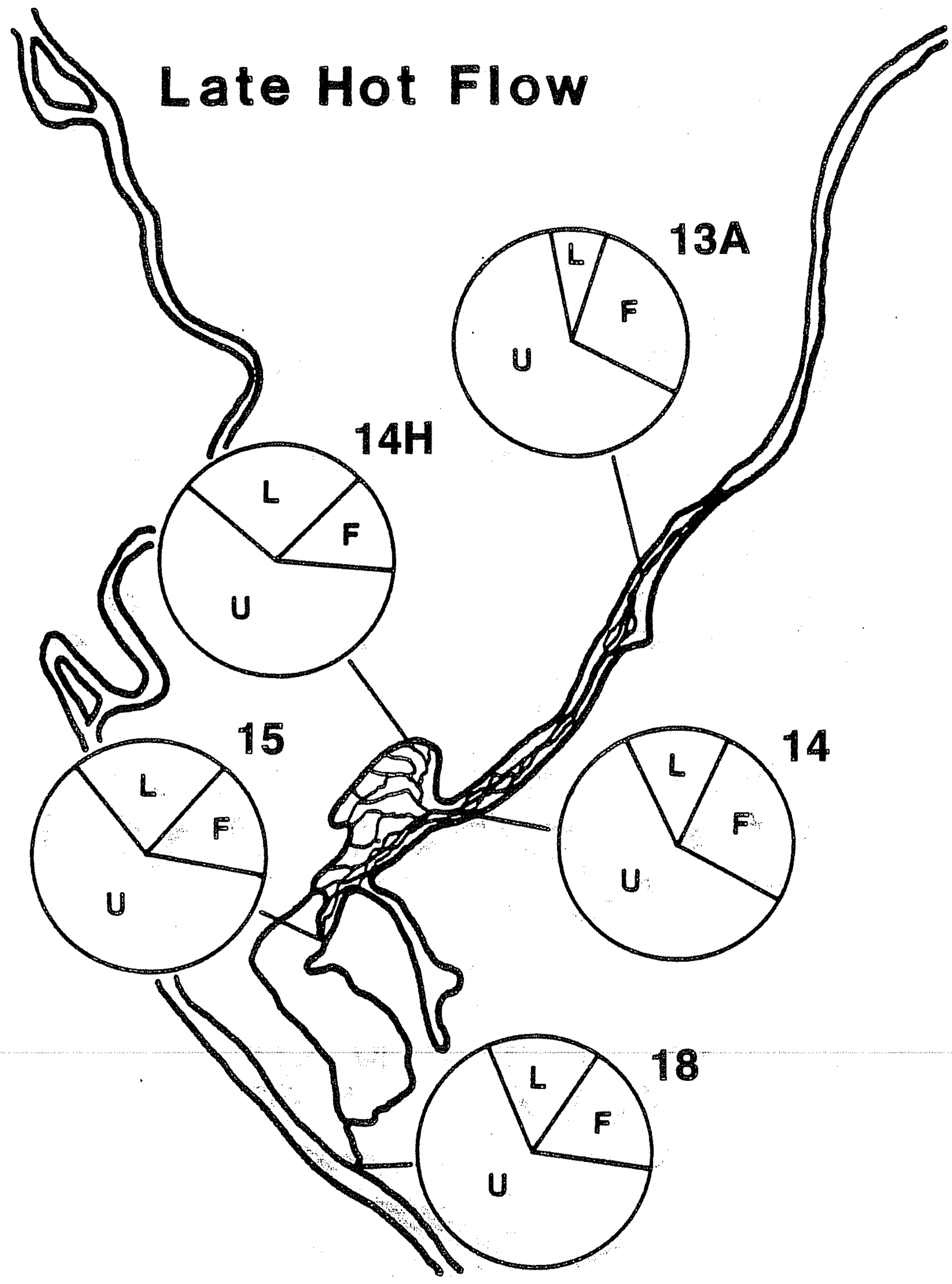
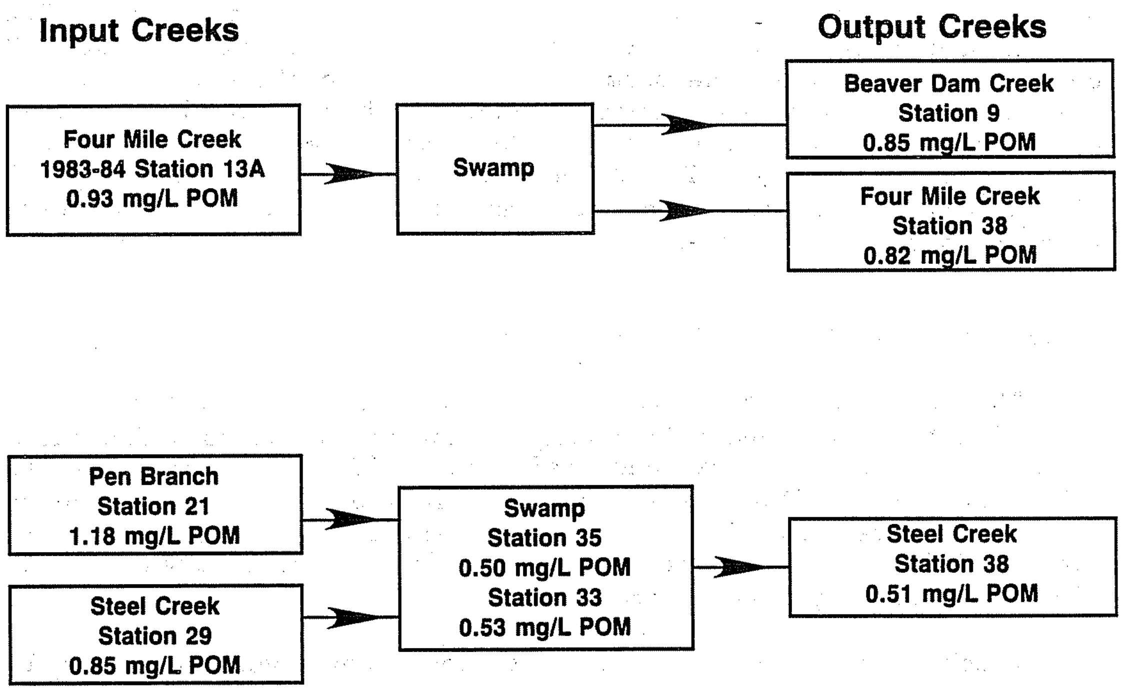


FIGURE V-3.21. Percent of Total AFDW in the Large (L, >500 µm), Fine (F, 500 >x> 45 µm), and Ultrafine (U, 45 >x> 0.45 µm) Size Classes of POM at Each Sampling Site During Late Hot Flow. Source: Hauer, 1985.



Station 13A = 0.20 - 5.11	Station 35 = 0.20 - 1.05	Station 9 = 0.44 - 1.52
Station 21 = 0.56 - 5.33	Station 33 = 0.24 - 1.42	Station 18 = 0.22 - 1.42
Station 29 = 0.43 - 1.57		Station 38 = 0.51 - 1.42

* *1983-84 Station 2 was not sampled in 1984-85*

FIGURE V-3.22. Mean POM Concentrations (mg/L C) in Savannah River Swamp and Selected Tributary Creeks and Output Channels. Arrows Designate Direction of Flow of Water. Source: Hauer, 1985.

The situation was very different for Pen Branch and Steel Creek. Exports of POM from Steel Creek were lower than either of the thermal exporting channels. Furthermore, the POM exports from Steel Creek were lower than the import POM concentrations in Pen Branch and Steel Creek above the swamp. In addition, the POM concentrations within the swamp were similar to those exported via the Steel Creek outflow channel. Thus, both Pen Branch and Steel Creek were importers of POM to the Savannah River swamp. This was especially true for the Pen Branch water, which lost 0.67 mg/L of POM between the entrance to the swamp and the exit via the Steel Creek channel (Hauer, 1985).

V.3.6.3.4 1983-1984 Leaf Decomposition

The general purpose of the leaf decomposition study was to determine the differences in decomposition rates due to differences in temperature, discharge, and leaf species (Hauer, 1985). Figures V-3.23 and V-3.24 illustrate the weight loss of leaves over time at the study sites in the streams and swamps, respectively, while Table V-3.31 shows the processing coefficients calculated for the 16-week period, by station and species.

Weight loss from leaf packs differed among species. After 16 weeks exposure, cypress leaves had the least weight loss and sweetgum leaves had the greatest weight loss. Rates of leaf decomposition were most similar among species at the thermal stream and swamp sites, where the least leaf decomposition occurred. In the nonthermal streams and swamp, sycamore and sweetgum leaves decomposed much more rapidly than cypress leaves. Among stream sites, total leaf weight remaining for each species (as percent initial weight) ranged from 84 to 69% for cypress, 84 to 24% for sycamore, and 64 to 18% for sweetgum. At swamp sites, trends were similar to those found at stream sites. Cypress leaf weight remaining after 16 weeks ranged from 62 to 56% of initial weight, while values for sycamore and sweetgum were 64-16% and 46 to 2%, respectively. Both sycamore and sweetgum leaves had significantly ($p < 0.05$) greater total loss of organic material at the nonthermal stream sites compared to the thermal stream sites.

At the thermal sites, leaves lost weight rapidly for the first four weeks, after which they decomposed slowly. At the nonthermal stream sites, leaves generally lost weight during the first week, then gained weight for several weeks. This was followed by continuous weight loss so that after 16 weeks the nonthermal sites had significantly more ($p < 0.05$) leaf decomposition than the thermal sites. The increase in leaf weight in the early part of the study period may have been due to colonization by bacteria and fungi, which would have increased the nutritional value as well as the weight of the leaves. Macroinvertebrate feeding may have been responsible for the subsequent rapid leaf weight losses at the nonthermal stream sites (Hauer, 1985).

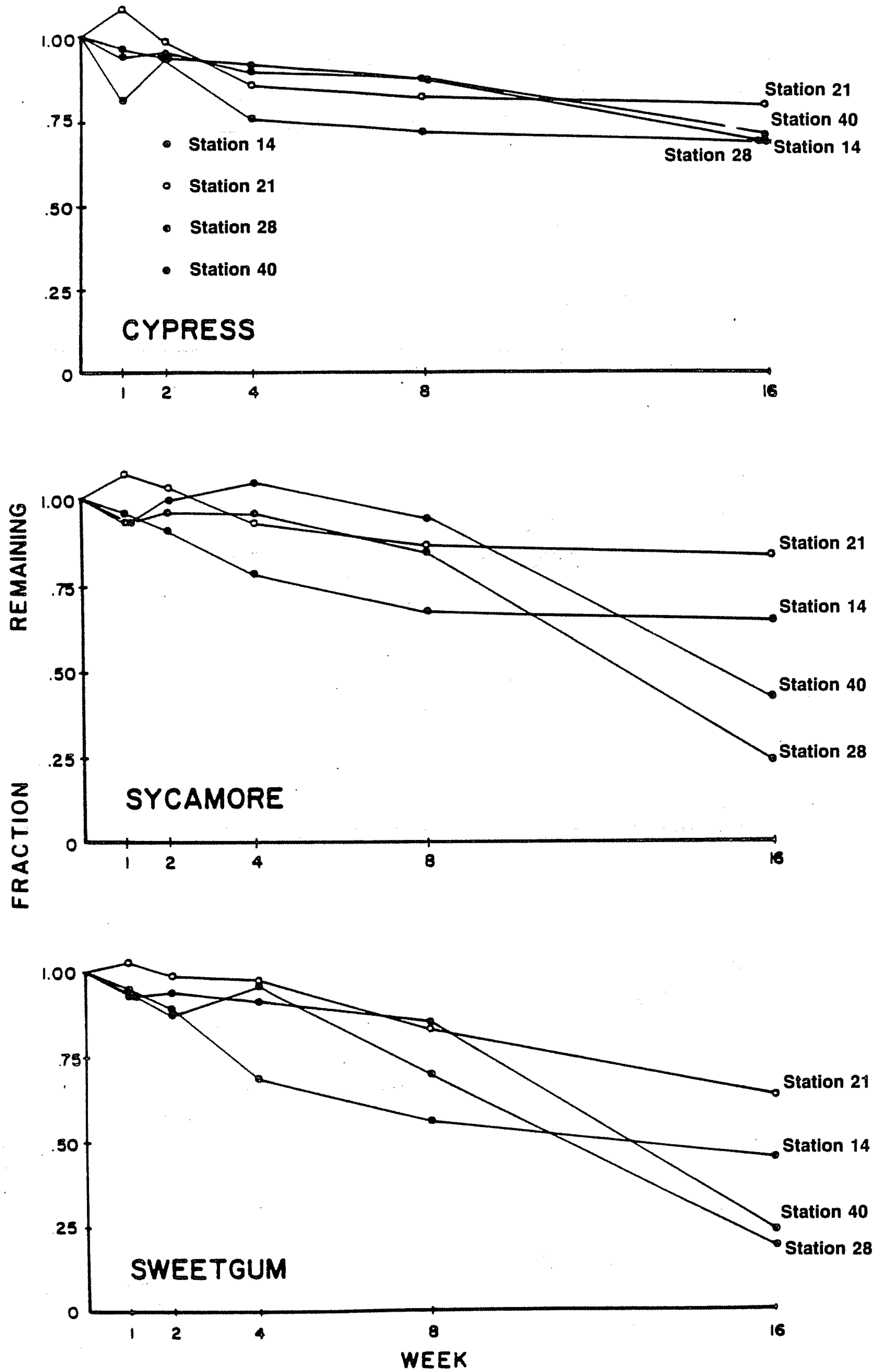


FIGURE V-3.23. Fraction of Initial, Total AFDW of Leaves Remaining from Four Study Streams After Time-Series Incubations (1983-1984). Source: Hauer, 1985

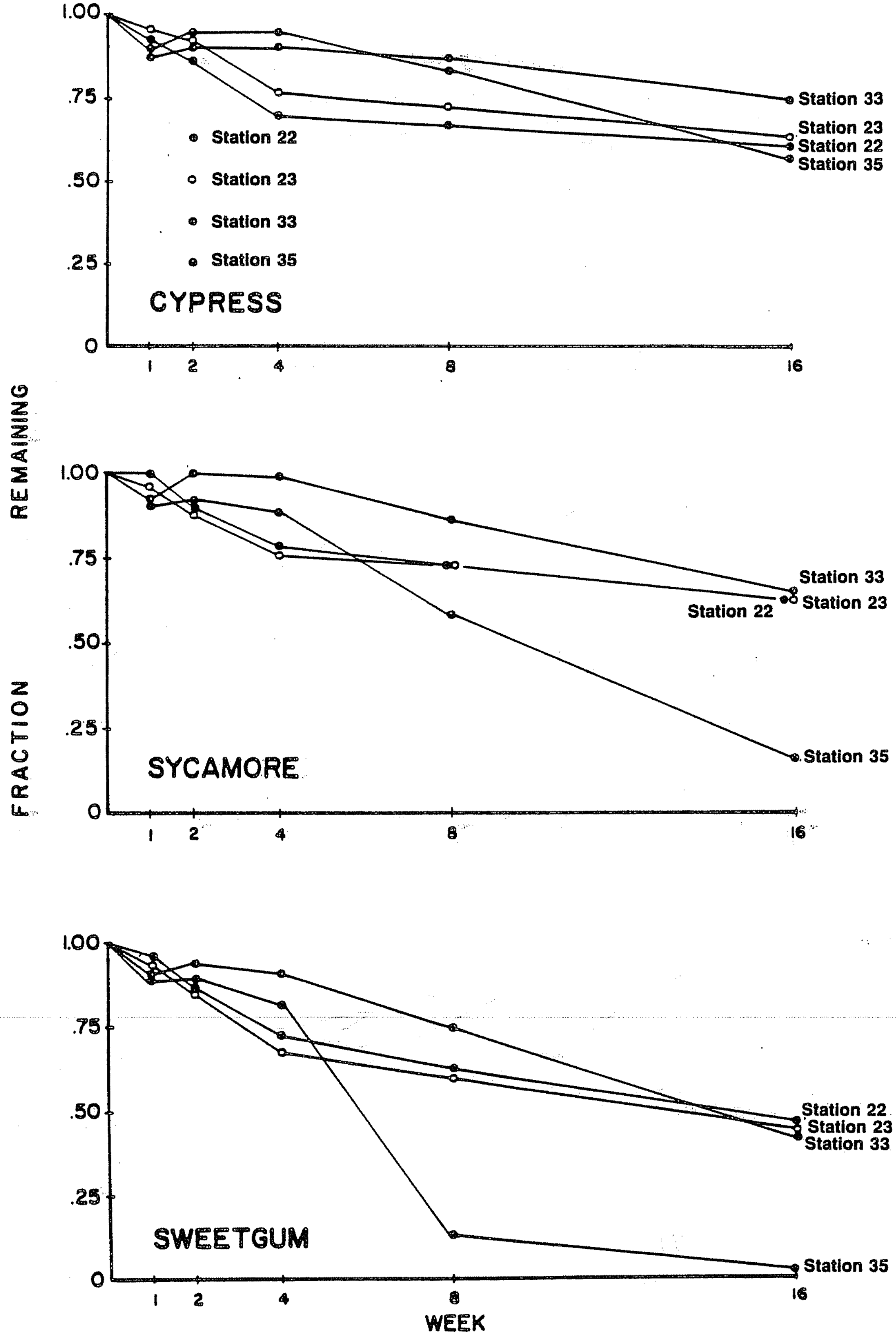


FIGURE V-3.24. Fraction of Initial, Total AFDW of Leaves Remaining from Four Study Streams After Time-Series Incubations (1983-1984). Source: Hauer, 1985

TABLE V-3.31

Processing Coefficients (k) Over the 16-Week Study Period for Cypress, Sycamore, and Sweetgum

Station	Habitat	Cypress	Sycamore	Sweetgum
14	Thermal Stream	0.0033	0.0038	0.007
21	Thermal Stream	0.0019	0.0015	0.0040
26	Post-Thermal Stream	0.0033	0.0062	0.0141
28	Post-Thermal Stream	0.0034	0.0129	0.0152
39	Natural Stream	0.0015	0.0071	0.0132
40	Natural Stream	0.0031	0.0071	0.0127
22	Thermal Swamp-Open Canopy	0.0045	0.0041	0.0069
23	Thermal Swamp-Closed Canopy	0.0043	0.0042	0.0071
33	Post-Thermal Swamp-Open Canopy	0.0027	0.0039	0.0073
35	Natural Swamp-Closed Canopy	0.0051	0.0161	0.0364

Source: Hauer, 1985.

At the Pen Branch site (Station 21) where maximum temperatures were close to 50°C, total leaf weight losses were less than at any other site, but not significantly lower than those at thermal Four Mile Creek (Station 14). However, taken together, the two thermal stream sites showed significantly lower rates of decomposition of sycamore and sweetgum leaves compared to the post-thermal and non-thermal stream sites (Stations 28 and 40). The slow leaf breakdown rates at both thermal sites may have been due to the lack of macroinvertebrate shredders, which were unable to survive the periodic high temperatures. The greatest leaf weight loss among stream sites was in post-thermal Steel Creek (Station 28), but this was not significantly greater than that at nonthermal Meyers Branch site (Station 40) for any species.

The thermal swamp sites in Pen Branch (Stations 22 and 23) had decomposition patterns similar to the thermal streams. There were no significant differences in decomposition rates between the thermal open canopy swamp site (Station 22) and the thermal closed canopy swamp site (Station 23) for any leaf species. However, there were significant differences between the two nonthermal swamp sites for both sycamore and sweetgum. Leaves of the two species at the closed canopy nonthermal swamp site (Station 35) lost significantly more weight than those at the nonthermal open canopy swamp site (Station 33). This was attributed to a difference in macroinvertebrate shredder activity, which was greater at the open canopy site (Hauer, 1985).

There were no significant differences in weight loss of any species when the thermal and post-thermal open canopy swamp sites (Stations 22 and 23) were compared, but weight loss of sycamore and sweetgum was significantly greater ($p < 0.01$) in the nonthermal closed canopy Steel Creek swamp site (Station 35) as compared to the thermal closed canopy Pen Branch swamp site (Station 23), again probably due to greater activity of invertebrate consumers. Total weight loss of sycamore and sweetgum leaves was significantly ($p < 0.05$) higher in Steel Creek (Station 28) than in the ambient temperature, open canopy swamp (Station 33), probably due to the greater invertebrate activity at the stream site (where natural sources of leaf material were more abundant).

In general, the greatest weight loss of leaf material occurred when temperatures were near ambient, natural sources of leaf litter were higher and macroinvertebrate shredders were abundant. The slowest weight loss rates occurred where temperatures were elevated and macroinvertebrate shredders were absent.

V.3.6.3.5 1984-1985 Leaf Litter Collection

The purpose of the leaf litter study was to estimate the amount of allochthonous organic matter entering the stream ecosystem directly from riparian sources. Representative open canopy sites as well as sites with complete and partial canopy development were sampled (see Table V-3.2).

Rates of litterfall in dry weight per surface area per year ($g/m^2/yr$), are presented in Table V-3.32. The results in Table V-3.33 are expressed per linear meter of stream instead of per unit surface area. This incorporates average stream width into the measurement.

The nonthermal and otherwise undisturbed reference stream sites (including small stream Stations 12, 20, 39, and 40, and large stream Stations 1, 2, 42, and 44 all had high leaf litterfall rates on an areal basis (≥335 $g/m^2/yr$), which did not differ significantly. However, the large reference streams all had higher mean litterfall per linear meter of stream (range of 447.0 - 715.0 g/month) than the small reference streams (range of 149.6 - 191.8 g/meter/month) and some of these differences were statistically significant ($p < 0.05$). Mean litterfall was significantly greater ($p < 0.05$) at the nonthermal reference streams in the fall than during the other seasons (Table V-3.34).

The more downstream stations on Steel Creek (Stations 28, 29, and 36) had litterfall rates similar to those at the reference sites (Tables V-3.32 and V-3.33). These downstream sites had more complete canopies than the more upstream stations (Stations 26 and 27), which had much lower litterfall rates (110-137 $g/m^2/yr$). On an areal basis (i.e., g dry wt/m^2 of stream channel), Station 26 had a mean litterfall rate significantly lower than all other stations, while Stations 28 and 29 had litterfall rates significantly higher than all other Steel Creek stations. On a linear meter basis, Station 29 had a litterfall rate that was significantly higher than all other stations, while the litterfall rate at Station 26 was significantly lower than all other stations except Station 27, the other upstream station. Highest litterfall rates consistently occurred during the fall, but only at Stations 26, 29, and 36 were the fall means significantly higher than those for all other months.

Litterfall rates differed substantially between the streams receiving heated reactor effluent (Four Mile Station 13 and Pen Branch Station 21) and the moderately thermal Beaver Dam Creek sites (Stations 5 and 7). At the upstream Beaver Dam Creek site (Station 5), which has a complete canopy, litter inputs (475 $g/m^2/yr$) were equivalent to those at the reference streams. The litterfall rate at Station 7 was moderate (Tables V-3.32 and V-3.33). The two sites on the reactor effluent streams had very

TABLE V-3.32

The Sum of Yearly Litter Inputs at Each Site Measured as Dry Weight $g/m^2/yr$ (October 1984-September 1985)

Station	Location/ Thermal Regime	Total Dry Weight ($g/m^2/yr^{-1}$)	N*
1	UTR-n	388.25	47
2	UTR-n	339.11	45
5	BD-t	475.35	48
7	BD-t	236.39	41
12	FM-n	372.94	47
13	FM-t	5.09	44
15	FMD-t	107.69	42
17	FMD-t	73.17	42
20	PB-n	549.91	48
21	PB-t	4.02	45
22	PBD-t	8.53	48
24	PBS-n	542.71	48
26	SC-n	136.78	48
27**	SC-n	109.45	39
28	SC-n	352.35	47
29	SC-n	504.29	48
33	SCD-n	93.07	43
34	SCS-n	296.98	44
35	SCS-n	267.93	45
36	SC-n	403.21	44
39	MB-n	598.28	48
40	MB-n	343.32	48
42	LTR-n	551.17	48
43†	LTR-n	363.99	24
53†	LTR-n	144.93	24
44	LTR-n	624.03	48

Note: Abbreviations are listed in Table V-3.2.

* N = total number of litter collections over the sampling period (3 traps/site x 16 collection times)

** Station 27 sum includes only 9 months - litter traps at that site were destroyed by bulldozers in July 1985.

† Station 43 sum includes 4 months, October 1984-January 1985; Station 53 sum includes 8 months, February 1985-September 1985.

Source: Firth et al., 1986.

TABLE V-3.33

Dry Weight (g/linear m/month) of Litter, Mean, N, Standard Error, Coefficient of Variation (CV), Minimum and Maximum Values are Given for Each Station Over all Months (October 1984-September 1985)

Station	Location/ Thermal Regime	Mean	N	Standard Error	CV	Minimum	Maximum
1	UTR-n	515.8	35	98.51	113.0	0.0	2319
2	UTR-n	447.0	33	99.57	128.0	0.0	1881
5	BD-t	178.3	36	27.06	91.07	0.0	660.8
7	BD-t	177.3	32	73.14	233.4	0.0	2242
12	FM-n	191.8	35	47.75	147.3	0.0	1035
13	FM-t	8.112	32	2.860	199.4	0.0	68.31
15	FMD-t	78.32	33	19.37	142.0	0.0	500.6
17	FMD-t	56.54	33	9.005	91.49	0.0	174.7
20	PB-n	185.9	36	44.51	143.7	0.0	1029
21	PB-t	3.379	33	1.366	232.2	0.0	33.98
22	PBD-t	2.311	36	0.6882	178.6	0.0	18.28
24	PBS-n	226.1	36	50.35	133.6	0.0	1110
26	SC-n	51.29	36	11.55	135.1	0.0	339.4
27*	SC-n	59.10	30	13.21	122.4	0.0	285.8
28	SC-n	120.8	35	19.75	96.72	3.674	423.4
29	SC-n	399.2	36	66.99	100.7	0.0	1746
33	SCD-n	33.78	31	15.82	260.8	0.0	449.1
34	SCS-n	208.8	32	48.71	132.0	0.0	907.6
35	SCS-n	158.3	33	49.15	178.3	0.0	1074
36	SC-n	396.9	32	135.2	192.8	0.0	4057
39	MB-n	149.6	36	9.944	119.7	12.06	805.3
40	MB-n	164.5	36	6.706	140.6	0.6602	722.2
42	LTR-n	597.1	36	10.43	136.3	4.478	2931
53**	LTR-n	217.4	24	12.88	95.96	0.0	790.8
43**	LTR-n	1137	12	11.15	49.03	490.8	1880
44	LTR-n	715.0	36	3.548	128.7	0.0	3284

Note: Abbreviations are listed in Table V-3.2.

* N = total number of monthly sums used in the analyses (3 traps/site x 12 months). During autumn several collections were made per month at each site, litter weights were summed by trap for each month.

** Includes October 1984-July 1985 only. Site was destroyed July 1985.

Source: Firth et al., 1986.

TABLE V-3.34

Multiple Comparisons of Litter Between Stations and Seasons at Nonthermal Stream Sites (1984-1985 Stations 1 and 2 - Upper Three Runs Creek, 12 - Four Mile Creek, 20 - Pen Branch, 39 and 40 - Meyers Branch, 42 and 44 - Lower Three Runs Creek) Using Duncan's Multiple Range Test ($p < 0.05$). Means of Stations are Ranked from Highest to Lowest and Stations Underscored by the Same Line are not Significantly Different (October 1984-September 1985)

g dry wt/linear m	42	44	2	1	39	12	20	40
g dry wt/m^2	No significant differences							

Seasons by Station

	Station	Seasons			
g dry wt/linear m or g dry wt/m^2	1	Fall	Summer	Spring	Winter
	2	Fall	Spring	Summer	Winter
	12	Fall	Spring	Summer	Winter
	20	Fall	Winter	Spring	Summer
	39	Fall	Winter	Spring	Summer
	40	Fall	Summer	Spring	Winter
	42	Fall	Summer	Spring	Winter
	44	Fall	Winter	Summer	Spring

Source: Firth et al., 1986.

low litterfall rates (5 and 4 $g/m^2/yr$) because there is almost no canopy over the stream channel at these sites.

Open canopy sites always had lower litter inputs than partial or closed canopy sites. The six open canopy sites included Four Mile Creek (Station 13) and delta (Stations 15 and 17), Pen Branch Creek (Station 21) and delta (Station 22), and Steel Creek Delta (Station 33). All but the Steel Creek Delta site had elevated water temperatures. On both an areal and linear basis, litterfall rates at the Four Mile Creek Delta sites (Stations 15 and 17) were significantly higher than that at all other open canopy sites, while litterfall rates at the Steel Creek Delta sites (Station 33) were significantly higher than at the three non-delta open canopy sites. Only at non-delta Stations 13 and 22 were fall litterfall rates significantly higher than at all other stations. The higher litterfall rates at the Steel Creek and Four Mile Creek Delta site stations were probably attributable to their higher densities of deciduous shrubs compared to the other open canopy sites.

Of the three swamp sites, Pen Branch (Station 24) had the highest litterfall rates (542.7 g/m/yr and 226.1 $g/m^2/yr$ on a linear and areal basis, respectively), but they were significantly higher than only Station 35. Its canopy is more dense than that of the Steel Creek swamp sites (Stations 34 and 35). All three swamp sites received significantly ($p < 0.05$) more litter during the fall than during the other seasons, on both an areal and linear basis.

V.3.6.3.6 1984-1985 Particulate Matter Study

This study measured the total weight of organic plus inorganic particles (mg/L), also referred to as TSS, and the weight of organic fraction or POM (mg/L AFDW) in whole water samples. Coarse (largest fraction) to fine (fine and medium fractions) ratios were calculated for each station for both TSS and POM. These data were used to quantify the relationship of cooling water discharge to stream seston dynamics. Undisturbed reference streams should be more retentive, with lower concentrations of seston and generally smaller sized particles.

Mean TSS concentrations in the nonthermal reference streams ranged from 1.8 to 19.7 mg/L (Table V-3.35). The small reference streams (Stations 20, 39, and 40) had significantly higher TSS and POM concentrations and significantly lower percent organic matter compared to the large reference streams (Stations 1, 53, 43, and 44). However, there was no significant difference in mean POM concentrations between the two groups of stations (range of 3.2 to 6.9 mg AFDW/L at the small reference sites and 0.8 to 3.5 mg AFDW/L at the large reference sites) (Table V-3.35). Smaller size particles made up a greater proportion of the total in large streams

TABLE V-3.35

The Annual Mean and Standard Error for Seston Total Weight, Percent Organic Content, and Organic Concentration of Whole Water are Given for Each Station (October 1984 - September 1985)

Station	Location/ Thermal Regime	N	Total Weight (mg TSS/L) Annual Mean	Standard Error	Percent Organic Annual Mean	Standard Error	Concentration (mg AFDW/L) Annual Mean	Standard Error
1	UTR-n	26	9.41	1.65	42.20	8.359	3.546	0.475
3	UTR-n	22	5.51	0.60	45.29	9.626	2.463	1.178
6	BD-t	22	12.62	1.29	21.94	10.34	2.753	2.324
8	BD-t	24	10.94	0.58	20.01	6.624	2.290	1.553
9	BD-t	24	11.20	1.21	22.35	15.48	3.322	5.524
14	FMD-t	22	5.40	0.63	31.12	8.312	1.535	0.538
15	FMD-t	18*	4.70	0.78	24.40	8.715	0.972	0.330
17	FMD-t	18	4.29	0.83	27.63	10.52	0.909	0.226
18	FM-t	24	5.94	0.43	22.19	5.053	1.255	0.373
20	PB-n	24	19.65	4.35	36.04	17.73	6.853	7.676
21	PB-t	24	9.95	1.53	23.61	5.253	2.075	0.784
22	PBD-t	23	4.42	0.93	34.12	7.989	1.266	0.603
24	PBS-n	24	4.05	1.33	43.53	16.56	2.502	6.506
25	SR-n	24	12.86	2.74	22.26	12.48	2.870	3.955
26	SC-n	24	30.20	9.45	17.41	4.948	4.639	6.210
27	SC-n	24	23.94	3.72	20.67	5.417	4.477	2.894
28	SC-n	24	27.64	6.77	21.70	4.028	5.111	5.575
29	SC-n	24	9.39	1.12	27.80	6.210	2.525	1.199
31	SCD-n	22	3.16	0.23	33.01	9.215	1.044	0.391
33	SCD-n	23	3.12	0.28	35.46	7.290	1.094	0.489
35	SCS-n	24	2.23	0.16	43.25	9.545	0.980	0.423
36	SC-n	24	3.06	0.22	36.61	7.343	1.080	0.317
37	SC-n	24	4.20	0.33	28.56	7.995	1.157	0.429
38	SR-n	24	8.83	1.57	22.41	4.267	1.750	0.829
39	MB-n	23	10.66	1.69	35.15	7.029	3.442	2.382
40	MB-n	23	7.63	1.58	37.62	11.40	3.201	5.129
42	LTR-n	21	6.09	1.53	46.16	17.36	2.504	2.466
53	LTR-n	16	3.87	0.28	47.10	6.51	1.812	0.546
43	LTR-n	8	1.77	0.19	47.02	6.717	0.830	0.311
44	LTR-n	24	3.80	0.35	49.82	10.07	1.927	0.919
45	LTR-n	24	7.60	1.87	42.08	16.87	3.134	6.606

* N = 19 for Station 15, organic concentration.

Note: Abbreviations are listed in Table V-3.1.

Source: Firth et al., 1986.

compared to small streams (Table V-3.36). However, the fine size fraction represented the greatest proportion of both TSS and POM concentrations at all reference sites (Firth et al., 1986). Large stream sites had significantly higher percent organic matter in all three size fractions than small streams, rendering it a higher quality food source.

Upstream stations in post-thermal Steel Creek (Stations 26-28) carried a significantly greater TSS load (24-30 mg/L) and significantly lower percent organic matter than did comparable small reference sites (Stations 20 and 39), but organic load in the two groups was not significantly different. Much of the particulate matter in transport was apparently inorganic silt. Similar trends were evident when Station 29 (located just above the delta) was compared to reference Station 40. As was the case with the reference streams, there was a downstream trend in the Steel Creek corridor (Stations 26-29) toward smaller sized particles with a higher organic content (Firth et al., 1986). The mean particle sizes at the Steel Creek sites were lower than at the reference sites. The Steel Creek sites all had significantly greater concentrations of fine-sized particles (TSS and POM) than did the reference sites. Except for Station 29, the Steel Creek sites did not differ from the reference sites in the concentration of medium sized particles. In the large size fraction, the Steel Creek TSS concentrations were either less than or not different from the reference streams. The percent organic matter in Steel Creek seston was almost always significantly lower than in the reference streams (for all size fractions).

Mean TSS concentrations at the thermal stream sites (Stations 6, 8, 9, 18, and 21) ranged from 5.9 to 12.6 mg/L, which was within the range of the nonthermal reference sites (Table V-3.35). The lowest mean TSS concentration was at Station 18, in Four Mile Creek downstream from the delta. Solids probably settle out as the water moves slowly through the Four Mile Creek Delta. Mean POM concentration at the thermal sites also fell within the range of the reference streams (1-4 mg/L, Table V-3.35). The percent organic content of the seston (Table V-3.35) was generally lower in the thermal streams (20-24%) than in the reference streams (29-50%), indicating that the thermal streams carried a fairly high inorganic silt load (Firth et al., 1986). At the thermal stream sites there was a higher proportion of smaller-sized particles (both TSS and POM) than at the reference sites (Firth et al., 1986). However, thermal Pen Branch carried a significantly higher concentration of large particle TSS than did Lower Three Runs Creek reference sites, but there was no significant difference in concentration of large POM. However, in all three size fractions, the POM concentration was significantly lower at the thermal Pen Branch site.

TABLE V-3.36

The Annual Mean and Standard Error for Seston Coarse to Fine Ratios for Organic Weight and Total Weight are Given for Each Station (October 1984 - September 1985)

Station	Location/ Thermal Regime	N	Organic Weight		Total Weight	
			Mean	Standard Error	Mean	Standard Error
1	UTR-n	12	0.3207	0.0619	0.2542	0.0441
3	UTR-n	12	0.3161	0.0462	0.2440	0.0396
6	BD-t	11	0.2563	0.0494	0.1619	0.0205
8	BD-t	12	0.1794	0.0269	0.0975	0.0113
9	BD-t	12	0.2718	0.0579	0.1546	0.0305
14	FMD-t	11	0.3862	0.0927	0.2853	0.0689
15	FMD-t	9	0.1256	0.0243	0.0886	0.0162
17	FMD-t	9	0.1406	0.0422	0.0801	0.0241
18	FM-t	12	0.2552	0.1142	0.1163	0.0156
20	PB-n	12	0.3558	0.0851	0.2483	0.0547
21	PB-t	12	0.2320	0.0389	0.4217	0.1115
22	PBD-t	12	0.1765	0.0240	0.1432	0.0159
24	PBS-n	12	5.004	2.468	2.492	1.274
25	SR-n	12	0.1503	0.0423	0.0951	0.0095
26	SC-n	12	0.1793	0.0449	0.3925	0.1194
27	SC-n	12	0.3909	0.0857	0.5588	0.0900
28	SC-n	12	1.448	0.8920	0.6690	0.2369
29	SC-n	12	0.2599	0.0417	0.3445	0.0866
31	SCD-n	12	0.1496	0.0191	0.1449	0.0232
33	SCD-n	12	0.2153	0.0330	0.1929	0.0265
35	SCS-n	12	0.2043	0.0648	0.1615	0.0472
36	SC-n	12	0.2481	0.0378	0.2249	0.0240
37	SC-n	12	0.6030	0.3221	0.2682	0.0552
38	SR-n	12	0.1820	0.0337	0.1361	0.0185
39	MB-n	12	0.5008	0.1514	0.4629	0.0881
40	MB-n	12	0.4211	0.0556	0.4684	0.1419
42	LTR-n	12	0.4199	0.1494	0.7972	0.3350
53	LTR-n	8	0.5634	0.1053	0.4359	0.0510
43	LTR-n	4	0.3594	0.0691	0.3279	0.0479
44	LTR-n	12	0.5369	0.1049	0.4537	0.0743
45	LTR-n	12	0.2908	0.0297	0.2548	0.0460

Source: Firth et al., 1986.

A comparison of Pen Branch Station 21 during K-Reactor operation with the reference stations on Lower Three Runs Creek (Stations 53, 43, and 44) showed that Pen Branch had a significantly greater TSS load. These differences were probably due to the high current velocity of Pen Branch Creek when the reactor was operating. However, there was no significant difference in POM concentrations, whereas the mean percent organic content in Pen Branch (24%) was significantly lower than in the reference sites. Periods of reactor operation and shutdown were compared at Pen Branch Station 21. The TSS and POM concentrations were significantly higher ($p < 0.01$) during reactor operation, and there were no significant differences ($p > 0.05$) in percent organic content (Firth et al., 1986). There were no significant differences in mean concentrations of TSS and POM in any of the three size classes at Station 21 based on the operating status of K Reactor, but percent organic matter in the large size fraction was significantly higher when the reactor was operating.

Beaver Dam Creek sites (Stations 6 and 8) had significantly greater ($p < 0.05$) TSS and significantly lower percent organic matter than the reference stream sites (Stations 1, 20, 39, 40, 43, and 44), but there was no significant difference in POM concentrations between the two groups of sites. The two Beaver Dam Creek stations were not significantly different from each other for seston parameters. Beaver Dam Creek had a greater concentration of smaller-sized TSS particles and significantly lower concentrations of medium-sized TSS particles than the reference streams. Concentrations of both medium and large POM and percent organic matter in all three size fractions were significantly lower in Beaver Dam Creek. The upstream site (Station 6) had a significantly higher concentration of large-sized particles (both TSS and POM) than the downstream site Station 8), located downstream from the slough. Apparently, large-sized particles settled out as the current velocity slowed in the slough area (Firth et al., 1986).

Mean TSS concentrations were lower at the delta sites than at the stream sites (Table V-3.35), a result of the lower current velocities in the deltas. Percent organic matter was also generally lower in the deltas, ranging from 24 to 35% (Table V-3.35). Thermal Pen Branch Delta (Station 22) was very similar to nonthermal Steel Creek Delta (Stations 31 and 33) in both TSS and POM concentrations. However, the mean concentration of fine particles (TSS) was significantly greater at the Pen Branch Delta site. There were no significant differences in any seston size class parameter at Station 22 as a result of K-Reactor operating status. The thermal Four Mile Creek Delta sites (Stations 14, 15, and 17), however, differed from those in Steel Creek Delta by having higher TSS concentrations and lower percent organic matter, indicating a higher silt load in Four Mile Creek Delta. This may have been due to slightly higher current velocities at these sites or to their locations with reference to the Steel Creek Delta station. The Steel Creek Delta sites were located downstream from an extensive swamp and delta area. The Four Mile Creek depositional area upstream from 1984-1985 Stations 14 and 15 was not as large, and fine particles may not have had time to settle out (Firth et al., 1986).

There were no significant differences for any seston parameter between the two nonthermal sites, while in thermal Four Mile Creek Delta, the only significant difference was the higher POM concentrations at Station 14 compared to more downstream Station 17. There were few consistent differences in the size class fractions between Station 22 in Pen Branch Delta and those in Four Mile Creek Delta (Stations 14, 15, and 17).

Of the six delta sites sampled during the study year, only Four Mile Creek Station 17 (the most upstream delta station) showed size fraction differences, most notably significantly higher concentrations of large particle TSS and POM, due, most probably, to the relatively swifter current regime at this station.

Seston dynamics in Four Mile Creek Delta were compared during reactor operation vs. reactor shutdown. No significant difference in total TSS or POM concentrations were observed, but the samples collected when the reactor was operating were much more variable. Particle size analysis indicated a significantly higher concentration of large particle TSS at 1984-1985 Station 14 when the reactor was operating, and significantly higher concentrations of medium and large TSS and POM at Station 14 compared to Station 17. When the reactor was down, there were no significant differences in concentrations of any seston size fraction between the two stations.

Particulate matter was evaluated at two swamp sites, Station 24 in Pen Branch swamp and Station 35 in Steel Creek swamp. TSS concentrations were generally lower at the swamp sites than at the stream sites, and percent organic matter was near the high end of the range encountered in the reference streams. While mean TSS and POM concentrations were twice as high at Station 24, there were no significant differences in these parameters when the data for the entire year were pooled. However, the particle size breakdown was different between the two sites. Pen Branch Delta Station 24 had significantly higher concentrations of both TSS and POM in the largest size fraction, and a higher percent organic matter in this size fraction, compared to Station 35. It is likely that the dense canopy and high litterfall rates at Station 24 accounted for these differences (Firth et al., 1986).

Data from sites upstream (Station 29) and downstream (Station 36) from the Steel Creek Delta swamp were compared. Mean TSS concentration was greater and percent organic matter was lower at the upstream site (Tables V-3.35 and V-3.37). Thus, the delta swamp served to remove much of the suspended particulate load from transport, and exported material with a higher organic content than it imported from upstream Steel Creek.

Differences in seston concentrations were found among the creek mouth stations. Percent organic matter was higher at the reference stream sites on Upper and Lower Three Runs Creeks (Stations 3 and 45, respectively), which themselves did not differ significantly for any seston parameters. This higher percent organic matter was attributable to the higher concentrations of particles and percent organic matter in the large and medium size fractions. The mouth of Beaver Dam Creek (Station 9) had a significantly greater mean TSS concentration (11 mg/L) than any of the other creek mouth sites (4-8 mg/L). Four Mile Creek mouth did not differ significantly from the reference streams in TSS concentration, but had a significantly lower ($p < 0.0014$) percent organic matter. The nonthermal sites had the highest percent organic matter in the fine size fraction. Although Four Mile Creek and Steel Creek both flow across a depositional delta before reaching the river, Four Mile Creek showed a higher TSS concentration and significantly lower percent organic matter.

When C Reactor was down, the concentrations of large and medium particulate TSS and percent organic matter in the medium size fraction at Station 18 (at the mouth of Four Mile Creek) was significantly lower than at comparable reference sites (Stations 3, 37, and 45, pooled data), but there was no significant difference in percent organic matter in the large fraction. When the reactor was operating, there was no significant difference at Station 18 and the reference sites with respect to concentrations of large and medium TSS, yet percent organic matter of these size fractions were significantly lower at Station 18. Concentrations of POM in all three size fractions were not affected by reactor operating status, and percent organic matter of fine particles was consistently and significantly lower at Station 18 than at the reference sites.

River seston at Station 25 was compared to the seston of the large reference streams (Stations 1, 53, 43, and 45). The river had a significantly higher mean TSS concentration and a significantly lower percent organic matter than the large reference streams. No differences were seen for POM concentrations.

TABLE V-3.37

The Annual Mean and Standard Error(s) in Different Size Fractions of Seston for Total Weight, Percent Organic Content, and Concentration of Whole Water are Given for Each Station (October 1984 - September 1985)

>100 µm Size Fraction

Station	Location/ Thermal Regime	N	Total Weight (TSS) (mg/L) Mean	S	Percent Organic Mean	S	Concentration (mg AFDW/L) Mean	S
1	UTR-n	24	2.102	2.168	51.72	8.653	1.131	1.291
3	UTR-n	21	1.466	1.533	55.04	10.34	0.7587	0.7102
6	BD-t	21	1.588	0.4938	30.37	12.00	0.4949	0.2897
8	BD-t	23	0.9138	0.4202	34.57	13.48	0.3209	0.2200
9	BD-t	24	1.408	1.371	33.11	13.45	0.4489	0.5123
14	FMD-t	22	1.033	0.7285	40.22	9.886	0.4222	0.3286
15	FMD-t	18	0.3594	0.2355	37.44	9.086	0.1373	0.1121
17	FMD-t	18	0.2964	0.2604	43.54	13.91	0.1373	0.1539
18	FM-t	24	0.6282	0.3395	33.66	18.65	0.1973	0.1577
20	PB-n	22	8.190	14.02	40.61	13.03	2.573	4.094
21	PB-t	24	2.516	2.165	19.24	9.635	0.3620	0.1913
22	PBD-t	24	0.4866	0.3145	37.20	11.11	0.1689	0.0963
24	PBS-n	24	5.813	13.43	65.84	22.67	5.310	12.36
25	SR-n	24	0.9576	1.545	27.02	15.25	0.4378	1.296
26	SC-n	23	25.67	94.12	20.17	21.82	0.8485	1.656
27	SC-n	24	8.939	5.401	14.75	4.708	1.309	1.073
28	SC-n	24	9.362	14.56	25.11	25.52	0.8594	1.089
29	SC-n	23	2.107	1.903	27.25	11.64	0.4333	0.2642
31	SCD-n	24	0.4052	0.3399	37.00	9.819	0.1518	0.1230
33	SCD-n	24	0.5209	0.3516	42.31	13.31	0.1918	0.1091
35	SCS-n	24	0.3561	0.4699	53.46	10.71	0.2065	0.3252
36	SC-n	24	0.5740	0.3136	42.20	10.92	0.2345	0.1289
37	SC-n	24	0.9026	0.5509	36.38	19.78	0.3818	0.5182
38	SR-n	23	0.8203	0.2977	29.13	10.69	0.2295	0.0937
39	MB-n	24	2.803	3.995	35.08	10.28	0.9031	1.245
40	MB-n	23	2.328	2.211	39.40	6.626	0.8474	0.8181
42	LTR-n	24	1.629	1.780	32.91	12.49	0.3706	0.3066
53	LTR-n	15	1.0175	0.4221	53.61	12.687	0.5692	0.2933
43	LTR-n	7	0.5049	0.2772	41.35	11.51	0.2003	0.1115
44	LTR-n	24	1.392	1.524	55.77	7.797	0.7499	0.6935
45	LTR-n	23	0.8896	0.6325	47.13	9.653	0.3972	0.2831

TABLE V-3.37, Contd

25-100 µm Size Fraction

Station	Location/ Thermal Regime	N	Total Weight (TSS) (mg/L) Mean	S	Percent Organic Mean	S	Concentration (mg AFDW/L) Mean	S
1	UTR-n	24	2.826	2.389	41.75	3.991	1.110	0.165
3	UTR-n	24	1.837	1.342	40.36	5.915	0.770	0.120
6	BD-t	22	2.593	1.696	16.42	3.383	0.392	0.042
8	BD-t	24	2.152	1.252	17.61	2.379	0.365	0.041
9	BD-t	24	2.485	1.177	18.95	11.59	0.472	0.078
14	FMD-t	21	0.5469	0.4539	30.23	6.762	0.163	0.031
15	FMD-t	18	0.2871	0.2678	29.20	12.50	0.065	0.129
17	FMD-t	18	0.2410	0.1182	27.92	10.02	0.059	0.006
18	FM-t	24	0.9450	0.5657	19.74	6.240	0.169	0.019
20	PB-n	24	7.476	12.64	27.28	5.181	1.609	0.503
21	PB-t	24	1.892	1.443	20.32	4.576	0.351	0.047
22	PBD-t	24	0.1919	0.1358	32.99	8.363	0.055	0.006
24	PBS-n	23	0.2956	0.3669	43.61	15.70	0.162	0.070
25	SR-n	22	1.981	1.065	16.24	3.956	0.314	0.041
26	SC-n	24	5.647	14.38	18.02	5.918	0.786	0.417
27	SC-n	23	5.410	3.939	17.96	3.249	0.914	0.125
28	SC-n	24	2.337	2.623	20.25	3.888	0.464	0.101
29	SC-n	24	1.836	0.8865	24.44	6.809	0.448	0.046
31	SCD-n	24	0.4524	0.2646	28.57	6.584	0.138	0.020
33	SCD-n	24	0.4119	0.2484	34.93	11.85	0.134	0.016
35	SCS-n	24	0.2553	0.1663	38.48	3.374	0.097	0.013
36	SC-n	24	0.5627	0.2904	30.89	3.941	0.169	0.017
37	SC-n	24	0.8954	0.4098	21.68	4.116	0.193	0.019
38	SR-n	23	1.685	0.8451	17.97	5.070	0.275	0.016
39	MB-n	24	1.694	1.197	31.72	4.803	0.514	0.068
40	MB-n	24	2.060	1.679	34.81	3.105	0.721	0.114
42	LTR-n	23	0.7554	0.4771	47.70	24.58	0.348	0.056
53	LTR-n	16*	1.145	0.4693	46.31	8.316	0.211	0.037
43	LTR-n	8*	0.5232	0.2592	40.47	3.226	0.535	0.061
44	LTR-n	24	1.577	1.336	43.42	3.523	0.680	0.109
45	LTR-n	24	1.842	1.810	34.32	10.16	0.485	0.052

* N = 16 and 8, respectively, in concentration columns.

TABLE V-3.37, Contd

<25 μm Size Fraction

Station	Location/ Thermal Regime	N	Total Weight (TSS) (mg/L) Mean	S	Percent Organic Mean	S	Concentration (mg AFDW/L) Mean	S
1	UTR-n	24*	10.82	19.72	45.73	19.63	7.466	3.915
3	UTR-n	24	9.215	21.11	46.97	16.80	7.438	4.271
6	BD-t	22	8.065	5.048	22.55	4.388	1.715	0.159
8	BD-t	24	6.759	1.294	20.10	3.180	1.378	0.842
9	BD-t	24	6.669	1.873	19.28	3.955	1.311	0.101
14	FMD-t	22	3.803	2.657	31.74	9.884	1.067	0.859
15	FMD-t	18	4.443	3.950	30.27	12.70	1.020	0.834
17	FMD-t	18	3.982	2.885	29.75	11.35	0.949	0.813
18	FM-t	24	4.486	1.631	25.12	8.830	1.030	0.790
20	PB-n	24	10.18	11.39	29.82	6.84	2.612	0.530
21	PB-t	23	7.387	8.928	26.60	8.523	1.477	0.142
22	PBD-t	24	3.651	3.018	33.37	14.20	0.938	0.633
24	PBS-n	24	1.954	0.5884	38.22	10.73	0.728	0.544
25	SR-n	24	8.598	12.17	24.70	8.379	1.607	0.255
26	SC-n	24	33.25	59.03	18.30	5.701	4.440	1.496
27	SC-n	24	15.82	15.39	22.56	5.054	3.202	0.499
28	SC-n	21	22.19	27.66	24.45	13.20	5.591	1.874
29	SC-n	22	5.835	4.840	28.16	5.329	1.570	0.239
31	SCD-n	23	2.195	0.8660	37.38	11.65	0.813	0.780
33	SCD-n	24	2.106	0.8197	38.35	10.04	0.817	0.782
35	SCS-n	24	1.738	0.4372	45.74	11.37	0.812	0.652
36	SC-n	24	1.834	0.4841	41.66	10.05	0.770	0.561
37	SC-n	24	2.920	1.644	32.25	10.99	0.965	0.151
38	SR-n	23	7.651	12.96	25.64	7.712	1.260	0.175
39	MB-n	23	3.193	2.586	40.43	12.69	1.163	0.184
40	MB-n	24	2.861	2.326	41.32	19.19	1.003	0.139
42	LTR-n	21	2.833	2.183	49.98	17.40	1.319	0.187
53	LTR-n	14	1.243	0.3390	45.67	15.42	0.346	0.595
43	LTR-n	7	0.8523	0.2471	43.75	23.82	0.583	0.716
44	LTR-n	22	2.355	2.752	53.83	14.29	1.087	0.192
45	LTR-n	23	4.530	8.995	42.29	20.88	0.999	0.212

* N = 25 in concentration column.

Source: Firth et al., 1986.

V.3.7 Macroinvertebrates

V.3.7.1 Introduction

Macroinvertebrates are important to the aquatic food web because they convert primary production and allochthonous organic matter in a stream to a useable food source for higher trophic levels such as fish. Therefore, disruption of macroinvertebrate communities could impact vertebrate communities in SRP surface streams. Macroinvertebrates are often used as indicators of the long-term conditions in a stream because they are relatively sedentary and are sensitive to stress. The structure and functioning of macroinvertebrate assemblages can indicate long term conditions in a stream and may be used in water quality evaluation (Weber, 1973).

The objective of the CCWS macroinvertebrate studies was to examine the impacts of SRP cooling water discharges on macroinvertebrate communities in SRP creeks, swamps, and the Savannah River, and the recovery of the macroinvertebrate communities in post-thermal Steel Creek. To accomplish this objective, the CCWS included studies of macroinvertebrate richness (number of taxa), density (no./m^2), and biomass (g AFDW/m^2). Thermal discharges have complex effects on macroinvertebrate communities (Hutchinson, 1976; Ward and Stanford, 1983). Increased water temperatures may accelerate or delay the emergence patterns of aquatic insects (Wise, 1980), and increase or decrease the number of generations per year (Parkin and Stahl, 1981; Rogers, 1980). Elevated thermal regimes may significantly reduce species richness (Ferguson and Fox, 1978; Howell and Gentry, 1974); however, other macroinvertebrate taxa may respond positively to increased water temperatures. For example, relative abundances of oligochaetes, nematodes, gastropods, and chironomid midges may increase dramatically with thermal enrichment (Nichols, 1981; Rasmussen, 1982; Laybourn, 1979; Wood, 1982; Vincent, 1967; Ferguson and Fox, 1978) leading to communities numerically dominated by one or several very tolerant species. The CCWS studies used a breakdown of macroinvertebrate feeding groups (Table V-3.38) to functionally differentiate macroinvertebrate communities of the SRP streams and swamp, and their response to cooling water releases.

The CCWS included sampling of both artificial and natural substrates to measure colonization of macroinvertebrates. In addition, macroinvertebrate drift was measured by sampling the number of macroinvertebrates transported downstream in a volume of water. Invertebrate drift is a natural phenomenon in streams and rivers (Waters, 1972), but can be greatly influenced by changes in hydrologic or thermal regimes (Wojtalik & Waters, 1970).

TABLE V-3.38

Macroinvertebrate Functional Groups and Their Modes of Feeding*

Functional Group	Feeding Mode
Scrapers	Shear off attached aufwuchs film (periphyton, fungi, bacteria, protozoa, etc.) from under water substrates.
Collector-gatherers	Glean sedimented organic deposits from the substrate.
Collector-filterers	Filter suspended particulate organic matter from water column.
Shredders	Skeletonize whole leaves and leaf fragments.
Piercers-herbivores	Pierce plant tissues or cells and suck fluids.
Predators-engulfers	Capture and ingest animals.

* After Merritt and Cummins, 1978.

V.3.7.2 Methods

Similar techniques were used to sample macroinvertebrates throughout both years of the study.

Modified Hester Dendy multiplate samplers (Hester & Dendy, 1962) were used in this study to quantitatively characterize macroinvertebrate community parameters on a monthly basis. This method is of great utility in comparative studies, since the plates present a uniform substrate for colonization at each sampling location. However, there are several sources of potential bias that must be recognized. On the one hand, plates may provide a more stable substrate than the shifting sands on the stream bottom. On the other hand, they do not allow penetration by organisms into the substrate (as would occur on a natural stream bottom), where environmental conditions are usually more stable. In either case, they would not adequately represent conditions in the stream sediments. Results from the 1983-1984 sampling of natural stream bottoms and from the 1984-1985 near surface and near bottom multiplate sampling indicate that both these sources of bias are inherent in the multiplate sampling methodology. As a result, multiplate samplers are most representative of conditions on snags, surfaces of wood, and rocks, which are the sites of most of the secondary macroinvertebrate production in southeastern streams (Benke, 1984).

Each sampler consisted of 14 tempered hardboard plates, 0.3 cm thick, separated by 0.3 cm spacers (Figure V-3.25). Total exposed surface area was 0.179 m^2. At all stream and swamp sites, samplers were suspended 0.5 m above a concrete block anchor on the stream bottom. At the river transects and in the creek mouths, near surface (0.5 m below the water surface) and near bottom (0.5 m above the bottom) samplers were deployed during the 1983-1984 study year using a similar apparatus. Because of the effects of sedimentation on colonization of the near bottom samplers, during the 1984-1985 study year, only the near surface samplers were deployed. The colonization time for the multiplate samplers was four weeks and samples were collected monthly. To minimize loss of organisms during sample recovery, a 500 μ mesh bag was placed around each as it was lifted from the water. The entire contents of the mesh bags was washed directly into prelabelled plastic bags, and kept on ice until processing in the laboratory began.

Macroinvertebrates were also sampled quarterly using leaf bags, and by sampling macrophyte beds, stream sediments, and macroinvertebrate drift. Leaf bags were constructed of plastic mesh (43 cm x 17 cm, with maximum mesh size 5 mm x 25 mm), and were filled with approximately 5 g each of sycamore (<u>Plantanus occidentalis</u>) and sweetgum (<u>Liquidambar styraciflua</u>) leaves, which had been collected at leaf abscision and air dried. Bags were

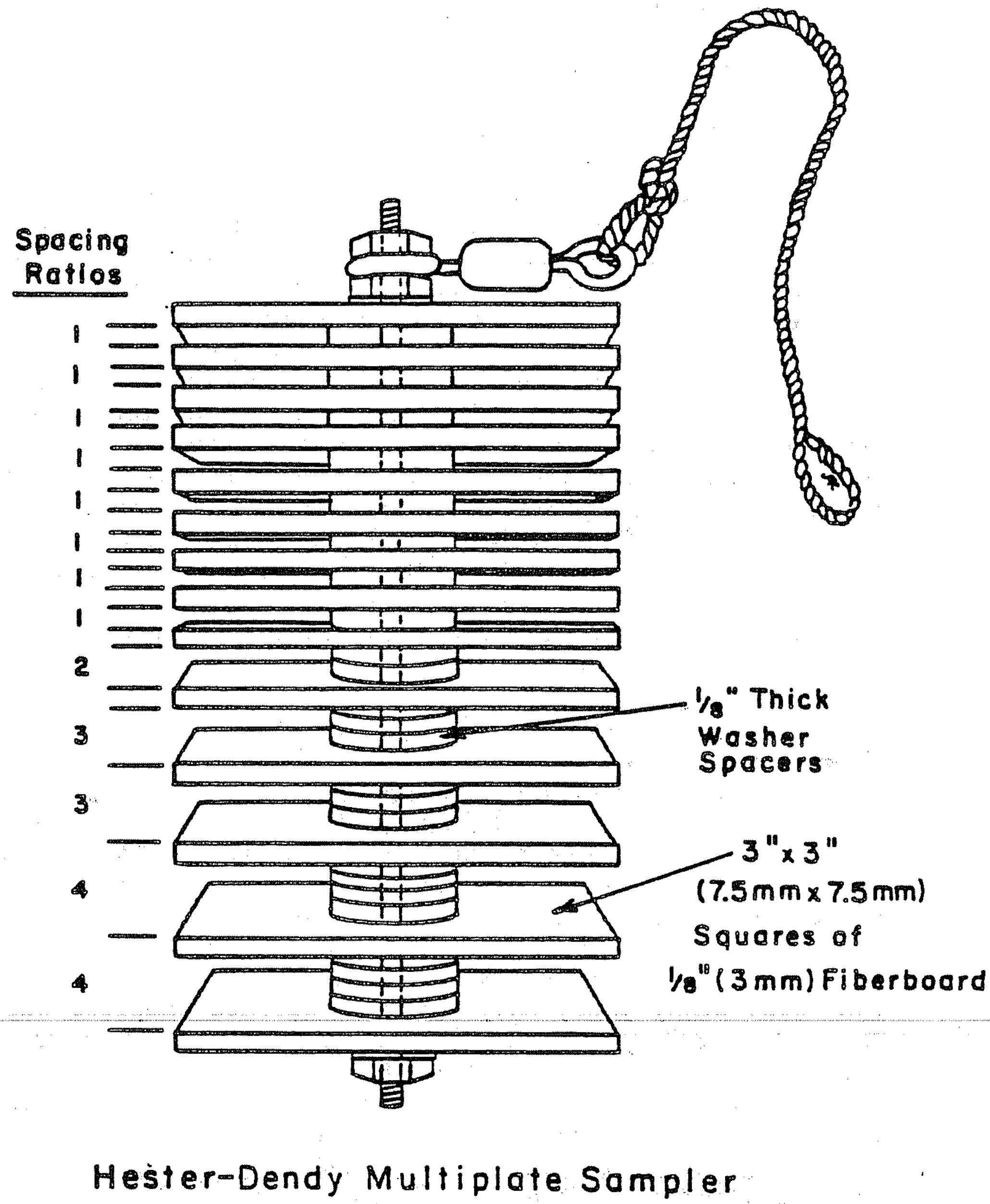


FIGURE 25. Diagram of the Multiplate Sampler Used in This Study

weighted to facilitate sinking at stations with swift current. The colonization period for the leaf bags was 4 weeks. After colonization, the bags and their contents were carefully removed from the stream bottom and placed in prelabelled plastic bags on ice for transport to and short-term storage in the laboratory.

Macrophyte beds were sampled by using stainless steel cylinders 90 cm long and 25.5 cm in diameter (area of 0.05 m^2) to isolate the plant material in the macrophyte beds. The cylinder was pushed into the stream bottom and all plant material (including roots and associated debris) was removed with a hand cultivator and small aquarium net. The remaining water and detritus in the cylinder was subsequently pumped through a 124 µm mesh net bag that trapped suspended organisms (Kondratieff & Kondratieff, 1985a). All collected material was placed in a prelabelled plastic bag and put on ice for transport and short term storage.

Stream sediments were sampled to a depth of about 14 cm using a steel tube 15.1 cm long and 7.5 cm in diameter (Kondratieff & Kondratieff, 1985). A sediment volume of 666.8 cm^3 was taken in each sample, which covered a surface area of 0.004 m^2. Each core was placed in a plastic bag and put on ice for transport and short term storage.

Artificial snags were constructed from two 3 x 20 cm pieces of freshly cut tag alder (Alnus rubra) tied to each other at right angles with plastic cable ties and suspended in the water 4-6 cm above the bottom. Each snag had an approximate surface area of 0.04 m^2. Each snag was weighted by a plastic vial filled with lead shot, thereby maintaining an upright position in the stream with the center of the snag perpendicular to the current. During the sampling period, much organic debris collected on the snags, and most of the macroinvertebrates were in the debris. Results were reported as organisms/g dry weight of debris as well as organisms/m^2 of snag. At the time of sample retrieval, each snag and the extraneous material caught by it were lifted from the water in a 500 µ mesh bag and placed on ice in a prelabelled plastic bag until laboratory processing began (Kondratieff & Kondratieff, 1985b).

Replicate macroinvertebrate drift samples were collected at each station by placing paired 0.5 m diameter opening, 505 µ mesh plankton nets, or 0.3 m x 0.45 m opening, 363 µm mesh drift nets directly into the current for a period of time required to filter approximately 50 m^3 of water. Plankton nets were used where the water was too deep to allow placement of drift nets. Care was taken to avoid disturbing the substrate during sampling. A General Oceanics Model 2030 digital current meter was mounted in the center of the opening of each net to record the volume of water filtered. Contents of the nets were washed into collecting bottles with enough concentrated buffered (pH 7) formalin containing 0.2 g/L Eosin red and 0.2 g/L Biebrich scarlet stains added to bring the formalin concentration to approximately 5%. The bottles were then sealed and stored for return to the laboratory.

In the laboratory, material from each macroinvertebrate collection was rinsed into a U.S. Standard No. 30 sieve (600 μm mesh). The Hester Dendy and snag samples were first disassembled, and the sample surfaces were scraped with a soft brush to dislodge attached organisms. Samples were preserved with sufficient concentrated buffered formalin to bring the final formalin concentration to approximately 5%. The formalin contained Eosin red and Biebrich scarlet stains which color animal tissue and permit easier separation of organisms from the detritus.

Macroinvertebrates were removed from detritus and plant material by using a stereomicroscope at 10X; the animals were stored in 70% ethanol. Organisms were identified to the lowest practical taxonomic level and enumerated. Major taxonomic works used in identification included Brigham et al. (1982), Britton and Fuller (1979), Merritt and Cummins (1984), Pennak (1978), Wiggins (1977), and Wood (1982). Densities of macroinvertebrates from the drift collections were reported in number of organisms/1000 m^3 to render them comparable to those reported in other studies. Number of taxa were reported per 50 m^3 sample, since this parameter can only be reported based on the volume of sample collected.

During both years, macroinvertebrates from the multiplate samplers were sorted into functional groups based on their mode of feeding (Merritt and Cummins, 1984; Table V-3.38), and ash-free dry weights were obtained for each group, as described by Kondratieff and Kondratieff (1985a). The organisms were dried to constant mass at 60°C, weighed (dry mass), combusted at 500°C for 1 hour, rewetted with distilled water, dried again, and reweighed to determine ash-free dry mass. Plant material from the macrophyte bed samples was air-dried and weighed (dry mass) after the macroinvertebrates were removed. Data were reported as number organisms/m^2, dry weight m^2, and AFDW/m^2 of the colonized surface area.

Quality assurance practices were maintained in all aspects of this work. Procedures used were derived from accepted methods published by manufacturers, regulatory agencies, and the scientific community.

Data were transformed to better satisfy the assumption of normality required for ANOVA. Homogeneity of variances between stations was tested for, using the F_{max}-test (Sokal & Rohlf, 1981). The appropriate transformations were applied, following Sokal and Rohlf (1981). These were $\log_{10}$ (x + 1) for most data; arcsine (x) for proportion data, and the square root of x + 0.5 for count data. Improvement of mean to variance relationship (that is, a decreased correlation between these statistics) was checked, using Taylor's Power Law (Taylor, 1961) according to Downing (1979) as described in Gurtz and Wallace (1984).

In order to evaluate SRP impacts on selected types of sites (e.g., thermal streams, open-canopy delta areas, etc.), similar stations were sometimes grouped to compare them with individual or pooled reference stations. The choice of reference sites with which stressed sites could be compared was based on characteristics of the station that were considered to be most important for the variable in question. For example, sites to be compared in the litter analyses were judged by canopy characteristics and riparian flora. One-way analyses of variance (ANOVA) and a posteriori Duncan's multiple range tests (MRT) were run under the General Linear Model procedure (SAS, 1982).

V.3.7.2.1 1983-1984 Sampling Program

All six sampling methods were used during the 1983-1984 study year (see Table V-3.2). Hester Dendy multiplate samplers, snag samplers, and leaf bags were deployed at all 12 stream and swamp stations. Macrophyte sampling was conducted at the four delta and swamp stations, while sediment core samples were collected at the other eight stations. At the five SRP creek mouths and 10 river transects, multiplate and drift sampling was conducted, while at the two intake canal stations, only drift samples were collected. During the 1983-1984 study year, multiplate samplers were deployed both near the surface and near the bottom of the five creek mouth stations.

Leaf bag and artificial snags were sampled from December 1983 to May 1984. Hester Dendy multiplate samplers were deployed from January 1984 to April 1984 and from June 1984 to August 1984. Sediments and macrophyte bed sampling was conducted monthly from December 1983 to May 1984. A master list of taxa was compiled at selected stations on a frequent basis for the period November 1983 to September 1984 (Kondratieff & Kondratieff, 1985a).

V.3.7.2.2 1984-1985 Sampling Program

Four techniques were utilized to sample macroinvertebrates during the 1984-1985 study year. Hester Dendy multiplate samplers and drift samplers were deployed at 29 stream and swamp stations while leaf bags were utilized at these same 29 stations, plus five additional stream and swamp sites (see Table V-3.2). Macrophyte sampling was conducted at the eight delta/swamp stations and Station 7 on Beaver Dam Creek where macrophyte growth was prominent. At five SRP creek mouths and eight river transects, multiplate sampling was continued, but Hester Dendy samples were deployed only near the surface. Drift samples were collected at these same 13 stations, and at three additional river transects as well as at the intake canal stations.

The river sites were also sampled in 1984-1985 using sampling methods similar to those of the previous year.

V.3.7.3 Results and Discussion

V.3.7.3.1 Taxa Richness

The 1983-1984 macroinvertebrate results for the stream sites for the period November 1983 to May 1984 (when all techniques were employed) are presented in Table V-3.39. Taxa richness, which was based on data from all samples collected, was consistently lower at the thermal sites (1983-1984 Stations 5, 13A, 14, 21). Mayflies of the genera Baetis, Stenonema, and Ephemerella, stoneflies of the genus Perlesta, caddisflies of the genus Cheumatopsyche, and dipterans of the tribe Tanytarsini were common at some or all of the nonthermal stations, but were absent or occurred in low numbers at the thermal sites, based on multiplate sampling. At the thermal sites receiving reactor effluents, only nematodes, oligochaetes, and chironomids were abundant. The mildly thermal Beaver Creek Station (Station 5) had better representation from dipterans, and was the only stream station with abundant snails of the genus Physa (based on multiplate sampling). Many of the species recorded from the thermal sites colonized during periods of reactor shutdown and were subsequently eliminated when the reactor was brought back online. During reactor operation, no taxa were present in main stream reaches at Four Mile Creek (Stations 13A and 14) and Pen Branch (Station 21) (Kondratieff & Kondratieff, 1985b). Only a few species of oligochaetes, nematodes, and midges of the family Chironomidae survived deep in the sediments. Thus, the resident number of taxa at the thermal sites was lower than suggested by data in Table V-3.39 (Gladden et al., 1985). The Meyers Branch reference (i.e., undisturbed) site (Station 40) had the highest number of taxa. The taxa richness in Steel Creek (Stations 26 and 28) was nearly as high, indicating that Steel Creek has had an excellent post-thermal recovery of its macroinvertebrate community (Gladden et al., 1985).

The results from the 1983-1984 macroinvertebrate collections in the swamp and delta are presented in Table V-3.40. The total number of taxa collected at the Pen Branch thermal delta sites (Stations 22 and 23) was substantially lower than the number collected from the nonthermal Steel Creek swamp sites (Stations 33 and 35). The Pen Branch Delta sites were dominated by thermally

TABLE V-3.39

Total Number of Macroinvertebrate Taxa at Each Stream Sampling Station and Average Density of Macroinvertebrates Collected on Leaf Bags, Artificial Snags, Plant Material Associated with Artificial Snags, Multiplate Samplers, and Sediment Cores. T = thermal; N = nonthermal (November 1983-May 1984)

			Average Density				
Location	Station	Total Taxa	No./ Leaf Bag	No./m2 Snag	No./g dry wt Plant	No./m2 Multiplate	No./m2 Sediment
BD	5(T)	34	103	1,358	11	1,844	5.141
FM	13A(T)	16	42	99	1	455	1,252
FM	14(T)	29	271	3,378	96	1,008	1,445
PB	21(T)	25	174	1,393	12	61	9,351
SC	26(T)	59	1,487	10,836	179	5,668	7,365
SC	28(T)	75	998	7,050	45	7,242	4,914
MB	39(N)	71	609	7,830	50	2,604	8,886
MB	40(N)	86	1,114	9,704	240	5,448	7,051

Note: Abbreviations are listed in Table V-3.2.

Source: Gladden et al., 1985.

TABLE V-3.40

Total Number of Macroinvertebrate Taxa at Each Swamp Sampling Station and Average Density of Macroinvertebrates Collected on Leaf Bags, Artificial Snags, Plant Material Associated with Artificial Snags, Multiplate Samplers, and Aquatic Macrophytes (T = thermal; N = nonthermal) (November 1983-May 1984)

			Average Density				
Location	Station	Total Taxa	No./ Leaf Bag	No./m^2 Snag	No./g dry wt Plant	No./m^2 Multiplate	No./g dry wt Macrophytes
PBD	22(T)	44	1,371	15,791	41	2,726	40
PDB	23(T)	38	585	2,457	370	1,784	11
SCS	33(N)	93	852	20,761	419	7,734	80
SCS	35(N)	82	1,336	20,115	176	9,858	54

Note: Abbreviations are listed in Table V-3.2.

Source: Gladden et al., 1985.

tolerant oligochaetes (Oligochaeta), nematodes (Nematoda), true flies (Diptera), snails (Gastropoda), and mayflies (Ephemeroptera). The highest numbers of taxa found in this study were at the Steel Creek swamp sites. Taxonomic differences between the thermal and nonthermal swamp stations (based on multiplate sampling) are similar to those of the thermal and nonthermal stream stations. One or both of the Steel Creek swamp stations was characterized by amphipods of the genus Hyalella, mayflies of the genus Stenonema, caddisflies of the genus Cheumatopsyche, and dipterans of the tribe Tanytarsini. Table V-3.41 is a list of species collected at Steel Creek, Steel Creek swamp, Meyers Branch, and Pen Branch Delta. The diverse Steel Creek swamp fauna consisted of both still-water and flowing-water species. At least 264 species of macroinvertebrates have been identified from the Steel Creek swamp, including 237 insect species (Kondratieff & Kondratieff, 1985).

The 1984-1985 taxa richness measurements are primarily from the Hester Dendy multiplate samples. Data from leaf bags, macroinvertebrate drift, and macrophyte samples were used to supplement the taxonomic lists for each station and to provide additional information on invertebrate populations. The results presented in this section include the number of taxa per station and the number of common taxa (Table V-3.42). Common taxa are defined for the purposes of this study as those represented by more than ten individuals and present for more than one collection period (Firth et al., 1986).

The 1984-1985 multiplate sampling of the nonthermal reference stations (Upper Three Runs Station 1, Four Mile Creek, Station 12, Pen Branch Station 20, and Meyers Branch Stations 39 and 40) resulted in a range of 60 to 70 taxa per station and 20 to 29 common taxa per station (Table V-3.42). Common taxa included mayflies (Ephemeroptera), stoneflies (Plecoptera), hydropsychid caddisflies (Trichoptera: Hydropsychidae), chironomids (Diptera: Chironomidae), blackflies (Diptera: Simulidae), dance flies (Diptera: Empididae), elmid beetles (Coleoptera: Elmidae), water mites (Hydracarina), nemadodes, and oligochaetes.

The Steel Creek post-thermal sites (Stations 26, 27, 28, and 29) had numbers of taxa similar to the nonthermal reference sites discussed above. The total number of taxa collected per station in Steel Creek ranged from 55 to 66 and the number of common taxa ranged from 20 to 36. Many of the taxa common to the Steel Creek stations were also common at some or all of the reference stations, including Baetis, Ephemerella invaria, Eurylophella temporalis, Stenonema modestum, Neoephemera youngi, Tricorythodes, Paragnetina fumosa, Perlesta placida, Ancyronyx variegatus, Macronychus glabratus, Stenelmis, Corydalus cornutus, Brachycentrus, Cheumatopsyche, Hydropsyche, Oecetis, Lype diversa, Emididae and Simulum (Table V-3.43). Similar stream structure, such as

TABLE 41

An Annotated Checklist of the Aquatic Macroinvertebrates of Steel Creek, Steel Creek Swamp, Meyers Branch, and Pen Branch Delta

Taxon	Functional Group*	Steel Creek	Steel Creek Swamp	Meyers Branch	Pen Branch Delta
Coelenterata (Hydroids, Jellyfish)					
Hydridae					
Hydra sp.	FG4	U	C	C	C
Turbellaria (Flatworms)					
Planariidae					
Dugesia tigrina (Girard)	FG4	C	A	A	C
Nematoda (Roundworms)	FG1	A	A	A	A
Annelida (Segmented Worms)					
Oligochaeta (Aquatic earthworms)					
Tubificidae	FG1	A	A	A	A
Limnodrilus spp.					
Other genera					
Naididae	FG1	A	A	A	A
Chaetogaster spp.					
Pristina spp.					
Other genera					
Hirudinea (Leeches)	FG4	U	C	C	C
Isopoda (Aquatic Sow Bugs)					
Asellidae					
Asellus sp.	FG1	C	C	C	U
Amphipoda (Scuds)					
Talitridae					
Hyalella azteca (Saussure)	FG1	A	A	A	C
Gammaridae					
Gammarus fasciatus Say	FG1	A	A	A	U
Decapoda (Crayfishes, Shrimps)					
Palaemonidae					
Palaemonetes paludosus (Gibbes)	FG3	A	A	A	
Cambaridae					
Cambarus latimanus (LeConte)	FG3	U	U	C	
Procambarus acutus acutus (Girard)	FG3	A	C	A	
Procambarus sp.	FG3	C	C	A	
Hydracarina (Water Mites)	FG4	A	A	A	A

TABLE 41, Contd

Taxon	Functional Group*	Steel Creek	Steel Creek Swamp	Meyers Branch	Pen Branch Delta
Insecta (Insects)					
Ephemeroptera (Mayflies)					
Baetis intercalaris McDunnough	FG1	A		C	
Baetis frondalis McDunnough	FG1	A	A	A	
Baetis sp.	FG1		C		R
Callibaetis sp.	FG1		U		
Siphlonurus sp.	FG1			U	
Siphloplecton simile Berner	FG1			U	
Heptagenia flavescens (Walsh)	FG2			U	
Brachycercus sp.	FG1			U	
Paraleptophlebia volitans (McDunnough)	FG1			U	
Habrophlebiodes americana (Banks)	FG1			U	
Baetisca obesa (Say)	FG1			R	
Baetisca rogersi Berner	FG1			U	
Pseudocloeon parvulum McDunnough	FG1	A		A	
Isonychia bicolor (Walker)	FG1	U		U	
Isonychia arida (Say)	FG1	U		C	
Stenonema modestum Banks	FG1	A	A	A	U
Stenonema sp.	FG1	C	C	C	
Stenacron inerpunctatum Say	FG1	C	C	C	
Dannella simplex (McDunnough)	FG1	U		C	
Ephemerella invaria (Walker)	FG1	A	C	A	R
Eurylophella temporalis (McDunnough)	FG1	U	A	A	R
Eurylophella sp.	FG1			U	
Serratella deficiens (Morgan)	FG1	A	C	A	
Neoephemera youngi Berner	FG1	A		A	
Caenis diminuta Walker	FG1	C	C	C	
Caenis simulans McDunnough	FG1	C	C	C	A
Tricorythodes sp.	FG1	C			
Leptophlebia cupida (Say)	FG1	U	C	A	
Hexagenia munda Eaton	FG1			C	
Odonata (Dragonflies and Damselflies)					
Boyeria vinosa (Say)	FG4	A	A	A	
Basiaeschna janata (Say)	FG4	U	C	U	
Gomphaeschna furcillata	FG4	U	C	U	
Epiaeschna heros (F.)	FG4		C		
Nasiaeschna pentacantha (Rambur)	FG4		U	C	
Anax junius (Drury)	FG4		U		
Arigomphus pallidus (Rambur)	FG4		U		
Gomphus lividus Selys	FG4	U	C	C	U
Gomphus exilis Selys	FG4	U	C	C	C
Gomphus diminutus Needham	FG4		U	R	
Gomphurus dilatatus (Rambur)	FG4	C	C		
Gomphurus sp.	FG4			R	

TABLE 41, Contd

Taxon	Functional Group*	Steel Creek	Steel Creek Swamp	Meyers Branch	Pen Branch Delta
Hylogomphus carolinus (Carle)	FG4			R	
Ophiogomphus incurvatus (Carle)	FG4			C	
Progomphus obscurus (Rambur)	FG4	U	U		
Hagenus brevistylus Selys	FG4		C	C	
Dromogomphus armatus Selys	FG4	U	C		
Macromia taeniolata Rambur	FG4	C	C		
Macromia georgina (Selys)	FG4	C			
Neurocordulia alabamensis Hodges	FG4	C	C	A	
Epicordulia regina (Hagen)	FG4		C		
Tetragoneuria cynosura (Say)	FG4	U	A	C	U
Tetragoneuria spinosa (Hagen)	FG4		C		
Perithemis tenera (Say)	FG4		C		
Celithemis sp.	FG4		U		
Calopteryx maculata (Beauvois)	FG4	A	A	A	
Calopteryx dimidata Burmeister	FG4	A	A	A	
Ladona deplanata (Rambur)	FG4		A		
Libellula incesta Hagen	FG4		A		A
Plathemis lydia (Drury)	FG4		U		U
Erthemis simplicicollis (Say)	FG4		A		A
Pachydiplax longipennis Burmeister	FG4		U		A
Tramea carolina (L.)	FG4		U		
Argia fumipennis (Burmeister)	FG4	A	A	A	A
Argia tibialis (Rambur)	FG4	A	C	A	
Argia moesta (Hagen)	FG4	C	C	U	R
Argia sedula (Hagen)	FG4	U	C		
Hataerina titia (Drury)	FG4	A	A	A	
Enallagma divagans (Selys)	FG4		C	A	R
Enallagma signatum (Hagen)	FG4	C	C	C	C
Enallagma spp.	FG4	C	C	C	C
Telebasis byersi Westfall	FG4	U	C		
Ischnura posita (Hagen)	FG4		C	A	C
Ischnura ramburi (Selys)	FG4		C		C
Lestes disjunctus australis (Walker)	FG4		U		
Helocordulia selysii Hagen	FG4			U	
Cordulegaster maculata Selys	FG4			C	
Zoraena bilineata Carle	FG4			U	
Plecoptera (Stoneflies)					
Allocapnia virginiana Frison	FG3			A	
Taeniopteryx lonicera Ricker and Ross	FG3	C		C	
Taeniopteryx robinae Kondratieff and Kirchner	FG3			A	
Amphinemura nigritta (Provancher)	FG3	A		A	
Leuctra ferruginea (Walker)	FG3			U	
Pteronarcys dorsata (Say)	FG3	C		C	
Helopicus bogaloosa Stark and Ray	FG4	A		C	

TABLE 41, Contd

Taxon	Functional Group*	Steel Creek	Steel Creek Swamp	Meyers Branch	Pen Branch Delta
Clioperla clio (Newman)	FG4	A		A	
Isoperla dicala Frison	FG4	C		C	
Isoperla sp. A	FG4	A	R	C	
Isoperla sp. B	FG4	U		U	
Acroneuria abnormis (Newman)	FG4	U		U	
Acroneuria arenosa (Pictet)	FG4	C	U	C	
Paragnetina fumosa (Banks)	FG4	A	U	C	
Paragnetina kansensis (Banks)	FG4	R	U	U	
Perlesta placida (Hagen)	FG4	A	A	A	R
Hemiptera (Bugs)					
Limnoporus canaliculatus (Say)	FG4	A	A	A	C
Gerris nubularis Drake and Hottes	FG4	A	A	A	C
Rhagovelia obesa Uhler	FG4	A	C	A	
Microvelia sp.	FG4	U	C	A	C
Belostoma lutarium (Stal)	FG4			C	
Belostoma spp.	FG4		C		C
Buenoa confusa Truxal	FG4		C		
Buenoa sp.	FG4		C		
Hesperocorixa brimleyi (Kirkaldy)	FG4		C		
Hesperocorixa sp.	FG4		C		
Palmacorixa buenoi Abbott	FG4		C		
Sigara alternata (Say)	FG4		C		
Sigara bradleyi (Abbott)	FG4		C		
Sigara sigmoidea (Abbott)	FG4		C		
Sigara spp.	FG4	A	C	A	C
Trichocorixa calva (Say)	FG4	C	C	A	
Trichocorixa sexcincta (Champion)	FG4		C		
Trichocorixa sp.	FG4		C		C
Mesovelia mulsanti White	FG4		C		C
Hydrometra martini Kirkaldy	FG4	C	C	C	C
Pelocoris femoratus (Palisot de Beauvois)	FG4		A		
Pelocoris carolinensis Torre Bueno	FG4		C		
Ranatra buenoi Hungerford	FG4		U		
Ranatra sp.	FG4		U		
Megaloptera (Dobsonflies and Fishflies)					
Corydalus cornutus (L.)	FG4	A	C	C	
Nigronia serricornias (Say)	FG4	U	U	U	
Chauliodes rastricornis Rambur	FG4	C	C	C	
Chauliodes pectinicornis (L.)	FG4	C	C	C	
Sialis americana (Rambur)	FG4	U	A	U	
Sialis vagans Ross	FG4			U	

TABLE 41, Contd

Taxon	Functional Group*	Steel Creek	Steel Creek Swamp	Meyers Branch	Pen Branch Delta
Neuroptera (Spongillaflies)					
Climacia aerolaris (Hagen)	FG4	C	U	C	
Sisyra vicaria (Walker)	FG4	C	U	C	
Trichoptera (Caddisflies)					
Cheumatopsyche pettiti (Banks)	FG1	A	A	A	
Cheumatopsyche richardsoni Gordon	FG1			U	
Cheumatopsyche pasella Ross	FG1	A	A	C	
Cheumatopsyche pinaca Ross	FG1	C	C	C	
Cheumatopsyche spp.	FG1	A	A	C	U
Hydropsyche incommoda (Hagen)	FG1	A	A	A	
Hydropsyche decalda Ross	FG1			U	
Hydropsyche betteni Ross	FG1			U	
Hydropsyche mississippiensis Flint	FG1	C	A	C	
Hydropsyche rossi Flint, Voshell, and Parker	FG1	A	A	U	
Hydropsyche spp.	FG1	C	C	C	U
Macrostemum carolina (Banks)	FG1	C	C	C	
Chimarra aterrima Hagen	FG1			C	
Chimarra florida Ross	FG1			U	
Chimarra moselyi Denning	FG1	A	A	C	
Lype diversa (Banks)	FG1	C		A	
Phylocentropus placidus (Banks)	FG1		A	A	
Neureclipsis melco Ross	FG1		U	U	
Neureclipsis crepuscularis (Walker)	FG1	U	U		
Nyctiophylax sp.	FG4		U		
Nyctiophylax affinis (Banks)	FG4			U	
Polycentropus cinereus Hagen	FG4	A	A	C	
Polycentropus sp.	FG4	C	C		
Brachycentrus nigrosoma (Banks)	FG1	U		C	
Brachycentrus numerosus (Say)	FG1	U		U	
Micrasema rusticum (Hagen)	FG3			C	
Lepidostoma carolina (Banks)	FG3			U	U
Nectopsyche candida (Hagen)	FG3	A	A	A	
Nectopsyche pavida (Hagen)	FG3	A	A	A	
Ceraclea diluta (Hagen)	FG1	C	C	C	
Ceraclea flava (Banks)	FG1			U	
Ceraclea maculata (Banks)	FG1	C	C	C	
Ceraclea tarsipunctata (Vorhis)	FG1		C	C	
Ceraclea ophioderus Ross	FG1			U	
Ceraclea protonepha Morse and Ross	FG1	A	C	A	
Ceraclea transversa (Hagen)	FG1	C	C	C	
Triaenodes ignitus (Walker)	FG4	A	C	A	
Triaenodes marginatus (Sibley)	FG4	U			
Triaenodes pernus Ross	FG4			C	
Triaenodes inflexa Morse	FG4		U	C	

TABLE 41, Contd

Taxon	Functional Group*	Steel Creek	Steel Creek Swamp	Meyers Branch	Pen Branch Delta
Triaenodes sp.	FG4				U
Oecetis cinerascens (Hagen)	FG4	U	C	U	U
Oecetis georgia Ross	FG4			R	
Oecetis inconspicua (Walker)	FG4	A	A	A	C
Oecetis osteni Milne	FG4			U	
Oecetis persimilis (Banks)	FG4	A	A	A	
Oecetis sphyra Ross	FG4	A		A	
Protoptila lega Ross	FG4	U		C	
Molanna tryphena Betten	FG4	U		C	
Hydroptila guniola Ross	FG4			C	
Hydroptila remita Blickle and Morse	FG4	C	C	C	
Hydroptila tridentata Holzenthal and Kelley	FG4			U	
Hydroptila spp.	FG4	A	A	C	U
Hydroptila waubesiana Betten	FG4			C	
Oxyethira lumosa Ross	FG4	C	C	C	
Oxyethira janella Denning	FG4	A	C	A	
Oxyethira savanniensis Kelley and Harris	FG4			C	
Oxyethira spp.	FG4	U	A	C	U
Pycnopsyche spp.	FG3	C	A	A	
Ironoquia sp.	FG3			U	
Ptilostomis ocellifera (Walker)	FG3		C	A	
Agarodes libalis Ross and Scott	FG3			U	
Agarodes wallacei Ross and Scott	FG3			U	
Agarodes sp.	FG3			C	
Anisocentropus pyraloides (Walker)	FG3			U	
Orthotrichia aegerfasciella (Chambers)	FG4		U		
Orthotrichia sp.	FG4		U		
Lepidoptera (Butterflies and Moths)					
Parapoynx obscuralis (Grote)	FG3	C	A	A	U
Paraponyx sp.	FG3		A		
Munroessa icciusalis (Walker)	FG3	C	A	A	U
Munroessa sp.	FG3		A		
Synclita sp.	FG3		C		
Coleoptera (Beetles)					
Ancyronyx variegata (Germar)	FG1	A	A	A	U
Dubiraphia quadrinotata (Say)	FG1	C		C	
Dubiraphia vittata (Melsheimer)	FG1	C	C	C	
Dubiraphia sp.	FG1		C		
Macronychus glabratus Say	FG3	A	A	A	U
Microcylloepus pusillus (Le Conte)	FG3	C	U		
Stenelmis markeli Motschulsky	FG2	C	C	C	

TABLE 41, Contd

Taxon	Functional Group*	Steel Creek	Steel Creek Swamp	Meyers Branch	Pen Branch Delta
Stenelmis sinuata LeConte	FG2	C	C	C	
Stenelmis sp.	FG2	A	C	C	
Donacia spp.	FG3	A	A	C	
Berosus aculeatus LeConte	FG4	C	C		
Berosus exiguus (Say)	FG4	C	C	C	
Berosus infuscatus LeConte	FG4	C	C	C	
Berosus spp.	FG4	C	C	C	U
Cymbiodyta blanchardi Horn			U		
Cymbiodyta sp.			U		
Enochrus blatchleyi (Fall)	FG1		C		
Enochrus cinctus (Say)	FG1		C		
Enochrus consortus Green	FG1		C		
Enochrus ochraceus (Melsheimer)	FG1	C	C	C	
Enochrus spp.	FG1	C	C	C	R
Hydrochara spangleri Smetana	FG4		C		
Hydrochara sp.	FG4	C	C	C	
Hydrobius fuscipes (L.)	FG4		C		
Helocombus bifidus (LeConte)	FG4		C		
Tropisternus collaris striolatus LeConte	FG4	C	C	C	C
Tropisternus lateralis nimbatus (Say)	FG4			C	
Tropisternus sp.	FG4	C	C		C
Hydrocanthus iricolor Say	FG4		C	C	
Hydrocanthus sp.	FG4	C		C	
Agabus sp.	FG4		C		
Celina augustata Aube	FG4		C		
Celina sp.	FG4		C		
Copelatus glyphicus (Say)	FG4		C		
Copelatus sp.	FG4		C		
Coptotomus sp.	FG4		C		
Hydroporus americanus Aube	FG4		C		
Hydroporus spp.	FG4	C	C	C	
Liodessus fuscatus Cotch	FG4		C		
Liodessus affinis (Say)	FG4		C		
Thermonectus ornaticollis Aube			C		
Haliplus punctatus Aube	FG3		C		
Peltodytes muticus (LeConte)	FG3		C		
Peltodytes oppositus Roberts	FG3		C		
Peltodytes sexmaculatus Roberts	FG3	C			
Peltodytes spp.	FG3		C	C	
Oulimnius latiusculus (LeConte)	FG1			U	
Gyrinus spp.	FG4	A		A	
Dineutus spp.	FG4	A		A	
Helichus basilis LeConte	FG3			C	
Helichus fastigiatus (Say)	FG3			C	
Ectopria nervosa Melsheimer	FG2			U	

TABLE 41, Contd

Taxon	Functional Group*	Steel Creek	Steel Creek Swamp	Meyers Branch	Pen Branch Delta
Diptera (Flies)					
Ceratopogonidae					
Bezzia spp.	FG4	C	C	C	A
Probezzia sp.	FG4	C	C	C	A
Forcipomyia sp.	FG4	C	C	C	
Chironomidae					
Tanypodinae					
Ablabesmyia spp.	FG4	C	C	C	C
Clinotanypus pinguis (Loew)	FG4	C	C	C	
Clinotanypus sp.	FG4	C	C	C	U
Larsia sp.	FG4	C	C	U	
Procladius bellus Loew	FG4	A	A	A	
Procladius sp.	FG4	C	C	A	A
Labrundia spp.	FG4			C	
Zavrelimyia sp.	FG4			U	
Diamesinea					
Potthastia longimanus (Kieffer)	FG1	C	C	C	
Odontomesa fulva (Kieffer)	FG1			U	
Orthocladiinae					
Brilla flaviforns (Johannsen)	FG3	C	C	C	
Corynoneura spp.	FG1	A	A	A	A
Cricotopus spp.	FG1	A	A	A	C
Heterotrissocladius marcidus (Walker)	FG1	C		U	
Paraphaenocladius sp.	FG1			U	
Orthocladius sp.	FG1			C	
Pseudorthocladius sp.	FG1			U	
Synorthocladius semivirens (Kieffer)	FG1			U	
Heterotrissocladius sp.	FG1	C	C	U	
Nanocladius sp.	FG1	U	U	C	
Eukiefferiella spp.	FG1	A		A	C
Parakiefferiella sp.	FG1	A	C	A	
Rheocricotopus spp.	FG1	A	C	A	
Synorthocladius sp.	FG1	C	C	U	
Tvetenia discoloripes group	FG1	C	C	C	C
Xylotopus par (Coquillett)	FG1			C	
Thienemaniella sp.	FG1			U	
Chironominae					
Chironomini					
Cryptochironomus spp.	FG4	C	C	A	C
Stenochironomus spp.	FG3			C	
Stictochironomus sp.	FG1			U	

TABLE 41, Contd

Taxon	Functional Group*	Steel Creek	Steel Creek Swamp	Meyers Branch	Pen Branch Delta
Parachironomus sp.	FG4			U	
Demicryptochironomus cuneatus (Townes)				U	
Demicryptochironomus sp.				U	
Dicrotendipes neomodestus (Molloch)	FG1			C	
Dicrotendipes spp.	FG1	C	A	C	A
Microtendipes spp.	FG1	C	C	C	
Paratendipes sp.	FG4			R	
Phaenopsecta sp.	FG2			U	
Paracladopelma sp.				R	
Paralauterborniella nigrohaltralis (Molloch)				R	
Paralauterborniella sp.		U	C	R	
Polypedilum spp.	FG1	A	A	A	A
Robackia claviger (Townes)	FG4	A	C	A	
Tribelos spp.	FG1	U	C	C	C
Tanytarsini					
Cladotanytarsus sp.		C	C	C	
Micropsectra spp.	FG1	C	C	C	C
Rheotanytarsus spp.	FG1	A	C	A	
Tanytarsus spp.	FG1	A	C	A	A
Chaoboridae					
Chaoborus punctipennis (Say)	FG4	C	C	C	
Culicidae					
Anopheles crucians-georgianus complex	FG1		C	C	
Anopheles punctipennis (Say)	FG1		C		
Anopheles spp.	FG1	U			
Aedes sp.	FG1		C		
Culex sp.	FG1		U		
Empididae					
Hemerodromia spp.	FG4	A	C	A	
Stratiomyiidae					
Odontomyia sp.	FG1	R	R		U
Tabanidae					
Chrysops spp.	FG1	C	C	C	U
Tabanus spp.	FG4		C		
Chlorotabanus crepuscularis (Bequaert)	FG4		R		

TABLE 41, Contd

Taxon	Functional Group*	Steel Creek	Steel Creek Swamp	Meyers Branch	Pen Branch Delta
Simuliidae					
Simulium tuberosum (Landstroem)	FG1	A		A	
Simulium vittatum Zetterstedt	FG1	U			
Simulium dixense Stone and Snoddy	FG1			C	
Simulium jonesi Stone and Snoddy	FG1			U	
Simulium sp.	FG1		C	C	R
Tipulidae					
Hexatomia spp.	FG1	U	U	C	
Tipula abdominalis (Say)	FG3	U	C	C	
Tipula furca Walker	FG3	U	C	C	
Tipula sp.	FG3	U		C	
Antocha opalizans Osten Saken	FG1	R		R	
Tanyderidae					
Protoplasma fitchii Osten Sacken				U	
Ptychopteridae					
Bittacomorpha sp.				U	
Athericidae					
Atherix lantha Webb				U	
Gastropoda (Snails, Limpets)					
Physa heterostropha (Say)	FG2	A	A	A	A
Campeloma decisum (Say)	FG2	U	C	C	
Ferrisia rivularis (Say)	FG2	U	C	C	
Menetus dilatatus (Gould)	FG2	C	U	C	
Gyraulus parvus (Say)	FG2	U	C	U	
Pseudosuccinea columella (Say)	FG2			U	
Goniobasis proxima (Say)	FG2			U	
Succinea ovalis Say	FG2	U			
Helisoma trivolvis (Say)	FG2	U	C		C
Helisoma anceps (Menke)	FG2	U	U		
Pelecypoda (Clams, Mussels)					
Sphaeriidae					
Corbicula fluminea (Muller)	FG1	A	C	C	
Elliptio complanata (Lightfoot)	FG1			C	

* FG1 - collectors; FG2 - scrapers; FG3 - shredders; FG4 - predators

TABLE V-3.42

Average Density, Biomass, Biomass per Individual and Number of Taxa, Total Number of Taxa and Number of Common Taxa Collected on Multiplate Samplers (October 1984-September 1985)

Station	Location/ Thermal Regime	Average Density (no./m^2)	Average Biomass (g AFDW/m^2)	Average Biomass/ Individual (mg AFDW/ind.)	Average Number of Taxa/ Sampler	Total Number of Taxa Collected*	Number Common Taxa Collected**
1	UTR-n	582.7	0.500	0.858	15.1	62	24
5	BD-t	1,626.9	0.118	0.073	8.2	36	11
6	BD-t	1,776.5	0.076	0.043	11.3	42	19
7	BD-t	1,131.9	0.173	0.153	15.1	61	29
8	BD-t	921.2	0.170	0.185	15.2	50	24
12	FM-n	2,109.3	0.351	0.166	19.0	67	26
14	FMD-t	1,012.1	0.158	0.156	6.3	45	18
15	FMD-t	1,532.8	0.088	0.057	8.2	35	19
16	FMD-t	1517.7	0.104	0.069	8.5	38	16
17	FMD-t	1,230.3	0.091	0.074	8.7	41	15
20	PB-n	695.2	0.187	0.269	15.2	70	20
21	PB-t	55.6	0.002	0.036	3.2	28	5
22	PBD-t	841.6	0.071	0.084	6.0	33	9
23	PBD-t	2,144.9	0.078	0.036	7.1	38	10
24	PBS-n	1,620.0	0.320	0.198	14.4	55	23
26	SC-n	496.0	0.553	1.115	11.6	55	20
27	SC-n	1,326.3	0.874	0.659	16.5	58	25
28	SC-n	940.3	0.192	0.204	14.4	66	24
29	SC-n	863.5	0.570	0.660	18.9	65	36
30	SCD-n	484.7	0.157	0.324	12.3	68	18
31	SCD-n	813.8	0.569	0.699	15.6	67	26
32	SCD-n	501.7	0.655	1.306	10.9	54	21
33	SCD-n	1,411.2	0.287	0.203	17.4	75	28
34	SCS-n	605.1	0.196	0.324	15.1	67	22
35	SCS-n	1,446.6	0.247	0.171	15.7	61	27
39	MB-n	565.0	0.073	0.129	13.5	60	22
40	MB-n	876.9	0.129	0.147	17.9	60	29
42	LTR-n	5,549.8	0.549	0.099	12.6	56	20
43	LTR-n	743.5	0.411	0.553	17.6	67	29

Note: Abbreviations are listed in Table V-3.2.

* Does not include individuals which were identified to a higher taxonomic level (e.g., order, family) when a lower taxonomic category (e.g., genus) within the group was present.

** Taxa with more than 10 individuals collected throughout the study and with individuals collected on more than one sample date.

Source: Firth et al., 1986.

TABLE V-3.43

List of Taxa with more than Ten Individuals that were Collected for more than one Month During the Study (October 1984-September 1985). All Data are from Multiplate Samplers.

Taxa	Functional Group	Stations																												
		1	5	6	7	8	12	14	15	16	17	20	21	22	23	24	26	27	28	29	30	31	32	33	34	35	39	40	42	43
Turbellaria	FG4			+	+	+	+									+						+	+	+	+	+			+	
Nematoda	FG1	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Oligochaeta	FG1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Hirudinea	FG4																				+	+	+	+	+	+			+	
Gastropoda	FG2																													
Family Ancylidae	FG2																													
Ferrissia rivularis	FG2		+	+	+	+										+	+	+	+	+	+		+	+	+		+	+		+
Family Hydrobiidae	FG2																													
Amnicola	FG2					+																+		+	+	+				+
Family Physidae																														
Physella heterostropha			+	+	+			+	+		+			+	+	+					+	+	+	+	+	+	+		+	
Family Planorbidae	FG2																													
Gyraulus parvus	FG2																				+								+	
Helisoma trivolvis	FG2				+											+					+	+	+						+	
Family Pleuroceridae																														
Elima (*Goniobasis* sp.)	FG2																													+
Family Viviparidae																														
Campeloma decisum																						+	+		+					+
Pelecypoda	FG1																													
Family Corbiculidae																														
Corbicula fluminea	FG1															+														
Crustacea																														
Isopoda																														
Asellus	FG1																				+	+	+	+						
Amphipoda	FG1																													
Family Gammaridae	FG1																													
Gammarus fasciatus	FG1																			+		+		+	+	+				
Family Talitridae																														
Hyalella azteca	FG1			+	+	+															+	+	+	+		+			+	

Source: Firth et al., 1986.

TABLE V-3.43, Contd

Taxa	Functional Group	Stations 1	5	6	7	8	12	14	15	16	17	20	21	22	23	24	26	27	28	29	30	31	32	33	34	35	39	40	42	43
Arachnida																														
Hydracarina		+	+	+	+	+	+		+							+	+	+	+	+		+	+	+	+	+	+	+	+	+
Insecta																														
Ephemeroptera	FG1																													
Family Baetidae	FG1																													
Baetis	FG1	+		+	+	+	+	+	+	+	+	+				+	+	+	+	+		+	+	+		+		+		+
Family Caenidae	FG1																													
Caenis			+	+	+			+	+	+	+			+	+	+			+	+	+	+	+	+	+	+	+	+		
Family Ephemerellidae	FG1																													
Ephemerella invaria	FG1	+										+				+			+		+							+		+
Eurylophella temporalis	FG1						+											+	+	+					+	+		+		+
Family Heptageniidae	FG1																													
Heptagenia	FG2	+																												
Stenacron interpunctatum	FG1				+					+	+					+						+		+	+	+				
Stenonema modestum	FG1	+		+	+	+	+	+	+	+	+	+				+	+	+	+	+		+		+	+	+	+	+		+
Family Neoephemeridae	FG1																													
Neoephemera youngi	FG1																			+	+							+		+
Family Oligoneuriidae																														
Isonychia										+																		+		
Family Tricorythidae	FG1																													
Tricorythodes	FG1			+				+	+			+					+	+	+	+								+		+
Odonata	FG4																													
Anisoptera	FG4																													
Family Libellulidae																														
Erythemis simplicicollis																					+									
Pachydiplax longipennis																+														
Zygoptera	FG4																													
Family Calopterygidae	FG4																													
Calopteryx	FG4																									+				
Hetaerina	FG4				+																									
Family Coenagrionidae	FG4																													
Argia	FG4				+																			+			+			
Enallagma	FG4				+																+	+	+	+	+					

Source: Firth et al., 1986.

TABLE V-3.43, Contd

	Functional	Stations																												
Taxa	Group	1	5	6	7	8	12	14	15	16	17	20	21	22	23	24	26	27	28	29	30	31	32	33	34	35	39	40	42	43
Plecoptera	FG4																													
Family Perlidae	FG4																													
Acroneuria abnormis	FG4	+																		+										+
Paragnetina fumosa	FG4	+															+	+	+	+							+	+		+
Perlesta placida	FG4	+					+					+						+	+	+							+	+		+
Family Perlodidae																														
Helopicus bogaloosa	FG4																	+		+										
Isoperla	FG4	+																		+										
Family Pteronarcyidae	FG3																													
Pteronarcys dorsata	FG3	+																		+										
Family Taeniopterygidae	FG3																													
Taeniopteryx longicera	FG3						+													+										
Taeniopteryx robinae	FG3						+																					+		
Hemiptera	FG4																													
Coleoptera	FG4																													
Family Elmidae	FG1																													
Ancyronyx variegatus	FG1						+					+						+	+	+							+	+		
Macronychus glabratus	FG1	+				+	+					+				+	+	+	+	+				+	+	+	+	+		+
Microcylloepus pusillus	FG1																	+												
Stenelmis	FG2	+				+											+	+	+											+
Family Eubriidae																														
Ectopria nervosa																												+		
Family Gyrinidae																														
Dineutes					+																					+				
Megaloptera																														
Family Corydalidae	FG4																													
Corydalus cornutus	FG4	+			+	+	+					+					+	+	+	+								+	+	
Trichoptera																														
Family Brachycentridae	FG1																													
Brachycentrus	FG1	+																	+	+								+		+
Family Hydrospsychidae	FG1																													
Cheumatopsyche spp.	FG1	+		+	+	+	+	+	+	+	+	+				+	+	+	+	+		+	+	+		+	+	+	+	+
Hydropsyche	FG1	+	+	+	+	+	+	+	+	+	+						+	+	+	+				+					+	
Macrostemum carolina	FG1						+																			+				

Source: Firth et al., 1986.

TABLE V-3.43, Contd

Taxa	Functional Group	Stations																												
		1	5	6	7	8	12	14	15	16	17	20	21	22	23	24	26	27	28	29	30	31	32	33	34	35	39	40	42	43
Family Hydroptilidae	FG4																													
Hydroptila	FG4					+		+									+													
Orthotrichia	FG4																									+				
Oxyethira	FG4						+		+							+						+	+	+	+	+	+			
Family Leptoceridae	FG1																													
Nectopsyche candida	FG3				+															+										
Oecetis	FG1					+	+					+				+				+		+		+		+	+	+	+	+
Family Philopotamidae	FG1																													
Chimarra	FG1					+	+	+	+	+	+																	+		
Family Polycentropodidae	FG1																													
Cernotina	FG4				+																									
Cyrnellus	FG1																												+	
Neureclipsis	FG1				+	+		+	+																					
Polycentropus	FG4				+																									
Family Phychamyiidae																														
Lype diversa												+								+							+	+		+
Diptera																														
Family Ceratopogonidae	FG4			+	+	+	+	+	+	+	+	+		+	+	+				+	+	+	+	+	+	+	+		+	+
Subfamily Forcipamyiinae	FG1							+	+	+																				
Family Chaoboridae	FG4																													
Chaoborus punctipennis	FG4															+														
Family Chironomidae	FG1																													
Subfamily Chironominae																														
Tribe Chironomini	FG1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Robackia claviger	FG4																			+										
Tribe Tanytarsini	FG1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Subfamily Diamesinae																														
Potthastia	FG1																					+		+						
Subfamily Orthocladiinae		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Subfamily Tanpodinae		+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Family Empididae	FG4	+	+	+	+	+	+					+					+	+	+	+							+	+	+	+
Family Simulidae	FG1																													
Simulium	FG1	+					+					+					+	+	+	+							+	+	+	+

FG1 - Collector-gatherers, collector-filterers; FG2 - scrapers; FG3 - shredders; FG4 - piercer-herbivores, piercer-carnivores, pierrcer-engulfers.

Source: Firth et al., 1986.

retention devices (i.e., snags), macrophyte abundance, and flow characteristics are probably responsible for the similarities in common taxa observed at the above stations. The delta and swamp area of Steel Creek (1984-1985 Stations 30, 31, 32, 33, 34, and 35) also had numbers of taxa similar to the nonthermal reference stations (Table V-3.43). The total number of macroinvertebrates collected in the Steel Creek Delta and swamp ranged from 54 to 75; the number of common taxa ranged from 18 to 28. The variety of habitats, microhabitat structure (e.g., wood volume, macrophyte richness and abundance, and current velocity regimes) at these stations were probably responsible for the high richness found on the multiplate samplers. Taxa that best distinguish these stations from those upstream at Stations 26-29 included turbellarians, hirudineans, the snail genus Amnicola and species Physella heterostropha, Helisoma trivolvis, and Campeloma decisum, the isopod genus Asellus, the amphipod species Gammarus fasciatus and Hyalella azteca, and the following insect genera: Heptagenia, Argia, Oxyethira, and Oecetes.

Taxa that were important above the delta (Stations 26-29) but which were either absent or in relatively low abundance in the delta/swamp stations included the following insect taxa: Tricorythodes, Paragnetina fumosa, Perlesta placida, Ancyronyx variegatus, Macronychus glabratus, Stenelmis, Corydalus cornutus, Hydropsyche, and Simulium.

The thermal Pen Branch sites (Stations 21, 22, and 23) and Four Mile Creek sites (Stations 14, 15, 16, and 17) had fewer taxa than other sites (Table V-3.42). Pen Branch Creek and the Pen Branch Delta had the lowest numbers of taxa. The average number of taxa collected at the Four Mile Creek sites was not as low as at the Pen Branch sites because there were extensive periods when C Reactor was shut down and not discharging thermal effluent into Four Mile Creek. The number of taxa collected at the Four Mile sites when the reactor was not operating was considerably higher than during reactor operation (Figure V-3.26).

At the Pen Branch stations, the only insects that were common were dipterans. At the Four Mile Creek sites, the following insect taxa were common: Baetis, Caenis, Stenonema modestum, Tricorythodes, Cheumatopsyche spp., Hydropsyche, Chimarra, and Neureclipsis.

Many of the insect taxa found to be common at Stations 7 or 8 are not common or absent from Stations 5 and 6 were common at only one of the two downstream stations (Table V-3.43). These included the gastropod Helisoma trivolvis, and the insects Stenacron interpunctatum, Hetaerina, Argia, Enallagma, Dineutus, Nectopsyche candida, Cernotina, and Polycentropus at Station 7, and the gastropod Amnicola and the insects Macronychus glabratus,

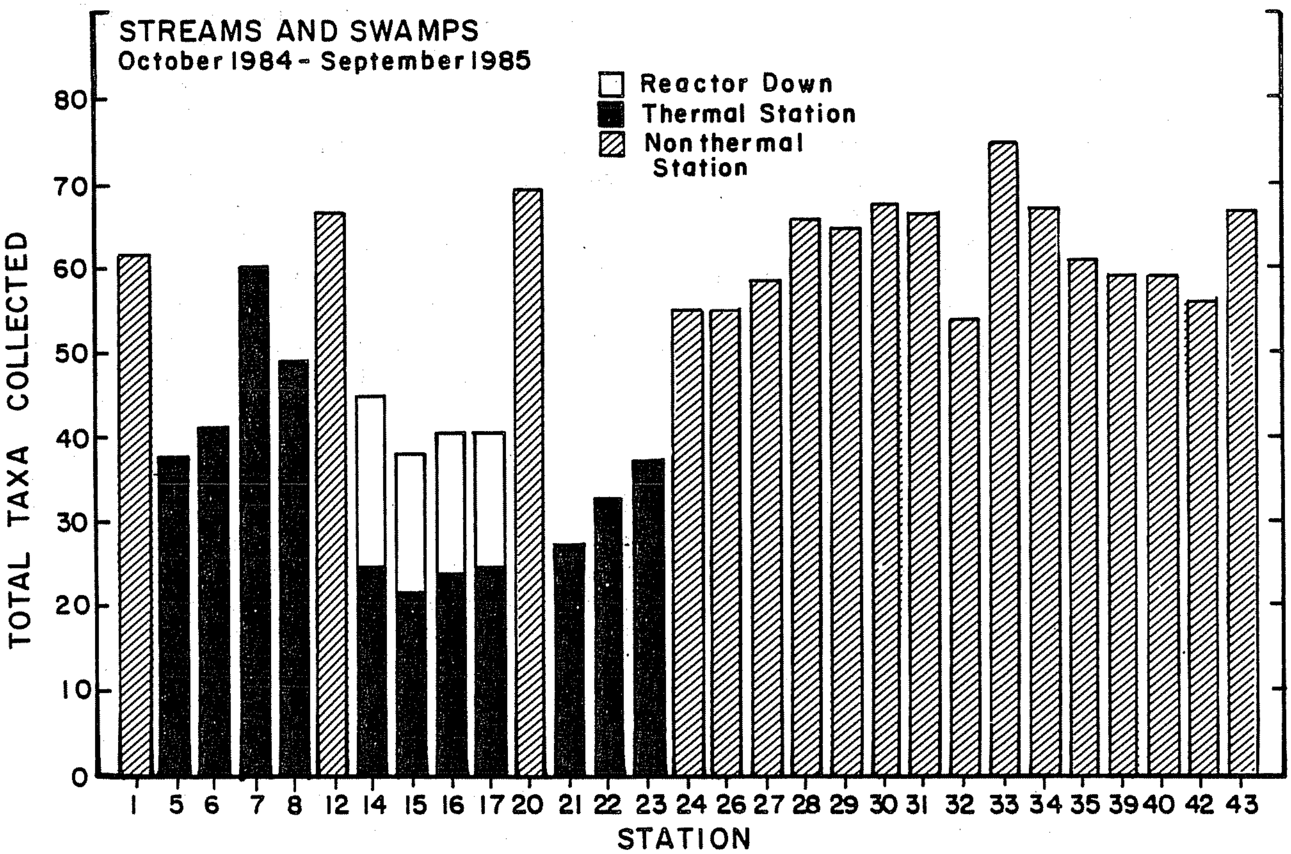


FIGURE V-3.26. Total Number of Invertebrate Taxa Collected from Multiplate Samplers at Stations in Thermal and Nonthermal Streams and Swamps (October 1984-September 1985).
Source: Firth et al., 1986.

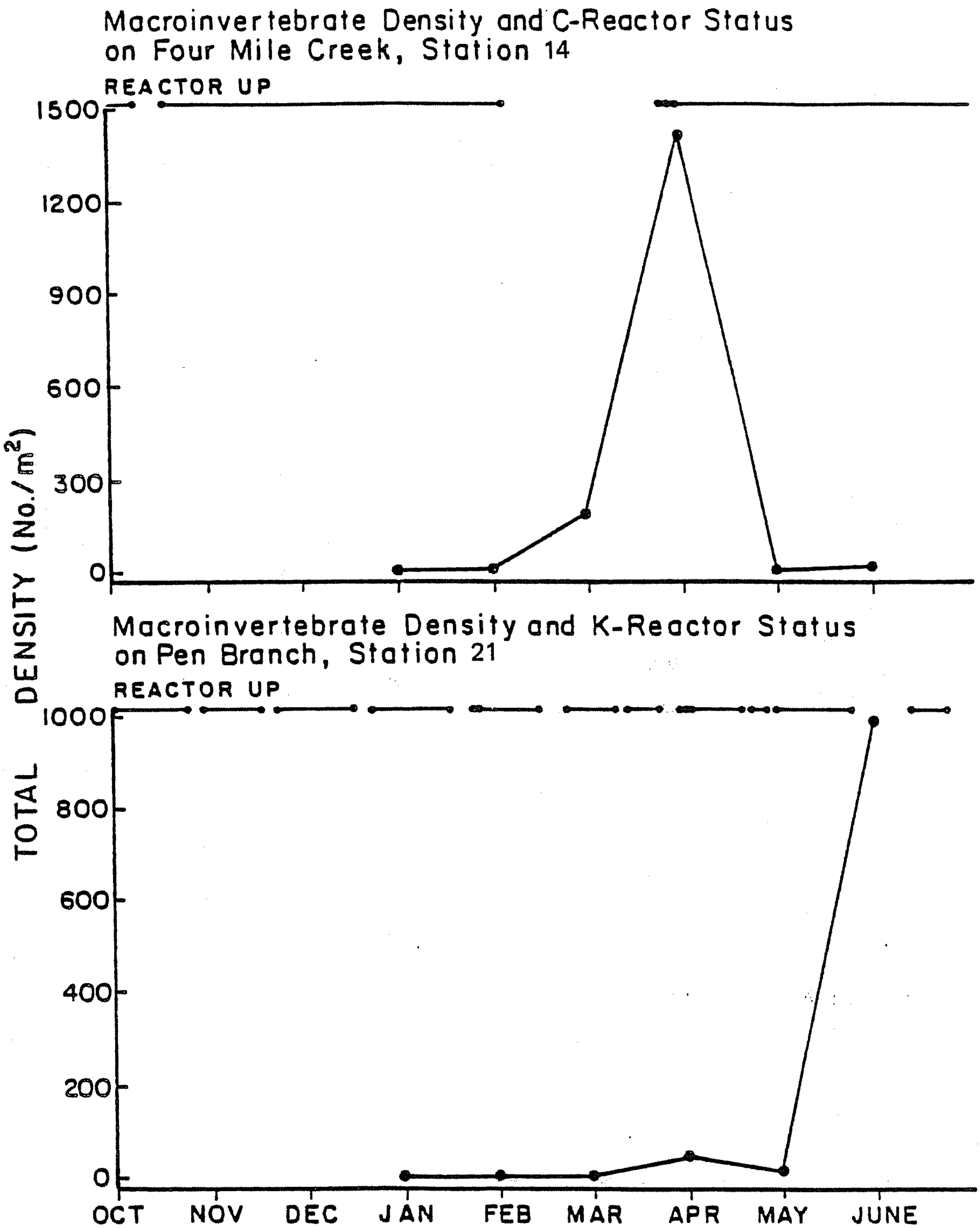
Microcylloepus pusillus, Hydroptilla, Oecetis, and Chimmara. Taxa common to Stations 7 and 8 but not common or absent at Stations 5 and 6 were few in number, but included the insects Corydalus cornutus and Neureclipsis.

The sites at Stations 7 and 8 on Beaver Dam Creek had numbers of taxa similar to those of the reference sites. However, the numbers of taxa at Stations 5 and 6, upstream on Beaver Dam Creek were lower. The lower numbers of taxa at Station 5 may be due in part, to high water velocities and lack of suitable substrate or may have been caused by pollutants in the effluent from D Area (Firth et al., 1986). However, with the exception of some minor violations, the D-Area effluent outfalls consistently met NPDES standards during the study period. In view of the compliance with NPDES standards, it appears unlikely that the levels of pollutants released from D Area during the study period were sufficient to adversely impact the macroinvertebrates at Stations 5 and 6. Variability in the numbers of macroinvertebrate taxa in upper Beaver Dam Creek may be related to perturbations that occurred prior to the initiation of the study or to habitat differences unrelated to the levels of pollutants in the various D-Area effluents. Furthermore, Stations 7 and 8 had structural features that may have enhanced the macroinvertebrate populations (abundant aquatic vegetation at Station 7 and abundant trailing vegetation at Station 8).

V.3.7.3.2 Macroinvertebrate Density

The average macroinvertebrate densities at the 1983-1984 stream sites are presented in Table V-3.39. All sampling methods, except the sediment cores, resulted in considerably higher densities at the nonthermal stream sites than at the thermal sites. The macroinvertebrate densities in Four Mile Creek and Pen Branch Creek were affected by reactor activity. Figure V-3.27 shows the relationship between reactor operation and macroinvertebrate densities at Four Mile Creek Station 14 and Pen Branch Station 21. In Four Mile Creek, during a C-Reactor shutdown in February and March 1984, there was rapid colonization by true flies, oligochaetes, and nematodes; however, macroinvertebrate densities plummeted after reactor startup. Macroinvertebrate densities at Pen Branch Station 21 were generally low. K-Reactor operations were more irregular and down periods were of shorter duration. There was, however, a large increase in macroinvertebrate densities in Pen Branch during a prolonged shutdown in May 1984.

Tables V-3.44 and V-3.45 present average macroinvertebrate densities from multiplate samplers at the 1983-1984 stream and swamp sites, respectively. The densities at Station 4 in Pen Branch were consistently the lowest, but those for Stations 2 and 3



Note: Reactor online periods are indicated by solid lines connecting dots at the top of each graph.

FIGURE V-3.27. The Sum of Macroinvertebrates Collected (total no./m^2) at Severely Thermal Sites (1983-1984 Station 14 on Four Mile Creek and 1983-1984 Station 21 on Pen Branch) in Relation to Reactor Operational Status (January-June 1984).
Source: Kondratieff and Kondratieff, 1985.

TABLE V-3.44

Composition of Stream Macroinvertebrate Community, Presented as Average Densities (no./m^2 multiplate sampler) at Stations 5 (Beaver Dam Creek), 13A and 14 (Four Mile Creek, 21 (Pen Branch, 26 and 28 (Steel Creek), 39 and 40 (Meyers Branch) (January-August 1984)

	Stations							
	Mildly Thermal	Severely Thermal			Post-thermal		Nonthermal	
Taxa	5	13A	14	21	26	28	39	40
Coelenterata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Turbellaria	0.0	0.0	0.0	0.0	0.3	0.5	0.0	0.4
Nematoda	395.3	6.6	99.0	8.8	14.4	17.6	7.4	17.3
Annelida								
Oligochaeta	454.6	21.8	43.4	1.9	239.0	61.5	15.9	31.9
Hirudinea	0.5	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Crustacea								
Isopoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphipoda	0.0	0.5	0.3	0.0	0.0	1.3	0.3	1.6
Decapoda	0.0	0.0	0.0	0.0	0.0	1.3	0.3	1.0
Hydracarina	32.2	0.3	1.0	0.5	41.8	29.0	14.6	38.9
Insecta								
Collembola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Odonata	0.8	0.0	0.0	0.0	0.0	9.0	0.3	0.0
Ephemeroptera	0.8	0.3	1.9	1.3	195.9	202.8	100.0	121.6
Plecoptera	0.0	0.0	0.0	0.0	6.6	32.5	12.2	67.6
Hemiptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Megaloptera	0.3	0.0	0.0	0.0	3.9	2.9	0.3	0.8
Neuroptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trichoptera	2.6	1.0	4.5	5.6	81.5	47.6	40.7	63.6
Lepidoptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coleoptera	0.8	0.5	0.8	1.0	86.8	50.6	9.8	23.7
Diptera	651.9	234.8	436.3	57.8	3,517.2	4,063.5	1,657.1	3,064.4
Gastropoda	56.9	2.4	7.2	0.5	0.3	1.0	2.4	3.7
Pelecypoda	1.1	0.0	0.3	0.0	0.0	3.7	0.0	2.6

Source: Kondratieff and Kondratieff, 1985.

TABLE V-3.45

Composition of Swamp Macroinvertebrate Community, Presented as Average Densities (no./m^2 multiplate sampler) at Stations 22 and 23 (Pen Branch swamp) and Stations 33 and 35 (Steel Creek swamp) (January-August 1984)

	Stations			
	Thermal		Post-thermal	
Taxa	Open Canopy 22	Closed Canopy 23	Open Canopy 33	Closed Canopy 35
Coelenterata	0.0	0.0	0.0	0.0
Turbellaria	0.3	0.0	5.8	9.3
Nematoda	672.7	601.3	7.9	20.7
Annelida				
Oligochaeta	664.4	159.7	348.9	335.8
Hirudinea	0.0	0.0	2.3	2.6
Crustacea				
Isopoda	0.0	0.0	11.8	0.5
Amphipoda	0.0	0.0	293.0	108.0
Decapoda	0.0	0.0	1.0	0.5
Hydracarina	4.2	0.8	20.0	88.9
Insecta				
Collembola	0.0	0.0	0.0	0.0
Odonata	0.3	1.0	12.4	10.9
Ephemeroptera	8.2	93.7	193.6	242.2
Plecoptera	0.3	0.0	0.3	0.3
Hemiptera	0.0	0.0	0.6	0.3
Neuroptera	0.0	0.0	0.0	0.3
Trichoptera	6.6	2.4	140.0	346.3
Lepidoptera	0.0	0.0	2.0	1.0
Coleoptera	0.5	1.0	7.9	17.0
Diptera	79.8	491.1	4,712.7	5,348.1
Gastropoda	300.0	80.4	160.9	70.0
Pelecypoda	0.0	0.0	0.3	0.3
Total	1,737.3	1,431.4	5,921.4	6,613.0

Source: Kondratieff and Kondratieff, 1985.

(Four Mile Creek) were also low relative to the post-thermal and nonthermal sites. The average densities at Station 3 (Four Mile Creek) were misleading because they included sampling during a prolonged C-Reactor shutdown during which there was rapid colonization in Four Mile Creek (Gladden et al., 1985). Three taxonomic groups dominated the invertebrate communities at all stream stations: true flies (Diptera, primarily the chironomid midges), nematodes, and oligochaetes. At the nonthermal stream sites, the macroinvertebrate community also included significant numbers of mayflies (Ephemeroptera), caddisflies (Trichoptera), and stoneflies (Plecoptera). These orders, which include thermally sensitive species, were usually not abundant in the thermal streams (Gladden et al., 1985).

The average densities of invertebrates found in the sediments of the stream sites in 1983-1984 are presented in Table V-3.39. High densities of a few macroinvertebrate taxa (i.e., chironomid midges, and oligochaetes) were found in the sediments at the severely thermal sites. Martin and Gentry (1974) have shown that sediments act as refugia for macroinvertebrates by reducing temperature extremes and allowing for temperature acclimation.

Average densities of macroinvertebrates collected from the thermal Pen Branch Delta swamp during the 1983-1984 study year were generally lower than those collected in the nonthermal Steel Creek swamp with especially large differences evident in the results of multiplate sampling (Table V-3.40). Based on the results of the multiplate sampling, the greatest difference in the thermal and nonthermal swamp stations was the one to two orders of magnitude higher densities of nematodes and the lower densities of most other taxa groups. The open canopy Pen Branch site (Station 22) had higher densities than the closed canopy site (Station 23).

During the 1984-1985 sampling year, the average densities of macroinvertebrates at the nonthermal stream reference sites (Stations 1, 12, 20, 39, and 40) ranged from 565 to 2,109 organisms/m^2 (Table V-3.42; Figure V-3.28). The average densities in post-thermal Steel Creek (Stations 26-29) ranged from 496 to 1,326 organisms/m^2. Densities in the Steel Creek Delta (Stations 30-33) were similar, ranging from 484 to 1,411 organisms/m^2, while densities in the Steel Creek swamp (Stations 34 and 35) ranged from 606 to 1,446 organisms/m^2. No downstream trends in macroinvertebrate density were evident.

The average densities of macroinvertebrates in most of the thermal streams were high, ranging from 1,012 to 1,533 organisms/m^2 in Four Mile Creek and 56 to 2,145 organisms/m^2 in Pen Branch (Table V-3.42). At these thermal sites there were large numbers of nematodes, oligochaetes, and chironomids (Diptera: Chironomidae), which could tolerate high temperatures, but relatively few other

FIGURE V-3.28. Annual Average Density (no./m^2) of Invertebrates on Multiplate Samplers at Stations in Thermal and Nonthermal Streams and Swamps (October 1984–September 1985)

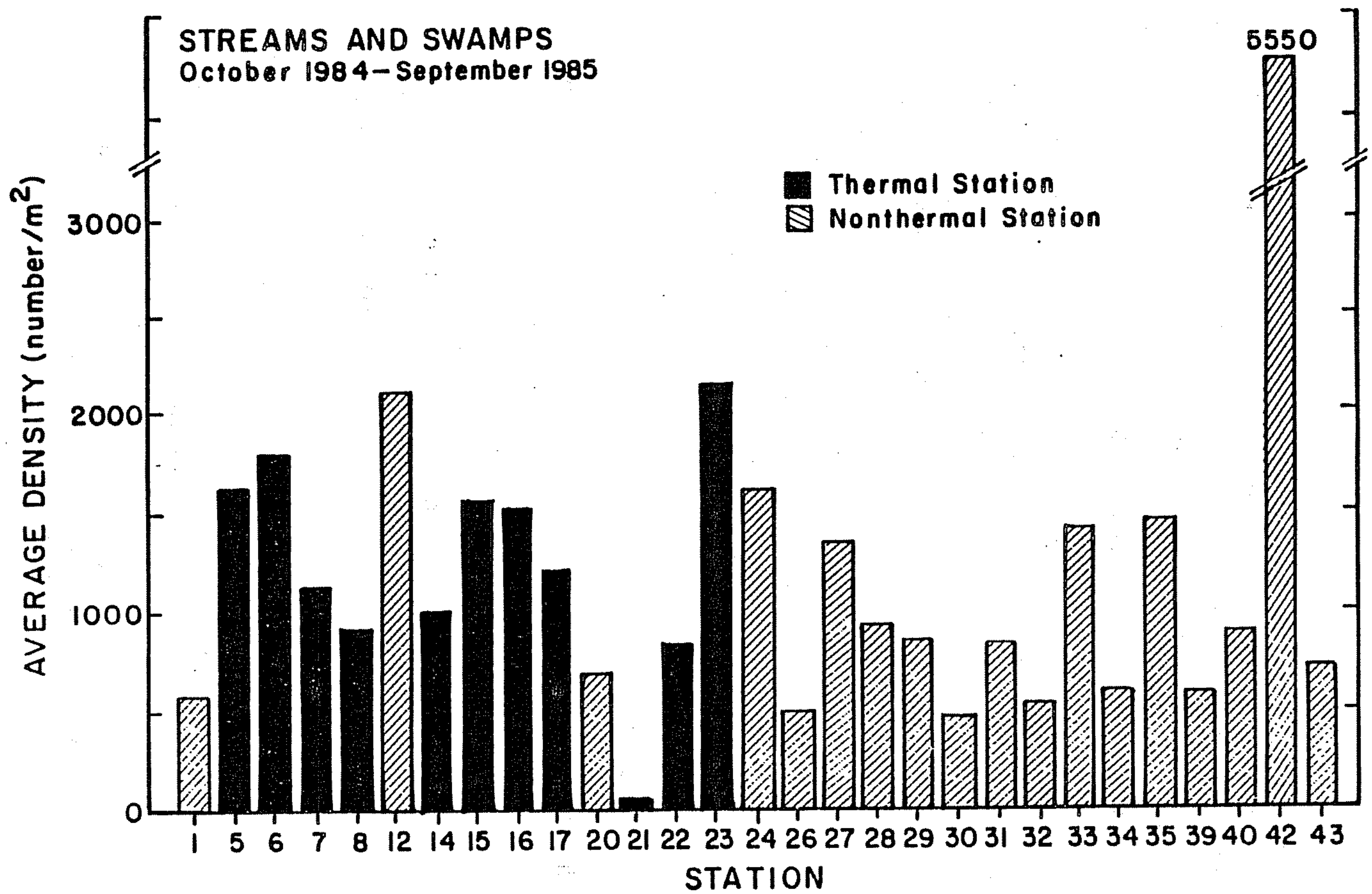


Figure 4-10. Annual average density (number/m^2) of invertebrates on multiplate samplers at stations in thermal and nonthermal streams and swamps (SSPLSA). October 1984 - September 1985.

taxa. Nematodes were a major component of the total density of invertebrates at Four Mile Creek and Pen Branch stations during times when the average water temperature exceeded 35°C (Firth et al., 1986).

In Four Mile Creek, the lowest density was at Station 14, the site closest to the reactor discharge point. Similarly, the site in Pen Branch with the highest water temperature (Station 21) had a very low macroinvertebrate density, while macroinvertebrate densities were higher at the cooler downstream sites. Therefore, it appears that the very high temperatures at the thermal stations nearest the reactor effluent outfall exceeded the thermal tolerances of most species of invertebrates.

Trends were very different in Beaver Dam Creek, where highest macroinvertebrate densities were found at the station nearest to the discharge point. In this case, the moderately elevated temperatures could be tolerated by many invertebrate taxa, and both the density and richness of the macroinvertebrate community were high.

In summary, the results of the study indicate that high temperatures, such as those experienced downstream of the reactor effluent outfall on Pen Branch and Four Mile Creek, reduce the occurrence and abundance of many intolerant taxa, while densities of a few tolerant taxa may increase dramatically.

V.3.7.3.3 Average Annual Biomass of Invertebrates

The macroinvertebrate biomass results (AFDW) from the 1983-1984 sampling program are illustrated in Figures V-3.29 and V-3.30. Biomass values in the thermal streams were much lower than in the nonthermal streams. Few macroinvertebrate taxa could survive the high stream temperatures that occurred during reactor operation (Kondratieff & Kondratieff, 1985) and those that did survive were generally small organisms, such as nematodes, oligochaetes, and chironomids.

The 1984-1985 macroinvertebrate biomass results reinforced the first years findings (Table V-3.42). The average macroinvertebrate biomass at the nonthermal reference streams (Upper Three Runs Creek Station 1, Four Mile Creek Station 12, Pen Branch Station 20, and Meyers Branch Station 39 and 40) ranged from 0.07 to 0.50 g AFDW/m^2, and were generally higher than at the thermal stream sites. In Steel Creek (Stations 26-29), macroinvertebrate average biomass ranged from 0.19 to 0.87 g AFDW/m^2. As in 1983-1984, the thermal stream sites had low average invertebrate biomass (Figure V-3.31). Biomass at the Pen Branch sites ranged from 0.002 to 0.078 g AFDW/m^2. The site at Station 21, which had the highest temperatures and wide fluctuations in discharge, had a lower

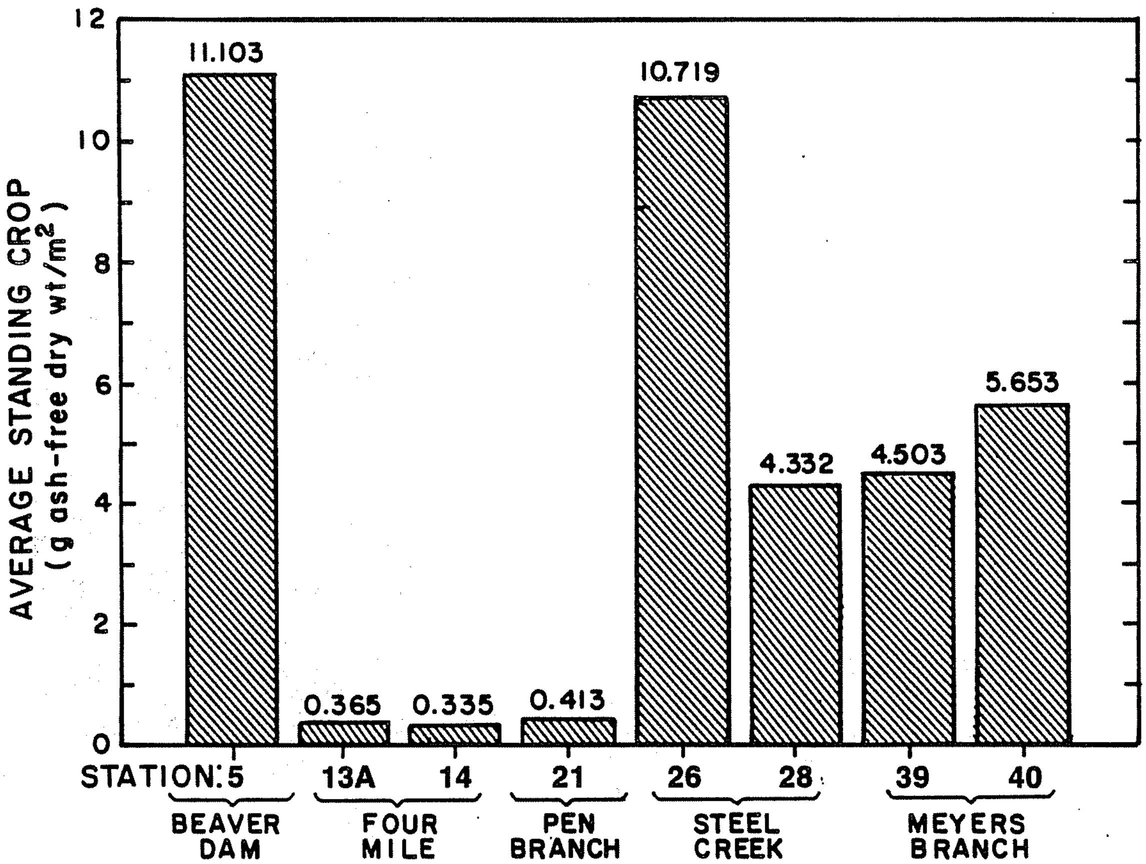


FIGURE V-3.29. Total Standing Crop (g AFDW/m^2) of Macroinvertebrates from 7 Collections from Hester Dendy Samplers at 1983-1984 Stations on Beaver Dam Creek (5), Four Mile Creek (13A,14), Pen Branch (21), Steel Creek (26,28), and Meyers Branch (39,40) (January-August 1984).
Source: Kondratieff and Kondratieff, 1985.

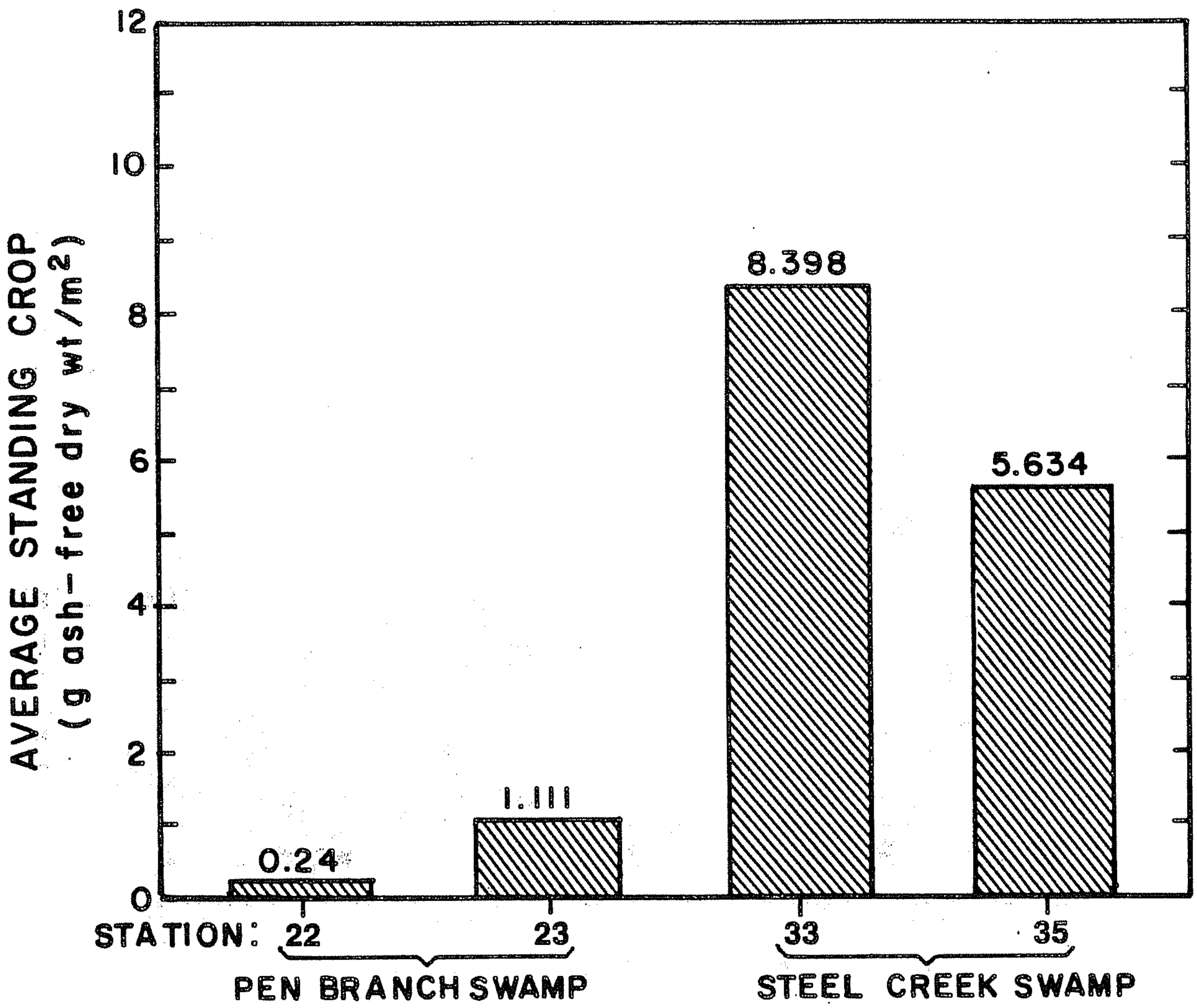


FIGURE V-3.30. Total Standing Crop (g AFDW/m^2) of Macroinvertebrates from 7 Collections from Hester Dendy Samplers at 1983-1984 Stations on Pen Branch Swamp (22,23) and Steel Creek Swamp (33,35). (January-August 1984). Source: Kondratieff and Kondratieff, 1985.

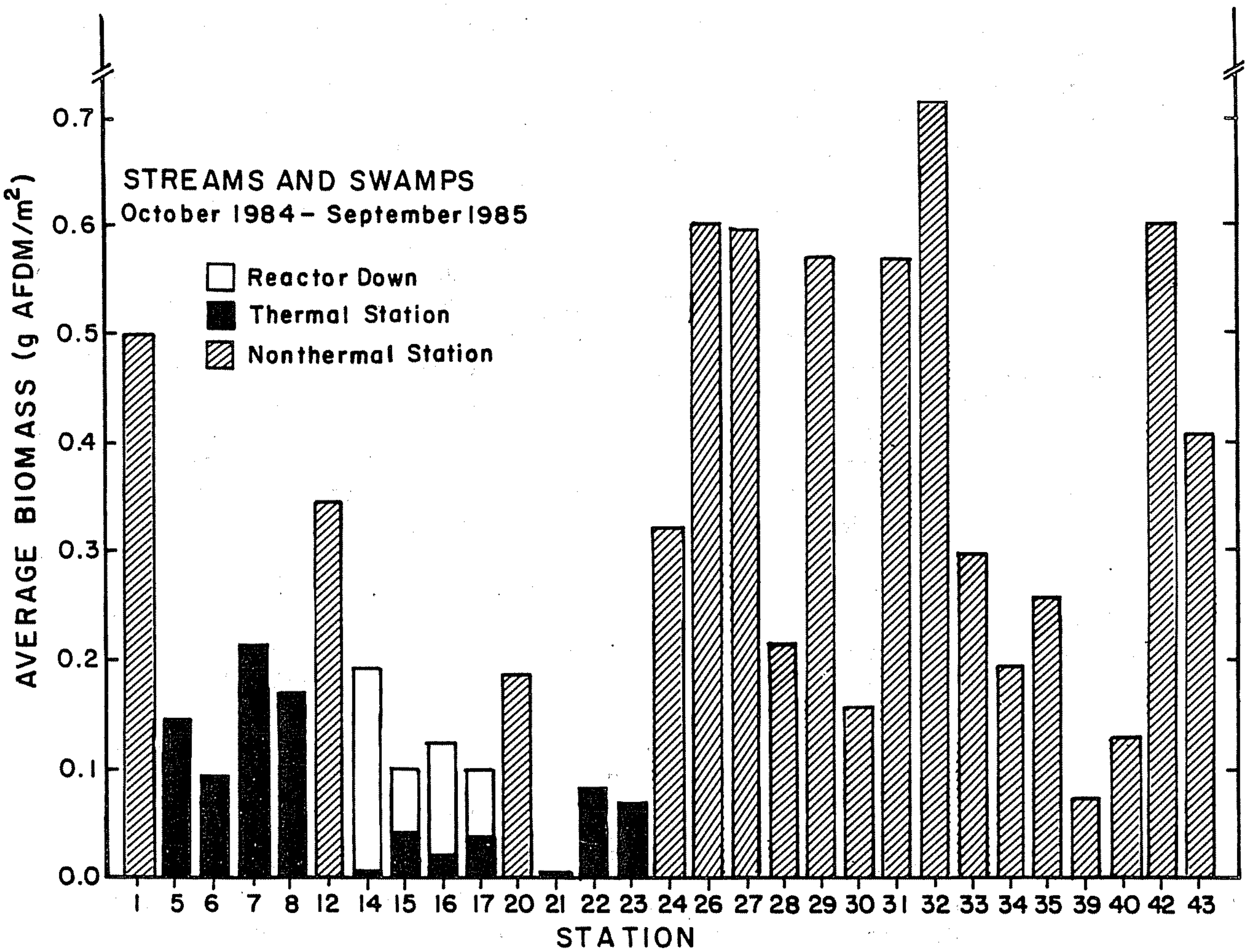


FIGURE V-3.31. Annual Average Biomass (g AFDW/m^2) of Invertebrates on Multiplate Samplers at 1984-1985 Stations in Thermal and Nonthermal Streams and Swamps. (October 1984-September 1985).
Source: Firth et al., 1986.

invertebrate biomass than any other site. Four Mile Creek (Stations 14-17) also had low average biomass (0.088 to 0.158 g AFDW/m^2), especially during months when the reactor was operating (October 1984-June 1985). In July, after cessation of C-Reactor operations, there was an increase in macroinvertebrate biomass at three of the four thermal stations in Four Mile Creek, and over the remainder of the study, biomass increased at Stations 14-17.

Beaver Dam Creek (Stations 5-8) had average biomass lower than most reference stream stations in 1984-1985. The two downstream stations had higher biomass than the stations closer to the discharge. Although the maximum water temperatures in Beaver Dam Creek rarely reached 35°C, macroinvertebrate biomass may have been affected by the elevated temperatures, and possibly by pollutants in the D-Area effluent (Firth et al., 1986). However, with the exception of some minor violations, the D-Area effluent outfalls consistently met NPDES standards during the study period. In view of the compliance with NPDES standards, it appears unlikely that the levels of pollutants released from D Area during the study period were sufficient to adversely impact the macroinvertebrate biomass in upper Beaver Dam Creek. Variability in macroinvertebrate biomass in Beaver Dam Creek may be related to perturbations that occurred prior to the initiation of the study. It should be noted that in Figure V-3.29 and the discussion of the 1983-1984 results, the biomass at Beaver Dam Creek Station 5 was higher than the biomass at the reference stations (Meyers Branch Stations 39 and 40. Although the biomass at Beaver Dam Creek stations was lower than at most reference stations in 1984-1985, it was higher than the biomass found at the Meyers Branch sites.

The average biomass at the Steel Creek Delta stations (Stations 30-33) ranged from 0.16 to 0.66 g AFDW/m^2. At the Steel Creek swamp stations (Stations 34 and 35), the average macroinvertebrate biomass were 0.20 and 0.25 g AFDW/m^2 (Table V-3.42).

In summary, thermal discharges into Four Mile Creek and Pen Branch had deleterious effects on macroinvertebrate biomass. In Pen Branch, where heated discharge was most severe (with maxima often exceeding 50°C), biomass was very low. Wide discharge fluctuations probably also contributed to the lower macroinvertebrate biomass. Biomass was also quite low in Four Mile Creek, especially during months when heated discharges occurred. Invertebrates responded favorably to cessation of thermal discharges in June 1985, with the pronounced increase in biomass. Under neither ambient or elevated thermal regimes were there any significant differences in biomass of functional groups among any of Four Mile Creek stream stations. Although biomass was lower at the Beaver Dam Creek stations than at comparable reference stations, water temperatures seldom exceeded 35°C, and were probably not responsible for the lower biomass. Other water quality parameters or differences in habitat may have been responsible. Average annual biomass of macroinvertebrates in Steel Creek corridor stations was similar to that at comparable reference stations, with large predatory insect larvae contributing a large proportion of the biomass at stations in both these groups.

V.3.7.3.4 Macroinvertebrate Functional Groups

Invertebrates collected on the multiplate samplers were sorted into functional feeding groups using the classification described by Merritt and Cummins (1984) (see Table V-3.38). The functional group breakdown of macroinvertebrate biomass from the 1983-1984 stream sites is presented in Figures V-3.32 and V-3.33. At the thermal stream sites, collector-gatherers and collector-filterers, primarily thermally tolerant filter-feeding midges and oligochaete worms, comprised a large percentage of the biomass (Kondratieff & Kondratieff, 1985). Predators were also important in the thermal stream sites.

At the Steel Creek sites (Stations 26 and 28) and at Meyers Branch Station 39, collector-gatherers dominated the macroinvertebrate biomass. The upstream Meyers Branch site had a more even distribution between collector-gatherers, predators, and scrapers.

The relative biomass of functional groups at Pen Branch 1983-1984 swamp stations is presented in Figure V-3.34. At Station 22, scrapers (primarily Physa) contributed over 50% of the total biomass. The relatively cooler, closed canopy Pen Branch Station 23 had a high proportion of collector-gatherers and a very low percentage of scrapers. Macroinvertebrate biomass at the Steel Creek swamp sites was more evenly distributed among several functional groups. The relatively large predator percentage was due to large sized individuals: damselflies (Odonata: Zygoptera) and leeches (Hirudinea). The functional groups present in the Steel Creek swamp were represented by many species, whereas the functional groups in Pen Branch swamp were represented by only a few thermally tolerant species (Kondratieff & Kondratieff, 1985).

Table V-3.46 presents the 1984-1985 mean biomass of each functional group at each sampling site. At the nonthermal reference sites, large predators such as stoneflies (Plecoptera: Perlidae) and dobsonflies (Megaloptera: Corydalus) contributed a large portion of the biomass. Collector gatherers and collector-filterers were also important. Shredders were important in Upper Three Runs Creek. There were no significant differences in biomass of any functional group at Four Mile Creek Stations 14 and 17, regardless of reactor operating status.

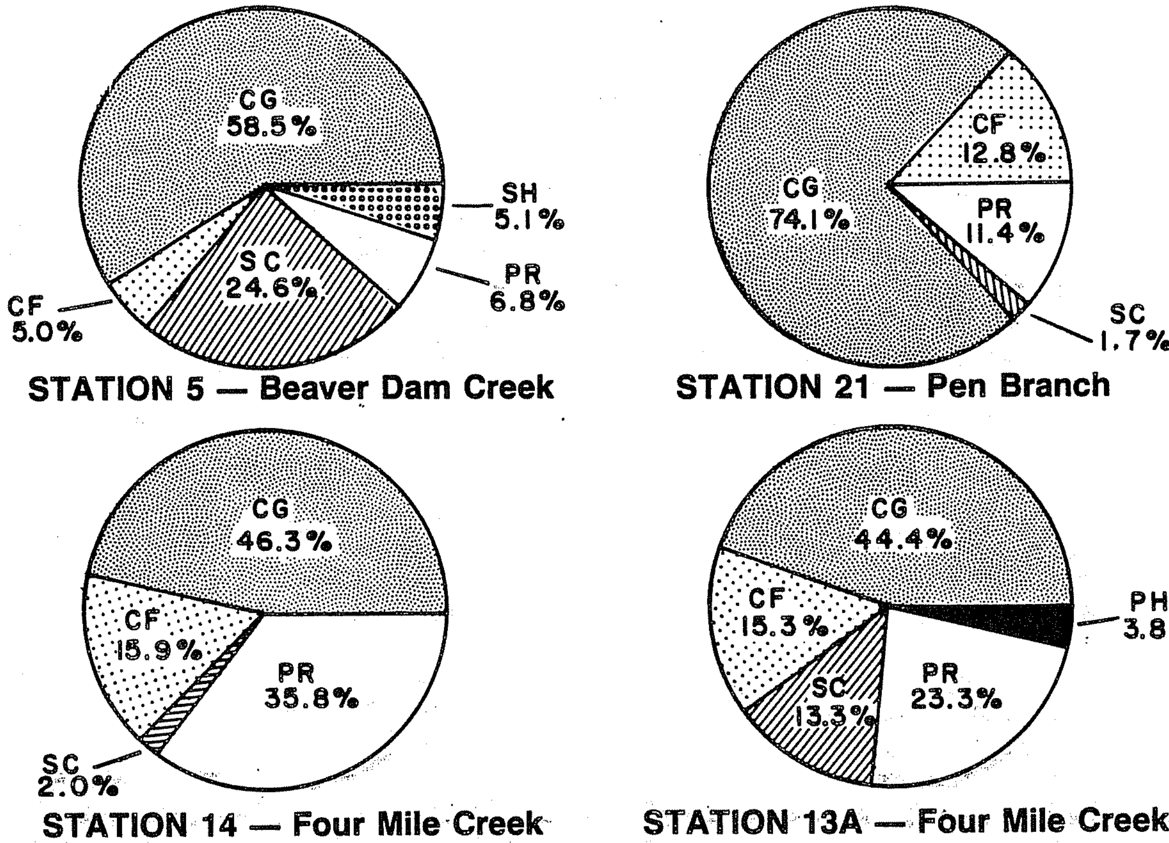


FIGURE V-3.32. Relative Biomass (percent of AFDW/m^2 of multiplate samplers) of Macroinvertebrate Functional Groups at 1983-1984 Stations 1 (Beaver Dam Creek), 2, 3 (Four Mile Creek), and 4 (Pen Branch); (CF = collector-filterer, CF = collector-gatherer, PH = piercer-herbivore, PR = predator, SC = scraper, SH = shredder) (January-August 1984).
Source: Kondratieff and Kondratieff, 1985.

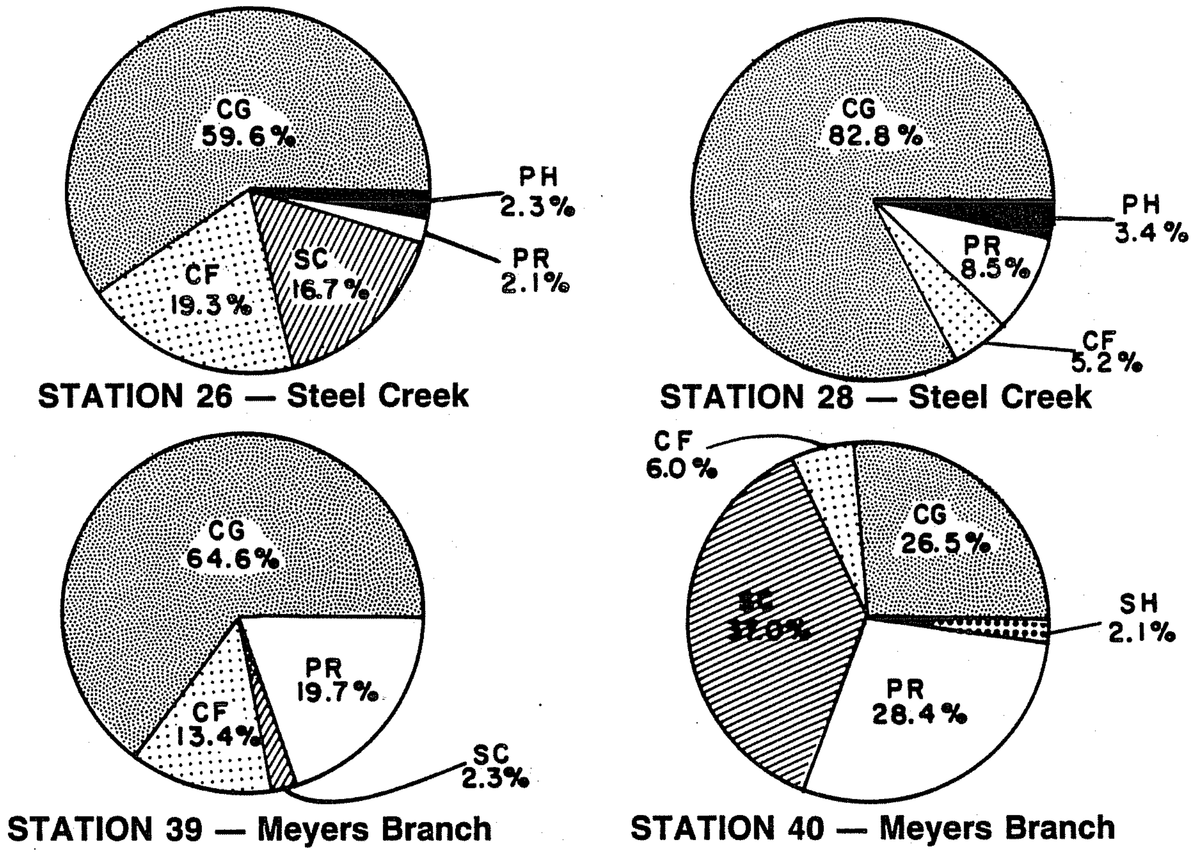


FIGURE V-3.33. Relative Biomass (percent of AFDW/m^2 of multiplate samplers) of Macroinvertebrate Functional Groups at 1983-1984 Stations 7, 8 (Steel Creek), 11 and 12 (Meyers Branch); (CF = collector-filterer, CF = collector-gatherer, PH = piercer-herbivore, PR = predator, SC = scraper, SH = shredder) (January-August 1984).
Source: Kondratieff and Kondratieff, 1985.

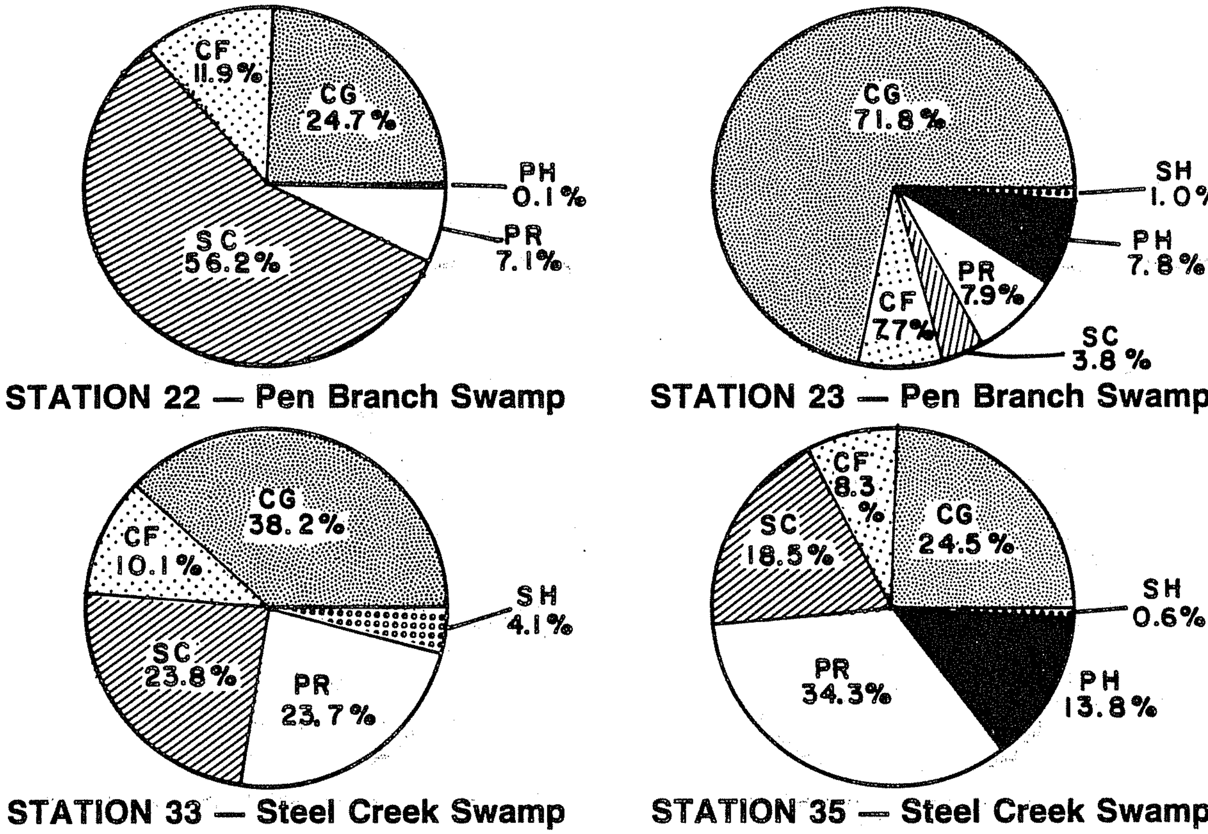


FIGURE V-3.34. **Relative Biomass (percent of AFDW/m^2 of multiplate samplers) of Macroinvertebrate Functional Groups at 1983-1984 Stations 5, 6 (Pen Branch swamp), 9 and 10 (Steel Creek swamp); (CF = collector-filterer, CF = collector-gatherer, PH = piercer-herbivore, PR = predator, SC = scraper, SH = shredder) (January-August 1984).**
Source: Kondratieff and Kondratieff, 1985.

TABLE V-3.46

Mean Biomass (g AFDW/m^2) of Invertebrate Functional Groups on Multiplate Samplers (October 1984-September 1985)

Station	Location/ Thermal Regime	Functional Group: Collector-Gatherers	Collector-Filterers	Scrapers	Predators	Piercer-Herbivores	Shredders	Piercer-Carnivores	Total
1	UTR-n	0.026	0.023	0.006	0.366	0.005	0.074	0.000	0.500
5	BD-t	0.048	0.004	0.001	0.066	0.000	0.000	0.000	0.118
6	BD-t	0.046	0.009	0.004	0.017	0.000	0.001	0.000	0.076
7	BD-t	0.057	0.004	0.002	0.109	0.000	0.001	0.000	0.173
8	BD-t	0.058	0.055	0.002	0.054	0.000	0.000	0.000	0.170
12	FM-n	0.065	0.215	0.001	0.068	0.000	0.002	0.000	0.351
14	FMD-t	0.047	0.090	0.003	0.018	0.001	0.000	0.000	0.158
15	FMD-t	0.054	0.016	0.002	0.016	0.000	0.000	0.000	0.088
16	FMD-t	0.068	0.027	0.001	0.008	0.000	0.000	0.000	0.104
17	FMD-t	0.051	0.005	0.015	0.020	0.000	0.000	0.000	0.091
20	PB-n	0.094	0.006	0.001	0.065	0.000	0.022	0.000	0.187
21	PB-t	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.002
22	PBD-t	0.025	0.007	0.033	0.006	0.000	0.000	0.000	0.071
23	PBD-t	0.023	0.005	0.014	0.018	0.000	0.000	0.017	0.078
24	PBS-t	0.204	0.009	0.057	0.050	0.000	0.000	0.000	0.320
26	SC-n	0.034	0.023	0.001	0.496	0.000	0.000	0.000	0.553
27	SC-n	0.113	0.050	0.001	0.709	0.000	0.000	0.000	0.874
28	SC-n	0.031	0.010	0.001	0.148	0.000	0.002	0.000	0.192
29	SC-n	0.059	0.013	0.004	0.431	0.000	0.063	0.000	0.570
30	SCD-n	0.022	0.001	0.026	0.055	0.000	0.041	0.012	0.157
31	SCD-n	0.105	0.002	0.307	0.045	0.000	0.086	0.023	0.569
32	SCD-n	0.021	0.003	0.419	0.147	0.001	0.065	0.001	0.655
33	SCD-n	0.124	0.108	0.004	0.033	0.000	0.019	0.000	0.287
34	SCS-n	0.038	0.001	0.077	0.025	0.000	0.053	0.000	0.196
35	SCS-n	0.112	0.054	0.001	0.029	0.000	0.051	0.000	0.247
39	MB-n	0.044	0.006	0.001	0.021	0.000	0.000	0.000	0.073
40	MB-n	0.060	0.010	0.002	0.048	0.000	0.010	0.000	0.129
42	LTR-n	0.120	0.211	0.075	0.141	0.001	0.000	0.000	0.549
43	LTR-n	0.040	0.011	0.052	0.278	0.000	0.030	0.000	0.411

Note: Abbreviations are listed in Table V-3.2.

Source: Firth et al., 1986.

Collector-gatherer biomass was significantly lower at Four Mile Creek Stations 15-17 compared to Station 24 in Pen Branch Delta only when C Reactor was operating. When C Reactor was operating, differences in biomass between Four Mile Creek Delta Stations 15-17 and Steel Creek Delta Stations 31 and 33 were due primarily to the small size of the collector-gatherers in Four Mile Creek and the relatively larger size of the collector-gatherers and other functional groups in Steel Creek. When C Reactor was not operating, differences in biomass that might be attributable to reactor discharge were not evident.

In Pen Branch, biomass of collector-gatherers was significantly higher at the most downstream station (Station 24) that experienced only moderately elevated temperatures compared to those at Stations 22 and 23. No other differences in functional group biomass were seen. Comparison of thermal Pen Branch Stations 22 and 23 with post-thermal Steel Creek Stations 31 and 33 revealed significantly higher biomass of collector-gatherers at the Steel Creek site, while biomass of collector-filterers and scrapers was significantly higher at Stations 33 and 31, respectively. No other significant differences were seen.

Except for the significantly higher biomass of collector-filterers at Station 8, there were no significant differences in functional group biomass at the three comparable (i.e., no macrophytes) Beaver Dam Creek Stations (Stations 5, 6, and 8). Comparison of Station 7 with similarly vegetated Station 33 on Steel Creek revealed significantly higher biomass of collector-gatherers and collector-filterers at the Steel Creek site.

At the Steel Creek stations, as at the reference stream stations, large predators and collectors made up most of the biomass. Shredders were important only at Station 29. There were no consistent differences in biomass among functional groups when (reference) Stations 12, 20, and 39 were compared to Stations 26-28.

Scrapers, such as limpets and snails, were important in the Steel Creek Delta (Stations 30-32) where the open canopy allowed periphyton growth, which supports scrapers. Predators such as damselflies, dragonflies (Odonata: Anisoptera), and leeches also comprised a large portion of the biomass at the delta stations. Collector-gatherers were important to the biomass at Steel Creek Delta Stations 31 and 33, but collector-filterers were important at delta Station 33 only. The site at Station 33 had a relatively high current velocity, and had a large population of net-spinning caddisflies (Trichoptera: Cheumatopsyche) as a result. Large shredders, although not abundant, were also important contributors to the biomass in the Steel Creek Delta.

The only Steel Creek swamp stations sampled to determine macroinvertebrate functional groups were Stations 34 and 35. Scrapers, primarily snails, comprised a large portion of the biomass at Station 34. Current velocity at Station 34 was low; consequently, collector-filterers were not important, and shredders, collector-gatherers and predators were the major contributors to the biomass. At Station 35, collector-gatherers, primarily Gammarus (an amphipod), and Stenonema (a mayfly), comprised the greatest proportion of the total biomass. Because of the higher current velocity at Station 35, the biomass of collector-filterers (primarily Trichoptera: Cheumatopsyche) was greater than at Station 34. Shredders (Trichoptera: Pycnopsyche and Lepidoptera: Paraponyx) and predators contributed to the biomass at Station 35.

In summary, in both Pen Branch and Four Mile Creek, lower biomass at the thermally impacted stations was due mainly to the lower biomass of collector-gatherers, which were of small size relative to those in post-thermal Steel Creek or the reference streams. A similar trend was evident when thermally impacted Station 7 on Beaver Dam Creek was compared with post-thermal Steel Creek Station 33, except in this case biomass of collector-filterers was also significantly lower at the thermally impacted site. Biomass of collector-filterers was also significantly higher at Station 8 compared to the more severely impacted Stations 5 and 6, but there was no significant difference in collector-gatherer biomass at these stations. Post-thermal Steel Creek had a functional group representation similar to that of the reference streams, with predators abundant. However, Steel Creek Delta sites had an abundance of scrapers, attributable to the open canopy and abundant periphyton growth at these sites.

V.3.7.3.5 Grouped Comparisons

To further investigate the effects of thermal discharges on the macroinvertebrates of the SRP creeks that receive reactor effluents, the 1984-1985 average monthly densities of 18 selected taxa (based on abundance and occurrence during most of the year) and functional groups from multiplate samplers located at selected pairs or groups of sites were compared. True reference sites with which to compare the disturbed sites were difficult to designate. The criteria for selecting stations for comparisons were similarities in habitat (e.g., stream size, substrate type, current velocity, canopy cover, and macrophyte abundance), location along a thermal gradient, and an expectation that the grouped sites would have similar macroinvertebrate communities if there were no disturbances.

The sites at Stations 14 and 17 in the Four Mile Creek Delta were compared to detect trends along a thermal gradient. Previous results indicated that both stations were impacted to some degree by reactor discharges. Lack of canopy at Station 14 disallowed comparison with unimpacted (reference) streams. Station 14 was located closer to the effluent discharge point and its range of water temperatures was 6.5 to 14.8°C higher than that at Station 17. Significantly lower specific densities of Caenis mayflies, Physella snails, and nematodes, as well as lower total densities of invertebrates were found at Station 14. No taxa were significantly more abundant at Station 14 than at Station 17; however, few taxa were able to survive the elevated temperatures at either station (Firth et al., 1986). When the reactor was not operating, many of the taxa were found at higher densities at both stations. During reactor shutdown there were no significant differences in densities between the two stations for any taxa except nematodes, which remained higher at Station 17 (Firth et al., 1986).

Invertebrate densities and biomass at thermal Stations 15-17 in the Four Mile Creek Delta were compared to nonthermal Station 24 in the Pen Branch swamp. Site characteristics were similar at the stations, except for current velocity, which was lower at Station 24. Total density, total biomass, and the densities of most taxa were higher at Station 24 than at the Four Mile Creek stations. When the reactor was not operating there was no significant difference in density between the stations for most taxa. These results indicate that the macroinvertebrate community in Four Mile Creek was adversely affected by the heated effluent from C Reactor, and that there was a rapid recovery of many taxa when the reactor was shut down (see Figures V-3.26, V-3.28, and V-3.31). During the short interval of reactor shutdown covered by this study (3 months), recolonization by species that disperse quickly and have high reproductive rates was rapid, demonstrating the potential for re-establishment of aquatic macroinvertebrate communities. This resulted in substantial increases in biomass at the thermal Four Mile Creek stations (Figure V-3.35). Continued study of Four Mile Creek without reactor operation is necessary to assess the recovery of taxa that disperse more slowly (Firth et al., 1986).

Throughout the second year of the CCWS, K Reactor was operating almost continuously and discharging heated effluent into Pen Branch Creek. Three stations on Pen Branch were compared: thermal Stations 22 and 23 and nonthermal Station 24. Of the three, Station 22 was located closest to the discharge and had the highest water temperatures.

Total densities of macroinvertebrates were significantly lower at Station 22, but were not significantly different between Stations 23 and 24. Nematodes, which are often abundant at thermal sites, showed significantly higher densities at Stations 22 and 23

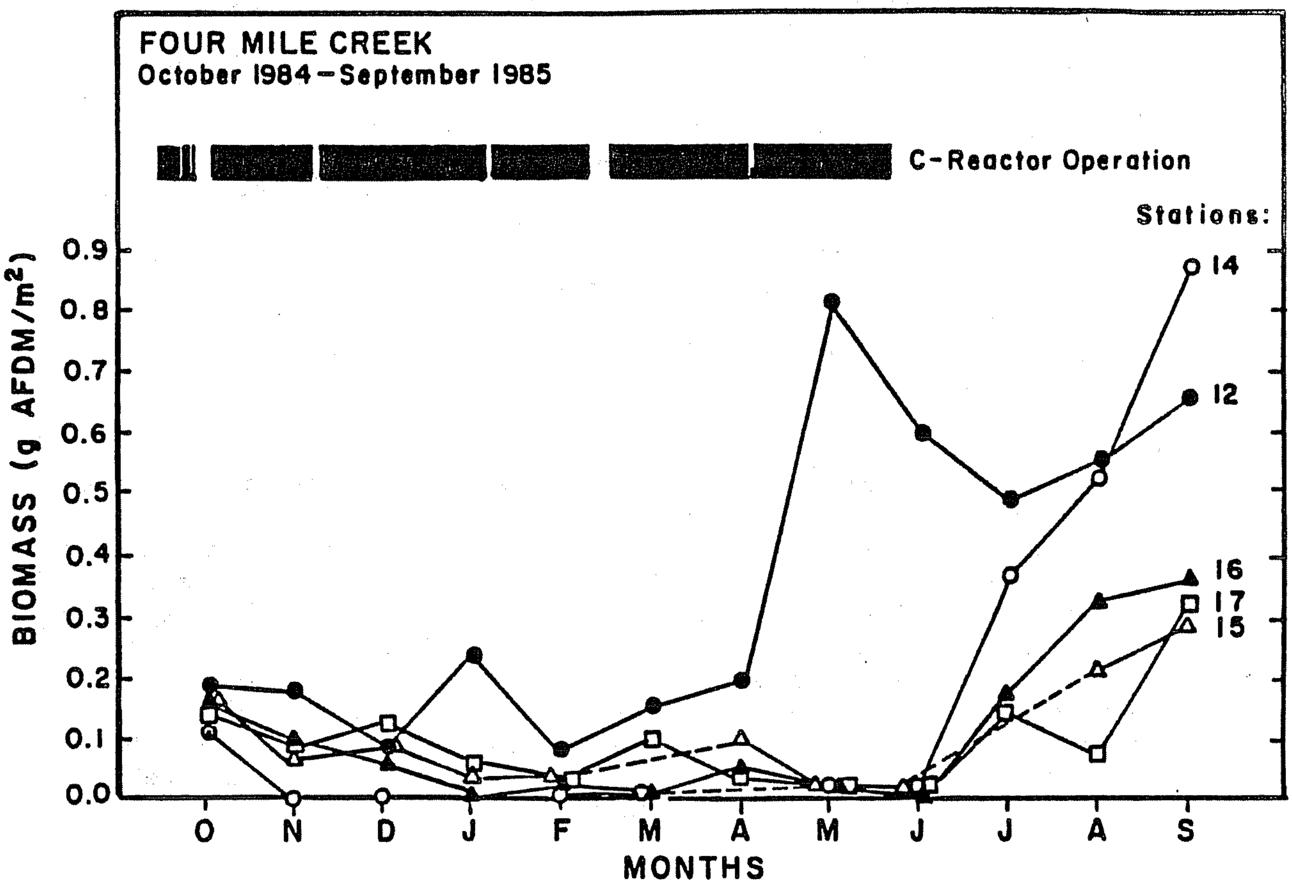


FIGURE V-3.35. Mean Monthly Biomass (g AFDW/m^2) of Invertebrates on Multiplate Samplers at Stations in Four Mile Creek (October 1984–September 1985)

than at Station 24. Of the two thermal sites, Station 23 had a significant higher mean density of nematodes than Station 22. Apparently the water temperatures at Station 22 were high enough to adversely affect the populations of some nematodes. The site at Station 24 had significantly higher densities of Tanytarsini flies, Stenonema mayflies, Machronychus and Stenelmis beetles, and Ferrissia (Gastropoda). Due to the significantly higher densities of small nematodes at Stations 22 and 23, and the significantly higher densities of several larger insect taxa in the collector-gatherer functional group, macroinvertebrate biomass was significantly higher at Station 24 than at the two other stations due to the larger average size of individuals at Station 24.

A comparison of post-thermal Steel Creek (Stations 26-28) stations and reference sites (Stations 12, 20, and 39) indicated that there were no clear cut differences in species composition and densities for most taxa, and differences could be explained by habitat factors unrelated directly to thermal discharges (e.g., current velocity, detritus in the sediments, canopy, etc.). For example, relatively high current velocities at Stations 12 and 27 appeared to be responsible for differences in densities of Cheumatopsyche, Hydropsyche, Simulium, and Chimarra. The significantly higher densities of Baetis at Steel Creek stations compared to several reference stations may be related to the open canopy on Steel Creek. Because densities of many macroinvertebrate taxa varied considerably among the Steel Creek stations, in no case were all of the Steel Creek stations found to differ significantly from all of the reference stations. Similar lack of clear cut differences was apparent based on the biomass data. The reference site most similar to Steel Creek was Station 39, located on its tributary, Meyers Branch. These similarities suggest that there has been excellent post-thermal recovery of the macroinvertebrate communities in Steel Creek (Firth et al., 1986).

V.3.7.3.6 River and Creek Mouth Studies

During the 1983-1984 study year, the multiplate samplers located near the water surface usually collected higher densities and higher biomass of organisms than those located near the bottom. Sedimentation may have reduced colonization of the bottom samplers (O'Hop et al., 1985). The near-surface samples were used in all subsequent analyses, and near-bottom samplers were not deployed during the 1984-1985 study year.

Results of multiplate sampling in the mouths of the creeks (Upper Three Runs, Beaver Dam, Four Mile, Steel, and Lower Three Runs) indicate that the macroinvertebrates of Four Mile Creek were adversely affected, most likely by thermal discharges during the 1983-1984 study year. Macroinvertebrate biomass, densities, and taxa richness were all significantly lower at the mouth of Four Mile Creek than at the other creek mouths (Table V-3.47). The differences were usually more pronounced during the summer months when water temperatures were highest (Figure V-3.36 and V-3.37; Tables V-3.48 and V-3.49). However, in August 1984, when high river levels prevented the thermal effluent from reaching the mouth of Four Mile Creek, invertebrate densities, biomass, and taxa richness increased on the surface samplers (Figure V-3.35).

During the 1984-1985 study year, biomass and species richness were again lowest in Four Mile Creek, but densities in Four Mile Creek were higher than in Beaver Dam Creek and Steel Creek. There were no significant differences in total density or biomass between any of the creek mouth stations. Annual means for the Four Mile Creek stations during the 1983-1984 study year were greatly influenced by the collections from the July-September 1985 period, when C Reactor was down. Densities and biomass of invertebrates in Four Mile Creek increased rapidly after the cessation of thermal discharges in late June 1985 (Figures V-3.35 and V-3.36). Organisms with short generation times, multiple generations per year, rapid grown rates and relatively high vagility (such as chironomid midges and heptageneiid mayflies) were abundant on the samplers in Four Mile Creek during the first three months of reactor outage. Other taxa would be expected to return if reactor outage was of sufficiently long duration. In general, densities and biomass in Four Mile Creek were lowest when average daily water temperatures regularly exceeded 35°C.

During both years of the study, the most common macroinvertebrate taxa colonizing the multiplate samplers in the creek mouths were the larval stages of true flies (Diptera) and caddisflies (Trichoptera), mayfly nymphs (Ephemeroptera), and the larval and adult stages of beetles (Coleoptera) (Table V-3.50). True flies (primarily Chironomidae) were usually the most abundant taxa, comprising 56 to 93% of the total number of organisms collected. Nematodes occurred at low densities at most creek mouth sites. However, nematodes represented a large percentage of the total density at the Four Mile Creek mouth site during some summer months in 1984 (O'Hop et al., 1985).

Collectors were the most abundant functional group at all creek mouth sites. Within this group, collector-gatherers numerically dominated the creek mouth stations during both years (Table V-3.51). However, the relative importance of collector-gatherers and collector-filterers differed during the two years of the study. During the 1983-1984 study year, collector-gatherers comprised 75 to 90% of the macroinvertebrate community density, with significantly fewer collector-gatherers in Four Mile Creek compared to the other creeks. During the 1984-1985 study year, collector-gatherers comprised only 52 to 81% of the macroinvertebrate community, with relatively stronger representation by

TABLE V-3.47

Macroinvertebrate Data Collected on the Multiplate Samplers in the Creek Mouth Stations: Average Number of Taxa per Sampler, Average Annual Density of Macroinvertebrates (no./m^2 of sampler), and Average Biomass (g AFDW/m^2 of sampler)

October 1983 - September 1984

Station	Average No. Taxa/Sampler	Average Density	Average Biomass
3	10.8	1633.3	0.118
9	12.2	1144.7	0.260
18	8.0	569.2	0.057
37	13.1	1234.1	0.198
45	12.4	1363.9	0.156

October 1984 - September 1985

Station	Average No. Taxa/Sampler	Average Density	Average Biomass
3	16.1	2839.5	0.190
9	13.4	1253.6	0.220
18	9.8	1433.7	0.100
37	14.4	889.5	0.153
45	13.8	1932.3	0.159

Source: O'Hop et al., 1985,1986.

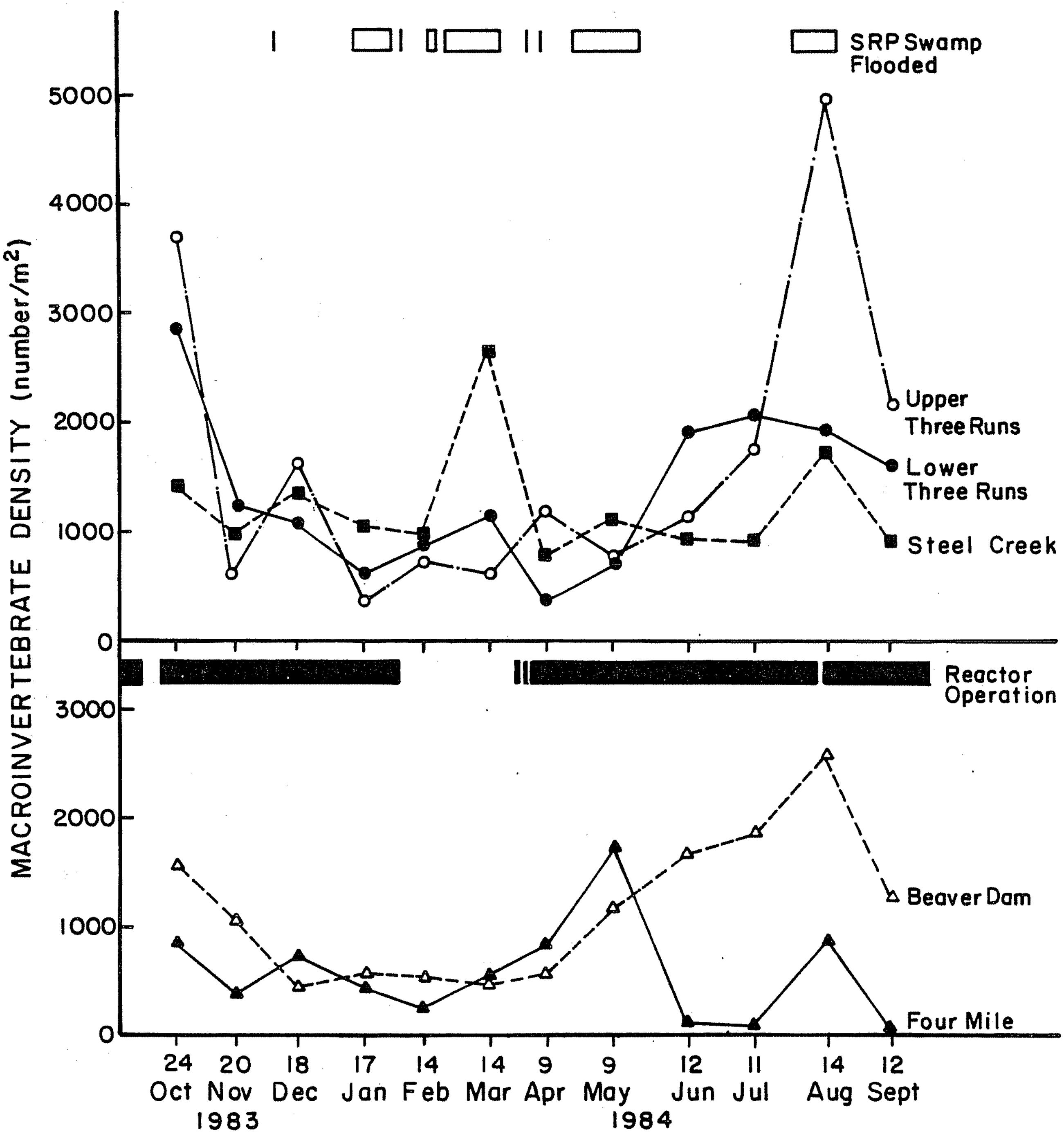


FIGURE V-3.36. Average Monthly Density (no./m^2 of substrate) of Macroinvertebrates on Multiple Samplers Suspended 0.5 Below the Surface in Savannah River Tributary Creek Mouth Stations Which Drain the SRP (October 1983-September 1984)
Source: O'Hop et al., 1985

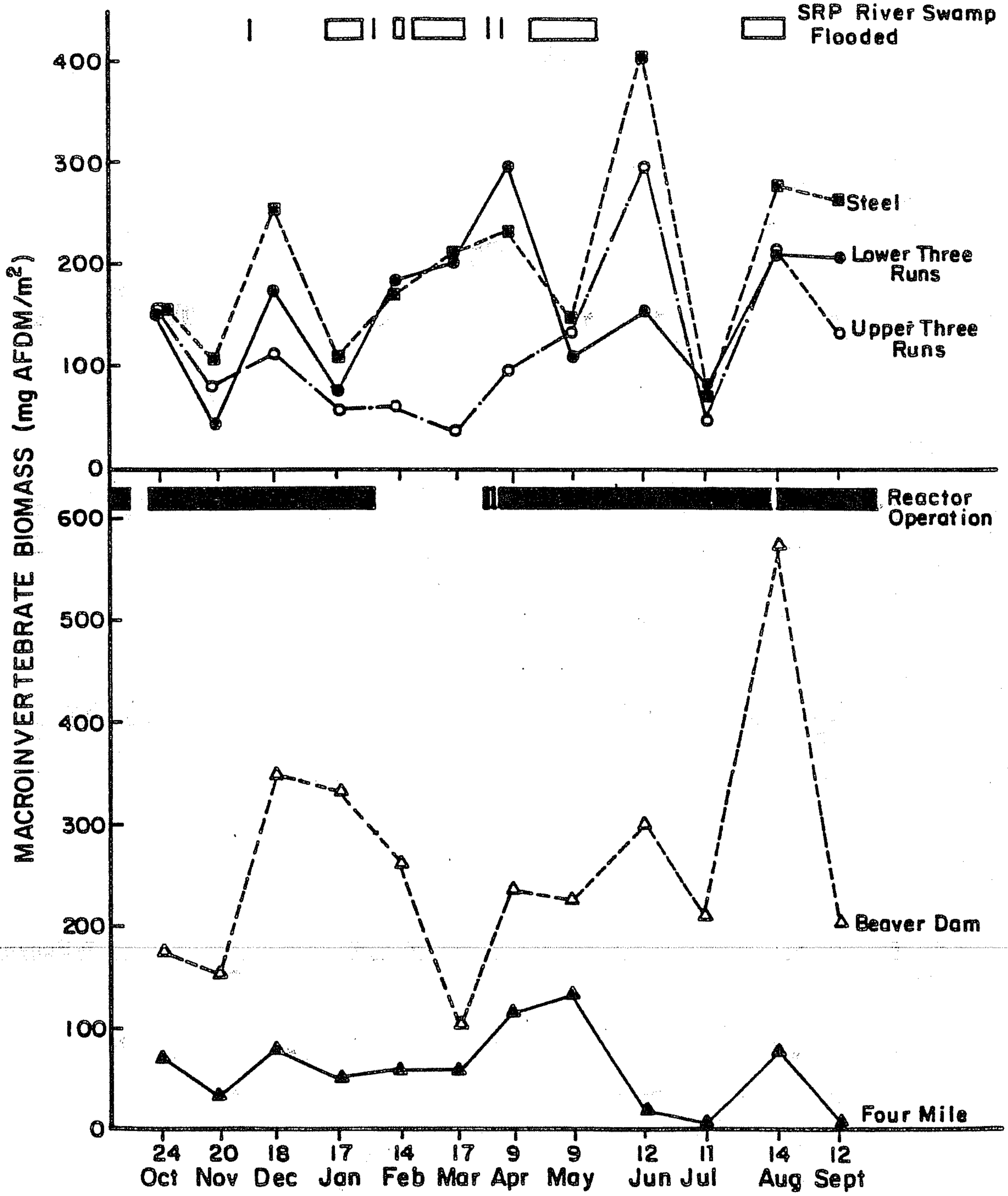


FIGURE V-3.37. Average Monthly Biomass of Macroinvertebrates on Multiplate Samplers in Savannah River Tributary Creek Mouth Stations Which Drain the SRP (October 1983–September 1984)
Source: O'Hop et al., 1985.

TABLE V-3.48

Total Densities (no./m^2 of sampler) of Macroinvertebrate Taxa Collected from Multiplate Samplers in the Savannah River and at the Mouths of Tributary Creeks that Drain the SRP

Station	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
October 1983 - September 1984												
4	25143.3	11251.3	2713.2	1417.1	664.8	843.5	791.4	2556.7	2871.5	4804.4	5383.6	1180.6
10	17134.0	6884.5	7921.7	1914.3	1134.0	707.6	884.5	-	3726.2	5359.4	6048.4	5951.5
11	25281.1	10284.9	2581.0	2130.3	1783.9	1649.9	3454.3	-	3696.4	6631.2	5934.8	4486.0
19	16478.5	10204.8	4227.1	3159.2	1277.4	1837.9	1331.4	4176.9	5067.0	8558.6	7575.4	6532.5
25	7404.0	8398.5	1519.5	1227.1	1931.0	1741.1	882.6	2314.7	1648.0	2670.3	1975.7	3357.5
38	13266.2	4994.4	2163.8	737.4	2154.5	1791.4	765.3	949.7	2508.3	3776.5	2871.5	2078.2
49	19288.6	6059.5	1903.1	290.5	797.0	1348.2	797.0	5724.3	2858.4	3558.6	7097.7	4789.5
41	15236.4	9331.4	1772.8	878.9	1858.4	2549.3	618.2	1983.2	1754.1	1806.3	4022.3	4901.3
46	18184.3	6119.1	843.5	1400.3	996.2	3689.9	216.0	232.7	1229.0	2547.4	-	5643.0
3	3705.7	600.5	1612.6	351.9	718.3	605.2	1182.4	779.3	1137.8	1748.6	4983.2	2173.1
9	1545.6	1067.0	456.2	551.2	508.3	491.6	553.0	1178.7	1681.5	1853.4	2582.8	1262.5
18	839.8	385.4	728.1	432.0	268.1	530.7	819.3	1705.7	102.4	80.0	843.5	94.9
37	1411.5	990.6	1359.4	1044.6	973.9	2644.3	772.8	1121.0	932.9	927.3	1722.5	908.7
45	2854.7	1225.3	1089.3	595.9	879.8	1135.9	381.7	705.7	1901.3	2070.7	1929.2	1597.7
October 1984 - September 1985												
4	15709.5	13581.0	5171.3	4372.4	6348.2	2149.0	1933.0	946.0	2608.9	7175.0	9076.4	5553.1
10	13061.5	8595.9	4540.0	3689.0	4782.2	4527.0	5852.9	2258.8	6134.1	4836.1	6284.9	5346.4
11	15497.2	8223.5	3260.7	3506.5	5927.4	6802.6	2981.4	2307.3	7381.8	5912.5	12977.7	10223.5
19	17839.9	7221.6	4895.7	5312.8	4906.9	4912.5	6778.4	6733.7	12003.8	6230.9	9078.2	9918.1
25	8975.8	7001.9	2491.6	1042.8	2141.5	1499.1	2402.2	2212.3	5605.2	8709.5	8748.6	9728.1
38	5545.6	5149.0	1528.9	1629.4	1653.6	2793.3	2711.4	2413.4	2655.5	3003.7	1892.0	2039.1
49	8273.7	5027.9	3420.9	1927.4	3035.4	3893.9	2294.2	1139.7	3392.9	3467.4	2862.2	514.0
41	7709.5	7795.2	3672.3	1568.0	1428.3	3134.1	1067.0	769.1	2055.9	4826.8	5506.5	4448.8
46	7389.2	8346.4	3307.3	711.4	1248.6	1847.3	1014.9	1113.6	2698.3	3698.3	5337.1	4333.3
3	8372.4	16722.5	3303.5	722.5	541.9	454.4	815.6	1020.5	338.9	858.5	389.2	534.5
9	977.7	808.2	1960.9	901.3	784.0	519.6	3266.3	990.7	716.9	722.5	2027.9	1366.9
18	1389.2	1243.9	681.6	711.4	1292.4	1438.5	2640.6	55.9	169.5	2309.1	4298.0	973.9
37	1184.4	1480.4	582.9	1243.9	620.1	1162.0	1176.9	1134.1	763.5	392.9	458.1	476.7
45	1752.3	6577.3	1152.7	864.1	556.8	1193.7	6541.9	2478.6	610.8	400.4	644.3	415.3

Source: O'Hop et al., 1985, 1986.

TABLE V-3.49

Biomass (g AFDW/m^2 of sampler) of Macroinvertebrate Taxa on Multiplate Samplers in Savannah River and at the Mouths of Tributary Creeks that Drain the SRP (October 1983-September 1984)

Station	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
October 1983 - September 1984												
4	1.624	0.658	0.282	0.090	0.028	0.057	0.114	0.181	0.350	0.605	0.737	0.104
10	1.303	0.430	2.029	0.110	0.083	0.059	0.166	-	1.041	0.819	1.275	0.765
11	1.762	0.760	0.347	0.154	0.183	0.161	0.405	-	0.936	0.909	1.138	0.528
19	1.324	0.787	0.351	0.142	0.062	0.151	0.759	0.355	1.135	1.232	1.283	1.473
25	0.806	0.681	0.151	0.085	0.094	0.232	0.693	0.256	0.525	0.088	0.780	0.292
38	0.575	0.537	0.281	0.086	0.135	0.123	0.561	0.154	0.552	0.087	1.339	0.213
49	1.569	0.430	0.219	0.051	0.086	0.108	0.510	0.560	1.057	0.486	0.711	0.350
41	1.501	0.746	0.264	0.084	0.127	0.341	0.498	0.508	0.913	0.064	0.637	0.272
46	2.075	0.552	0.082	0.079	0.129	0.126	0.268	0.285	0.572	0.077	-	0.129
3	0.154	0.080	0.112	0.057	0.059	0.035	0.094	0.124	0.294	0.063	0.211	0.131
9	0.173	0.154	0.347	0.332	0.256	0.101	0.254	0.225	0.295	0.208	0.570	0.200
18	0.072	0.032	0.079	0.052	0.058	0.057	0.113	0.131	0.027	0.002	0.072	0.002
37	0.158	0.107	0.252	0.107	0.168	0.206	0.230	0.143	0.403	0.069	0.276	0.260
45	0.152	0.041	0.171	0.078	0.181	0.203	0.294	0.108	0.151	0.079	0.209	0.202
October 1984 - September 1985												
4	1.167	0.519	0.844	0.316	0.494	0.121	0.465	0.094	0.309	1.072	0.959	1.179
10	0.852	0.438	0.175	0.448	0.312	0.306	1.024	0.321	0.897	0.686	0.777	0.795
11	0.990	0.366	0.151	0.375	0.228	0.404	1.183	0.317	0.265	0.851	1.099	1.639
19	1.220	0.463	0.219	0.477	0.292	0.453	1.260	0.741	1.318	0.972	1.209	1.037
25	0.656	0.331	0.145	0.173	0.143	0.324	0.489	0.364	0.827	1.378	1.212	2.454
38	0.327	0.338	0.086	0.227	0.135	0.350	0.553	0.944	0.383	0.720	0.294	0.677
49	0.749	0.402	0.169	0.279	0.312	0.737	1.323	0.393	0.383	0.546	0.819	0.103
41	0.479	0.602	0.334	0.202	0.149	2.206	0.911	0.333	0.290	0.956	0.882	0.804
46	0.723	0.557	0.270	0.159	0.112	0.536	1.380	0.332	0.218	0.687	0.781	0.641
3	0.243	0.218	0.101	0.119	0.170	0.166	0.259	0.335	0.100	0.129	0.307	0.136
9	0.045	0.058	0.648	0.067	0.147	0.188	0.479	0.074	0.066	0.296	0.273	0.297
18	0.046	0.052	0.035	0.066	0.071	0.100	0.061	0.004	0.009	0.175	0.218	0.368
37	0.085	0.049	0.064	0.162	0.085	0.358	0.213	0.165	0.089	0.096	0.073	0.401
45	0.175	0.163	0.063	0.126	0.159	0.371	0.263	0.085	0.038	0.320	0.078	0.070

Source: O'Hop et al., 1985, 1986.

TABLE V-3.50

Average Percentage Density of Important Taxonomic Groups on Multiplate Samplers Located in the Mouths of Creeks Draining the SRP (October 1983 - September 1985)

Taxon	Creek Stations 10/83 - 9/84					10/84 - 9/85				
	3	9	18	37	45	3	9	18	37	45
Turbellaria	-	-	-	-	-	0.1	0.2	<0.1	0.5	0.4
Nematoda	0.3	<0.1	7.2	<0.1	0.2	0.1	0.2	1.8	0.2	0.2
Oligochaeta	-	-	-	-	-	1.3	2.0	13.2	7.9	2.3
Hirudinea	-	-	-	-	-	<0.1	<0.1	<0.1	0.4	<0.1
Gastropoda	0.1	<0.1	5.0	1.0	0.7	<0.1	<0.1	1.5	0.4	2.7
Pelecypoda	<0.1	0.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.0
Hydracarina	0.2	1.2	0.7	0.9	0.2	0.2	0.7	0.2	0.9	<0.1
Isopoda	0.1	<0.1	0.2	<0.1	0.0	<0.1	<0.1	0.0	<0.1	<0.1
Amphipoda	0.0	0.1	3.5	1.3	0.1	<0.1	<0.1	<0.1	4.5	0.4
Decapoda	-	-	-	-	-	0.0	0.0	0.0	<0.1	0.0
Collembola	-	-	-	-	-	<0.1	0.0	0.0	0.0	0.0
Ephemeroptera	2.0	18.5	9.6	8.2	16.2	11.9	12.4	11.7	7.9	14.8
Odonata	0.0	<0.1	0.2	0.1	<0.1	0.0	<0.1	<0.1	0.3	0.0
Plecoptera	1.1	0.4	0.2	0.1	0.4	3.1	0.2	0.5	0.2	0.2
Coleoptera	0.7	4.6	0.7	1.4	0.6	2.0	5.5	<0.1	2.4	0.8
Megaloptera	-	-	-	-	-	0.1	2.2	<0.1	<0.1	<0.1
Trichoptera	2.8	7.3	8.0	12.7	7.0	7.3	3.2	3.0	8.7	10.7
Lepidoptera	-	-	-	-	-	<0.1	0.0	0.0	<0.1	0.0
Diptera	92.6	67.4	64.5	73.7	74.7	73.7	75.2	68.0	65.7	67.4

Source: O'Hop et al., 1985.

TABLE V-3.51

Average Percent of Total Density (no./m^2 of sampler) of Macroinvertebrate Functional Groups Collected from Multiplate Samplers in the Savannah River and the Mouths of Tributary Creeks

October 1983 - September 1984

Station	Collectors: Gatherers	Collectors: Filterers	Scrapers	Shredders	Predators
4	70.0	22.6	2.0	0.2	5.2
10	63.1	31.7	1.6	0.0	3.6
11	57.4	38.0	1.8	0.1	2.7
19	62.4	33.6	1.3	0.0	2.7
25	58.7	34.2	4.8	0.1	2.1
38	54.9	38.0	3.4	0.0	3.7
49	48.4	44.2	5.8	0.2	1.4
41	48.7	41.9	7.8	0.4	1.2
46	43.1	41.4	13.5	0.2	1.8
3	90.5	4.2	0.5	0.1	4.7
9	85.1	7.6	3.3	0.1	3.9
18	75.8	10.7	5.2	0.0	8.2
37	78.7	16.2	0.4	0.1	4.6
45	86.0	7.9	1.6	0.1	4.4

October 1984 - September 1985

Station	Collectors: Gatherers	Collectors: Filterers	Scrapers	Shredders	Predators
4	42.0	52.0	1.7	0.2	4.1
10	34.3	59.7	1.9	<0.1	3.9
11	34.8	59.3	2.7	0.1	3.0
19	32.7	63.1	1.3	<0.1	2.8
25	31.4	61.3	4.7	0.1	2.5
38	38.8	54.3	1.9	0.2	4.8
49	38.8	48.2	6.6	0.3	6.1
41	31.1	54.0	10.7	0.3	3.9
46	29.8	56.0	10.8	0.2	3.2
3	51.8	35.3	2.5	0.9	9.6
9	65.9	25.2	3.6	<0.1	5.2
18	80.7	12.4	2.2	<0.1	4.7
37	64.5	29.4	0.5	<0.1	5.4
45	57.9	34.0	3.0	<0.1	4.9

Source: O'Hop et al., 1985,1986.

collector-filterers and especially predators during the second year. In contrast to the results for 1983-1984, collector-gatherers constituted a larger proportion of the fauna in Four Mile Creek than in any other creek during the 1984-1985 study year. Thermal discharges into Four Mile Creek reduced densities or eliminated all but the most tolerant taxa during some months and those tolerant forms were collector-gatherers. Trends for biomass (Table V-3.52) generally paralleled those for density during both years of the study.

Annual summary data from the multiplate sampling of the Savannah River sites are presented in Table V-3.53. River stations, in general, had higher average densities of macroinvertebrates than did creek mouth stations. There were no significant differences ($p > 0.05$) in macroinvertebrate taxa richness, densities or biomass that could be attributed solely to location upstream or downstream of a creek confluence during either of the two study years. Those differences that were found were probably related to site differences (e.g., current) rather than to effluents from SRP operations (O'Hop et al., 1985, 1986). Most differences in invertebrate densities and biomass on the samplers were attributed to season. Trends were similar for both study years (Tables V-3.48 and V-3.49). Total density and biomass were highest during October, and declined to relatively low values during the winter and early spring. Density and biomass rose during late spring, with relatively higher values during the summer. The groups responsible for the greatest densities were true flies, mayflies, caddisflies, stoneflies, and beetles. Faunal composition of the river stations was generally similar, with few taxa being collected at only one station. The macroinvertebrates collected from the river sites were dominated by collectors (including collector-filterers and collector-gatherers). The relatively greater importance of collector-filterers, especially net-spinning caddisflies (Trichoptera: Hydropsychidae), blackflies (Diptera: Simuliidae) and tanytarsine midges (Diptera: Chironomidae) at the river transects compared to the mouths of the creeks was probably attributable to the stronger currents in the river. There were no significant differences in functional group densities attributed to the location of the river transect (O'Hop et al., 1985, 1986).

Invertebrate drift densities were generally similar among river stations (Table V-3.54), but showed substantial year-to-year differences. During the 1983-1984 study year, mean annual drift ranged between 1100 and 1600 organisms/1000 m^3, and was generally highest in October and lowest in July. During the 1984-1985 study year, average drift was higher (range from 1350 and 3250 organisms/1000 m^3), and showed much greater and different seasonal trends, with highest values in May and lowest in July. The low July rates were probably due to low river discharge rates. Drift is often positively correlated with discharge rates, possibly due to

TABLE V-3.52

Average Percent of Total Biomass (g AFDW/m^2 of sampler) of Macroinvertebrate Functional Groups Collected on Multiplate Samplers in the Savannah River and the Mouths of Tributary Streams

Station	Collectors	Scrapers	Shredders	Predators
October 1983 - September 1984				
4	80.1	13.7	0.5	5.7
10	83.9	9.5	0.0	6.6
11	78.6	12.5	0.4	8.5
19	82.8	10.9	0.1	6.2
25	60.6	22.1	0.7	16.6
38	67.3	15.0	0.2	17.6
49	74.2	19.7	0.3	5.8
41	61.0	20.6	4.2	14.2
46	57.2	30.5	0.5	11.8
3	52.8	10.0	0.8	36.4
9	62.3	10.9	0.0	26.7
18	81.3	8.9	0.0	9.8
37	77.7	2.7	0.6	19.0
45	81.1	9.1	1.9	7.9
October 1984 - September 1985				
4	78.5	9.2	0.5	11.8
10	75.2	12.5	0.1	12.1
11	76.3	14.3	0.2	9.2
19	77.5	9.7	0.2	12.6
25	66.0	19.9	0.3	13.8
38	75.3	8.3	1.2	15.2
49	61.7	18.1	1.2	19.0
41	59.6	15.9	3.0	21.5
46	55.4	19.6	3.8	21.2
3	65.9	10.8	5.0	18.4
9	70.4	1.7	<0.1	27.9
18	78.2	7.8	<0.1	14.0
37	77.2	0.5	0.2	21.9
45	82.0	4.8	0.3	13.0

Source: O'Hop et al., 1985,1986.

TABLE V-3.53

Macroinvertebrate Data Collected on the Multiplate Samplers in the River Stations: Average Number of Taxa per Sampler, Average Annual Density of Macroinvertebrates (no./m^2 of sampler), and Average Biomass (g AFDW/m^2 of sampler)

Station	Average No. Taxa/Sampler	Average Density	Average Biomass
October 1983 - September 1984			
4	17.0	4968.5	0.403
10	16.8	5242.4	0.735
11	17.6	6174.0	0.753
19	17.2	5868.9	0.755
25	14.6	2922.5	0.390
38	15.7	3171.4	0.387
49	13.5	4542.7	0.511
41	14.5	3892.7	0.496
46	12.0	3736.9	0.398
October 1984 - September 1985			
4	20.2	6218.7	0.628
10	20.3	5823.6	0.586
11	20.9	7083.5	0.706
19	21.4	7986.0	0.805
25	17.2	5046.6	0.708
38	21.5	2751.2	0.419
49	20.7	3270.8	0.518
41	18.9	3665.1	0.679
46	18.2	3420.5	0.533

Source: O'Hop et al., 1985,1986.

TABLE V-3.54

Invertebrate Drift Density (no./1,000 m³) at Stations in the Savannah River and in the Mouths of Tributary Creeks Draining the SRP

October 1983 - July 1984

Station	October	February	May	July	Mean
River Stations					
47	2243.5	639.3	887.4	860.7	1157.7
4	2216.3	938.8	985.2	705.2	1186.4
10	1997.4	833.1	864.2	453.2	1037.0
11	1423.9	734.7	881.8	668.1	927.1
19	1579.4	876.6	1478.7	345.3	1070.0
25	1711.5	1078.4	1316.7	623.5	1182.5
38	1667.6	1069.5	1296.0	936.2	1242.3
49	1908.9	1092.1	1497.2	865.0	1340.8
41	1777.2	1186.7	791.7	525.3	1070.2
46	2317.7	1189.7	1397.6	327.3	1303.6
Intake Canals					
1G	2258.1	274.5	807.6	326.2	916.6
3G	806.9	195.3	-*	364.5	455.6
Creek Mouth Stations					
3	320.7	572.5	963.6	527.3	596.0
9	375.1	157.9	2026.8	210.5	692.6
18	425.8	674.7	1680.2	268.7	762.3
37	873.6	2650.0	2681.0	1094.7	1824.8
45	860.1	705.8	822.9	257.8	661.6

TABLE V-3.54, Contd

October 1984 - July 1985

Station	October	February	May	July	Mean
River Stations					
47	1059.6	2664.9	4740.5	729.8	7298.7
4	893.1	1446.8	5032.6	440.8	1953.3
10	773.7	1842.0	4286.9	702.2	1901.2
11	931.0	1492.6	4594.8	714.9	1933.3
19	843.3	2018.9	5159.4	596.4	2184.5
48	929.8	3777.9	5100.3	546.1	2588.5
25	1027.1	2471.3	8930.1	513.8	3235.6
38	808.8	1951.2	3737.1	720.9	1729.5
49	1325.2	2351.6	3540.4	549.7	1949.7
41	717.5	2038.5	2299.7	361.2	1354.2
46	892.6	2010.4	2776.3	405.4	1516.8
Intake Canals					
1G	220.8	1130.7	811.5	936.1	774.8
3G	218.9	806.0	999.4	3526.1	1387.6
Creek Mouth Stations					
3	582.5	-*	362.0	188.1	377.6
9	1660.3	222.6	573.5	162.6	654.7
18	1279.5	1167.4	539.3	226.9	803.3
37	567.2	913.4	242.2	194.8	429.4
45	4328.8	1264.7	213.5	168.2	1493.8

* Not sampled.

Source: O'Hop et al., 1986.

increases in water velocity which can dislodge organisms from the substrate. Drift densities in the intake canals were usually lower than in the river, the major exception being July 1985. Drift densities in the mouths of Savannah River tributary creeks (Table V-3.54) showed no obvious pattern, during the year of the study (Table V-4.53). The only significant differences in drift densities that could possibly be related to thermal discharges into the creeks were the higher values for nematodes in Four Mile Creek during November, February, and May. The differences that occurred may have been due to differences in discharges between the creeks.

The taxonomic composition of the drift was similar among river stations (Tables V-3.55 and V-3.56), and consisted primarily of chironomids (Diptera: Chironomidae), oligochaetes, Stenonema mayflies, and Cheumatopsyche caddisflies. There were seasonal variations in the taxonomic composition of the drift samples (O'Hop et al., 1985) that may have been caused by seasonal behavioral patterns or life cycles of aquatic insects (Fjellheium, 1980; Hall et al., 1980).

The taxonomic composition of the drift samples from the intake canals (Tables V-3.57 and V-3.58) often differed from the river stations, which probably reflects differences in the flow characteristics of the intake canals and the river. Chironomids (Diptera: Chironomidae), oligochaetes, and at times, water mites (Hydracarina) were the major components of the drift in the intake canals.

In the creek mouths, midges (dipterans) were the most abundant taxa, followed by nematodes, water mites, isopods, amphipods, grass shrimp, springtails, mayflies, beetles, and caddisflies (Tables V-3.57 and V-3.58). There were differences in taxonomic composition of the drift among the several stations. Only at Four Mile Creek were nematodes an important component of the drift. This was the only indication in the study of any relationship of drift to SRP operations. Taxa richness in the creek mouths was generally high in May and low in July. Four Mile Creek and Steel Creek usually had the highest taxa richness in the drift.

Gladden et al. (1985) reported on the macroinvertebrate drift collections from SRP creek mouth sites in the year preceding the CCWS (October 1982-September 1983). The mean number of organisms collected per 1,000 m^3 ranged from 3,686 in the mouth of Steel Creek to 10,179 in the mouth of Four Mile Creek (Table V-3.59). These drift densities were all much higher than those measured during the 1983-1985 study years. In Four Mile Creek, there was a greater than 10-fold difference between the two study years. The high average at Four Mile Creek was due to a very high drift density in May when 19,649 organisms/1,000 m^3 were collected. The May sampling date coincided with a sharp drop in river level and a

TABLE V-3.55

Average Annual Density (no./1,000 m^3) of Macroinvertebrate Drift Collected at Locations in the Savannah River (October 1983 - September 1984)

Taxon	Stations 4	10	11	19	25	38	41	46	47	49
Turbellaria	7.0	9.4	5.9	3.5	3.3	9.4	2.7	3.0	4.8	4.7
Nemotoda	15.7	8.1	14.7	17.6	24.9	15.3	17.3	17.2	11.9	16.6
Hirudinea	1.6	0.9	0.3	0.0	0.8	0.0	0.0	0.5	0.4	0.5
Gastropoda	4.2	2.1	2.8	0.4	2.4	0.4	0.5	0.3	2.6	1.6
Ancylidae	1.5	0.3	0.0	0.0	0.0	0.4	0.6	0.0	0.9	0.3
Amnicola spp.	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Physella heterostropha	3.3	0.3	0.0	0.8	1.1	2.4	0.0	0.3	1.1	0.3
Planorbidae	1.1	0.0	0.0	0.9	0.0	0.4	0.0	0.0	0.3	0.9
Helisoma spp.	1.0	0.3	0.3	0.4	0.0	1.0	0.0	0.0	0.0	0.0
Menetus dilatatus	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Pelecypoda	0.5	1.3	0.7	0.7	0.0	0.4	0.5	0.0	0.4	0.4
Corbicula fluminea	4.2	0.9	4.7	1.0	1.9	2.3	1.4	0.3	1.1	1.7
Sphaeriidae	1.2	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.7	1.2
Hydracarina	99.2	107.3	86.5	75.2	58.4	92.5	86.4	83.9	106.0	78.0
Asellus	0.7	0.7	2.9	1.0	4.7	2.2	2.5	0.9	1.4	2.7
Amphipoda	0.0	0.2	0.0	0.0	0.0	0.0	0.4	0.6	0.4	0.3
Gammarus fasciatus	5.9	0.0	5.9	0.0	5.4	6.3	0.6	1.8	0.0	5.0
Hyalella azteca	2.3	6.0	1.0	10.7	7.7	13.7	8.8	11.7	6.7	14.6
Decapoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0
Palaemonetes paludosus	0.0	0.0	0.0	0.0	0.3	1.9	0.0	0.0	0.0	0.3
Cambaridae	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Procambarus	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Collembola	11.6	9.5	7.7	10.0	9.1	7.2	8.3	8.8	14.5	6.8
Ephemeroptera	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Baetidae	2.6	4.0	4.9	6.5	7.5	4.2	2.3	4.3	5.3	3.4
Baetis	21.4	20.7	15.6	17.2	31.5	36.2	33.6	30.0	36.8	32.6
Callibaetis	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Heterocloeon	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pseudocloeon parvulum	7.0	10.3	4.3	5.2	7.8	3.1	2.6	3.0	6.2	3.2
Caenis	0.3	2.4	8.0	6.9	25.7	14.6	8.7	9.9	1.0	16.6
Ephemerellidae	6.2	0.0	1.3	0.0	4.3	8.7	0.0	9.6	4.6	4.8

TABLE V-3.55, Contd

Taxon	Stations 4	10	11	19	25	38	41	46	47	49
Dannella simplex	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Ephemerella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Ephemerella invaria	2.9	3.2	0.9	1.2	2.3	3.4	0.8	1.3	0.3	1.5
Eurylophella temporalis	4.4	12.6	5.2	10.4	13.6	5.3	6.9	41.9	3.8	4.4
Hexagenia	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.7
Heptageniidae	2.3	4.2	4.8	3.4	4.3	2.2	5.6	6.6	0.4	6.1
Heptagenia	2.7	2.7	0.7	1.7	3.3	3.2	6.5	4.2	0.0	4.5
Pseudiron	0.8	1.3	2.0	1.9	1.5	2.9	3.3	2.2	2.1	1.7
Spinadis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
Stenacron interpunctatum	0.0	0.0	0.0	0.3	1.2	0.0	0.3	0.4	0.0	0.3
Stenonema modestum	16.8	15.6	14.2	13.3	23.7	28.5	33.5	32.6	13.1	37.6
Paraleptophlebia	0.9	0.2	0.8	6.0	5.9	9.3	2.4	0.8	0.4	5.1
Neoephemera youngi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.4
Isonychia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Tricorythidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
Tricorythodes	59.2	53.3	40.1	38.4	39.0	36.9	19.1	19.4	53.1	45.2
Anisoptera	4.3	6.5	3.0	5.0	5.4	7.3	10.8	4.5	2.3	9.5
Boyeria vinosa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Neurocordulia molesta	0.0	0.0	0.0	0.0	0.4	0.7	0.0	0.0	0.0	0.0
Gomphidae	3.4	0.0	0.0	0.6	1.1	2.5	0.4	2.1	0.0	1.8
Libellulidae	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Libellula spp.	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.3	0.0	0.0
Zygoptera	0.3	0.3	0.0	2.2	0.4	0.0	0.3	1.1	0.7	1.4
Calopteryx spp.	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Coenagrionidae	0.4	0.4	0.8	0.4	1.8	0.0	0.0	0.0	0.0	0.0
Argia spp.	0.3	0.5	0.7	0.0	00	0.3	0.3	1.1	0.4	0.3
Enallagma spp.	0.0	1.2	2.5	1.1	3.1	3.0	2.5	0.6	3.3	1.3
Lestes	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Plecoptera	1.3	2.0	2.5	1.5	2.3	0.0	0.3	0.0	1.1	2.4
Nemocapnia carolina	1.8	1.5	0.4	1.5	4.4	2.4	5.4	3.9	0.0	2.4
Nemouridae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0
Shipsa	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.4	0.0	0.0
Perlidae	0.0	0.5	0.9	0.8	1.4	0.6	1.1	1.9	0.7	0.0
Acroneuria abnormis	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.0	0.0

TABLE V-3.55, Contd

Taxon	Stations 4	10	11	19	25	38	41	46	47	49
Perlesta placida	1.2	1.1	1.1	0.9	4.1	4.5	3.7	3.4	0.0	3.1
Perlodidae	0.0	0.6	0.0	0.3	0.0	0.0	0.0	0.0	0.4	0.0
Taeniopteryx robinae	0.0	0.2	0.7	0.0	0.0	0.2	0.8	0.0	0.4	0.0
Belostoma	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.5	0.0	0.0
Corixidae	3.1	3.0	1.8	2.2	3.0	1.1	2.7	1.4	3.6	2.0
Palmacorixa	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Sigara	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
Trichocorixa	0.0	0.3	0.0	0.0	0.0	0.4	0.5	0.0	0.0	0.3
Gerridae	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.5	0.0	0.0
Hydrometra	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Mesovelia mulsanti	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Nepidae	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Neoplea	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Curculionidae	0.0	0.0	0.0	0.4	0.4	0.0	0.0	1.4	0.0	0.0
Dytiscidae	0.0	0.0	0.8	0.0	0.4	0.0	0.0	0.0	0.8	0.0
Coptotomus	0.4	0.4	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0
Dytiscus	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.9	0.0
Hydroporus	1.4	2.1	1.4	2.8	11.3	6.4	1.1	5.0	1.8	7.1
Hygrotus	0.4	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Liodessus	1.4	2.3	1.1	1.2	0.4	0.7	1.2	1.0	0.0	0.3
Elmidae	0.3	0.7	0.3	0.0	0.4	0.4	0.4	0.7	0.0	0.0
Ancyronyx variegatus	9.9	6.9	4.7	7.8	4.4	5.7	5.8	4.8	5.1	12.4
Dubiraphia	0.0	0.4	0.4	0.7	0.7	0.0	0.3	0.5	0.7	0.4
Macronychus glabratus	2.7	3.1	3.1	0.3	6.9	4.9	4.1	4.5	1.3	3.7
Stenelmis	0.9	0.3	4.8	2.0	2.9	1.3	4.7	5.5	0.7	2.4
Dineutes	1.0	1.4	1.7	1.0	3.9	4.2	3.0	2.3	1.2	4.1
Gyrinus	0.4	0.0	0.4	0.3	0.0	0.0	0.9	0.7	0.0	0.0
Berosus	0.0	0.6	0.0	0.0	0.0	0.6	0.3	0.5	0.0	0.0
Tropisternus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Chauliodes	0.4	0.0	0.0	0.4	0.0	0.0	0.0	0.5	0.0	0.0
Corydalus cornutus	0.0	0.0	0.3	0.4	0.0	1.1	0.0	1.1	0.0	0.0
Sialis	0.0	0.0	0.0	0.3	1.1	0.0	1.8	0.8	0.0	0.0
Sisyridae	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.6

TABLE V-3.55, Contd

Taxon	Stations 4	10	11	19	25	38	41	46	47	49
Climacia areolaris	0.0	0.0	0.0	0.4	1.7	0.3	1.4	0.0	0.7	0.0
Trichoptera	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brachycentrus	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Micrasema	0.0	0.3	0.0	0.0	0.4	0.4	0.5	0.3	0.0	0.0
Hydropsychidae	6.7	10.1	6.3	6.1	6.6	4.4	11.4	11.9	1.3	8.7
Cheumatopsyche spp.	81.8	66.8	63.5	59.9	118.2	112.4	84.5	77.0	65.0	132.1
Hydropsyche spp.	15.4	8.5	7.9	7.4	8.5	13.7	9.4	7.5	7.3	18.2
Macrostomum carolina	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Hydroptilidae	1.1	0.0	1.2	0.3	0.4	0.4	0.0	0.0	0.0	0.0
Hydroptila	0.8	0.4	0.8	0.3	0.8	0.4	0.7	1.3	1.7	1.4
Oxyethira	1.8	2.6	3.0	2.8	9.5	21.5	9.8	10.1	4.5	5.5
Lepidostomatidae	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.0	0.0	1.5
Leptoceridae	1.2	2.4	0.8	0.7	1.3	2.6	0.0	0.0	0.0	0.0
Ceraclea	3.8	1.4	0.4	0.9	0.4	0.3	3.7	3.4	1.3	0.6
Leptocerus americanus	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nectopsyche	18.9	15.3	9.9	11.2	14.1	16.7	37.0	27.6	15.8	22.8
Oecetis	16.3	12.5	12.9	10.9	16.5	18.4	12.8	12.5	12.8	14.3
Triaenodes	0.0	0.0	0.0	0.3	0.0	0.0	0.5	0.9	0.0	1.4
Ironoquia	0.3	0.3	1.1	0.7	0.0	0.7	0.6	2.1	2.1	1.3
Pycnopsyche	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0
Philopotamidae	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Chimarra	18.8	20.3	19.6	20.6	42.6	34.2	39.0	43.3	6.6	44.9
Polycentropodidae	0.0	0.0	0.3	0.0	1.4	0.0	0.0	0.4	0.0	0.3
Cernotina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Cyrnellus	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.0
Neureclipsis	3.8	2.7	2.7	2.6	2.6	4.6	2.4	1.0	3.2	4.2
Phylocentropus	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Polycentropus	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
Munroessa	0.0	0.0	0.0	0.0	0.0	1.0	3.5	3.3	0.0	0.0
Neargyractis	0.0	0.0	0.0	0.0	0.5	0.6	0.0	0.3	0.0	0.0
Parapoynx	0.3	0.0	0.7	0.0	0.0	1.9	0.0	0.0	0.4	0.4
Ceratopogoniinae	5.2	2.3	5.6	2.1	7.1	2.9	5.1	3.5	7.3	4.2
Forcipomyiinae	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.4	0.0
Chaoborus punctipennis	24.0	26.1	23.0	23.2	25.4	22.5	6.6	8.5	46.9	24.6

TABLE V-3.55, Contd

Taxon	Stations 4	10	11	19	25	38	41	46	47	49
Chironomidae	609.5	498.8	459.2	594.2	481.2	533.6	389.6	618.8	627.3	580.1
Tanypodinae	12.6	14.1	11.2	17.1	35.0	22.4	30.4	20.1	18.3	30.5
Culicidae	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.5	0.4	0.0
Aedes	0.4	0.3	0.8	0.4	0.5	0.4	0.0	0.3	1.2	0.4
Anopheles	1.0	0.0	0.0	0.3	0.4	0.4	0.0	0.4	0.0	0.0
Culex	0.4	0.4	1.1	4.4	5.5	2.3	1.0	0.0	2.2	0.6
Empididae	11.2	9.5	4.0	6.7	3.4	4.5	3.6	5.6	9.6	6.9
Ephydridae	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Psychodidae	0.7	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.3	0.0
Bittacomorpha	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
Simulium	22.2	26.7	21.9	25.9	43.0	47.5	103.8	91.3	13.6	74.6
Chrysops	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0
Tipulidae	0.6	0.0	0.0	0.0	0.4	0.3	0.3	1.0	0.4	0.9
Total	1186.4	1037.0	927.1	1070.0	1182.5	1242.3	1070.1	1303.6	1157.7	1340.8

Source: O'Hop et al., 1985.

TABLE V-3.56

Average Annual Density (no./1,000 m^3) of Macroinvertebrate Drift Collected at Locations in the Savannah River (October 1984 - September 1985)

Taxon	Stations 47	4	10	11	19	48	25	38	49	41	46
Turbellaria	17.6	4.5	14.6	6.7	6.7	7.7	5.7	5.7	9.6	2.4	2.4
Nemotoda	97.4	71.0	95.8	77.7	98.1	90.6	76.6	48.0	48.7	41.1	48.1
Oligochaeta	1366.6	1118.9	971.2	985.6	1192.4	1593.2	1995.4	882.1	908.9	558.4	623.0
Hirudinea	0.4	0.0	1.8	0.7	0.5	0.7	1.1	0.0	1.9	0.0	0.6
Gastropoda	1.8	0.9	1.1	1.0	0.6	0.3	1.5	0.4	0.2	0.4	0.7
Ancylidae	1.2	0.3	0.4	0.0	0.8	0.0	0.7	0.0	0.0	0.0	0.0
Ferrissia rivularis	1.9	0.0	0.4	0.9	0.8	0.0	0.0	1.5	1.5	0.3	2.0
Laevapex fuscus	0.3	0.3	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.7	0.4
Amnicola spp.	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pseudosuccinea columella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0
Physella heterostropha	0.9	1.3	1.4	0.4	2.6	0.4	1.1	0.9	1.1	0.0	0.0
Planorbidae	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gyraulus parvus	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Helisoma trivolvis	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corbicula fluminea	0.0	0.0	0.0	0.3	0.0	1.8	0.0	1.1	0.5	0.3	0.0
Sphaeriidae	0.9	0.9	1.5	0.4	0.3	0.0	0.4	0.4	0.0	0.0	0.0
Hydracarina	52.6	63.6	66.7	89.4	93.7	65.5	85.1	63.7	89.4	86.8	97.6
Asellus	0.0	0.0	0.8	0.3	0.9	0.7	0.8	0.7	1.6	1.4	0.9
Amphipoda	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.4	0.0	0.0	0.0
Gammarus fasciatus	0.0	0.0	0.4	0.6	0.0	0.7	0.0	2.7	6.6	0.4	1.6
Hyalella azteca	3.6	2.4	1.8	0.4	2.1	2.0	5.3	2.6	4.3	4.8	1.2
Decapoda	0.0	0.0	0.0	0.0	0.3	0.0	0.7	0.0	0.0	0.0	0.0
Palaemonetes paludosus	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Collembola	3.1	3.1	2.5	3.6	3.8	3.3	4.4	2.0	2.8	0.7	2.4
Isotomidae	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
Baetidae	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baetis	13.3	10.1	10.2	11.3	14.5	19.1	23.2	16.1	12.7	20.8	15.4
Callibaetis	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Pseudocloeon parvulum	1.2	1.1	1.4	1.7	2.9	5.3	3.6	4.3	3.5	1.1	0.3
Baetisca sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Caenis	0.0	1.3	2.0	3.4	6.1	8.6	16.2	11.7	5.2	1.7	6.0
Ephemerellidae	0.0	0.0	0.0	0.0	0.4	0.4	0.7	0.0	0.0	0.4	0.0

TABLE V-3.56, Contd

Taxon	Stations 47	4	10	11	19	48	25	38	49	41	46
Ephemerella invaria	1.3	0.7	1.8	0.0	2.9	1.9	4.7	4.0	2.2	7.4	6.1
Eurylophella temporalis	7.2	7.1	3.3	4.7	5.0	11.4	19.7	8.9	14.7	20.2	24.8
Heptageniidae	2.0	1.7	1.1	1.6	2.4	2.9	3.3	1.7	0.0	2.7	2.0
Heptagenia	2.6	4.1	2.2	1.0	1.2	1.1	6.9	8.2	9.1	8.1	11.0
Pseudiron	0.5	0.3	1.3	0.0	1.5	1.5	2.7	3.0	2.8	3.2	2.7
Spinadis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
Stenacron interpunctatum	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.5	0.7	0.0	0.0
Stenonema modestum	21.2	30.7	26.5	32.5	30.5	28.8	47.1	31.5	51.0	47.4	51.3
Paraleptophlebia	0.0	0.0	0.0	0.3	0.0	0.4	1.1	1.0	2.6	1.0	0.0
Neoephemera youngi	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Isonychia	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.4	0.0	0.0	0.0
Tricorythidae	0.0	0.9	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Tricorythodes	24.0	9.0	18.3	13.1	12.5	16.8	23.5	15.2	12.1	13.7	15.2
Anisoptera	3.8	2.6	2.2	2.0	5.2	3.0	5.0	1.3	2.1	4.3	1.1
Gomphidae	0.3	0.0	1.5	0.0	0.7	2.5	1.0	0.7	1.9	0.4	2.7
Micromia spp.	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Calopteryx spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
Hetaerina spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Coenagrionidae	0.3	0.2	0.8	2.4	0.3	1.1	2.8	0.4	0.2	1.2	1.9
Argia spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0
Enallagma spp.	0.0	0.3	0.5	0.6	0.0	0.4	1.5	0.9	0.7	2.1	0.3
Lestes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Plecopteras	0.3	0.0	0.0	0.0	0.0	1.7	0.8	0.7	0.5	2.6	1.0
Capniidae	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	1.4
Hemocapnia carolina	1.5	3.4	2.9	1.1	2.5	4.4	9.9	3.6	8.8	3.4	4.7
Allopera furcula	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.7
Perlidae	0.0	1.4	3.2	1.3	0.6	2.4	2.1	2.2	4.6	5.7	7.5
Perlesta placida	6.6	4.3	2.9	4.0	5.2	15.8	25.3	14.4	13.1	14.2	10.5
Isoperla	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Pteronarcys dorsata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Taeniopterygidae	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Taeniopteryx robinae	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Hemiptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Belostoma	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0

TABLE V-3.56, Contd

Taxon	Stations 47	4	10	11	19	48	25	38	49	41	46
Corixidae	0.3	0.3	0.8	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.0
Trichocorixa	2.7	0.6	2.0	1.2	0.9	0.0	0.7	0.0	0.4	0.0	0.0
Gerridae	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Hydrometra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Curculionidae	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.4	0.0
Dytiscidae	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Hydroporus	0.9	0.3	0.4	0.3	0.3	1.3	3.5	1.7	2.2	1.5	0.0
Elmidae	0.3	0.0	1.2	0.4	0.0	0.6	0.4	0.0	0.0	0.7	0.0
Ancyronyx variegatus	5.9	3.7	4.7	6.5	6.5	6.1	7.1	8.0	4.0	5.4	4.8
Dubiraphia	0.0	0.0	0.4	1.2	0.3	0.4	0.3	0.0	0.0	0.0	0.4
Macronychus glabratus	1.3	1.5	0.4	0.7	1.6	2.1	0.7	3.5	2.3	3.3	1.6
Microcylloepus pusillus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Stenelmis	0.0	1.9	1.4	0.7	3.5	2.4	5.4	4.5	3.0	3.8	0.4
Dineutes	7.4	4.3	6.9	4.1	5.1	8.6	17.5	5.8	6.4	6.6	9.0
Gyrinus	0.3	0.0	0.0	0.6	0.0	0.7	0.3	0.0	0.0	0.0	0.0
Haliplus	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Peltodytes	0.8	0.0	0.0	0.3	0.0	0.4	0.0	0.0	0.0	0.0	0.0
Hydrochus	0.0	0.0	0.4	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Berosus	0.3	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Tropisternus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0
Noteridae	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Corydalus cornutus	0.0	0.3	0.0	0.0	0.0	0.3	0.4	0.4	0.9	0.4	0.0
Climacia areolaris	0.7	1.4	1.8	1.3	1.3	3.4	3.4	6.1	3.1	1.2	2.7
Sisyra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Brachycentrus	0.0	0.3	0.4	0.0	0.0	0.0	0.4	0.0	0.3	0.0	0.0
Micrasema	0.5	0.9	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydropsychidae	0.3	5.1	4.5	13.2	4.9	9.5	20.2	4.5	3.9	1.3	2.4
Cheumatopsyche spp.	76.1	51.0	70.9	47.0	56.9	82.5	91.5	59.3	95.3	60.1	67.7
Hydropsyche spp.	9.3	10.2	12.8	14.2	15.2	8.3	17.1	17.8	32.9	12.3	14.9
Macrostemum carolina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Hydroptila	1.2	1.0	1.9	1.2	0.0	0.0	0.4	1.2	0.3	1.8	0.8
Ochrotrichia	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oxyethira	1.7	0.0	1.8	1.1	0.3	1.1	3.3	3.7	1.7	2.3	2.0

TABLE V-3.56, Contd

Taxon	Stations 47	4	10	11	19	48	25	38	49	41	46
Lepidostoma	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ceraclea	2.6	4.0	3.6	3.8	2.0	1.8	4.7	3.0	5.8	7.6	3.2
Nectopsyche	0.0	2.7	1.5	0.4	1.9	0.3	0.0	1.8	0.0	0.0	1.2
Nectopsyche candida	3.3	1.0	6.5	5.3	1.4	2.9	8.3	0.4	10.4	3.9	6.9
Oecetis	2.3	2.2	1.2	1.1	3.0	1.4	5.1	3.1	2.9	1.8	3.1
Triaenodes	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Limnephilidae	0.0	0.0	0.0	0.4	0.3	0.4	0.3	0.0	0.0	0.0	1.1
Ironoquia	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.8	0.7	0.4
Pycnopsyche	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Chimarra	0.5	2.1	1.5	3.3	3.5	6.5	8.0	6.8	16.8	12.9	13.9
Neureclipsis	2.4	1.9	0.7	1.1	1.4	2.5	2.1	1.6	0.0	1.1	1.2
Nyctiophylax	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Polycentropus	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lype diversa	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
Munroessa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Parapoynx	0.4	0.0	0.0	0.0	0.3	0.6	0.0	0.0	0.0	0.4	0.4
Synclita	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	1.1
Ceratopogonidae	4.3	3.9	4.3	5.9	7.1	6.2	11.7	4.0	8.5	2.7	3.4
Forcipomyiinae	0.3	0.0	0.0	0.0	0.0	1.0	0.3	0.0	0.0	0.0	0.4
Chaoborus punctipennis	10.7	2.4	5.6	5.1	3.6	9.7	11.3	4.4	2.9	4.8	2.0
Chironomidae	442.1	425.9	460.7	467.2	456.2	459.7	549.1	363.8	373.9	294.3	347.6
Tanytarsini	50.9	49.5	24.9	48.4	26.1	25.0	21.9	21.6	57.7	7.8	11.1
Tanypodinae	10.7	6.3	8.8	11.0	15.4	16.7	22.8	14.0	13.9	13.9	11.1
Aedes	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.0	0.0
Anopheles	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.4	0.0	0.4
Uranotaenia	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Empididae	14.6	9.2	10.9	15.1	13.3	8.6	9.1	7.2	7.6	6.5	6.1
Psychodidae	0.0	0.8	0.0	0.3	0.4	0.0	0.3	0.0	0.0	0.0	0.0
Simulium	6.9	9.6	13.2	20.1	19.1	19.4	21.3	34.3	58.0	32.6	43.7
Tipulidae	0.0	0.0	0.0	0.7	0.3	0.0	0.7	0.4	0.8	1.1	0.4
Tipula	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.3
Total	2298.7	1953.3	1901.2	1933.3	2154.5	2588.5	3235.6	1729.5	1949.7	1354.2	1516.0

Source: O'Hop et al., 1986.

TABLE V-3.57

Average Annual Density (no./1,000 m^3) of Macroinvertebrate Drift Collected at Locations in SRP Creek Mouths and Intake Canals (October 1983 - September 1984)

Taxon	Stations 3	9	18	37	45	1G	3G
Turbellaria	0.0	3.0	4.5	2.3	0.0	22.8	3.2
Nematoda	0.0	1.1	89.9	2.4	3.3	0.7	1.7
Hirudinea	0.0	0.0	4.0	3.8	0.0	0.0	0.0
Gastropoda	0.0	0.0	0.0	1.3	3.6	0.0	3.9
Amnicola spp.	0.0	0.0	0.0	1.6	0.0	9.9	0.0
Physella heterostropha	0.0	1.2	1.4	2.4	0.9	1.2	0.0
Planorbidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Helisoma spp.	0.0	0.0	3.4	1.2	0.0	21.0	0.0
Pelecypoda	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Corbicula fluminea	0.0	0.0	0.0	0.0	0.0	3.9	0.0
Sphaeriidae	0.0	1.2	0.0	1.2	0.0	8.4	0.0
Hydracarina	68.6	22.0	21.8	532.2	35.0	146.4	70.6
Asellus	17.5	11.9	30.0	3.1	5.5	0.0	0.0
Amphipoda	0.0	0.0	0.0	2.0	0.0	0.0	0.0
Gammarus fasciatus	2.0	8.7	4.5	10.7	2.5	0.0	0.8
Hyalella azteca	1.1	9.6	31.4	41.0	5.6	3.4	1.1
Palaemonetes paludosus	0.0	0.0	0.0	31.3	2.1	0.0	0.0
Collembola	25.8	0.0	11.8	0.0	1.3	0.0	0.0
Baetidae	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Baetis	12.0	20.4	24.0	238.8	46.7	14.7	12.5
Pseudocloeon parvulum	0.9	0.0	0.0	0.0	1.3	0.6	2.9
Caenis	5.3	66.6	58.5	42.1	0.9	0.6	0.0
Ephemerellidae	0.0	0.0	11.8	0.0	0.0	0.0	0.0
Ephemerella invaria	0.0	0.0	0.0	0.0	1.3	0.0	0.0
Eurylophella temporalis	3.5	0.0	0.0	2.8	16.3	0.0	0.0
Heptageniidae	0.0	1.1	0.0	1.4	1.5	0.0	0.7
Heptagenia	1.1	0.0	0.0	0.0	1.3	0.5	0.0
Pseudiron	0.0	0.0	0.0	0.0	0.0	0.6	0.0
Stenonema modestum	3.7	17.2	3.1	13.3	7.9	1.5	0.0
Paraleptophlebia	0.0	0.0	0.0	0.0	0.0	0.7	0.0
Tricorythodes	2.1	3.3	0.0	1.8	6.6	2.0	0.0
Anisoptera	0.9	0.0	4.4	0.0	2.1	3.4	2.6
Gomphidae	0.0	0.0	0.0	0.0	0.0	0.0	2.1
Neurocordulia molesta	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Argia spp.	0.0	0.0	2.3	0.0	0.0	0.0	0.0
Enallagma spp.	1.5	6.1	0.0	1.3	0.0	1.8	0.0
Ischnura spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Nemocapnia carolina	1.1	0.0	0.0	0.0	0.0	0.0	0.0
Nemouridae	0.0	0.0	1.7	0.0	0.0	0.0	0.0
Perlesta placida	0.0	0.0	0.0	0.0	2.2	0.0	0.0
Isoperla	4.6	0.0	0.0	0.0	1.3	0.0	0.0
Taeniopterygidae	0.0	0.0	1.9	0.0	0.0	0.0	0.0

TABLE V-3.57, Contd

Taxon	Stations 3	9	18	37	45	1G	3G
Corixidae	0.9	0.0	4.7	0.0	0.0	14.6	1.5
Palmacorixa	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Trichocorixa	1.1	0.0	0.0	0.0	0.0	0.0	0.0
Gerridae	0.0	0.0	3.7	0.0	0.0	0.0	0.0
Hydrometra	0.0	1.7	0.0	0.0	0.0	1.6	0.0
Notonecta	0.0	0.0	0.0	0.0	0.0	0.6	0.0
Veliidae	1.7	1.1	0.0	0.0	0.0	0.0	0.0
Dytiscidae	1.1	0.0	0.0	0.0	0.0	0.0	0.0
Coptotomus	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Dytiscus	0.0	0.0	0.0	0.0	0.0	7.2	0.0
Hydroporus	4.3	0.0	0.0	1.2	9.6	0.6	0.0
Liodessus	0.0	0.0	0.0	1.2	0.0	0.0	0.0
Elmidae	0.0	0.0	0.0	0.0	3.6	0.0	0.0
Ancyronyx variegatus	2.0	0.0	2.8	2.3	19.2	6.3	8.3
Dubiraphia	1.2	0.0	0.0	0.0	4.2	0.0	0.0
Macronychus glabratus	4.3	3.5	0.0	14.2	0.0	0.6	0.0
Stenelmis	7.8	23.9	0.0	0.0	0.0	0.0	0.0
Dineutes	4.0	0.0	0.0	6.1	2.2	0.5	1.4
Haliplus	0.0	0.0	0.0	0.0	0.0	0.6	0.0
Peltodytes	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Gyrinus	0.0	0.0	0.0	5.3	0.0	0.0	0.0
Hydrochus	0.0	0.0	0.0	0.0	3.6	0.0	0.0
Chauliodes	1.2	0.0	0.0	0.0	0.0	0.0	0.0
Climacia areolaris	2.2	0.0	0.0	0.0	0.0	0.0	0.8
Brachycentrus	0.0	0.0	0.0	0.0	0.0	0.0	2.5
Zygoptera	0.0	1.7	0.0	2.5	0.0	1.8	3.4
Micrasema	2.1	0.0	0.0	0.0	1.4	0.0	0.0
Hydropsychidae	0.0	0.0	0.0	0.0	0.0	0.0	3.2
Cheumatopsyche spp.	33.5	3.4	17.8	16.5	35.7	3.6	6.9
Hydropsyche spp.	10.4	0.0	5.4	3.6	12.7	0.7	0.0
Macrostemum carolina	0.0	0.0	0.0	4.3	0.0	0.0	0.0
Hydroptila	0.0	1.4	1.3	0.0	0.0	1.2	0.0
Oxyethira	0.9	5.1	2.0	180.9	3.6	3.3	1.0
Leptoceridae	0.0	2.0	0.0	0.0	0.0	0.0	0.0
Leptocerus americanus	0.0	0.0	0.0	0.0	0.0	0.6	0.0
Nectopsyche	0.0	0.0	0.0	4.5	1.3	7.1	11.9
Oecetis	3.4	0.0	0.0	7.5	2.9	1.6	5.2
Triaenodes	1.1	0.0	0.0	0.0	0.0	0.0	0.0
Chimarra	0.0	9.9	0.0	10.5	1.4	1.2	3.9
Polycentropodidae	0.0	0.0	1.3	1.3	0.0	0.0	0.0
Neureclipsis	0.0	0.0	0.0	0.0	2.5	0.5	2.9
Nyctiophylax	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Phylocentropus	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Polycentropus	0.0	0.0	0.0	1.9	0.0	0.0	0.0
Lype diversa	0.0	0.0	0.0	0.0	2.2	0.0	0.0

TABLE V-3.57, Contd

Taxon	Stations 3	9	18	37	45	1G	3G
Pyralidae	0.0	1.1	2.3	1.7	0.0	0.0	0.0
Munroessa	0.0	0.0	0.0	47.3	0.0	0.0	0.0
Neargyractis	0.0	0.0	0.0	1.4	0.0	0.0	0.0
Parapoynx	1.2	0.0	0.0	4.2	0.0	0.0	0.0
Ceratopogoniinae	0.0	3.8	4.0	1.5	1.4	0.0	1.0
Chaoborus punctipennis	1.2	3.9	0.0	0.0	1.4	7.9	2.0
Chironomidae	284.9	417.4	269.1	427.4	278.4	593.5	279.1
Tanypodinae	51.1	17.6	92.9	53.3	52.9	11.4	4.2
Aedes	3.2	0.0	0.0	0.0	0.0	0.0	0.7
Anopheles	0.0	0.0	2.3	1.8	0.0	0.6	0.0
Culex	0.0	1.4	3.1	0.0	0.9	1.3	1.0
Empididae	2.1	0.0	0.0	0.0	2.6	0.0	0.0
Psychodidae	0.0	1.1	2.0	0.0	0.0	0.0	0.0
Simulium	11.1	19.2	34.5	84.5	68.5	3.7	8.5
Tipulidae	0.0	0.0	3.0	0.0	0.0	0.0	0.0

Source: O'Hop et al., 1985.

TABLE V-3.58

Average Annual Density (no./1,000 m^3) of Macroinvertebrate Drift Collected in the Mouths of Creeks that Drain the SRP (October 1984 - September 1985)

Taxon	Creek Mouth Stations					Intake Canal Stations	
	3	9	18	37	45	1G	3G
Turbellaria	0.0	18.3	0.0	6.4	9.4	2.5	7.8
Nemotoda	0.0	12.2	80.2	2.4	0.0	5.8	17.4
Oligochaeta	9.4	163.7	278.5	137.0	59.4	300.6	751.0
Hirudinea	0.0	3.2	0.0	0.0	0.0	0.0	0.0
Gastropoda	0.0	2.9	0.0	0.0	0.0	1.5	3.3
Ferrissia rivularis	0.0	0.0	0.0	1.3	1.5	0.0	0.3
Amnicola spp.	0.0	0.0	0.0	0.0	1.5	0.0	0.0
Pseudosuccinea columella	0.0	0.0	1.1	0.0	0.0	0.0	0.8
Physella heterostropha	0.0	0.0	2.3	0.0	0.0	0.8	8.1
Corbicula fluminea	0.0	0.0	0.0	2.1	0.0	1.5	40.6
Hydracarina	0.0	13.9	10.6	75.1	40.6	29.7	16.2
Asellus	0.0	0.0	8.4	0.0	0.0	0.0	0.0
Amphipoda	0.0	0.0	0.0	1.5	0.0	0.0	0.0
Gammarus fasciatus	0.0	0.0	0.0	27.5	92.4	0.0	0.0
Hyalella azteca	0.0	2.9	30.3	0.0	1.7	0.0	0.0
Collembola	0.0	0.0	0.0	2.4	0.0	2.3	9.5
Podura aquatica	0.0	0.0	0.0	5.2	0.0	0.0	0.0
Baetidae	2.3	0.0	1.6	1.5	0.0	0.7	0.0
Baetis	46.3	15.9	6.6	7.2	82.3	5.9	5.0
Pseudocloeon parvulum	4.2	0.0	0.0	0.0	0.0	2.7	0.0
Caenis	9.6	8.6	18.3	1.1	3.1	0.0	1.5
Ephemerella invaria	0.0	0.0	3.3	0.0	10.5	0.7	0.0
Eurylophella temporalis	6.6	3.2	3.3	3.8	40.3	0.7	2.6
Heptageniidae	6.6	0.0	0.0	0.0	0.0	0.0	0.6
Heptagenia	0.0	0.0	6.6	4.8	6.1	0.0	0.0
Stenonema modestum	4.6	9.7	1.6	1.1	47.0	3.1	2.1
Leptophlebiidae	2.3	0.0	0.0	0.0	0.0	0.0	0.0
Paraleptophlebia	0.0	0.0	0.0	0.0	23.7	0.0	0.0
Tricorythodes	4.0	0.0	0.0	0.0	8.0	0.0	2.7
Anisoptera	0.0	0.0	4.5	1.1	1.7	0.0	3.3
Gomphidae	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Coenagrionidae	0.0	5.6	0.0	1.3	1.5	0.0	1.9
Enallagma spp.	0.0	1.6	3.3	2.9	0.0	0.0	0.8
Lestes	0.0	0.0	0.0	2.7	0.0	0.0	0.0
Plecoptera	4.2	0.0	0.0	0.0	0.0	0.0	0.0
Perlidae	0.0	0.0	2.3	0.0	3.0	0.7	0.0
Perlesta placida	2.6	0.0	1.5	0.0	3.0	0.9	0.0
Corixidae	0.0	0.0	0.0	0.0	0.0	1.8	2.2
Trichocorixa	0.0	0.0	0.0	0.0	0.0	2.2	0.0
Gerridae	0.0	0.0	0.0	0.0	0.0	0.9	1.7
Curculionidae	0.0	1.2	0.0	2.4	0.0	0.0	3.3

TABLE V-3.58, Contd

Taxon	Creek Mouth Stations 3	9	18	37	45	Intake Canal Stations 1G	3G
Hydroporus	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Elmidae	0.0	6.5	0.0	0.0	1.5	0.0	0.0
Ancyronyx variegatus	0.0	2.9	1.8	4.2	16.3	1.7	2.5
Dubiraphia	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Macronychus glabratus	0.0	9.7	0.0	1.5	4.6	1.8	3.1
Microcylloepus pusillus	0.0	0.0	0.0	0.0	1.5	0.0	0.0
Stenelmis	0.0	4.3	0.0	0.0	0.0	0.8	0.0
Dineutes	0.0	0.0	1.8	1.1	13.3	0.0	3.1
Peltodytes	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Hydrochus	0.0	0.0	0.0	0.0	0.0	0.8	0.0
Chauliodes	0.0	0.0	0.0	0.0	0.0	0.7	1.0
Micrasema	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Gyrinus	0.0	0.0	0.0	0.0	2.9	0.0	0.0
Sialis	4.8	0.0	0.0	0.0	0.0	0.3	0.0
Climacia areolaris	0.0	0.0	0.0	0.0	3.0	0.0	0.0
Brachycentrus	0.0	1.5	0.0	0.0	3.1	0.0	0.0
Hydropsychidae	4.8	0.0	0.0	0.0	0.0	0.8	0.3
Cheumatopsyche spp.	12.7	6.3	10.5	9.4	48.7	5.0	4.9
Hydropsyche spp.	4.0	0.0	0.0	5.0	2.2	0.0	3.0
Hydroptila	0.0	0.0	0.0	0.0	1.5	0.0	1.4
Oxyethira	0.0	2.9	0.0	4.8	0.0	0.0	0.0
Lepidostomatidae	0.0	0.0	0.0	1.3	0.0	0.0	0.0
Lepidostoma	4.0	0.0	0.0	0.0	0.0	0.0	0.0
Ceraclea	0.0	0.0	0.0	0.0	0.0	1.2	0.7
Nectopsyche	0.0	1.2	0.0	0.0	0.0	0.7	0.0
Nectopsyche candida	0.0	0.0	1.8	0.0	1.5	0.9	2.6
Oecetis	2.3	1.2	0.0	0.0	30.6	0.7	0.0
Triaenodes	0.0	0.0	0.0	0.0	0.0	0.4	0.0
Limnephilidae	0.0	0.0	0.0	1.3	6.0	0.0	0.0
Chimarra	0.0	4.9	0.0	1.1	0.0	0.0	0.0
Neureclipsis	0.0	0.0	0.0	0.0	1.5	0.4	0.7
Lype diversa	0.0	0.0	0.0	0.0	61.1	0.7	0.0
Pyralidae	0.0	1.6	0.0	0.0	0.0	0.0	0.0
Munroessa	0.0	0.0	0.0	7.2	0.0	0.0	0.0
Parapoynx	0.0	0.0	0.0	1.3	0.0	0.4	0.0
Ceratopogonidae	6.3	0.0	0.0	0.0	0.0	0.4	1.6
Ceratopogoniinae	0.0	0.0	1.8	0.0	0.0		
Forcipomyiinae	0.0	8.0	0.0	0.0	0.0	0.0	1.5
Chaoborus punctipennis	0.0	0.0	1.8	0.0	0.0	4.1	3.3
Chironomidae	138.0	317.1	135.9	42.1	106.7	380.8	453.6
Chironomini	0.0	1.5	3.8	25.5	108.6	0.0	0.0
Tanytarsini	43.2	15.9	85.3	35.1	577.7	4.0	6.6
Orthocladiinae	0.0	7.9	18.7	13.1	1.4	0.0	0.0
Tanypodinae	18.7	3.4	63.8	2.5	9.6	0.9	2.2

TABLE V-3.58, Contd

Taxon	Creek Mouth Stations 3	9	18	37	45	Intake Canal Stations 1G	3G
Culex	0.0	0.0	0.0	0.0	3.0	0.0	1.6
Empididae	8.0	2.9	0.0	2.6	15.3	1.4	4.3
Psychodidae	0.0	0.0	0.0	1.1	0.0	0.0	0.0
Simulium	27.8	0.0	8.8	28.7	35.0	1.3	2.2
Stratiomyidae	0.0	0.0	1.1	0.0	0.0	0.0	0.0
Tabanidae	0.0	0.0	2.0	0.0	0.0	0.0	0.0
Total	377.6	654.7	803.3	479.4	1493.8	774.8	1387.6

Source: O'Hop et al., 1986.

TABLE V-3.59

Mean Number of Macroinvertebrate Taxa Collected/50 m^3 Drift Sample and Mean Density of Organisms/1,000 m^3 (February, May, and July 1983)

Sampling Location (creek mouth)	Taxa	Density
Upper Three Runs Creek	10.5	4,436
Beaver Dam Creek	16.4	5,656
Four Mile Creek	11.5	10,179*
Steel Creek	12.3	3,686
Lower Three Runs Creek	11.5	3,975

* High density was due to extremely high drift density in May.

corresponding rapid rise in water temperature at the mouth of Four Mile Creek, which resulted when thermal discharges from C Reactor began to follow the stream channel rather than move laterally through the swamp. Temperatures in the mouth of Four Mile Creek were observed to increase from ambient river temperature (14°C) to 35°C within a few days. It is likely that the high drift densities occurred when a large number of macroinvertebrates were killed by the sudden temperature increase in the creek (Gladden et al., 1985).

In summary, the results of multiplate sampling in the mouths of creeks (Upper Three Runs, Beaver Dam, Four Mile, Steel, and Lower Three Runs) draining the SRP indicate that the macroinvertebrate community of Four Mile Creek was impacted by thermal discharges. Four Mile Creek samples displayed significantly lower species richness, density and biomass of aquatic macroinvertebrates during periods when C Reactor was on-line. The effects of thermal discharges were more pronounced in the summer months, when temperatures probably exceeded the thermal maxima of most aquatic invertebrates. Shifts in the seasonal abundance in Four Mile Creek were noted for <u>Hyalella</u>, <u>Caenis</u>, and <u>Physella</u>. River levels were high during August 1984, which prevented the thermal plume from reaching the sampling sites at the creek mouths. This resulted in higher densities, biomass and taxa richness in Four Mile Creek. High river levels during cooler months did not appear to affect macroinvertebrate density, biomass or taxa richness.

Savannah River stations located above and below the confluences of the creeks draining the SRP showed significant seasonal differences in invertebrate densities, but location above and below the creek confluences was usually not significant. Few significant differences in invertebrate densities could be attributed solely to location above or below the creek confluences, and the differences that were found do not appear to be related to SRP operations.

No significant differences in functional group densities on artificial substrates were found that could be attributed solely to location above or below the confluences of creeks draining the SRP. Invertebrate drift was similar among the river stations, with all stations showing distinct seasonal cycles. However, trends for the two study years were quite different, both seasonally and on an annual basis. No effects of location (above and below the confluences of creeks draining the SRP) on the numbers of invertebrate drift, could be attributed solely to water discharges from creeks draining to SRP.

V.3.8 Summary of the Effects of Thermal Effluent on the Lower Food Chain Communities

V.3.8.1 Introduction

Thermal effects on lower food chain organisms can have a significant effect on the structure and function of aquatic ecosystems. For example, death of riparian zone trees caused by high water temperatures or high discharges removes an important allochthonous energy source from the system. Processing of leaves and other organic matter into usable food is also affected by alterations in discharge rates and temperature. High discharge abrasion, but the high temperatures may slow down microbial and macroinvertebrate processing of organic matter. The physical structures of logs, debris, roots, and vegetation that retain organic matter and provide habitat for organisms may be altered by changes in discharge rates and temperature. Furthermore, the shape of the channel itself may be altered, affecting its suitability as habitat. Productivity by autochthonous energy sources (periphyton and macrophytes) tends to increase with slightly elevated temperatures. Increased light, a result of the death of streamside trees, also enhances the growth of aquatic plants. However, increased temperatures affect species composition by reducing species richness or altering species dominance. Extremely high temperatures may eliminate most or all species.

The following is a summary of the findings of the CCWS concerning the effects of the SRP thermal discharges on aquatic lower food chain communities. The summary is organized by habitat group as follows: nonthermal reference streams, Steel Creek, thermal streams, deltas, swamp, and the Savannah River.

V.3.8.2 Nonthermal Streams

Water temperatures in nonthermal streams showed normal seasonal cycles, with lowest monthly means in January and highest means in the mid-summer months. Maximum water temperatures were usually below 30°C in the fall through spring period and did not exceed 33°C during the summer. Due to the presence of Par Pond, temperatures in Lower Three Runs Creek were depressed during winter compared to other nonthermal streams.

In the small nonthermal streams (excluding Steel Creek), stream structure was complex. Logs and sticks were the most important structural features, but trailing roots, debris jams, and occasional cypress knees also contributed to the structure. The log density was higher in the upstream reaches than it was downstream. At the large nonthermal stream sites, stream structure was more diverse: logs and sticks were important, but unlike the smaller streams, trailing vegetation and macrophytes were important at several of the large nonthermal sites. There were no obvious and consistent seasonal trends in any of the mapped stream structure parameters.

In the nonthermal streams, the energy base was primarily allochthonous and leaf litter input was high. Leaves that fell into the stream (primarily during fall, except for those few sites dominated by evergreens) were colonized by microbes and rapidly broken down by physical abrasion and macroinvertebrate shredders. In the nonthermal streams, seston concentrations were within the range expected for southeastern U.S. blackwater streams. The fine size fraction of suspended particulates was more concentrated than the larger size fractions, and there was a high percentage of organic matter in the seston. Small nonthermal streams had higher concentrations of suspended solids than large streams, but a smaller proportion of this material was organic. Smallest size particles were proportionally more abundant in large streams, and large particles were proportionally more abundant in small streams. Autochthonous food sources were generally not significant, due to light limitations. Often the canopy provided by the streamside trees was complete and dense. As a result, periphyton and macrophyte biomass was low, especially during summer when canopy cover was densest and light was most limited. The macroinvertebrate communities were diverse (56 to 70 taxa) and included pollution-sensitive taxa.

V.3.8.3 Steel Creek

The Steel Creek corridor received thermal effluent until 1968. As a result, its morphometry and stream structure were different from the nonthermal reference streams. In its upper reaches, the channel edge was even and regular compared to the reference streams and the channel was eroded to a greater depth. The riparian vegetation consisted of shrubs and small trees rather than mature forest. There was less wood in the channel than in the reference streams, and most of the structural habitat was provided by less permanent structures such as sticks and macrophyte beds. Downstream, numerous channels braided through a floodplain that had dense vegetation consisting of willows, alders, wax myrtle, and other shrubs and small trees interspersed with cattails, smartweed (Polygonum), and other marsh plants, but no big trees. There were no obvious and consistent seasonal trends in any of the mapped stream structure parameters.

During this study, water temperatures in Steel Creek followed the same seasonal cycle as in nonthermal streams. However, average temperatures were sometimes elevated by several degrees, due mainly to the open canopy which allowed considerable solar heating.

In the Steel Creek corridor, litter inputs were low at the upstream sites because of the lack of riparian trees, while the downstream sites, with partial canopy from bottomland hardwoods and shrubs, had litter inputs more similar to those of the reference streams. Although not as pronounced as in the nonthermal streams, litterfall inputs peaked in the fall. Leaves decomposed faster in Steel Creek than in the reference streams due, presumably, to abrasion from the relatively high sediment load in Steel Creek.

There was a high concentration of suspended particles in transport at the two upstream Steel Creek sites, but the percent organic content of the seston was lower than in the reference streams. There was a downstream trend toward smaller sized particles with a higher organic content, and the mean particle sizes at Steel Creek corridor sites were smaller than at reference sites. In general, the higher current velocity of Steel Creek and the lack of retention structures resulted in a higher inorganic silt load.

Autochthonous energy sources were more important in open canopy Steel Creek than in the shaded reference streams and periphyton biomass was generally high. One Steel Creek stream station (Station 28) also had high macrophyte biomass. The macrophyte flora at the Steel Creek Delta sites was diverse, and exhibited pronounced seasonal changes in relative abundance. At this site, Steel Creek flows in small, shallow channels through a wooded floodplain, which is regularly inundated. The canopy is partial to open in some areas. Macroinvertebrate densities, biomass, and taxa richness at the Steel Creek corridor sites were similar to those at the reference streams, indicating a significant post-thermal recovery of the macroinvertebrate community. Many of the taxa common to samples at these stations were also common at the reference stream stations.

V.3.8.4 Thermal Streams

The temperature regimes in thermal streams were a function of ambient air temperatures, solar radiation and particularly discharges of heated water, and varied widely depending on reactor status. Streams receiving discharges of heated reactor cooling water (Four Mile Creek and Pen Branch) experienced mean monthly temperatures in excess of 35°C (generally considered to be near the upper lethal temperature maxima of most stream biota) and monthly maximum temperatures exceeding 40°C throughout the year when the reactors were operating. After reactor shutdown in late June 1985, water temperatures in Four Mile Creek returned to near ambient. Water temperatures in Beaver Dam Creek were elevated over those in nonthermal streams because of heated water discharges from a coal-fired generating plant, but seldom exceeded 35°C.

Wood provided the primary stream structure in the thermal streams receiving reactor effluents (Pen Branch and Four Mile). Stumps and logs that accumulated when the streamside forest was killed in the 1950s were more abundant than in the reference streams. Debris was also abundant, but trailing roots and macrophytes were scarce. There were no obvious and consistent seasonal trends in any of the mapped stream structure parameters.

The thermal streams receiving reactor effluents had temperatures that excluded many plants and animals when the reactors were operating (≤45°C). Breakdown of leaves in the reactor streams was rapid at first due to abrasion from inorganic sediment particles, but was not as complete as in the nonthermal streams, due to the absence of invertebrate shredders. Concentrations of TSS were significantly higher when the reactor was operating compared to when it was idle, due to the higher current velocities during periods of reactor operation. There was no significant difference in the percent organic matter due to reactor activity. TSS loads were higher than in the reference streams, but the organic contents of the particulates were very low. Fine size particles were more abundant than the other size fractions, and the concentration of fine particles was significantly greater than in the reference streams.

Periphyton biomass was low at Pen Branch and Four Mile Creek stations experiencing the highest temperatures (>45°C) from reactor cooling water effluents. When water in these streams was at ambient temperature (due to reactor shutdown), periphyton biomass was significantly higher. At cooler thermal sites, periphyton biomass was high and was dominated by blue-green algae, which were not abundant at the nonthermal sites. In general, periphyton biomass in thermal creeks was highest in winter, due to the stimulating effects of the warm water, and lowest in summer, when creek temperatures inhibited periphyton growth. Seasonal trends for macrophyte density paralleled those for periphyton, with highest biomass in winter (due to the stimulating effects of the warm water) and lowest biomass in summer. Macroinvertebrate populations had low biomass and low densities except for a few tolerant forms such as oligochaetes and some chironomids. When the reactors were shut down, the streams were rapidly colonized by algae and invertebrates. The taxa richness, density, and biomass of some macroinvertebrate groups that were absent during reactor operations increased during reactor shutdowns, as seen in the summer of 1985 in Four Mile Creek. Vagility and reproductive potential of recolonizing taxa were important factors in determining the rate of recovery of fauna after thermal discharges to Four Mile Creek ceased.

Beaver Dam Creek receives effluent from a coal fired power plant in D Area, which increases the water temperature of the creek by a maximum of 10°C. All of the stations sampled were located below the D-Area effluent outfalls. There was no apparent negative effect on the aquatic communities from the elevated temperatures. However, the increased discharge rates along with the fly ash and other pollutants in the various D-Area effluents appeared to periodically stress communities in upstream reaches. Miller (1984) documented wide shifts in pH in Beaver Dam Creek. During the 1984-1985 study, waters at Beaver Dam Creek stations were generally gray and turbid, with the trends generally decreasing downstream. However, with exception of some minor violations, the D-Area effluent outfalls consistently met NPDES standards during the study period. In view of the compliance with NPDES standards, it appears unlikely that the levels of pollutants released from D Area during the study period were sufficient to cause adverse impacts to the aquatic communities in upper Beaver Dam Creek. Variability in the composition and structure of the aquatic communities in Beaver Dam Creek may be related to perturbations that occurred prior to the initiation of the study, or to habitat differences unrelated to the levels of pollutants in the various D-Area effluents.

Beaver Dam Creek stations upstream from the slough area had abundant woody debris and trailing vegetation, but turbidity and high current velocity limited the growth of macrophytes. In the slough area, low current velocity and abundant macrophyte beds helped to retain organic matter. Downstream from the slough, large logs and wood were even more abundant than at the upstream stations. Macrophytes were absent due to high current velocity and high turbidity.

Litterfall at the most upstream station on Beaver Dam Creek was high, and instream primary production was low. Farther downstream, where the canopy was more open, periphyton biomass was higher, and thermal effluents may actually have enhanced periphyton production. In the slough area, macrophyte biomass was high and litter inputs were low. The macrophyte flora at this site was diverse and showed distinct changes in species composition over the year. Particulate matter imported from upstream settled out in the low velocity slough area. Although macroinvertebrate densities in Beaver Dam Creek were comparable to those of reference streams, macroinvertebrate biomass was lower, especially at the two stations closest to the thermal outfall. These trends are attributable to the relatively greater importance of small nematodes at the most upstream stations, and the low abundance of a number of larger insect and crustacean taxa. Taxa richness was also low at the two stations upstream from the slough, due to the absence of several insect and crustacean taxa.

V.3.8.5 Deltas

The SRP deltas, which were forested swamps prior to SRP operations, have suffered extensive tree loss due to SRP thermal reactor effluents and increased sediment deposition. During this study, two of the deltas (Pen Branch Delta and Four Mile Creek Delta) were still receiving thermal effluent. The third (Steel Creek Delta) had not received thermal effluent since 1968, but it still had an open canopy because the swamp forest had not grown back.

Stations in the Four Mile Creek Delta experienced greatly elevated temperatures when C Reactor was operating. During spring 1985, maximum temperatures ranged from 51.7°C at the north (i.e., upstream) end of the delta to 47.5°C at the south end. Even at the mouth of Four Mile Creek (below the delta) springtime temperatures reached 45°C. A similar situation was apparent for Pen Branch Delta, when maximum springtime temperatures exceeded 44°C. In contrast, the maximum temperatures in Steel Creek Delta reached 35°C at only one station during the summer of 1985.

Nonthermal Steel Creek Delta had high macrophyte and periphyton biomass. The abundant beds of aquatic plants provided excellent habitat for macroinvertebrates and undoubtedly increased the retentiveness of the system. There were seasonal changes in the abundance of different species, including the dominant taxa at sites in the Steel Creek Delta. There were no obvious and consistent seasonal trends in any of the other mapped stream structure parameters. Litterfall, which peaked in the fall, was lower than in forested swamp areas, and most of the particulate matter in transport was fine-sized. TSS concentrations were low, percent organic matter values were higher compared to upstream stations, and values for both parameters were comparable to those found in Pen Branch and Four Mile Creek deltas. Invertebrate biomass and diversity were high. The abundant macrophytes in the Steel Creek Delta exerted a major influence on the macroinvertebrate community by providing habitat, substrate for periphyton growth, and detritus as a food source. Unlike the thermal deltas, the Steel Creek Delta periphyton community was not dominated by blue-green algae. Instead, the assemblage included cooler-water forms such as green algae and diatoms, indicative of absence of thermal stress.

In the thermal deltas of Four Mile Creek and Pen Branch, high water temperatures excluded extensive growths of macrophytes in the channels. Without macrophytes, the habitat structure and energy base of these delta ecosystems were very different from those of the Steel Creek Delta. Wood was abundant in both thermal deltas, mainly in the form of cypress and tupelo gum logs. Wood provided most of the structure in these thermal delta areas, and showed no obvious seasonal trends. The energy base for the food chain in the thermal deltas included particulate matter transported from upstream and autochthonous production by blue-green algae. Slow current velocities allowed deposition of particulate matter. In the Four Mile Creek Delta, TSS concentrations and the size of particles in suspension decreased from the upstream to the downstream end of the delta. Both Four Mile Creek and Pen Branch deltas are expanding into the deeper areas of the swamp as deposition of sediment continues. Litter inputs to the open canopy delta were low. Macroinvertebrate richness values were particularly low when the reactors were operating, with thermally tolerant taxa such as oligochaetes, chironomids, and nematodes numerically dominating the community in both thermal deltas. During reactor shutdown, densities and biomass of many invertebrate taxa increased rapidly.

V.3.8.6 Swamp

The effects of SRP operations on the Steel Creek and Pen Branch swamp systems included thermal effects, increased discharge, and sedimentation. Prior to SRP operations, the swamp systems consisted primarily of second growth forests of cypress and tupelo gum. In the delta regions discussed in the previous section, the swamp trees were killed by thermal reactor effluents. In the areas that still have a forest, heavy siltation and continuous flooding continue to cause tree kills and the size of the delta continued to expand.

In the 1984-1985 study year, swamps in thermal Pen Branch and post-thermal Steel Creek were studied and compared. Temperatures in Steel Creek and Pen Branch swamps did not exceed 32°C during the study and were only slightly warmer than ambient. The Pen Branch swamp Station 24 was the study site that most closely resembled a natural swamp forest. The canopy was dense and few aquatic macrophytes grew in the channels. Habitat and channel structure were provided mainly by wood, which showed no obvious and consistent seasonal trends. The canopy in Steel Creek swamp was more open. The energy bases for the two swamp systems differed. Litterfall in Pen Branch was significantly higher than in Steel Creek, with both peaking in the fall. In the Steel Creek swamp, on the other hand, periphyton biomass was higher than in the Pen Branch swamp, and extensive macrophyte beds developed, with maximum cover in the spring. These macrophyte beds provided excellent animal habitat, and undoubtedly increased the retentiveness of the system. The flora at the Steel Creek swamp sites was diverse and there were seasonal changes in the abundance of different species and the dominant taxa at each site. The TSS concentrations were low and the percentage of organic matter in the seston was high in both swamps. Both swamp systems retained particulate matter from upstream. Both systems had high macroinvertebrate biomass, densities, and taxa richness.

V.3.8.7 Savannah River

The lower food chain of the Savannah River does not appear to be measurably impacted by SRP thermal effluents. Temperatures exhibited normal seasonal cycles with highest values (less than 28°C) in summer and lowest readings (8°C) in winter. Temperatures were very consistent across sampling sites, and there was little indication that thermal discharges from SRP streams influence temperatures in the Savannah River on more than a localized scale. Periphyton production varied seasonally, with high biomass in the summer and low biomass in the winter. However, the annual mean periphyton biomass did not differ significantly among river transects. The only significant difference attributed to thermal effects was periphyton biomass downstream from Four Mile Creek during the cooler months. Neither the multiplate or drift sampling of macroinvertebrates showed significant differences among river stations. Taxonomic composition and functional group densities of macroinvertebrate communities were similar among the river stations. Most river stations showed highest macroinvertebrate densities and biomass during October 1983, lowest values during winter, and relatively high values during summer.

V.3.9 Conclusions

Water temperature, the nature of the riparian vegetation, and water velocity were found to be most important to animal habitat and lower food chain structure and functioning in SRP streams and swamps and in the adjacent Savannah River. All of these parameters are or have been affected in those streams receiving SRP cooling water discharges.

Water temperature is an important controlling factor in regulating aquatic ecosystem structure and function. Under ambient temperature conditions, streams on the SRP generally have diverse macroinvertebrate assemblages, including environmentally sensitive taxa. Where temperature regimes were extreme (i.e., in Pen Branch and Four Mile Creek) normal stream organisms were excluded from the channels and a very simplified food chain existed in the restricted habitat available. However, when the reactors were not operating, macroinvertebrate communities responded rapidly with increases in density, biomass, and taxa richness. The macroinvertebrate community in Steel Creek was very similar to those of reference streams, indicating that it has recovered from the effects of previous reactor effluents. Under the mild thermal regime characteristic of Beaver Dam Creek, the energy base and community structure were probably not affected by temperature.

In addition to the direct effect on organisms, greatly elevated temperatures have killed riparian trees, especially in upstream floodplain areas and in the deltas, where cypress-tupelo gum swamp forests have been eliminated. The nature of the riparian vegetation has much to do with determining the energy base of the aquatic ecosystem. Natural streams on the SRP have complete canopy cover, leading to high rates of litterfall, low rates of autochthonous primary production (periphyton and macrophytes), and a food web dependent on allochthonous leaf material. Macroinvertebrate functional feeding groups in these streams were similar to those recorded for other blackwater streams of the southeast. Presence of riparian trees contributes greatly to the complexity of stream structure, due to the abundance of wood, debris dams, trailing roots and cypress knees. In open canopy thermal streams and deltas, where temperatures exceeded the tolerance of most species (35-40°C), thermally tolerant blue-green algae predominated. They formed dense mats on the stream bottom and structural elements, the latter consisting almost exclusively of wood. In post-thermal and (still) open canopy Steel Creek, the energy base is dominated by autotrophs more than any of the other SRP streams. Periphyton biomass was higher than in reference streams, and extensive macrophyte beds have developed, providing (along with wood) abundant and diverse habitat. In the upstream areas, the macrophyte beds were not as effective in retaining organic matter as were reference streams with more permanent structure. However, based on studies in the delta/swamp areas, macrophyte beds were very effective in retaining organic matter. Since both the Steel Creek and Pen Branch swamps were nonthermal, channel structure and the energy base of the lower food chain were determined by canopy characteristics more than temperature. The more open canopy Steel Creek swamp ecosystem was more diverse, due mainly to the presence of macrophyte beds, which also contributed to the high quality of the seston leaving the Steel Creek swamp. The swamp ecosystem provided a buffer for the increased discharges and sediment loads.

Water velocity has been substantially altered on streams receiving reactor effluents. Discharge on these streams is increased 10-fold or more when reactors are operating. Water velocity controls both the suspended load (concentration and particle size distribution of seston) and the nature of the substrate (depending on whether it is an erosional or depositional environment), as well as the development of the stream channel itself. In thermal streams, high discharge has eroded the natural stream bottom and transported it downstream. Along with the elevated temperatures, deposition of this sediment load in the swamps has contributed to the demise of the cypress-tupelo gum forests and the development of treeless deltas, which continue to slowly expand into the surrounding swamp forest. Changes in substrate characteristics and channel depth can impact development of macrophyte beds. In Beaver Dam Creek, water velocity has increased somewhat due to power plant discharges, but not to the same extent as in the reactor streams, and the Beaver Dam Creek ecosystem has not been severely impacted. The SRP delta/swamp ecosystem functions as an effective buffer and sedimentation zone for the increased discharges and sediment loads from the thermal streams, and their retentive capacities contributed to absence of measurable effects of SRP discharges on the Savannah River.

V.4 FISH COMMUNITIES OF THE SAVANNAH RIVER PLANT STREAMS, SWAMP SYSTEM, AND THE SAVANNAH RIVER

V.4.1 Introduction

This chapter reports the results of the two-year CCWS (September 1983 to September 1985) on the fish communities that inhabit the streams and swamp system of the Savannah River Plant (SRP) and the Savannah River. Although the fishes of the Savannah River have been the subject of numerous ecological investigations (see Matthews, 1982, for a compilation and review of the fisheries literature for the Savannah River between 1951 and 1976), only recently have efforts been directed towards understanding the effects of SRP discharges on fish movement and distribution. In 1978, McFarlane et al. (1978) and the Georgia Game and Fish Division (1982) examined fish communities 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, with 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. Studies were also conducted during the 1982-1985 spawning seasons (February-July) to determine spatial and temporal patterns of ichthyoplankton abundance and species composition in the Savannah River and tributary streams.

All material in this chapter, including literature citations, is taken from the following reports:

<u>1983-1984</u>

Paller, 1985
Paller and Osteen, 1985
Paller et al., 1985

<u>1984-1985</u>

Paller and Saul, 1986
Paller et al., 1986a
Paller et al., 1986b

The primary objectives of the fisheries studies were: (1) to characterize the fish communities of the SRP and the Savannah River and (2) to assess the direct and indirect effects of SRP cooling water intakes and discharges on the fish communities.

The results of the two-year study are divided into discussions of adult fish and ichthyoplankton (fish eggs and larvae). The major objectives of the adult fish study were to examine the abundance and distribution of fishes near the SRP 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, and to utilize this information to assess impacts of cooling water intake and release on fish populations of the SRP. The adult fish study was comprised of two programs: (1) the quarterly program, which was designed to assess annual patterns of distribution and abundance of adult and juvenile fish throughout the study area by sampling each station once during each quarter; and (2) the overwintering program, which was designed to assess fish distributions near the thermal discharges during the winter by sampling each station once or twice weekly from November through April.

The other half of this chapter discusses the ichthyoplankton communities of the Savannah River, between River Miles (RM) 187.1 and 29.6 in 1983-1984 and between RM 187.1 and 89.3 in 1984-1985, and the SRP swamp creeks. The Savannah River was divided into three sections for describing the ichthyoplankton community, as follows: the upper farfield (RMs 166.6-187.1), the nearfield (RMs 128.9-157.3), which was adjacent to the SRP, and the lower farfield (RMs 29.6-120.0 in 1983-1984; RMs 89.3-120.0 in 1984-1985).

The major objectives of the ichthyoplankton studies were: (1) to evaluate the relative contribution of the three river sections and their tributary streams to the ichthyoplankton community of the Savannah River system; (2) to examine the abundance and distribution of ichthyoplankton in SRP streams and swamps in relation to temperature and habitat; (3) to quantify ichthyoplankton entrainment at the cooling water intakes; and, (4) to assess the effects of SRP thermal discharges on the ichthyoplankton communities of the SRP and adjacent Savannah River. This section also includes the results from three studies conducted concurrently with the ichthyoplankton sampling program. A gear comparison study and a diel study were completed in the Steel Creek mouth and swamp, and a comparison of larval distributions between microhabitats was done in the Savannah River.

This chapter also reports on laboratory studies that were conducted to determine acceptable maximum temperatures and rates of temperature change in the swamp that allow critical early life stages of fish characteristic of the SRP to survive and grow successfully. Early life stages of fish were exposed to thermal regimes reflecting actual conditions in the swamp due to reactor startups and shutdowns during the spawning and post-hatch growth period.

V.4.2 Adult Fish

V.4.2.1 Introduction

There are several potential direct and indirect thermal discharge and cooling water withdrawal effects at the SRP that could impact Savannah River fish populations. For example, the SRP can impact the Savannah River fish community directly by impingement of adult fish at the cooling water intakes. Thermal discharges from the SRP may produce lethal temperatures in some areas of the creeks and swamp adjacent to the Savannah River. Fish will usually avoid areas of high water temperature; however, during cooler seasons, areas with moderately elevated temperatures can attract fish. During periods of reactor shutdown, cold shock may result in fishes that have become acclimated to the warmer water in the thermal effluent. Also, because spawning in most species is largely controlled by water temperature, thermal discharges can alter the spawning activities of fish.

This chapter reports the results from adult fish collections taken quarterly in the Savannah River adjacent to the SRP, in the intake canals, and in the lower reaches of the thermal and non-thermal creeks draining the SRP. Sampling began in September 1983 and ended in August 1985. This chapter also contains the results from the overwintering study of adult fishes conducted weekly and biweekly between November 1983 and April 1984, and between November 1984 and April 1985. The quarterly and overwintering studies of adult fishes were designed to determine species occurrence, relative abundance, and distribution of fishes in the SRP study area.

V.4.2.2 Materials and Methods

V.4.2.2.1 Quarterly Study

The quarterly study was designed to determine species composition, relative abundance, and distribution of adult and juvenile fishes in the vicinity of SRP. Two different collection techniques were utilized in order to compensate for the selectiveness of each technique: electrofishing (which selects for surface-dwelling fishes) and hoopnetting (which selects for bottom-dwelling fishes).

The first year of the quarterly adult and juvenile fish sampling program began in November 1983 and continued through August 1984. Four collections were made at each station within a 10- to 12-day period during November 1983, January 1984, June 1984, and August 1984. The study area included the mouths of the five major onsite creeks, two intake canals leading to the SRP pump-houses, and 12 sample stations in the Savannah River (Table V-4.1; Figure V-4.1).

TABLE V-4.1

Sampling Stations for the Savannah River Adult Fisheries Study (November 1983-August 1984)

River Mile	Sampling Station Location
River Transect*	
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
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*	
157.1	1G canal
155.3	3G canal
Creek Mouth**	
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

* 300 m along each bank.
** 150 m along each bank.

Source: Paller and Osteen, 1985.

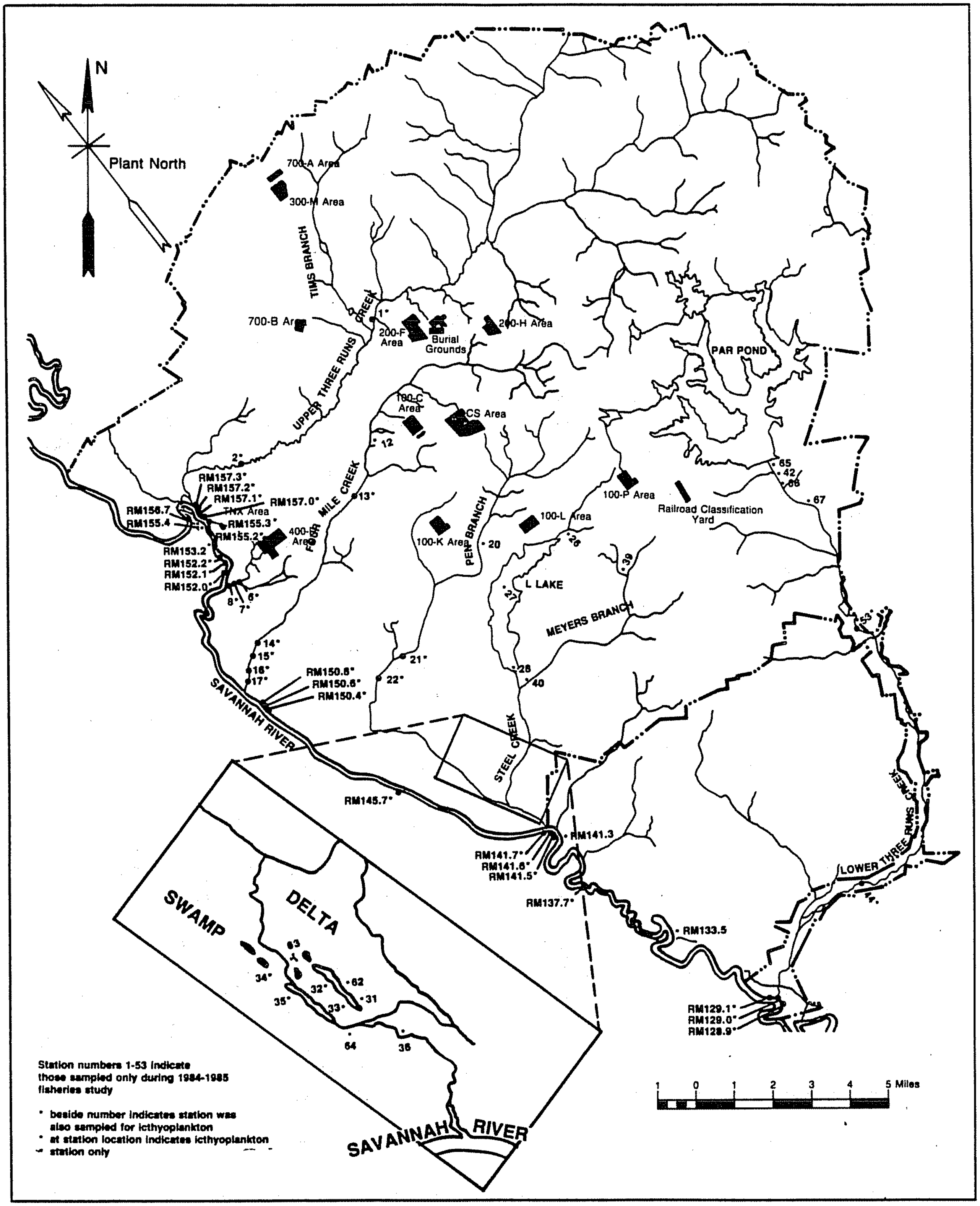


FIGURE V-4.1. **A Map of the Savannah River Plant Indicating the Sampling Locations on the Streams Which Drain the SRP (November 1984-August 1985). These Stations were Sampled Only During the 1984-1985 Sampling Program.** Source: Paller and Saul, 1986.

The quarterly adult and juvenile fish sampling program was continued in November 1984 through August 1985. All of the sampling stations monitored in the 1983 through 1984 quarterly study were sampled during the 1984-1985 period. One additional river station (River Transect 145.7, Table V-4.2) was added. In addition, 15 new stations were added in the channels and swamps of the major SRP creeks (Table V-4.3; Figure V-4.1). However in the 1984-1985 program, each transect was sampled once per quarter rather than four times within a 10-12 day period as was done in 1983-1984.

Electrofishing procedures were identical for the two years of sampling. At each sample station, electrofishing was conducted from an aluminum boat equipped with electrodes mounted on a boom and suspended in the water approximately 3 m from the boat. Each electrofishing sample station consisted of 300 m of shoreline subdivided into contiguous 100 m transects. All river and intake canal sample stations consisted of a right and left shoreline, while creek mouth, creek and swamp stations consisted of a single 300 m transect. If a sample station was too hot (>35°C) or too shallow to support fish, the area was qualitatively sampled with a backpack electrofisher (Paller & Saul, 1986).

Hoopnet collections were made at all of the sample stations listed in Tables V-4.1 and V-4.2 during the sampling period. This method was added to the fisheries sampling program specifically to obtain data on catfishes because they were not effectively collected by the electrofishing technique. All nets were checked 72 hours after they were placed in the field. Catch per unit effort (CPUE) was expressed as number of individuals/net/day.

All fish collected by electrofishing or hoopnetting were identified to species. Fishes over 150 mm (200 mm for some species) were tagged by inserting a numbered dart tag (Floy Model 68B) in the subdorsal area. Fishes under 150 mm (200 mm for some species) were marked by excision of a pelvic fin. After being measured and marked or tagged, all fish were released in their respective sample locations. Taxonomic keys used for identification included: 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 A-4.1.

Other parameters measured in conjunction with electrofishing were temperature, dissolved oxygen, pH, conductivity, alkalinity, and water velocity. Chemical and physical parameters were measured near the surface along both banks at each river and canal sample station. Water velocity and chemical measures were measured in mid-channel at each station (see Paller & Saul, 1986 for detailed methodologies).

TABLE V-4.2

Sampling Stations for the Savannah River Adult and Juvenile Quarterly Fisheries Study (November 1984-August 1985)

River Mile	Sampling Station Location
River Transect*	
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*	
157.1	1G canal
155.3	3G canal
Creek Mouth**	
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

* 300 m along each bank.
** 150 m along each bank.

Source: Paller and Osteen, 1985.

TABLE V-4.3

Adult and Juvenile Fish Quarterly Electrofishing Stations in the Channels and Swamps of Upper Three Runs Creek, Beaver Dam Creek, Four Mile Creek, Pen Branch, and Lower Three Runs Creek Which 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

Source: Paller and Saul, 1986.

V.4.2.2.2 Overwintering Study

The primary objective of the overwintering study was to determine the extent to which fishes congregated in and around the thermal discharges during the cooler months (November-April). To evaluate overwintering in the thermal plumes, the study area was divided into four habitats: (1) Savannah River thermal stations (downstream from the thermal discharges from Four Mile and Beaver Dam creeks on the South Carolina bank of the river); (2) Savannah River nonthermal stations; (3) nonthermal creek stations (Steel Creek and Lower Three Runs Creek); and (4) thermal creek stations (Four Mile Creek and Beaver Dam Creek).

In the 1983-1984 overwintering study, moving sample stations were used in the thermal creeks to track fish movement in relation to temperature. In the 1984-1985 overwintering study, the moving sample stations were abandoned because of difficulties in separating the effects of temperature and habitat on catch rate. Instead, three fixed sample stations were established in the thermal creeks.

During both years of the overwintering study, all sample stations were sampled weekly in December, January, February, and March. Biweekly sampling was conducted during the transition months of November and April. Electrofishing and hoopnetting procedures and equipment were the same as for the quarterly program.

Fisheries data were collected as described for the quarterly sampling program and included species identification, length, and weight. In the overwintering study, measurements of chemical and physical parameters were taken at the creek or river bottom, in addition to the surface measurements.

V.4.2.2.3 Impingement Study

From September 1983 through September 1985, collections were made of fish impinged in a 24-hour period on the traveling screens at the 1G, 3G, and 5G pumphouses. Data were collected on randomly chosen sample days for a total of 107 days in the 1983-1984 period and 97 days in the 1984-1985 period. 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 from the traveling screens at the pumphouses to the nearby Savannah River floodplain swamp. The distal end of the net was tied closed and the debris that was washed from the screens over a 24-hour period was collected. Fish were removed from the debris and returned to the laboratory for analysis.

In the laboratory each fish was identified, weighed, and measured for length when possible. Some specimens were badly decayed, suggesting that they had died before they were impinged. Because their time of death was unknown, these fish were included in the counts but not in the total weight of fish impinged.

The Savannah River Plant Power Department provided information on pumping rates, number of pumps, and volumes of water pumped each sampling day. The impingement rate was calculated by dividing the number of fish collected over a 24-hour period by the total volume of water pumped during the same time period. These values are expressed as the number of fish per 10^6 m^3 (million cubic meters) to allow for comparisons of impingement rates among pumphouses.

V.4.2.3 Results and Discussion

This section contains the results from the adult and juvenile fish studies for the 1983-1984 and 1984-1985 sampling years. Results from the quarterly and overwintering programs will be discussed separately because the objectives of the two programs were different.

V.4.2.3.1 Quarterly Study

The quarterly study was designed to assess annual patterns of distribution and abundance of adult and juvenile fishes throughout the study area. During the 1983-1984 quarterly study, 12,160 adult and juvenile fishes were collected. The following year, 10,000 adult and juvenile fishes were collected during the same sample period. These total annual catches are not directly comparable because of the different numbers of stations sampled and the differing sampling intensities for the two years of the study. A total of 75 species were collected (Appendix V-4.1), including three species that were collected during the 1984-1985 sampling year that had not been captured as adults during the previous sampling period: needlefish (*Strongylura marina*), river goby (*Awaous tajesica*), and sailfin shiner (*Notropis hypselopterus*).

On the basis of the total electrofishing catch from all stations, the most numerically abundant fishes in the 1983-1984 sampling period (excluding minnows and other small fishes) were the redbreast sunfish (*Lepomis auritus*), bluegill (*L. macrochirus*), largemouth bass (*Micropterus salmoides*), spotted sucker (*Minytrema melanops*), spotted sunfish (*Lepomis punctatus*), chain pickerel (*Esox niger*), and bowfin (*Amia calva*; Table V-4.4). The remaining species that were collected each represented less than 4.5% of the total.

TABLE V-4.4

Species, Excluding Minnows and Small Fishes, Caught by Electrofishing and Hoopnetting in the Savannah River, Intake Canals, and Tributary Creeks on the Savannah River Plant (November 1983-August 1984)*

Species	Electrofishing Percent Number	Electrofishing Percent Weight	Hoopnetting Percent Number	Hoopnetting Percent Weight
American shad	0.9	0.2	0.7	0.6
Blueback herring	1.5	0.1	0.0	0.0
Gizzard shad	2.0	1.9	0.5	0.4
Threadfin shad	0.6	0.1	0.0	0.0
American eel	3.3	1.7	3.0	3.9
Striped bass	0.6	0.7	0.3	1.1
Striped mullet	2.5	3.2	0.0	0.0
Spotted sucker	8.5	24.7	1.3	2.9
Silver redhorse	1.5	5.3	0.5	1.1
Lake chubsucker	<0.1	<0.1	0.0	0.0
Unid. chubsucker	<0.1	<0.1	0.0	0.0
Highfin carpsucker	<0.1	0.1	0.0	0.0
Quillback carpsucker	0.3	6.8	0.1	0.7
Golden shiner	0.4	<0.1	0.6	0.0
Yellow perch	1.9	0.6	0.4	0.1
Pirate perch	2.4	<0.1	0.0	0.0
Mud sunfish	<0.1	<0.1	0.0	0.0
Bluespotted sunfish	0.8	<0.1	0.0	0.0
Flier	0.1	<0.1	0.1	<0.1
Redbreast sunfish	16.7	2.6	9.7	3.5
Pumpkinseed	0.3	<0.1	0.2	<0.1
Warmouth	1.5	0.3	0.2	<0.1
Bluegill	14.1	1.0	5.2	1.3
Redear sunfish	3.8	2.1	1.7	1.0
Spotted sunfish	7.9	0.9	1.3	0.2
Dollar sunfish	3.0	0.1	0.0	0.0
Unid. sunfish	0.1	<0.1	0.0	0.0
Black crappie	2.3	0.8	6.8	2.0
White crappie	<0.1	<0.1	0.0	0.0
Largemouth bass	8.9	6.8	0.0	0.0
Redeye bass	<0.1	<0.1	0.0	0.0
White bass	<0.1	<0.1	0.0	0.0
Hybrid (striped & white bass)	<0.1	<0.1	0.2	0.2
Channel catfish	0.5	1.1	21.0	35.1
White catfish	<0.1	0.1	9.0	14.8

* Sample taken quarterly.

Source: Paller and Osteen, 1985.

TABLE V-4.4, Contd

Species	Electrofishing Percent Number	Electrofishing Percent Weight	Hoopnetting Percent Number	Hoopnetting Percent Weight
Flat bullhead	0.2	<0.1	29.2	10.8
Brown bullhead	<0.1	<0.1	0.7	0.3
Yellow bullhead	0.0	0.0	0.1	<0.1
Snail bullhead	0.0	0.0	0.1	<0.1
Chain pickerel	5.0	1.1	0.0	0.0
Redfin pickerel	1.9	0.8	0.0	0.0
Unid. pickerel	0.0	0.0	0.2	0.1
Longnose gar	1.0	1.5	5.6	13.4
Spotted gar	0.1	0.4	0.4	0.7
Florida gar	0.0	0.0	0.1	<0.1
Bowfin	5.0	34.8	1.4	5.8
Hogchoker	0.4	<0.1	0.1	<0.1
Total percent	100.0	99.8	100.1	100.0
Total number	3844		1816	
Total weight (kg)	1301.7		260.1	
Number of species	44		29	

Source: Paller and Osteen, 1985.

Approximately 4,890 shiners (genus Netropis) were collected, making them the most abundant type of small fish (88.9%) in the study area (Table V-4.5). The relative abundance of the minnows and other small fishes collected by electrofishing was only an estimate because many of the small fishes that were electroshocked were not captured.

The most abundant fishes captured by hoopnetting during the 1983-1984 sampling period were the flat bullhead (Ictalurus platycephalus), channel catfish (I. punctatus), redbreast sunfish, white catfish (I. catus), black crappie (Pomoxis nigromaculatus), longnose gar (Lepososteus oculatus), and bluegill. None of the other species captured by hoopnetting represented more than 3.0% of the total catch.

In the 1984-1985 sampling period, the most abundant fishes collected by electrofishing (excluding minnows and other small fishes) were the redbreast sunfish, spotted sucker, spotted sunfish, largemouth bass, bluegill, and the American eel (Anguilla rostrata; Table V-4.6). Each of the other species collected by electrofishing represented less than 5% of the total.

The relative abundance estimates for 1984-1985 were influenced by large numbers of fish captured at new electrofishing sample stations added to the program in 1985 (see Section V.4.2.2 for a list of the stations). As a result, the 1985 relative abundance estimates could not be compared directly to the relative abundance estimates for previous years. In order to make comparisons between 1984-1985 and previous years, relative abundances were calculated separately for the "old" (1983-1984) electrofishing stations (those in the river, intake canals, and creek mouths).

The numerically dominant species at the old electrofishing stations included redbreast sunfish, spotted sucker, bluegill, largemouth bass, and bowfin (Table V-4.6). A total of 1,666 fish were captured from the old sample stations during 1984-1985; considerably fewer than during previous years (Paller et al., 1984; Paller & Osteen, 1985). The reduced catch during 1984-1985 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 V.4.2.2).

Approximately 2,647 shiners were collected in 1984-1985, making them the most abundant type of small fish (94%) in the study area (Table V-4.7). As in 1983-1984, the relative abundance of the minnows and other small fishes collected was only an estimate because many fish that were electroshocked were not captured.

TABLE V-4.5

Minnows and Other Small Fishes Collected by Electrofishing in the Savannah River, Intake Canals on the Savannah River Plant and Tributary Creeks (November 1983-August 1984)

Taxa	Number	Percent
Shiners (Notropis spp.)*	4,890	88.9
Golden shiner	84	1.5
Eastern silvery minnow	31	0.6
Mississippi silvery minnow	3	0.1
Pugnose minnow	40	0.7
Rosyface chub	14	0.3
Bluehead chub	2	<0.1
Creek chub	1	<0.1
Lined topminnow	98	1.8
Mosquitofish	57	1.0
Savannah darter	1	<0.1
Tesselated darter	75	1.4
Swamp darter	1	<0.1
Blackbanded darter	18	0.3
Speckled madtom	6	0.1
Tadpole madtom	1	<0.1
Swampfish	1	<0.1
Brook silverside	120	2.2
American shad	45	0.8
Blueback herring	14	0.3
Banded pygmy sunfish	1	<0.1
Total	5,502	100.0

* Species included the bannerfin shiner, coastal shiner, whitfin shiner, spottail shiner, yellowfin shiner, ironcolor shiner, dusky shiner, and taillight shiner.

Source: Paller and Osteen, 1985.

TABLE V-4.6

Species, Excluding Minnows and Small Fishes, Caught by Electrofishing and Hoopnetting in the Savannah River, Intake Canals and Tributary Creeks on the SRP (November 1984-August 1985). Samples were Taken Quarterly in November, February, May, and August

Species	Old Electro-fishing Stations*		New Electro-fishing Stations**		Total Electrofishing		Hoopnetting†	
	Percent Number	Percent Weight	Percent Number	Percent Weight	Percent Number	Percent Weight	Percent Number	Percent Weight
Longnose gar	0.7	0.9	0.4	5.7	0.5	2.3	3.0	7.0
Bowfin	5.3	36.4	1.0	14.1	2.7	29.5	2.5	16.6
American eel	3.3	1.8	6.8	6.7	5.4	3.3	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	0.2	1.1	0.4	0.5	0.5	0.4
Gizzard shad	1.8	1.5	0.2	0.9	0.9	1.3	0.7	0.7
Redfin pickerel	0.8	0.1	0.7	0.3	0.7	0.1	0.0	0.0
Chain pickerel	1.3	1.0	0.6	1.3	0.9	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	0.1	<0.1	0.2	<0.1	0.0	0.0
Quillback carpsucker	0.1	2.8	0.0	0.0	0.1	1.9	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	1.7	1.8	1.1	0.6	0.2	0.1
Lake chubsucker	0.1	<0.1	0.1	0.2	0.1	0.1	0.0	0.0
Unid. chubsucker	0.1	<0.1	0.4	0.6	0.3	0.2	0.0	0.0
Spotted sucker	12.6	34.3	6.3	28.2	8.8	32.4	2.2	4.6
Silver redhorse	0.5	2.4	<0.1	0.7	0.2	1.9	0.7	1.7

* Old stations were sample stations in the Savannah River, intake canals and creek mouths that were sampled during previous years of the study (1983-1984).

** New stations were sample stations in the swamps and upper reaches of the Upper Three Runs Creek, Beaver Dam Creek, Four Mile Creek, Pen Branch, and Lower Three Runs Creek that were added to the program in 1984-1985.

† Stations in the Savannah River, intake canals and the mouths of SRP tributary creeks.

Source: Paller and Saul, 1986.

TABLE V-4.6, Contd

Species	Old Electro-fishing Stations*		New Electro-fishing Stations**		Total Electrofishing		Hoopnetting†	
	Percent Number	Percent Weight	Percent Number	Percent Weight	Percent Number	Percent Weight	Percent Number	Percent Weight
Snail bullhead	0.2	<0.1	0.1	<0.1	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	1.0	0.6	0.6	0.2	0.0	0.0
Flat bullhead	0.5	0.1	0.4	0.3	0.5	0.1	38.0	15.9
Channel catfish	0.8	2.3	0.4	5.2	0.6	3.2	11.9	18.2
Pirate perch	1.7	<0.1	5.0	0.2	3.6	0.1	0.0	0.0
Needlefish	0.1	<0.1	0.1	<0.1	0.1	<0.1	0.0	0.0
Striped bass	0.0	0.0	0.0	0.0	0.0	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	0.2	<0.1	0.2	<0.1	0.0	0.0
Redbreast sunfish	23.9	3.3	53.7	13.7	41.6	6.5	5.5	1.9
Pumpkinseed	0.4	<0.1	0.0	0.0	0.1	<0.1	0.2	0.1
Warmouth	1.4	0.2	2.3	1.7	1.9	0.7	0.5	0.2
Bluegill	9.5	0.8	3.0	1.2	5.6	0.9	9.4	2.7
Dollar sunfish	2.5	0.1	3.4	0.4	3.0	0.2	0.0	0.0
Redear sunfish	2.6	1.0	0.6	0.7	1.4	0.9	3.0	1.3
Spotted sunfish	12.9	1.5	5.0	1.3	8.2	1.4	1.5	0.2
Lepomis spp.	0.0	0.0	1.6	<0.1	1.0	<0.1	0.5	0.2
Unid. sunfish	0.0	0.0	0.2	<0.1	0.1	<0.1	0.0	0.0
Redeye bass	0.1	<0.1	0.0	0.0	0.1	<0.1	0.0	0.0

* Old stations were sample stations in the Savannah River, intake canals and creek mouths that were sampled during previous years of the study (1983-1984).

** New stations were sample stations in the swamps and upper reaches of the Upper Three Runs Creek, Beaver Dam Creek, Four Mile Creek, Pen Branch, and Lower Three Runs Creek that were added to the program in 1984-1985.

† Stations in the Savannah River, intake canals and the mouths of SRP tributary creeks.

Source: Paller and Saul, 1986.

TABLE V-4.6, Contd

Species	Old Electro-fishing Stations*		New Electro-fishing Stations**		Total Electrofishing		Hoopnetting†	
	Percent Number	Percent Weight	Percent Number	Percent Weight	Percent Number	Percent Weight	Percent Number	Percent Weight
Largemouth bass	8.7	3.9	3.7	12.4	5.7	6.6	0.2	0.3
Black crappie	0.8	0.4	<0.1	<0.1	0.3	0.3	6.5	2.7
Yellow perch	2.8	0.8	0.9	0.3	1.6	0.7	0.7	0.5
Striped mullet	2.5	3.8	0.1	0.4	1.0	2.8	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	<0.1	<0.1	<0.1	<0.1	0.0	0.0
Total weight (kg)		402.7		180.8		583.5		164.0
Total number	1666		2460		4126		403	
Total percent	100.0	99.8	100.0	100.0	99.8	99.9	99.7	100.0
Number of species††	35		30		36		23	

* Old stations were sample stations in the Savannah River, intake canals and creek mouths that were sampled during previous years of the study (1983-1984).

** 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 1984-1985.

† Stations in the Savannah River, intake canals and the mouths of SRP tributary creeks.

†† 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.

Source: Paller and Saul, 1986.

TABLE V-4.7

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
Unid. 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	2806	99.9

Source: Paller and Osteen, 1985.

The most abundant fishes collected by hoopnetting in 1984-1985 were the flat bullhead, channel catfish, bluegill, white catfish, black crappie, and redbreast sunfish (Table V-4.6). None of the other fishes captured by hoopnetting represented more than 3.2% of the total catch. Hoopnetting relative abundance values were directly comparable between 1983-1984 and 1984-1985 because the same sample stations were studied during both years (hoopnetting collections were not made at the new sample stations in the swamps and upper reaches of the creeks).

From the data gathered during the 1983-1984 and 1984-1985 sampling years, it has been determined that the study area supports a diverse fish community with representatives from all the trophic levels (Scott & Crossman, 1973). The dominant predators included largemouth bass, bowfin, channel catfish, pickerel (Esox spp.), longnose gar, and white catfish. Fishes found in the intermediate trophic level included sunfishes, flat bullheads, and the American eel. Threadfin shad (Dorosoma petenense), gizzard shad (D. cepedianum), spotted sucker, silver redhorse (Moxostoma anisurum), and quillback carpsucker (Carpiodes cyprinus) comprised the lower trophic level that utilizes plankton and detritus as a food source. The smallest forage fishes, such as minnows, shiners, and brook silversides, feed on zooplankton and macroinvertebrates, and then are fed upon by larger fish.

To evaluate habitat preferences, the SRP study area was divided into four habitat types; thermal creeks, nonthermal creeks, intake canals, and the Savannah River. The thermal creeks included Four Mile Creek, Beaver Dam Creek, and refuge areas in Pen Branch. The nonthermal creeks included Upper Three Runs Creek, Lower Three Runs Creek, and Steel Creek. In 1984-1985, the river habitat designation was divided into thermal sites (those stations just downstream from the mouths of thermal creeks along the South Carolina bank) and nonthermal sites (the remaining river sample stations). Table V-4.8 lists means and ranges for water temperature and five other water quality parameters measured at each sampling site during the quarterly sampling program conducted from November 1984 through August 1985.

For both 1983-1984 and 1984-1985, the relative abundances of fishes found within each type of habitat were similar (Tables V-4.9 through V-4.12). However, the species composition found in the intake canals was different than the species composition found in other habitats. For example, larger fishes were comparatively scarce in the canal habitat during both sampling years. Chain pickerel were common in the canals in 1983-1984, but relatively uncommon in this habitat in 1984-1985, probably because the canal habitat had been altered when the macrophyte beds were removed by dredging in the summer of 1985 (Paller & Osteen, 1985).

TABLE V-4.8

Mean (and range) of Physical-Chemical Parameters Measured at Each Sampling Site on or Near the SRP During the Quarterly Sampling Program (November 1984-August 1985)

Station	N	Temp. °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)

Source: Paller and Saul, 1986.

TABLE V-4.8, Contd

Station	N	Temp. °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, Contd				
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)	13.0 (15.0-21.0)	- -
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)	-* -
			Creek Transects				
Lower Three Runs Creek							
53 (Rd 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)	- -	45.5 (16.0-75.0)
44 (Rd 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)	- -	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)

* Missing samples.

Source: Paller and Saul, 1986.

TABLE V-4.8, Contd

Station	N	Temp. °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, Contd				
Four Mile Creek							
13 (Rd A)		-	-	-	-	-	-
14 (Rd A-13)	1	10.2 (-)	-	4.6 (-)	80.0 (-)	-	-
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 (-)	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 (-)	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 (-)	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 (Rd 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 (-)	79.8 (45.0-60.0)
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 (-)	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 (-)	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 (-)	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)

Source: Paller and Saul, 1986.

TABLE V-4.8, Contd

Station	N	Temp. °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, Contd				
Upper Three Runs Creek							
1 (Rd 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 (-)	62.0 (40.0-97.0)
2 (Rd 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 (0)	45.3 (32.0-58.0)
157.2 (mouth)	12	14.1 (6.0-20.6)	8.0 (6.7-8.8)	5.9 (47.7-7.6)	36.5 (22.0-80.0)	34.4 (30.0-36.3)	24.7 (22.0-30.0)
Pen Branch Creek							
21 (Rd A-13.3)	5	20.3 (18.0-24.8)	7.7 (7.0-9.7)	6.1 (5.5-7.0)	79.4 (69.0-88.0)	18.1 (-)	77.0 (-)
22 (delta)	11	26.7 (16.8-34.1)	8.2 (6.6-9.8)	7.5 (7.2-8.0)	83.0 (74.0-90.0)	16.8 (-)	20.0 (18.0-22.0)

Source: Paller and Saul, 1986.

TABLE V-4.9

Relative Abundance of Fishes Caught by Electrofishing in the Savannah River, Intake Canals, Ambient Temperature Creeks, and Thermal Creeks on the Savannah River Plant (November 1983-August 1984)

	Percent Number				Percent Weight			
Taxa	River	Canal	Ambient Creeks*	Thermal Creeks**	River	Canal	Ambient Creeks*	Thermal Creeks**
American shad	1.2	0.0	0.4	0.8	0.2	0.0	0.9	1.3
Blueback herring	1.8	1.1	0.4	0.8	0.1	<0.1	<0.1	<0.1
Gizzard shad	1.8	3.6	0.2	1.5	1.6	5.3	0.3	1.1
Threadfin shad	0.7	0.2	0.2	3.8	0.1	<0.1	<0.1	1.6
American eel	2.9	0.2	12.2	2.3	1.6	0.2	6.2	0.8
Striped bass	0.6	0.5	0.2	1.5	0.5	1.4	0.3	2.2
Striped mullet	2.8	2.6	0.4	0.8	3.1	6.0	0.9	0.9
Spotted sucker	8.9	5.2	14.1	3.1	23.0	35.2	31.3	12.5
Silver redhorse	2.1	0.1	0.2	0.0	6.6	0.5	1.5	0.0
Lake chubsucker	<0.1	0.0	0.2	0.0	<0.1	0.0	<0.1	0.0
Unid. chubsucker	<0.1	0.0	0.0	0.0	<0.1	0.0	0.0	0.0
Highfin carpsucker	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quillback carpsucker	0.4	0.1	0.0	0.0	8.0	5.3	0.0	0.0
Golden shiner	0.3	0.9	0.2	0.0	<0.1	0.2	<0.1	0.0
Yellow perch	0.7	6.3	1.9	0.0	0.3	2.6	1.1	0.0
Pirate perch	2.5	0.8	5.0	0.0	<0.1	<0.1	0.1	0.0
Mud sunfish	<0.1	0.0	0.0	0.0	<0.1	0.0	0.0	0.0
Bluespotted sunfish	0.3	2.0	2.1	0.8	<0.1	0.1	<0.1	<0.1
Flier	0.1	0.1	0.0	1.5	<0.1	<0.1	0.0	0.2
Redbreast sunfish	19.6	8.3	14.1	15.4	2.5	2.9	1.9	4.7
Pumpkinseed	0.2	1.0	0.0	0.0	<0.1	0.2	0.0	0.0
Warmouth	1.3	1.4	3.2	1.5	0.2	1.2	0.4	0.7
Bluegill	10.9	29.5	6.9	4.6	0.9	1.7	0.4	1.0
Redear sunfish	3.4	4.6	1.1	16.2	1.6	3.7	0.6	10.5
Spotted sunfish	9.7	2.9	6.7	3.1	1.0	0.2	1.0	0.3

* Steel Creek, Upper Three Runs, and Lower Three Runs.
** Four Mile Creek and Beaver Dam Creek.

Source: Paller and Osteen, 1985.

TABLE V-4.9, Contd

Taxa	Percent Number: River	Percent Number: Canal	Percent Number: Ambient Creeks*	Percent Number: Thermal Creeks**	Percent Weight: River	Percent Weight: Canal	Percent Weight: Ambient Creeks*	Percent Weight: Thermal Creeks**
Dollar sunfish	2.2	5.1	4.8	0.8	0.1	0.4	0.1	<0.1
Unid. sunfish	<0.1	0.1	0.2	0.0	<0.1	<0.1	<0.1	0.0
Black crappie	2.5	1.7	1.5	2.3	0.9	0.8	0.6	1.1
White crappie	0.0	0.1	0.0	0.0	0.0	<0.1	0.0	0.0
Largemouth bass	9.6	5.8	8.0	16.9	7.0	2.8	5.9	19.1
Redeye bass	<0.1	0.0	0.0	0.0	<0.1	0.0	0.0	0.0
White bass	<0.1	0.0	0.0	0.0	<0.1	0.0	0.0	0.0
Hybrid (striped & white bass)	0.1	0.0	0.0	0.0	<0.1	0.0	0.0	0.0
Channel catfish	0.3	0.2	0.4	6.2	0.8	0.7	2.1	8.5
White catfish	<0.1	0.0	0.0	0.0	0.1	0.7	0.0	0.0
Flat bullhead	0.2	0.1	0.0	0.0	<0.1	<0.1	0.0	0.0
Brown bullhead	0.1	0.0	0.0	0.0	<0.1	0.0	0.0	0.0
Chain pickerel	3.3	10.7	5.3	3.1	0.7	2.7	2.5	0.9
Redfin pickerel	1.2	2.7	4.4	5.4	0.3	1.3	3.4	2.5
Longnose gar	1.2	0.2	1.1	2.3	1.7	0.5	1.1	3.2
Spotted gar	0.1	0.1	0.4	0.8	0.2	0.1	0.9	3.0
Bowfin	6.0	1.8	4.2	4.6	36.8	23.8	36.3	23.9
Hogchoker	0.6	0.0	0.0	0.0	<0.1	0.0	0.0	0.0
Total percent	99.6	100.0	100.0	100.1	100.0	99.8	99.8	100.0
Total number	3268	969	476	130				
Total weight (kg)					1006.9	154.8	98.4	41.6
Average weight (kg)					0.31	0.16	0.21	0.32
Number of species	42	32	29	24				

* Steel Creek, Upper Three Runs, and Lower Three Runs.
** Four Mile Creek and Beaver Dam Creek.

Source: Paller and Osteen, 1985.

TABLE V-4.10

Relative Abundance of Fishes Caught by Hoopnetting in the Savannah River, Intake Canals, Ambient Temperature Creeks, and Thermal Creeks on the Savannah River Plant (November 1983-August 1984)

	Percent Number				Percent Weight			
Taxa	River	Canal	Ambient Creeks*	Thermal Creeks**	River	Canal	Ambient Creeks*	Thermal Creeks**
American shad	0.3	0.0	2.5	1.7	0.2	0.0	3.0	<0.1
Gizzard shad	0.2	3.9	0.0	0.0	0.2	5.2	0.0	0.0
American eel	3.0	0.6	5.1	1.7	3.5	2.8	6.5	2.0
Striped bass	0.5	0.0	0.0	0.0	1.5	0.0	0.0	0.0
Spotted sucker	1.3	2.2	0.4	1.7	2.7	10.6	1.0	3.4
Silver redhorse	0.5	0.0	1.1	0.0	0.9	0.0	3.1	0.0
Quillback carpsucker	0.1	0.0	0.0	0.0	0.9	0.0	0.0	0.0
Yellow perch	0.5	0.6	0.0	0.0	0.2	0.2	0.0	0.0
Flier	0.1	0.6	0.0	0.0	<0.1	0.1	0.0	0.0
Redbreast sunfish	10.4	19.0	2.2	1.7	3.4	16.3	0.8	0.6
Pumpkinseed	0.2	0.6	0.4	0.0	<0.1	0.1	0.1	0.0
Warmouth	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Bluegill	3.8	22.3	2.2	0.0	1.0	8.6	0.6	0.0
Redear sunfish	2.1	0.0	0.7	3.3	1.1	0.0	0.4	2.0
Spotted sunfish	1.1	0.6	1.1	8.3	0.1	0.3	0.2	1.4
Black crappie	4.8	25.7	5.1	3.3	1.4	12.5	1.5	1.7
Hybrid (striped & white bass)	0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Channel catfish	19.0	5.6	32.7	58.3	31.2	19.9	50.0	78.1
White catfish	10.0	0.6	11.3	3.3	16.3	0.7	14.6	1.4

* Steel Creek, Upper Three Runs, and Lower Three Runs.
** Four Mile Creek and Beaver Dam Creek.

Source: Paller and Osteen, 1985.

TABLE V-4.10, Contd

	Percent Number				Percent Weight			
Taxa	River	Canal	Ambient Creeks*	Thermal Creeks**	River	Canal	Ambient Creeks*	Thermal Creeks**
Flat bullhead	31.7	14.5	32.0	5.0	10.5	14.4	13.2	1.7
Brown bullhead	0.8	0.0	1.1	0.0	0.4	0.0	0.2	0.0
Yellow bullhead	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Snail bullhead	0.1	0.0	0.0	0.0	<0.1	0.0	0.0	0.0
Unid. pickerel	0.0	1.7	0.0	0.0	0.0	1.3	0.0	0.0
Longnose gar	7.5	0.6	0.7	3.3	17.1	3.6	<0.1	4.5
Spotted gar	0.2	0.0	0.7	5.0	0.7	0.0	0.9	<0.1
Florida gar	0.0	0.0	0.0	1.7	0.0	0.0	0.0	<0.1
Bowfin	1.5	1.1	0.7	1.7	6.4	3.4	4.0	3.4
Hogchoker	0.1	0.0	0.0	0.0	<0.1	0.0	0.0	0.0
Total percent	100.4	100.2	100.0	100.0	100.0	100.0	100.1	100.2
Total number	1302	179	275	60				
Total weight (kg)					567.3	35.6	56.5	25.0
Number of species	27	16	17	14				

* Steel Creek, Upper Three Runs, and Lower Three Runs.
** Four Mile Creek and Beaver Dam Creek.

Source: Paller and Osteen, 1985.

TABLE V-4.11

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	Non-thermal*	Thermal**	Intake Canal	Non-thermal Creeks†	Thermal Creeks††	Non-thermal	Thermal	Intake Canal	Non-thermal Creeks	Thermal Creeks
Spotted gar										
Longnose gar	0.7	1.0	0.4	0.2	3.2	0.7	2.3	0.1	5.2	5.2
Bowfin	6.7	2.1	1.8	0.8	6.3	38.2	12.9	37.8	13.3	26.0
American eel	2.6			7.4	5.8	1.2			9.3	2.4
Blueback herring	0.3	2.1				<0.1	0.1			
American shad	1.1	2.1		0.1	0.5	0.2	0.1		1.2	<0.1
Gizzard shad	1.5	1.0	4.0		3.7	1.4	1.8	4.3		3.3
Threadfin shad										
Unid. clupeid										
Redfin pickerel	0.4	2.1	1.8	0.7	1.1	<0.1	0.2	0.2	0.3	0.2
Chain pickerel	1.2		2.6	0.6	0.5	1.1		0.8	1.1	1.4
Golden shiner	0.3	1.0		0.1		<0.1	0.2		<0.1	
Quillback carpsucker	0.2					3.5				
Unid. carpsucker	0.2					<0.1				
Creek chubsucker	0.1			1.8		0.2			2.1	
Lake chubsucker	0.1			0.1		<0.1			0.3	
Spotted sucker	14.8	15.5	4.4	6.4	7.4	35.2	53.1	32.0	29.5	17.0
Unid. chubsucker	0.1			0.4		<0.1			0.7	
Silver redhorse	0.7		0.4	<0.1		2.8		3.3	0.8	
Snail bullhead	0.1			0.1	0.5	<0.1			<0.1	<0.1
White catfish	0.1					0.1				
Yellow bullhead				1.0	0.5				0.5	0.5
Brown bullhead										
Flat bullhead	0.7			0.4	0.5	0.1			0.4	0.2
Channel catfish	0.3	2.1		0.1	8.4	0.9	9.1		1.6	19.8
Pirate perch	1.8	1.0	0.4	5.2		<0.1	<0.1	<0.1	0.2	
Needlefish		1.0		0.1			0.4		<0.1	
Striped bass										
Mud sunfish										
Flier	0.1					<0.1				
Bluespotted sunfish	0.2		0.4	0.3		<0.1		0.1	<0.1	
Redbreast sunfish	25.2	21.6	19.6	53.7	23.2	2.6	1.2	2.0	17.0	4.5

* All river transects except those just below Beaver Dam Creek and Four Mile Creek.
** RMs 152.0 below Beaver Dam Creek and 150.4 below Four Mile Creek.
† Upper Three Runs, Steel Creek, and Lower Three Runs.
†† Beaver Dam Creek, Four Mile Creek, and Pen Branch.

Source: Paller and Saul, 1986.

TABLE V-4.11, Contd

	Percent Number					Percent Weight				
	River		Creeks			River		Creeks		
Taxa	Non-thermal*	Thermal**	Intake Canal	Non-thermal Creeks†	Thermal Creeks††	Non-thermal	Thermal	Intake Canal	Non-thermal Creeks	Thermal Creeks
Pumpkinseed		0.4	0.4			<0.1		0.1		
Warmouth	1.0	1.2	1.8	2.2	2.6	0.2	<0.1	0.1	1.9	0.5
Bluegill	5.2	4.7	30.3	3.3	5.8	0.5	0.3	4.1	1.2	1.1
Dollar sunfish										
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		8.0		0.1	0.2		0.7	
Lepamis sp.			5.3					7.0		
Unid. sunfish										
Redeye bass										
Largemouth bass		2.1					3.0			
White crappie										
Black crappie	4.9	4.3	23.7	4.0		2.4	1.5	25.4	1.2	
Yellow perch	0.7	2.1				0.4	1.8			
Striped mullet	0.4					0.6				
Hogchocker										
Unknown										
Total percent	100.0	99.8	100.0	100.0	99.9	99.9	99.9	100.0	100.0	99.9
Total number	287	47	38	25	6					
Total weight (kg)						124,783	17,076	4,506	13,882	3,756
Number of taxa¶	19	12	9	11	3					

* All river transects except those just below Beaver Dam Creek and Four Mile Creek.
** RMs 152.0 below Beaver Dam Creek and 150.4 below Four Mile Creek.
† Upper Three Runs, Steel Creek, and Lower Three Runs.
†† Beaver Dam Creek, Four Mile Creek, and Pen Branch.
¶ 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; unknown taxa were not included.

Source: Paller and Saul, 1986.

TABLE V-4.12

Relative Abundance of Fishes Caught 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)

	Percent Number					Percent Weight				
	River		Creeks			River		Creeks		
Taxa	Non-thermal*	Thermal**	Intake Canal	Non-thermal Creeks†	Thermal Creeks††	Non-thermal	Thermal	Intake Canal	Non-thermal Creeks	Thermal Creeks
Spotted gar										
Longnose gar	3.8			4.0		8.6			4.8	
Bowfin	2.1			16.0		15.9			52.9	
American eel										
Blueback herring										
American shad				8.0					4.6	
Gizzard shad	1.0					0.9				
Threadfin shad										
Redfin pickerel										
Chain pickerel										
Unid. pickerel	0.7					0.3				
Golden shiner										
Quillback carpsucker										
Unid. carpsucker										
Creek chubsucker	0.4					0.1				
Lake chubsucker										
Spotted sucker	2.4	2.1	2.6			5.7	1.7	2.1		
Unid. chubsucker										
Silver redhorse	1.0					2.2				
Snail bullhead										
White catfish	6.3	23.4		4.0	33.3	20.3	42.4		18.7	55.6
Yellow bullhead										
Brown bullhead										
Flat bullhead	48.4	10.6	2.6	32.0		19.0	4.6	4.7	10.3	
Channel catfish	10.5	34.0			33.3	18.2	34.4			32.4
Pirate perch										
Needlefish										
Striped bass	0.4					0.8				
Mud sunfish										
Flier	2.8		13.2			0.6		9.0		
Bluespotted sunfish										

* All river transects except those just below Beaver Dam Creek and Four Mile Creek.
** RMs 152.0 below Beaver Dam Creek and 150.4 below Four Mile Creek.
† Upper Three Runs, Steel Creek, and Lower Three Runs.
†† Beaver Dam Creek, Four Mile Creek, and Pen Branch.

Source: Paller and Saul, 1986.

TABLE V-4.12, Contd

	Percent Number					Percent Weight				
	River		Creeks			River		Creeks		
Taxa	Non-thermal*	Thermal**	Intake Canal	Non-thermal Creeks†	Thermal Creeks††	Non-thermal	Thermal	Intake Canal	Non-thermal Creeks	Thermal Creeks
Redbreast sunfish	4.2	10.6	10.5	4.0		1.3	4.4	13.3	1.4	
Pumpkinseed			2.6					2.0		
Warmouth		2.1		4.0			1.6		0.7	
Bluegill	8.0	4.3	26.3	12.0		1.8	1.8	28.0	4.7	
Dollar sunfish	2.2	1.0	5.2	3.4	1.1	0.1	0.1	0.6	0.4	<0.1
Redear sunfish	2.4	1.0	5.5	0.5	2.1	1.0	1.0	2.4	0.3	1.3
Spotted sunfish	15.5	17.5	1.1	5.2	8.9	1.4	2.7	0.4	1.8	0.6
Lepamis sp.				1.6					<0.1	
Unid. sunfish				0.2					<0.1	
Redeye bass	0.2					<0.1				
Largemouth bass	8.7	16.5	8.5	2.8	16.3	3.8	7.3	4.0	9.7	14.8
White crappie										
Black crappie	1.0		0.4	0.1		0.4		0.5	0.1	
Yellow perch	1.1	1.0	10.0	1.1		0.3	0.5	4.0	1.0	
Stripped mullet	3.0	4.1	1.1		1.6	4.0	6.6	3.3		1.2
Hogchoker	0.2					<0.1				
Unknown			<0.1						<0.1	
Total percent	100.0	100.0	100.1	99.9	100.0	99.9	99.9	100.1	99.9	100.0
Total number	1125	97	271	2453	190					
Total weight (g)						324,220	21,350	26,347	154,165	57,444
Number of taxa¶	33	21	20	28	20					

* All river transects except those just below Beaver Dam Creek and Four Mile Creek.
** RMs 152.0 below Beaver Dam Creek and 150.4 below Four Mile Creek.
† Upper Three Runs, Steel Creek, and Lower Three Runs.
†† Beaver Dam Creek, Four Mile Creek, and Pen Branch.
¶ 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; unknown taxa were not included.

Source: Paller and Saul, 1986.

The relative abundance of fish species in the river was comparable between 1983-1984 and 1984-1985. Differences were noted, however, between the thermal and nonthermal river stations in 1984-1985. Largemouth bass, channel catfish, and white catfish comprised a greater percentage of the total collection at the thermal river sample stations while flat bullheads were collected in greater percentages in the nonthermal river habitat. In general, the fish communities in the river were more diverse than those in the other habitats (Paller & Osteen, 1985).

In 1983-1984, largemouth bass, channel catfish, redbreast sunfish, redear sunfish, and gar (longnose, spotted, and Florida) were the dominant species in the thermal creeks. In 1984-1985, the most abundant species in these thermal habitats were the largemouth bass, redbreast sunfish, channel catfish, and white catfish. (It should be noted that even though these species occurred in greater percentages in the thermal creeks, they occurred in fewer numbers than in nonthermal habitats.) Fewer species were collected from the thermal creeks than from the nonthermal habitats, probably due to avoidance of the thermal streams by most fishes (Paller & Osteen, 1985). In 1983-1984, for example, in refuge areas in Pen Branch and in portions of Four Mile Creek, mosquitofish were the dominant, and sometimes the only species present.

Tables V-4.9 through V-4.12 show that the species composition in the nonthermal creeks was similar for the 1983-1984 and 1984-1985 sampling years. The species composition in the nonthermal creeks was similar to that of the nonthermal river habitat, with both being numerically dominated by redbreast sunfish, spotted sucker, bluegill, spotted sunfish, American eel, black crappie, flat bullhead, and largemouth bass. However, species richness was greater in the river, probably due to the greater habitat diversity there.

The relative abundance of minnows and other small fishes also differed between the major habitats in the study area (Tables V-4.13 and V-4.14). Shiners were dominant in the Savannah River, thermal creeks, and nonthermal creeks in 1983-1984, and in all five habitats in 1984-1985. By comparison, shiners were surpassed in abundance by topminnows (*Fundulus* spp.) in the intake canals in 1983-1984. In 1984-1985, coastal shiners (*Notropis petersoni*) comprised the greatest percentage of small fish in the thermal river and creeks. Thus, like the largemouth bass, channel catfish, and white catfish, the coastal shiner appears to be an important species in the thermal habitats (Paller & Saul, 1986).

Species composition exhibited considerable seasonal variation during both years of the study. For example, largemouth bass comprised 17.8% of the electrofishing catch from the nonthermal creeks in June 1984, but zero percent in August 1984. Similarly,

TABLE V-4.13

Relative Abundance of Minnows and Other Small Fishes Collected by Electrofishing in the Savannah River, Intake Canals, Ambient Creeks, and Thermal Creeks on the Savannah River Plant (November 1983-August 1984)

Taxa	River	Intake Canals	Ambient* Creeks	Thermal** Creeks
Shiners (*Notropis* spp.)	91.9	26.0	86.3	93.2
Bannerfin shiner	x†		x	x
Coastal shiner	x	x	x	x
Whitefin shiner	x	x	x	x
Spottail shiner	x	x		x
Yellowfin shiner	x			
Ironcolor shiner	x	x	x	x
Dusky shiner	x		x	
Taillight shiner		x		
Golden shiner	0.6	18.6	0.4	1.9
Eastern silvery minnow	0.6	0.0	0.4	0.0
Mississippi silvery minnow	0.1	0.0	0.0	0.0
Pugnose minnow	0.7	1.9	0.8	0.0
Rosyface chub	0.3	0.0	0.0	0.0
Bluehead chub	<0.1	0.0	0.0	0.0
Lined topminnow	0.1	33.8	1.2	0.5
Mosquitofish	0.8	4.8	0.0	3.4
Savannah darter	<0.1	0.0	0.0	0.0
Tesselated darter	0.9	11.5	1.2	0.0
Swamp darter	<0.1	0.0	0.0	0.0
Blackbanded darter	0.3	0.4	1.6	0.5
Speckled madtom	0.1	0.0	0.0	0.0
Tadpole madtom	<0.1	0.0	0.0	0.0
Swampfish	<0.1	0.0	0.0	0.0
Brook silverside	2.0	1.5	8.3	0.5
American shad	0.9	1.5	0.0	0.0
Blueback herring	0.3	0.0	0.0	0.0
Banded pygmy sunfish	0.0	0.0	0.4	0.0
Total percent	99.6	100.0	100.2	100.0
Total number	4571	269	253	208
Total species	26	14	13	11

* Steel Creek, Upper Three Runs, and Lower Three Runs.
** Four Mile Creek and Beaver Dam Creek.
† The presence of individual shiner species was noted but not quantified.

Source: Paller and Osteen, 1985.

TABLE V-4.14

Relative Abundance of Minnows and Other Small Fishes Collected by Electrofishing in the Thermal and Nonthermal Areas of the Savannah River, Intake Canals, and the Thermal and Nonthermal Tributary Creeks on the SRP (November 1984-August 1985)

	River				Intake Canals		Creeks			
	Nonthermal*		Thermal**				Nonthermal†		Thermal††	
	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	1.0	0	0.0
Bluehead chub	2	0.0	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	30.6	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	2.9
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	37.0	89	87.3
Notropis spp.	75	7.0	17	10.9	1	6.7	135	9.3	5	4.9
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	0.7	1	0.6	0	0.0	7	0.5	0	0.0
Banded plygmy 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	100.1	156	99.8	15	100.0	1456	100.2	101	99.1

* All river transects except those just below Beaver Dam Creek and Four Mile Creek.
** RMs 152.0 below Beaver Dam Creek and 150.4 below Four Mile Creek.
† Upper Three Runs Creek, Steel Creek, and Lower Three Runs Creek.
†† Beaver Dam Creek, Four Mile creek, and Pen Branch.

Source: Paller and Saul, 1986.

flat bullhead dominated the nonthermal river hoopnetting collections during November and February in the 1984-1985 study (63.5 and 62.9%, respectively), but were less abundant during May and August (28.4 and 12.9%, respectively; Tables V-4.15 through V-4.18). Some of the factors affecting the seasonal variations in abundance include migration, mortality, recruitment of juvenile fish, changes in water level that affected collection efficiency, and seasonal changes in behavior and habitat preference that affected the susceptibility to capture. Some of the most important behavioral changes were the increased movement and activity that accompanied spawning during May. The behavioral changes brought migratory fishes into the study area and made some of the resident fishes more susceptible to capture as they moved into shallower water to spawn (Paller & Osteen, 1985).

Fish collected by electrofishing were used to estimate catch per unit effort (CPUE) or the number of fish per 100 m of shoreline. The CPUE at sample stations in the Savannah River in 1983-1984 ranged from a high of 1.0 to 10.8 fish/100 m during November to a low of 0.3 to 2.6 fish/100 m during August. The low CPUEs during August and also January were probably the result of high water levels that enabled fish to move out of the river and creeks and into the floodplain swamp. There were statistically significant differences between the river sample stations during all months, probably due to habitat variation and the tendency of fishes to congregate in areas with food or shelter. However, there were no significant differences between river sample stations that indicated SRP impacts (Paller & Osteen, 1985).

The CPUE in the intake canals was higher than in the river and creeks in 1983-1984 averaging 5.3 fish/100 m over the entire sampling period compared to 2.7 fish/100 m in the river, 3.4 fish/100 m in the nonthermal creeks and 1.3 fish/100 m in the thermal creeks. The comparatively high catches from the intake canals were linked to the presence of large numbers of bluegill, chain pickerel, and other fishes in the extensive macrophyte beds in the intake canals.

Seasonal trends in the intake canals were generally similar to those in the river, with high values in November and June, and low values in January and August (Table V-4.19). Catch rates in the nonthermal creeks in 1983-1984 were generally similar to those in the river (Table V-4.19), with low CPUEs in January (mean of 1.5 fish/100 m) and in August (mean of 0.8 fish/100 m) and relatively high CPUEs in November (mean of 7.4 fish/100 m) and June (mean of 4.0 fish/100 m).

In thermally influenced Four Mile Creek, catch rates were low in November (zero fish/100 m) when the mean temperature was 35.8°C and low in June (0.7 fish/100 m) when the mean temperature was 36.6°C (Table V-4.19). Higher catch rates occurred at lower creek

TABLE V-4.15

Seasonal Changes in the Relative Abundance (percent number) of Dominant Fishes Captured by Electrofishing in the Savannah River, Intake Canals, Thermal Creeks, and Nonthermal Creeks on the Savannah River Plant (November 1983-August 1984)

	November 1983				January 1984				June 1984				August 1984			
	TC*	NTC**	IC†	SR††	TC	NTC	IC	SR	TC	NTC	IC	SR	TC	NTC	IC	SR
Nonandromous Fishes																
Sunfish	64.3	44.2	75.4	52.9	50.0	38.9	46.7	32.9	42.1	32.7	31.6	52.0	26.9	7.1	42.9	21.1
Largemouth bass	7.1	4.2	3.7	10.2	6.7	5.6	5.4	7.4	35.3	17.4	6.7	10.0	0.0	0.0	10.2	7.9
Black crappie	0.0	0.0	0.3	1.2	0.0	1.9	8.6	2.6	2.0	3.5	1.1	3.1	3.8	7.1	0.7	7.2
Bowfin	0.0	3.1	1.1	6.1	6.7	1.9	2.3	8.7	2.0	4.9	2.5	4.5	11.5	14.2	1.4	10.2
American eel	0.0	17.7	0.5	3.4	6.7	9.3	0.0	2.9	0.0	5.6	0.0	2.4	0.0	0.0	0.0	3.0
Spotted sucker	0.0	13.5	1.3	8.3	6.7	33.3	10.1	26.1	2.0	9.7	8.1	6.8	0.0	3.6	2.0	2.3
Yellow perch	0.0	0.8	2.1	0.6	0.0	1.9	10.9	0.8	0.0	4.2	9.2	0.8	0.0	0.0	4.8	0.4
Pickerel	0.0	6.5	6.5	1.8	13.3	1.9	5.4	3.5	2.0	10.4	25.1	7.4	19.2	50.0	15.6	6.0
Shad	0.0	0.0	1.6	1.4	10.0	1.9	4.7	7.1	0.0	0.0	3.6	1.3	15.4	3.6	8.8	8.6
Anadromous Fishes																
American shad	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	2.0	0.7	0.0	0.3	0.0	3.6	0.0	6.8
Blueback herring	0.0	0.0	2.7	2.1	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.1	3.8	7.1	0.7	9.4
Striped bass	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.3	0.0	0.0	0.0	0.3	7.7	3.6	2.7	6.0
Other	28.6	10.0	4.8	10.7	0.0	3.4	5.1	7.4	12.6	10.9	12.1	11.0	11.7	0.0	10.2	11.1
Total number	14	260	355	1453	30	54	128	310	60	135	326	1224	26	28	147	265
Total species	5	19	21	28	11	14	21	28	12	22	24	32	14	11	24	30

* Thermal creeks: Four Mile Creek and Beaver Dam Creek.
** Nonthermal creeks: Upper Three Runs, Steel Creek, and Lower Three Runs Creek.
† Intake canals.
†† Savannah River.

Source: Paller and Osteen, 1985.

TABLE V-4.16

Seasonal Changes in the Relative Abundance (percent number) of Fishes Captured by Hoopnetting in the Savannah River, Intake Canals, Thermal Creeks, and Nonthermal Creeks on the Savannah River Plant (November 1983-August 1984)

	November 1983				January 1984				June 1984				August 1984			
	TC*	NTC**	IC†	SR††	TC	NTC	IC	SR	TC	NTC	IC	SR	TC	NTC	IC	SR
Nonandromous Fishes																
Sunfish	0.0	0.0	53.6	19.7	20.0	0.0	23.3	7.2	21.7	21.2	44.8	29.5	16.7	4.7	16.7	3.2
American eel	0.0	7.1	1.8	3.9	0.0	3.0	0.0	0.8	4.3	12.1	0.0	4.4	0.0	0.0	0.0	0.4
Spotted sucker	0.0	0.0	0.0	0.0		0.0	6.7	11.2	4.3	1.5	2.3	0.5	0.0	0.0	0.0	0.4
Black crappie	0.0	0.0	10.7	5.3	20.0	0.0	20.0	0.0	0.0	18.2	37.9	8.1	0.0	2.3	16.7	1.4
Channel catfish	95.2	39.3	14.3	20.5	20.0	0.0	0.0	7.2	43.5	25.8	2.3	10.7	50.0	59.3	0.0	32.9
White catfish	0.0	7.1	0.0	9.7	10.0	28.4	0.0	4.0	0.0	3.0	1.1	13.8	16.7	7.0	0.0	7.9
Flat bullhead	0.0	42.9	17.9	34.7	10.0	61.2	36.7	58.4	4.3	3.0	1.1	5.5	16.7	24.4	66.7	50.4
Gar	4.8	0.0	0.0	2.5	10.0	0.0	0.0	0.0	17.4	4.5	1.1	20.8	0.0	1.2	0.0	2.1
Anadromous Fishes																
American shad	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	10.6	0.0	1.0	0.0	0.0	0.0	0.0
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
Striped bass	0.0	0.0	0.0	0.0	0.0	0.0	0.8	3.2	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.4
Other	0.0	3.6	1.7	3.7	10.0	7.4	13.3	8.0	0.0	0.0	9.4	5.4	0.0	1.1	0.0	0.9
Total number	21	56	56	513	10	67	30	125	23	66	87	384	6	86	6	280
Total species	2	5	7	13	8	5	8	12	9	14	11	24	4	9	3	16

* Thermal creeks: Four Mile Creek and Beaver Dam Creek.
** Nonthermal creeks: Upper Three Runs, Steel Creek, and Lower Three Runs Creek.
† Intake canals.
†† Savannah River.

Source: Paller and Osteen, 1985.

TABLE V-4.17

Seasonal Changes in the Relative Abundance (percent number) of the Most Common Fishes Captured by Electrofishing in Thermal and Nonthermal Areas of the Savannah River, Intake Canals, and the Thermal and Nonthermal Tributary Creeks on the SRP (November 1984-August 1985)

	November 1984					February 1985					May 1985					August 1985				
	NTR*	TR**	IC†	NTC††	TC¶	NTR	TR	IC	NTC	TC	NTR	TR	IC	NTC	TC	NTR	TR	IC	NTC	TC
Nonandromous Fishes																				
Bowfin	1.4	0.0	1.3	0.3	8.0	8.5	14.3	10.0	0.5	7.1	5.0	0.0	0.0	1.1	10.0	9.0	3.6	2.6	1.0	3.1
American eel	3.6	0.0	0.0	10.5	10.0	0.0	0.0	0.0	8.0	5.4	3.8	0.0	0.0	7.4	10.0	1.9	0.0	0.0	4.2	1.6
Shad	1.8	0.0	0.0	0.0	2.0	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	1.6
Pickerel	3.2	2.8	9.3	1.8	2.0	8.5	0.0	10.0	0.5	3.6	0.8	3.8	2.8	1.7	0.0	1.0	0.0	1.7	0.8	0.0
Spotted Sucker	9.5	11.1	0.0	6.7	2.0	48.9	71.4	20.0	10.3	10.7	21.8	19.2	11.3	7.7	0.0	11.5	3.6	1.7	3.2	10.9
Sunfish	54.5	61.1	74.7	59.9	42.2	14.9	0.0	40.0	63.0	48.2	52.7	34.6	57.7	67.6	40.0	54.0	53.6	63.5	84.7	42.2
Largemouth bass	15.5	11.1	9.3	2.2	30.0	2.1	0.0	20.0	4.9	5.4	4.6	15.4	1.4	2.6	10.0	8.4	28.6	11.6	2.3	17.2
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	0.2	0.0	1.3	0.0	0.0	0.1	0.0
Yellow perch	1.4	0.0	4.0	0.3	0.0	0.0	0.0	0.0	0.3	0.0	2.5	3.8	23.9	3.5	0.0	0.5	0.0	6.1	0.3	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	0.5	0.0	1.0	0.0	0.0	0.0	1.6
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
Other	5.9	2.8	1.3	18.2	4.0	14.9	14.3	0.0	12.4	10.7	7.1	23.1	1.4	7.9	30.0	9.4	7.1	3.5	3.3	21.9
Total number	220	36	75	626	50	47	7	10	387	56	239	26	71	660	20	619	28	115	780	64
Total species	21	11	12	21	13	14	3	5	18	15	25	12	14	23	10	29	9	14	23	14

* All river transects except those just below Beaver Dam Creek and Four Mile Creek.
** RMs 152.0 below Beaver Dam Creek and 150.4 below Four Mile Creek.
† Intake canals.
†† Upper Three Runs Creek, Steel Creek, and Lower Three Runs Creek.
¶ Four Mile Creek, Beaver Dam Creek, and Pen Branch.

Source: Paller and Osteen, 1985.

TABLE V-4.18

Seasonal Changes in the Relative Abundance (percent number) of the Most Common Fishes Captured by Hoopnetting in Thermal and Nonthermal Areas of the Savannah River, Intake Canals, and the Thermal and Nonthermal Tributary Creeks on the SRP (November 1984-August 1985)

	November 1984					February 1985					May 1985					August 1985				
	NTR*	TR**	IC†	NTC††	TC¶	NTR	TR	IC	NTC	TC	NTR	TR	IC	NTC	TC	NTR	TR	IC	NTC	TC
Nonandromous 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	75.0	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¶¶	9.4	33.3	100.0	25.0	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
Other	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	8	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

* All river transects except those just below Beaver Dam Creek and Four Mile Creek.
** RMs 152.0 below Beaver Dam Creek and 150.4 below Four Mile Creek.
† Intake canals.
†† Upper Three Runs Creek, Steel Creek, and Lower Three Runs Creek.
¶ Four Mile Creek, Beaver Dam Creek, and Pen Branch.
¶¶ Includes several species of Lepomis.

Source: Paller and Osteen, 1985.

TABLE V-4.19

Seasonal Changes in the Catch per Unit Effort (CPUE) of Dominant Fishes Captured by Electrofishing in the Savannah River, Intake Canals, Thermal Creeks, and Nonthermal Creeks of the Savannah River Plant (November 1983 - August 1984)

Habitat	November 1983		January 1984		June 1984		August 1984	
	Mean CPUE*	Mean °C	Mean CPUE	Mean °C	Mean CPUE	Mean °C	Mean CPUE	Mean °C
Nonthermal river	4.9 ±0.3**	18.0 ±0.1	1.0 ±0.1	8.1 ±0.1	4.2 ±0.2	20.9 ±0.2	0.8 ±0.1	21.0 ±0.1
River thermal plume area	7.7 ±1.3	20.2 ±0.5	1.8 ±0.5	9.4 ±0.6	4.3 ±0.9	21.4 ±0.4	1.8 ±0.6	20.8 ±0.3
Intake canals	7.9 ±1.3	17.5 ±0.1	2.8 ±0.5	7.9 ±0.2	7.5 ±0.7	0.8 ±0.3	3.1 ±0.5	21.2 ±0.2
Nonthermal creek	7.4 ±1.7	14.7 ±0.4	1.5 ±0.4	8.0 ±0.4	4.0 ±0.7	21.2 ±0.9	0.8 ±0.3	21.9 ±0.4
Thermal creek***								
Four Mile Creek	0.0 ±0.0	35.8 ±1.5	1.9 ±0.6	20.7 ±4.9	0.7 ±0.4	36.6 ±1.4	1.6 ±0.5	21.0 ±0.3†
Beaver Dam Creek	1.2 ±0.3	22.8 ±0.6	0.8 ±0.3	13.3 ±3.2	3.6 ±0.9	20.2 ±2.0	0.8 ±0.4	20.7 ±0.4†

* Catch per unit effort.

** Approximately 264 samples were taken each quarter in the nonthermal river habitat, 24 in the thermal river habitat, 48 in the intake canals, 36 in the nonthermal creek habitat, 12 in Four Mile Creek, and 12 in Beaver Dam Creek. Value is mean ± 1 S.E.

*** Four Mile and Beaver Dam Creek are separate because they differed in temperature.

† High river levels reversed the flow in the thermal creeks during August resulting in ambient temperatures near the creek mouth.

temperatures: 1.9 fish/100 m were caught in January when the mean temperature was 0.7°C, and 1.6 fish/100 m were caught in August when the mean temperature was 21.0°C (high river levels had pushed the thermal plume back into the swamp; Paller and Osteen, 1985).

Beaver Dam Creek was, on the average, much cooler than Four Mile Creek (Table V-4.19). Beaver Dam Creek averaged 19.2°C over the entire 1983- 1984 sampling period, Four Mile Creek averaged 28.5°C, and the nonthermal creeks combined averaged 16.5°C. The CPUE in Beaver Dam Creek ranged from a mean of 0.8 fish/100 m in January and August to 3.6 fish/100 m in June.

The only indication of SRP impacts discernible from the hoopnetting data in 1983-1984 was the low CPUE in Four Mile Creek. In November (when the creek had a mean temperature of 35.8°C) the catch rate averaged zero fish/net day while in June (when the creek had a mean temperature of 36.6°C) the catch rate averaged 0.5 fish/net day.

As in 1983-1984, the electrofishing CPUE results from the 1984-1985 sampling period (Table V-4.20) indicate that thermally influenced Four Mile Creek had the lowest catch rates. Generally, the CPUE in Four Mile was zero fish/100 m. The only exception was in August 1985 when C Reactor was shut down and creek temperatures subsequently dropped. Then the CPUE in Four Mile Creek was similar to the CPUE for the other creeks. CPUE in moderately thermal Beaver Dam Creek was variable and exhibited no obvious relationship to temperature (Paller & Osteen, 1985). The CPUE was highly variable at most of the other sample stations (Table V-4.20).

In general, the hoopnetting CPUE in 1984-1985 was highly variable and exhibited no consistent habitat or temperature-related patterns (Paller & Osteen, 1985). The major exception to this was Four Mile Creek where the CPUE was consistently low, ranging from zero to 0.3 fish/net day. In addition, the CPUE in Beaver Dam Creek was often below that in the nonthermal creeks, ranging from zero to 0.7 fish/net day. There was no evidence of a reduced CPUE in the thermal river habitat.

V.4.2.3.2 Overwintering Study

The basic objective of the overwintering study was to determine the extent to which fishes congregated in and around the thermal discharges from Four Mile Creek and Beaver Dam Creek during the winter months. During the 1983-1984 overwintering study, 2,744 adult and juvenile fishes were collected, 1226 by electrofishing and 1518 by hoopnetting.

TABLE V-4.20

Seasonal Changes in the Catch Per Unit Effort (CPUE) of Dominant Fishes Captured by Electrofishing in the Savannah River, Intake Canals, Thermal Creeks, and Nonthermal Creeks of the Savannah River Plant (November 1984 - August 1985)

	November 1984		February 1985		May 1985		August 1985	
Habitat	Mean CPUE	Mean °C	Mean CPUE	Mean °C	Mean CPUE	Mean °C	Mean CPUE	Mean °C
Nonthermal river	3.1 (0.0)*	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**								
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)

* 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.

** Four Mile and Beaver Dam Creek are separate because they differed in temeperature.

During February and March of 1984, C Reactor was off line. As a result, Four Mile Creek, the warmer of the two thermal streams being studied, was at ambient temperatures during mid-winter when the attractive effects of the heated discharge were expected to be greatest. This should be considered when reviewing the results. Furthermore, ambient water temperatures were relatively warm during early November (1983-1984 sampling year) so responses to the thermal effluents were more typical of those expected during summer than those expected during the winter (Paller & Osteen, 1985). Therefore, the early November data were not included in the following analysis. To evaluate overwintering in the thermal plumes, the study area was divided into four habitats as in the electrofishing and hoopnetting studies: the river thermal plume area, the nonthermal river, the nonthermal creeks, and the thermal creeks.

To obtain information on overwintering in the heated areas, the CPUE was compared between the thermal and nonthermal creek mouths. In the 1984-1985 overwintering study, water temperature and five other water quality parameters were measured at each sample station and are listed in Table V-4.21. Four Mile Creek ranged in temperature from 11.5°C at all three sections of the creek to 39.8°C at the station furthest upstream. The mean temperature in Four Mile Creek during the 1984-1985 overwintering study was 30.1°C. Beaver Dam Creek experienced the greatest temperature range at its mouth, ranging from 10.0 to 25.5°C. The mean temperature in Beaver Dam Creek for all stations was 19.0°C. Several species exhibited marked differences in their CPUE value between the thermal and nonthermal habitats. Based on electrofishing and hoopnetting CPUE data from the 1983-1984 and 1984-1985 overwintering programs, the species that appeared to congregate in the thermal habitats were redear sunfish, channel catfish, longnose and spotted gar, gizzard and threadfin shad, white catfish, largemouth bass (collected in greater numbers in the thermal river stations only), and black crappie. It should be noted that while gizzard shad were relatively abundant in the thermal habitats compared to the nonthermal habitats in the 1983-1984 overwintering collections, they were more abundant in the nonthermal habitats during 1984-1985. Tables V-4.22 through V-4.25 list the CPUE data from the thermal and nonthermal sampling stations for both years of study.

To obtain more information on the use of the thermal habitats by the species mentioned in this section, CPUE for thermal and nonthermal creeks calculated from the 1983-1984 overwintering study (November 1983 - April 1984) were compared with similar data from the quarterly study (June and August 1984). These data are presented in Table V-4.26 along with ratios of CPUE in thermal and nonthermal creeks. It should be noted that the lower reaches of the thermal creeks were not heated during August due to unusually high river levels. Thus, the following comparisons, although they provided information on the thermal responses of important Savannah

TABLE V-4.21

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	Temp. °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)

Source: Paller and Saul, 1986.

TABLE V-4.21, Contd

River Mile	N	Temp. °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	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	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	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	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	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 Creek							
Zone 3	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	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	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)

Source: Paller and Saul, 1986.

TABLE V-4.22

Abundance of Fishes Caught by Electrofishing During the Overwintering Program (November 1983-April 1984)

Species	River						Creek					
	Nonthermal*			Thermal**			Nonthermal†			Thermal††		
	Number	Percent	CPUE¶	Number	Percent	CPUE	Number	Percent	CPUE	Number	Percent	CPUE
American shad	6	0.8	0.01	0	0.0	0.00	3	3.2	0.02	1	0.6	0.01
Blueback herring	2	0.3	<0.01	2	0.9	0.02	0	0.0	0.00	0	0.0	0.00
Gizzard shad	104	14.2	0.12	23	10.4	0.18	8	8.6	0.06	30	16.8	0.24
Threadfin shad	13	1.8	0.01	60	27.1	0.48	2	2.2	0.02	3	1.7	0.02
Unid. shad	2	0.3	<0.01	0	0.0	0.00	0	0.0	0.00	2	1.1	0.02
American eel	15	2.0	0.02	3	1.4	0.02	4	4.3	0.03	0	0.0	0.00
Striped bass	1	0.1	<0.01	1	0.5	<0.01	0	0.0	0.00	0	0.0	0.00
White bass	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
Hybrid - (white & stripped bass)	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
Striped mullet	24	3.3	0.03	0	0.0	0.00	1	1.1	0.01	2	1.1	0.02
Spotted sucker	147	20.1	0.17	12	5.4	0.10	20	21.5	0.16	13	7.3	0.11
Silver redhorse	52	7.1	0.06	1	0.5	0.01	0	0.0	0.00	0	0.0	0.00
Quillback carpsucker	5	0.7	0.01	0	0.0	0.00	0	0.0	0.00	1	0.6	0.01
Golden shiner	5	0.7	0.01	1	0.5	0.01	0	0.0	0.00	1	0.6	0.01
Creek chubsucker	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	1	0.6	0.01
Lake chubsucker	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	1	0.6	0.01
Yellow perch	12	1.6	0.01	1	0.5	0.01	2	2.2	0.02	0	0.0	0.00
Pirate perch	22	1.2	0.03	0	0.0	0.00	0	0.0	0.00	1	0.6	0.01
Logperch	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
Bluespotted sunfish	3	0.4	<0.01	1	0.5	0.01	1	1.1	0.01	2	1.1	0.02

* All sample stations on the river except those below Four Mile and Beaver Dam Creeks.

** River sample stations just below Four Mile Creek and Beaver Dam Creek.

† Steel Creek and Lower Three Runs Creek.

†† Four Mile Creek and Beaver Dam Creek.

¶ Catch per unit effort was calculated by dividing total catch of each species by total effort expended during overwintering program.

Source: Paller and Osteen, 1985.

TABLE V-4.22, Contd

Species	River						Creek					
	Nonthermal*			Thermal**			Nonthermal†			Thermal††		
	Number	Percent	CPUE¶	Number	Percent	CPUE	Number	Percent	CPUE	Number	Percent	CPUE
Flier	3	0.4	<0.01	0	0.0	0.00	2	2.2	0.02	6	3.4	0.05
Redbreast sunfish	59	8.0	0.07	28	12.7	0.22	7	7.5	0.06	8	4.5	0.07
Warmouth	10	1.4	0.01	9	4.1	0.07	1	1.1	0.01	4	2.2	0.03
Bluegill	32	4.4	0.04	14	6.3	0.11	4	4.3	0.03	6	3.4	0.05
Redear sunfish	14	1.9	0.02	12	5.4	0.10	2	2.2	0.02	26	14.5	0.21
Spotted sunfish	42	5.7	0.05	13	5.9	0.10	6	6.5	0.05	7	3.9	0.06
Dollar sunfish	7	0.9	0.01	0	0.0	0.00	1	1.1	0.01	3	1.7	0.02
Black crappie	18	2.4	0.02	7	3.2	0.06	2	2.2	0.02	1	0.6	0.01
Largemouth bass	37	5.0	0.04	12	5.4	0.10	10	10.8	0.08	20	11.2	0.16
Channel catfish	2	0.3	<0.01	2	0.9	0.02	0	0.0	0.00	4	2.2	0.03
White catfish	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	1	0.6	0.01
Flat bullhead	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	1	0.6	0.01
Chain pickerel	22	3.0	0.03	5	2.3	0.04	7	7.5	0.06	6	3.4	0.05
Redfin pickerel	11	1.5	0.01	7	3.2	0.06	3	3.2	0.02	5	2.8	0.04
Longnose gar	19	2.6	0.02	1	0.5	0.01	1	1.1	0.01	10	5.6	0.08
Spotted gar	2	0.3	<0.01	0	0.0	0.00	0	0.0	0.00	6	3.4	0.05
Bowfin	48	6.6	0.05	6	2.7	0.05	5	5.4	0.04	7	3.9	0.06
Unid. fish	2	0.3	<0.01	0	0.0	0.00	1	1.1	0.01	0	0.0	0.00
Total	733	99.8	0.85	221	100.3	1.75	93	100.4	0.75	179	100.6	1.48
Number of species		36			22			22			29	

* All sample stations on the river except those below Four Mile and Beaver Dam Creeks.
** River sample stations just below Four Mile Creek and Beaver Dam Creek.
† Steel Creek and Lower Three Runs Creek.
†† Four Mile Creek and Beaver Dam Creek.
¶ Catch per unit effort was calculated by dividing total catch of each species by total effort expended during overwintering program.

Source: Paller and Osteen, 1985.

TABLE V-4.23

Abundance of Fishes Caught by Hoopnetting During the Overwintering Program (November 1983-April 1984)

	River						Creek					
	Nonthermal*			Thermal**			Nonthermal†			Thermal††		
Species	Number	Percent	CPUE¶	Number	Percent	CPUE	Number	Percent	CPUE	Number	Percent	CPUE
American shad	3	0.3	<0.01	0	0.0	0.00	6	5.7	0.05	0	0.0	0.00
Blueback herring	16	1.5	0.02	3	2.0	0.03	0	0.0	0.00	0	0.0	0.00
Gizzard shad	21	1.9	0.03	2	1.4	0.02	0	0.0	0.00	1	0.5	0.01
American eel	3	0.3	<0.01	1	0.7	0.01	2	1.9	0.02	0	0.0	0.00
Striped bass	5	0.5	0.01	1	0.7	0.01	1	1.0	0.01	0	0.0	0.00
White bass	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
Hybrid - (striped & white bass)	3	0.3	<0.00	1	0.7	0.01	0	0.0	0.00	1	0.5	0.01
Striped mullet	5	0.5	0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
Spotted sucker	54	5.0	0.07	3	2.0	0.03	4	3.8	0.04	3	1.6	0.03
Silver redhorse	14	1.3	0.02	0	0.0	0.00	2	1.9	0.02	0	0.0	0.00
Quillback carpsucker	0	0.0	0.00	1	0.7	0.01	0	0.0	0.00	4	2.2	0.04
Creek chubsucker	5	0.5	0.01	2	1.4	0.02	0	0.0	0.00	0	0.0	0.00
Lake chubsucker	8	0.7	0.01	2	1.4	0.02	0	0.0	0.00	1	0.5	0.01
Yellow perch	7	0.6	0.01	1	0.7	0.01	1	0.0	0.01	0	0.0	0.00
Mud sunfish	3	0.3	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
Flier	17	1.6	0.02	2	1.4	0.02	1	1.0	0.01	8	4.3	0.07
Redbreast sunfish	43	4.0	0.06	6	4.1	0.05	6	5.7	0.05	13	7.0	0.12
Green sunfish	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
Warmouth	37	3.4	0.05	3	2.0	0.03	0	0.0	0.00	10	5.4	0.09
Bluegill	29	2.7	0.04	4	2.7	0.04	4	3.8	0.04	12	6.5	0.11

* All sample stations on the river except those below Four Mile and Beaver Dam Creeks.

** River sample stations just below Four Mile Creek and Beaver Dam Creek.

† Steel Creek and Lower Three Runs Creek.

†† Four Mile Creek and Beaver Dam Creek.

¶ Catch per unit effort was calculated by dividing total catch of each species by total effort expended during overwintering program.

Source: Paller and Osteen, 1985.

TABLE V-4.23, Contd

Species	River						Creek					
	Nonthermal*			Thermal**			Nonthermal†			Thermal††		
	Number	Percent	CPUE¶	Number	Percent	CPUE	Number	Percent	CPUE	Number	Percent	CPUE
Redear sunfish	18	1.7	0.02	16	10.8	0.14	1	1.0	0.01	22	11.9	0.19
Spotted sunfish	11	1.0	0.01	1	0.7	0.01	2	1.9	0.02	5	2.7	0.04
White crappie	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
Black crappie	38	3.5	0.05	4	2.7	0.04	3	2.9	0.03	10	5.4	0.09
Largemouth bass	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	3	1.6	0.03
Channel catfish	119	11.0	0.15	41	27.7	0.37	1	1.0	0.01	41	22.2	0.36
White catfish	43	4.0	0.06	14	9.5	0.13	2	1.9	0.02	9	4.9	0.08
Flat bullhead	525	48.6	0.67	35	23.6	0.32	64	61.0	0.58	23	12.4	0.20
Brown bullhead	6	0.6	0.01	0	0.0	0.00	1	1.0	0.01	0	0.0	0.00
Yellow bullhead	3	0.3	<0.01	1	0.7	0.01	0	0.0	0.00	0	0.0	0.00
Snail bullhead	3	0.3	<0.01	0	0.0	0.00	1	1.0	0.01	1	0.5	0.01
Chain pickerel	0	0.0	0.00	1	0.7	0.01	0	0.0	0.00	0	0.0	0.00
Redfin pickerel	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
Unid. pickerel	0	0.0	0.00	1	0.7	0.01	0	0.0	0.00	0	0.0	0.00
Longnose gar	19	1.8	0.02	0	0.0	0.00	0	0.0	0.00	15	8.1	0.13
Spotted gar	4	0.4	0.01	0	0.0	0.00	0	0.0	0.00	1	0.5	0.01
Bowfin	7	0.6	0.01	2	1.4	0.02	3	2.9	0.03	2	1.1	0.02
Hogchoker	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
Unid. fish	7	0.6	0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
Total percent	1080	100.3	1.39	148	100.4	1.37	105	100.4	0.97	185	99.8	1.65
Number of species		35			24			18			20	

* All sample stations on the river except those below Four Mile and Beaver Dam Creeks.
** River sample stations just below Four Mile Creek and Beaver Dam Creek.
† Steel Creek and Lower Three Runs Creek.
†† Four Mile Creek and Beaver Dam Creek.
¶ Catch per unit effort was calculated by dividing total catch of each species by total effort expended during overwintering program.

Source: Paller and Osteen, 1985.

TABLE V-4.24

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-August 1985)

	River						Creek					
	Nonthermal*			Thermal**			Nonthermal†			Thermal††		
Species	Number	Percent	CPUE¶	Number	Percent	CPUE	Number	Percent	CPUE	Number	Percent	CPUE
Spotted gar	3	0.2	<0.01	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	4	7.1	0.10
Bowfin	106	6.6	0.12	19	3.3	0.15	16	5.4	0.13	4	7.1	0.10
American eel	35	2.2	0.04	4	0.7	0.03	58	19.7	0.46	1	1.8	0.02
Blueback herring	6	0.4	0.01	1	0.2	0.01	0	0.0	0.00	1	1.8	0.02
American shad	18	1.1	0.02	6	1.1	0.05	4	1.4	0.03	0	0.0	0.00
Gizzard shad	28	1.8	0.03	48	8.4	0.38	14	4.8	0.11	11	19.6	0.26
Threadfin shad	0	0.0	0.00	94	16.5	0.75	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
Chain pickerel	13	0.8	0.01	4	0.7	0.03	1	0.3	0.01	1	1.8	0.02
Quillback carpsucker	1	0.1	<0.01	1	0.2	0.01	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
Lake chubsucker	1	0.1	<0.01	1	0.2	0.01	0	0.0	0.00	1	1.8	0.02
Spotted sucker	207	13.0	0.23	99	17.3	0.79	56	19.0	0.44	9	16.1	0.21
Unid. chubsucker	1	0.1	<0.01	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
Silver redhorse	3	0.2	<0.01	1	0.2	0.01	0	0.0	0.00	1	1.7	0.02
Snail bullhead	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
White catfish	2	0.1	<0.01	1	0.1	0.01	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			
Brown bullhead	0	0.0	0.00	1	0.2	0.01	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	2	3.6	0.05
Channel catfish	3	0.2	<0.01	3	0.5	0.02	0	0.0	0.00	0	0.0	0.00

* All sample stations on the river except those below Four Mile and Beaver Dam Creeks.
** RMs 150.4 below Four Mile Creek, and 152.0 below Beaver Dam Creek.
† Mouths of Steel Creek and Lower Three Runs Creek.
†† Mouths of Four Mile Creek and Beaver Dam Creek.

Source: Paller and Saul, 1986.

TABLE V-4.24, Contd

	River						Creek					
	Nonthermal*			Thermal**			Nonthermal†			Thermal††		
Species	Number	Percent	CPUE¶	Number	Percent	CPUE	Number	Percent	CPUE	Number	Percent	CPUE
Pirate perch	62	3.9	0.07	5	0.9	0.04	15	5.1	0.12	0	0.0	0.00
Striped bass	15	0.9	0.02	15	2.6	0.12	2	0.7	0.02	1	1.8	0.02
Flier	3	0.2	<0.01	1	0.2	0.01	1	0.3	0.01	1	1.8	0.02
Bluespotted sunfish	2	0.1	<0.01	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	4	7.1	0.10
Pumpkinseed	2	0.1	<0.01	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
Bluegill	102	6.4	0.12	24	4.2	0.19	20	6.8	0.16	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
Redear sunfish	42	2.6	0.05	18	3.2	0.14	3	1.0	0.02	1	1.8	0.02
Spotted sunfish	250	15.7	0.28	35	6.1	0.28	12	4.1	0.10	5	8.9	0.12
<u>Lepomis</u> sp.	5	0.3	0.01	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
Largemouth bass	140	8.8	0.16	47	8.2	0.37	26	8.8	0.21	9	16.1	0.21
Black crappie	18	1.1	0.02	8	1.4	0.06	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
Striped mullet	44	2.8	0.05	42	7.4	0.33	0	0.0	0.00	0	0.0	0.00
Hogsucker	7	0.4	0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
Total	1596	100.2	1.81	571	100.3	4.53	294	99.8	2.33	56	100.0	1.31
Number of species	36			30			19			16		

* All sample stations on the river except those below Four Mile and Beaver Dam Creeks.
** RMs 150.4 below Four Mile Creek, and 152.0 below Beaver Dam Creek.
† Mouths of Steel Creek and Lower Three Runs Creek.
†† Mouths of Four Mile Creek and Beaver Dam Creek.

Source: Paller and Saul, 1986.

TABLE V-4.25

Number, Relative Abundance, and Catch per Unit Effort (CPUE; no./net/day) of Fishes Caught by Hoopnetting During the Overwintering Program in Thermal and Nonthermal Areas of the Savannah River, and Thermal and Nonthermal Tributary Creeks on the SRP (November 1984-August 1985)

	River						Creek					
	Nonthermal*			Thermal**			Nonthermal†			Thermal††		
Species	Number	Percent	CPUE	Number	Percent	CPUE	Number	Percent	CPUE	Number	Percent	CPUE
Spotted gar	1	0.1	<0.01	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	8	8.2	0.06
Bowfin	17	1.1	0.02	3	1.4	0.02	2	1.1	0.02	4	4.1	0.03
American eel	8	0.5	0.01	1	0.5	0.01	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	6	6.1	0.05
American shad	7	0.4	0.01	0	0.0	0.00	1	0.6	0.01	0	0.0	0.00
Gizzard shad	23	1.5	0.03	0	0.0	0.00	4	2.2	0.03	1	1.0	0.01
Unid. pickerel	2	0.1	<0.01	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
Creek chubsucker	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	1	1.0	0.01
Spotted sucker	46	2.9	0.05	3	1.4	0.02	7	3.9	0.06	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
Silver redhorse	8	0.5	0.01	1	0.5	0.01	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
Yellow bullhead	2	0.1	<0.01	2	0.9	0.02	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	3	3.1	0.02
Flat bullhead	966	61.5	1.10	73	33.2	0.58	85	47.5	0.67	13	13.3	0.10
Channel catfish	74	4.7	0.08	40	18.2	0.32	11	6.1	0.09	21	21.4	0.17
Striped bass	4	0.3	<0.01	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	4	4.1	0.03

* All sample stations on the river except those below Four Mile and Beaver Dam Creeks.
** RMs 150.4 below Four Mile Creek, and 152.0 below Beaver Dam Creek.
† Mouths of Steel Creek and Lower Three Runs Creek.
†† Mouths of Four Mile Creek and Beaver Dam Creek.

Source: Paller and Saul, 1986.

TABLE V-4.25, Contd

	River						Creek					
	Nonthermal*			Thermal**			Nonthermal†			Thermal††		
Species	Number	Percent	CPUE	Number	Percent	CPUE	Number	Percent	CPUE	Number	Percent	CPUE
Redbreast sunfish	124	7.9	0.14	17	7.7	0.13	31	17.3	0.25	6	6.1	0.05
Green sunfish	1	0.1	<0.01	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
Warmouth	10	0.6	0.01	2	0.9	0.02	3	1.7	0.02	0	0.0	0.00
Bluegill	78	5.0	0.09	19	8.6	0.15	11	6.1	0.09	9	9.2	0.07
Dollar sunfish	1	0.1	<0.01	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	10	10.2	0.08
Spotted sunfish	26	1.7	0.03	10	4.5	0.08	5	2.8	0.04	0	0.0	0.00
Lepomis sp.	5	0.3	0.01	1	0.1	0.01	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
Black crappie	44	2.8	0.05	10	4.5	0.08	2	1.1	0.02	12	12.2	0.10
Yellow perch	9	0.6	0.01	0	0.0	0.00	6	3.4	0.05	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
Hogchoker	1	0.1	<0.01	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
Total	1571	100.2	1.78	220	100.1	1.75	179	100.1	1.42	98	100.0	0.78
Number of species	31			18			17			13		

* All sample stations on the river except those below Four Mile and Beaver Dam Creeks.
** RMs 150.4 below Four Mile Creek, and 152.0 below Beaver Dam Creek.
† Mouths of Steel Creek and Lower Three Runs Creek.
†† Mouths of Four Mile Creek and Beaver Dam Creek.

Source: Paller and Saul, 1986.

TABLE V-4.26

Catch per Unit Effort Between Thermal and Nonthermal Creeks During Winter and Summer (November 1983-April 1984)*

Species	Summer** Thermal	Summer** Nonthermal	Winter† Thermal	Winter† Nonthermal
Spotted sucker††	1.0 (0.02)¶¶	10.5 (0.21)	1.0 (0.11)	1.5 (0.16)
Redear sunfish††	3.5 (0.21)	1.0 (0.06)	10.5 (0.21)	1.0 (0.02)
Channel catfish¶	1.0 (0.27)	3.5 (0.94)	36.0 (0.36)	1.0 (0.01)
White catfish†	1.0 (0.02)	5.6 (0.11)	4.0 (0.08)	1.0 (0.02)
Flat bullhead†	1.0 (0.04)	8.0 (0.32)	1.0 (0.20)	2.9 (0.58)
Longnose gar††	1.0 (0.06)	1.0 (0.06)	8.0 (0.08)	1.0 (0.01)

* Thermal creeks were Four Mile Creek and Beaver Dam Creek. Nonthermal creeks were Steel Creek and Lower Three Runs Creek.
** Data were collected during June and August 1984.
† Data were collected between November 1983-April 1984.
†† Collected by electrofishing.
¶ Collected by hoopnetting.
¶¶ Actual catch per unit effort (CPUE).

Source: Paller and Osteen, 1985.

River species to thermal effluents, were not necessarily indicative of conditions when water levels were normal. The summer/winter comparisons were not made during the 1985 study, although they would be relevant because the overwintering CPUE data between 1983-1984 and 1984-1985 sample years were so similar.

Based on the results shown in Table V-4.26, there were three types of responses by fish populations in the thermal creeks during the 1983-1984 sample year. The first type was displayed by spotted suckers and flat bullheads (Table V-4.26); each strongly avoided the thermal creeks during the summer (thermal/nonthermal ratios less than 0.15) and weakly avoided them during the winter (thermal/nonthermal ratios between 0.3 and 1.0). The second type of response was exhibited by channel catfish and white catfish; both avoided the thermal creeks during the summer (thermal/nonthermal ratios less than 0.3), but congregated in them during the winter (thermal/nonthermal ratios greater than 3.5). These fishes appeared to be avoiding extremes of either heat or cold in order to maintain an optimum body temperature (Paller & Osteen, 1985). The third type of response was exhibited by redear sunfish and longnose gar. These species did not avoid the thermal creeks during the summer (thermal/nonthermal ratios ranging from 1.0 to 3.5) and congregated in them during the winter (thermal/nonthermal ratios greater than 3.5). This trend was more pronounced with the redear sunfish, which exhibited the highest catch rates in the thermal creeks compared to the nonthermal creeks during both summer and winter. As will be discussed in Section V.4.2.3.3, members of the sunfish family are among the most thermally tolerant of the species on the SRP. The temperatures measured in the thermal creeks during the summer were as high as 38°C, several degrees higher than the generally accepted limit for survival of fish populations. These results suggest that temperatures above 35°C were transient in occurrence. The congregation of this species in the thermal creeks during both summer and winter suggests that factors other than temperature, such as habitat preferences, may have been influential. The CPUE for the longnose gar was equal in the thermal and nonthermal creeks during the winter. During years of average river levels, temperatures would be higher and avoidance probably greater, particularly in Four Mile Creek where temperatures in the mouth can exceed 40°C (Paller & Osteen, 1985).

Table V-4.24 shows that the CPUE for all species combined was approximately twice as high in the thermal habitats as in the nonthermal habitats during the winter. This denotes an overall attraction to the thermal areas during the winter. The total hoopnetting CPUE was the same in the thermal and nonthermal river habitats and only 60% higher in the thermal creeks than in the nonthermal creeks (Table V-4.25). The differences between the electrofishing and hoopnetting results may have been due in part to the selectivity of each technique (Paller & Osteen, 1985).

A summary of the electrofishing results was provided by averaging results from all thermal areas together (Four Mile Creek, Beaver Dam Creek, and the thermal river stations), averaging all nonthermal areas together (Steel Creek, Lower Three Runs Creek, and the nonthermal river stations), and plotting the results against the sample date. Figures V-4.2 and V-4.3 depict this for the 1983-1984 and 1984-1985 overwintering programs, respectively. The mean CPUE in the thermal areas was higher than the mean CPUE in the nonthermal areas on 18 of the 21 overwintering sample dates in 1983-1984 and 17 of the 21 sampling dates in 1984-1985. Based on these results, thermal habitats on the SRP appear to serve as winter refugia for several taxa.

Congregation of fishes in thermal areas during winter suggests the possibility of negative effects due to crowding, competition, and temperature-induced increases in metabolic rate. The overall condition of species in thermal and nonthermal areas in winter was calculated using a coefficient of condition defined as weight (mg) x 100/length (cm). The only species that exhibited significantly lower condition in the thermal creeks during 1983-1984 study year was the redear sunfish, while only the gizzard shad and channel catfish showed lower condition in thermal creeks during the 1984-1985 study year. None of the fishes exhibited obvious external differences in disease or parasitism between the thermal and nonthermal habitats.

Fish overwintering in thermal habitats can be adversely affected by either cold shock following a reactor shutdown or thermal shock due to rapidly increasing temperatures following reactor startup. Only one fish kill was observed in the thermal creeks during the course of this study. In late March 1984, following startup of C Reactor after an extended period of down time, a fish kill was observed in the lower reaches of Four Mile Creek.

V.4.2.3.3 Temperature and Fish Occurrence

The relationship between elevated temperatures and the distribution of adult and juvenile fishes was illustrated by plotting the electrofishing CPUE against temperature. All data used in this analysis were collected only from the sample station in the mouth of Four Mile Creek in order to minimize the effects of habitat differences between sampling stations.

Data from the Four Mile Creek mouth were collected on 74 sample dates over a three-year period involving both the quarterly and overwintering study programs. From one to three contiguous 100 m zones were sampled on each sampling date. When more than one zone was sampled on a given date, the CPUE values for each zone were averaged together to give a single mean value for that date. Unlike the CPUE values that were calculated for all sampling dates,

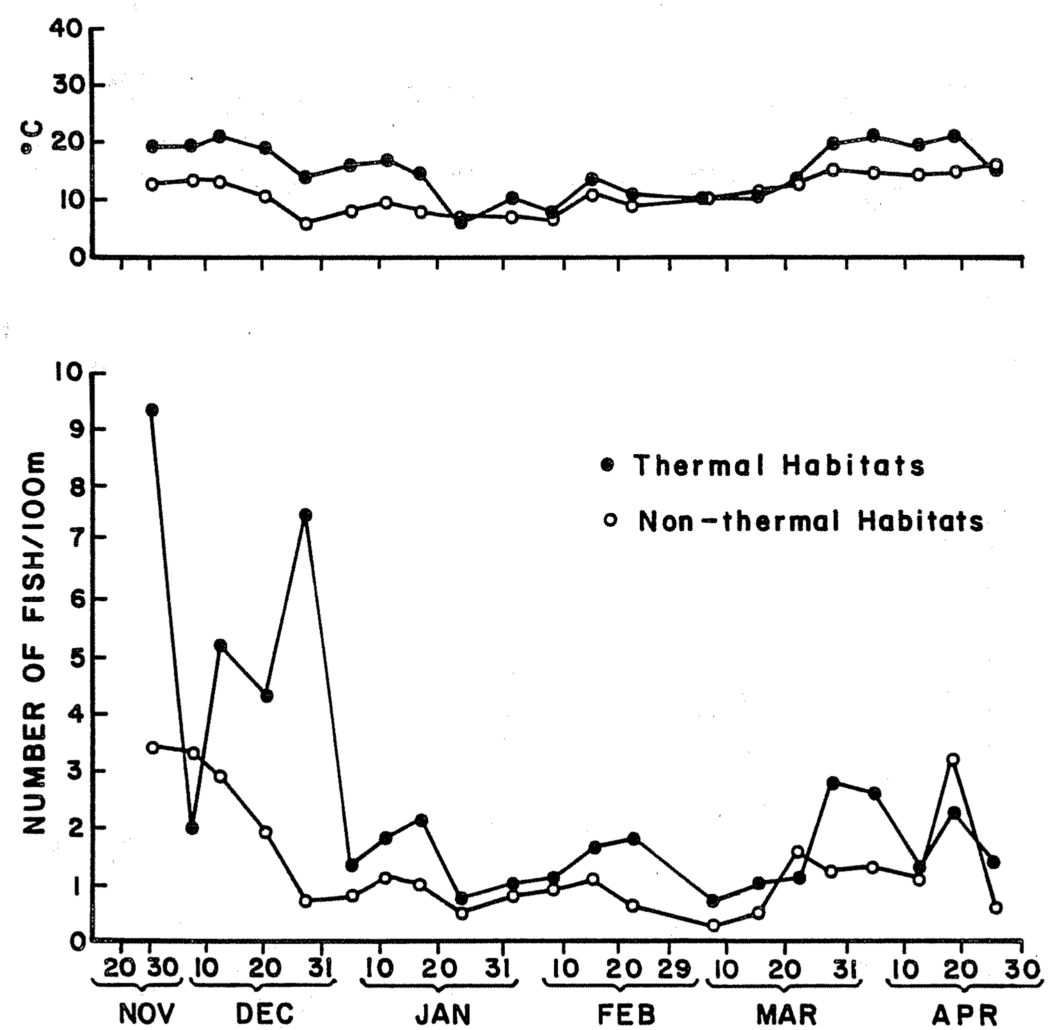


FIGURE V-4.2. Electrofishing Catch per Unit Effort and Temperature in Thermal and Nonthermal Habitats on the Savannah River Plant (November 1983-April 1984). Thermal Habitats Included Heated Creek Mouths and Heated Areas in the Savannah River While Nonthermal Habitats Included Unheated Creek Mouths and Unheated Areas in the Savannah River.

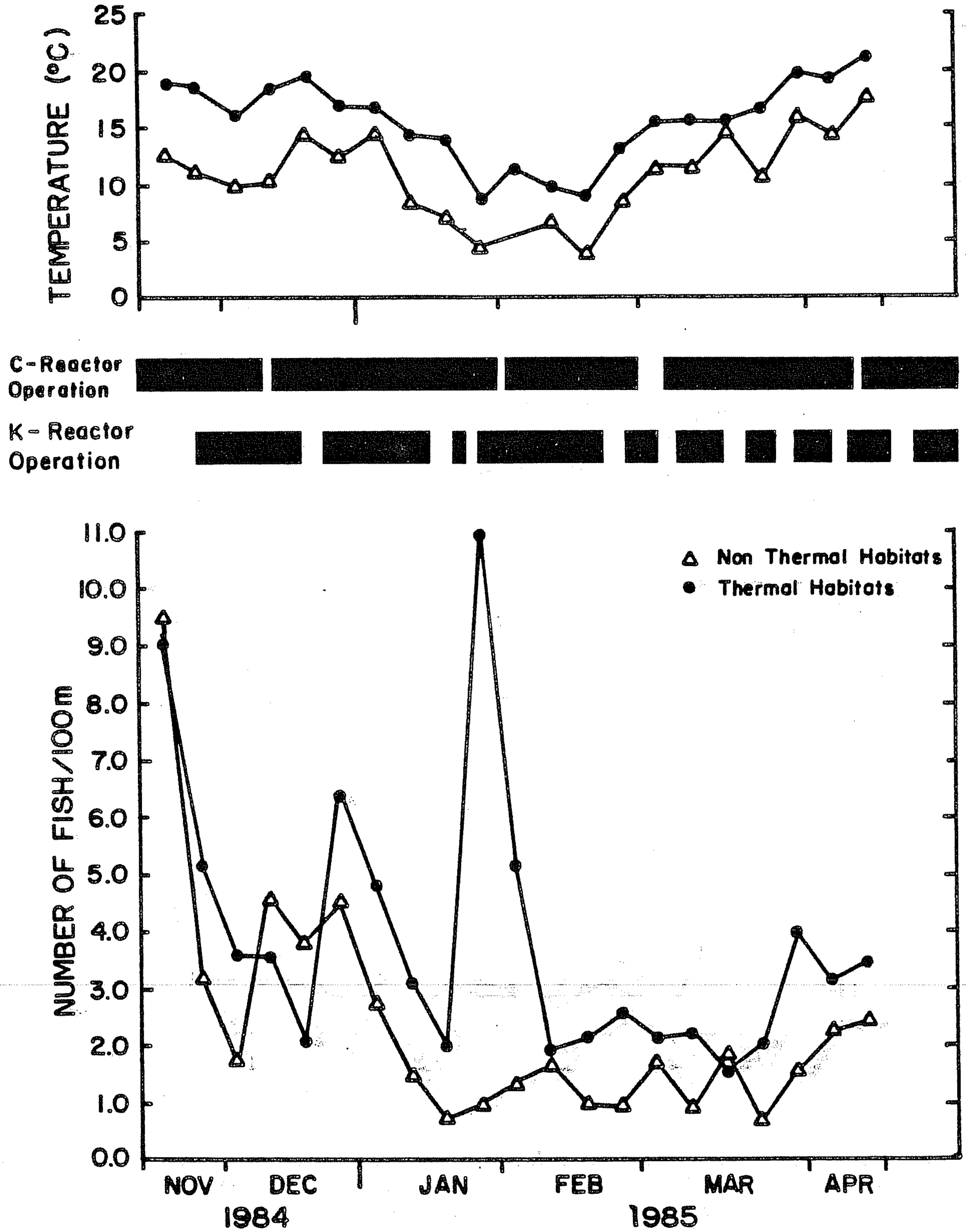


FIGURE V-4.3. Mean Number of Fish/100 m Collected by Electrofishing and Mean Temperature (°C) in Thermal Habitats (Four Mile Creek, Beaver Dam Creek, and the river transects just below them) and Nonthermal Habitats (Steel Creek, Lower Three Runs Creek, and River Transects Without any Thermal Influence (November 1984-April 1985).

the species number and Shannon-Weaver diversity (H^1) were only calculated for dates on which three zones were sampled.

In the mouth of Four Mile Creek, the CPUE was highly variable at temperatures below approximately 30°C for the three years of monitoring (Figures V-4.4 and V-4.5). While relatively high CPUEs occurred at temperatures from 30 to 35°C, the percentage of zero catches was considerably higher (60%) than the percentage of zero catches at temperatures below 30°C (10.5%). At temperatures above 35°C, the CPUE was generally zero 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 to be able to support relatively large numbers of some species. 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. Zero catches may be related to the temperature fluctuations that occur in Four Mile Creek due to changes in reactor activity.

The taxa most abundant at temperatures approaching 35°C were sunfishes, largemouth bass, gar, and shad. Centrarchids (sunfish and bass) were particularly dominant at high temperatures, although most centrarchids collected near 35°C were also collected at relatively low temperatures (Figure V-4.6). Bluegill were not collected at temperatures above 30°C even though the reported temperature tolerance for bluegill is as high as 32.2°C (Fry and Pearson, 1952; cited in Brown, 1974). Despite the differences observed in species abundances at the various temperatures, the Shannon-Weaver diversity index and species richness showed no significant relationship with temperatures below 35°C. Above 35°C, very few fishes of any species were collected (Figures V-4.7 and V-4.8; Paller & Saul, 1986).

The 35°C upper temperature limit suggested for adult and juvenile fishes in Four Mile Creek corresponded with the 35°C upper temperature limit previously suggested for ichthyoplankton in the SRP creeks and swamps (Paller et al., 1986a). However, ichthyoplankton catch rates were also depressed at temperatures ranging from 27°C to 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 identificable ichthyoplankton at temperatures approaching 35°C. These data suggest that temperatures in the 30 to 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 species other than centrarchids. Results 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 found that the majority of the fishes left the canal

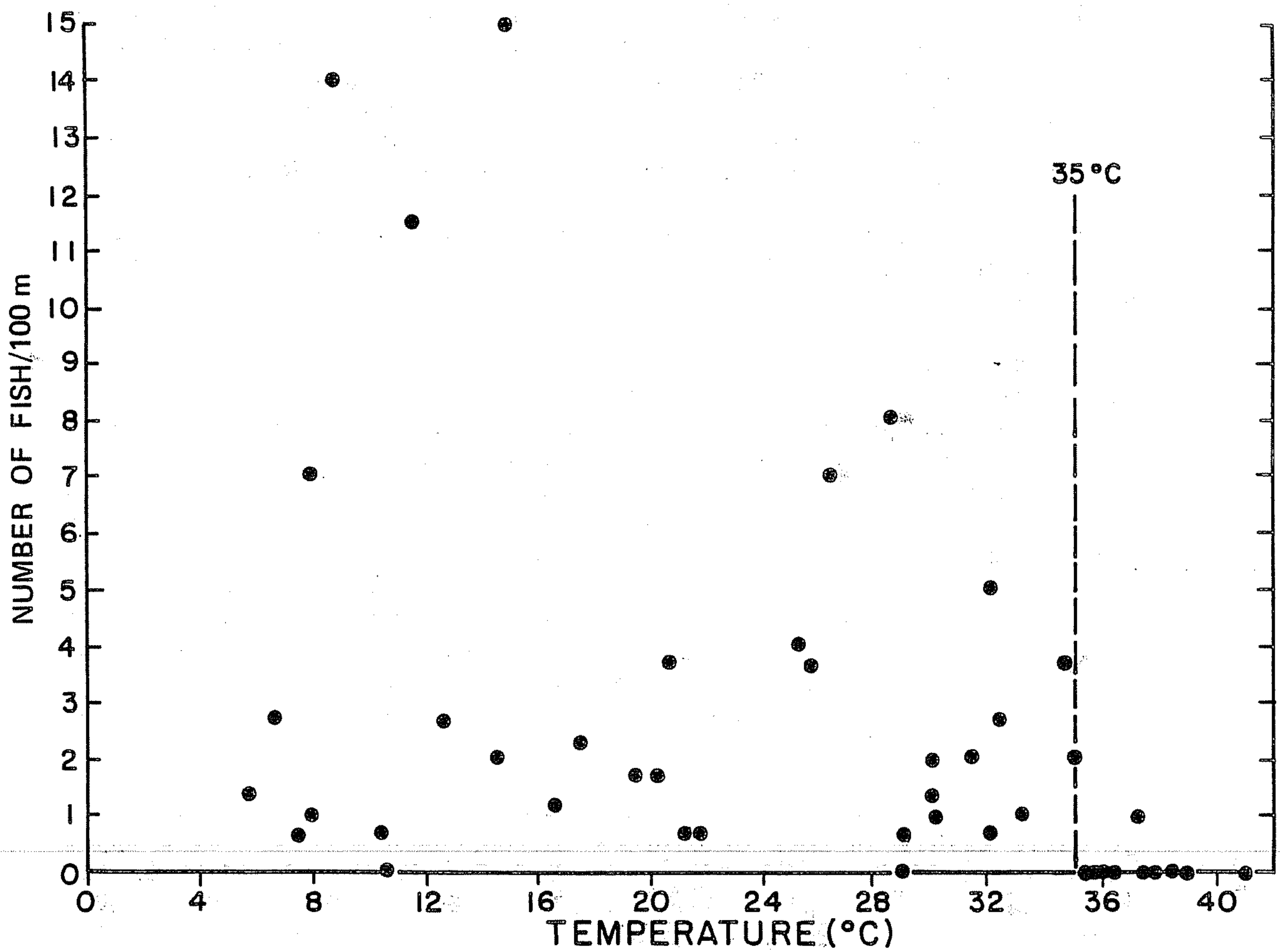


FIGURE V-4.4. Electrofishing Catch per Unit Effort and Temperature in Four Mile Creek (October 1982–August 1984)

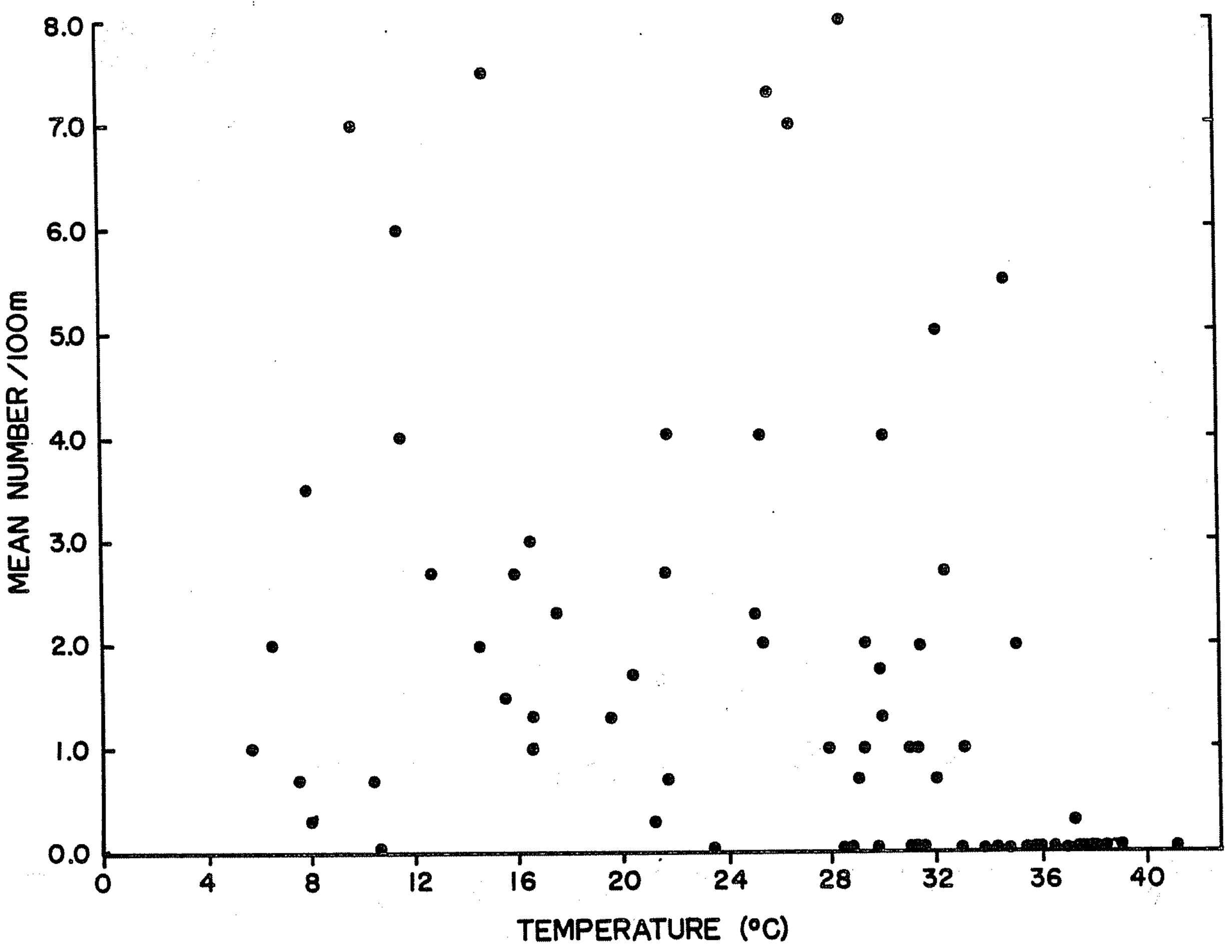


FIGURE V-4.5. Mean Number of Fish/100 m Collected by Electrofishing at Different Temperatures in the Mouth of Four Mile Creek (November 1984–August 1985)

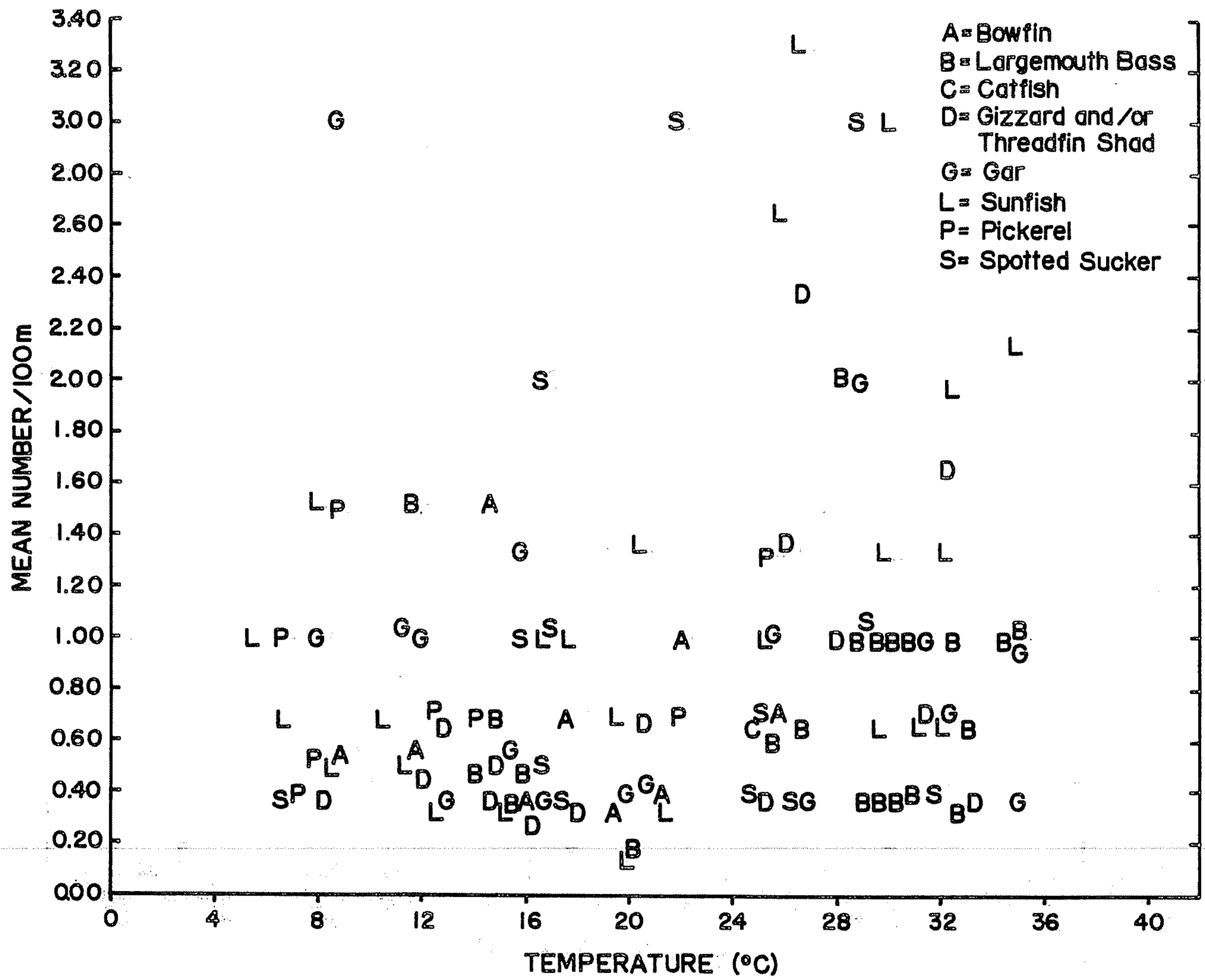


FIGURE V-4.6. Mean Number of Fish/100 m for Common Species Collected by Electrofishing at Different Temperatures (°C) in the Mouth of Four Mile Creek (November 1984–August 1985)

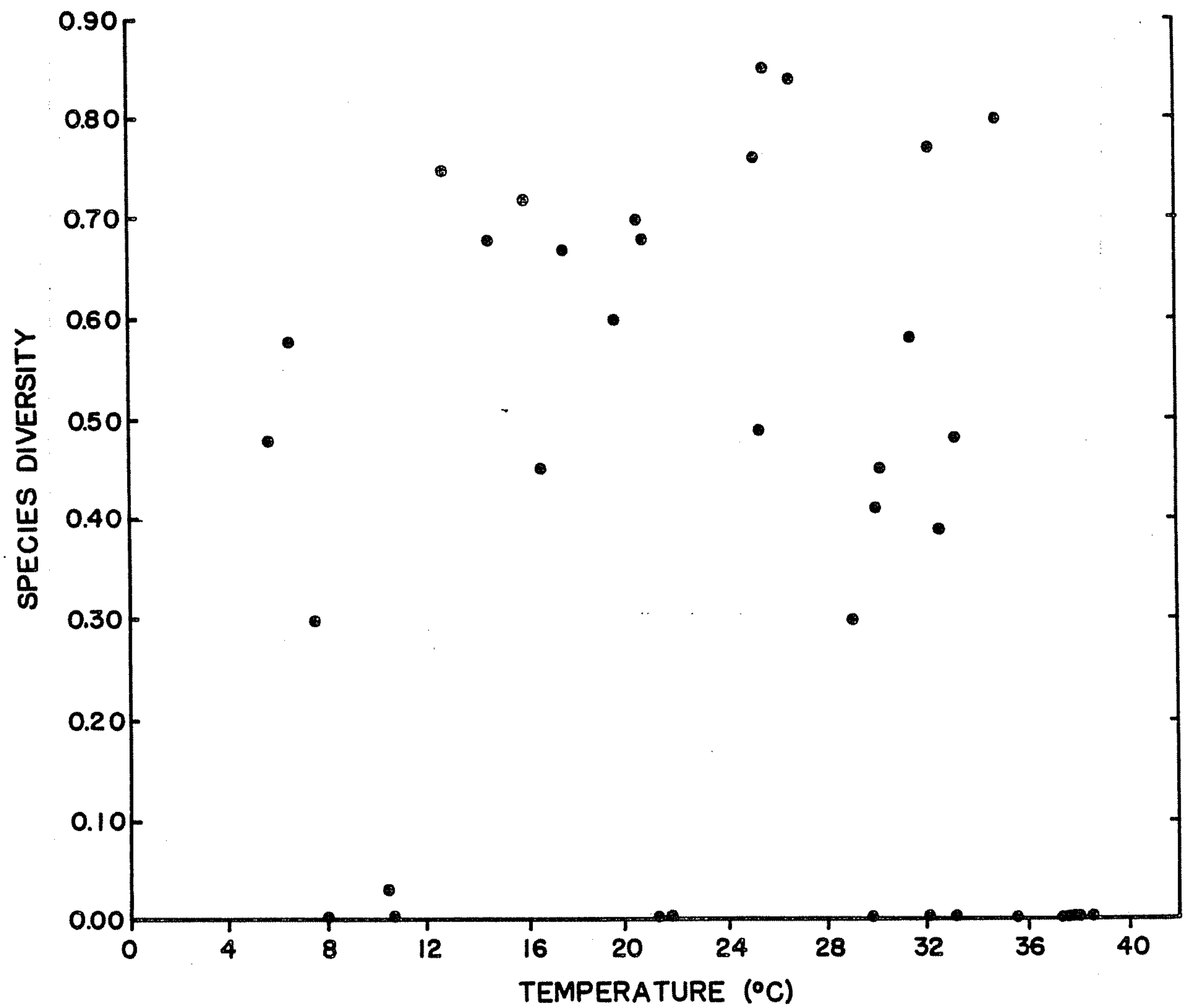


FIGURE V-4.7. Shannon-Weaver Species Diversity for Fishes Collected by Electrofishing at Different Temperatures (°C) in the Mouth of Four Mile Creek (November 1984-August 1985) Source: Paller and Saul, 1986.

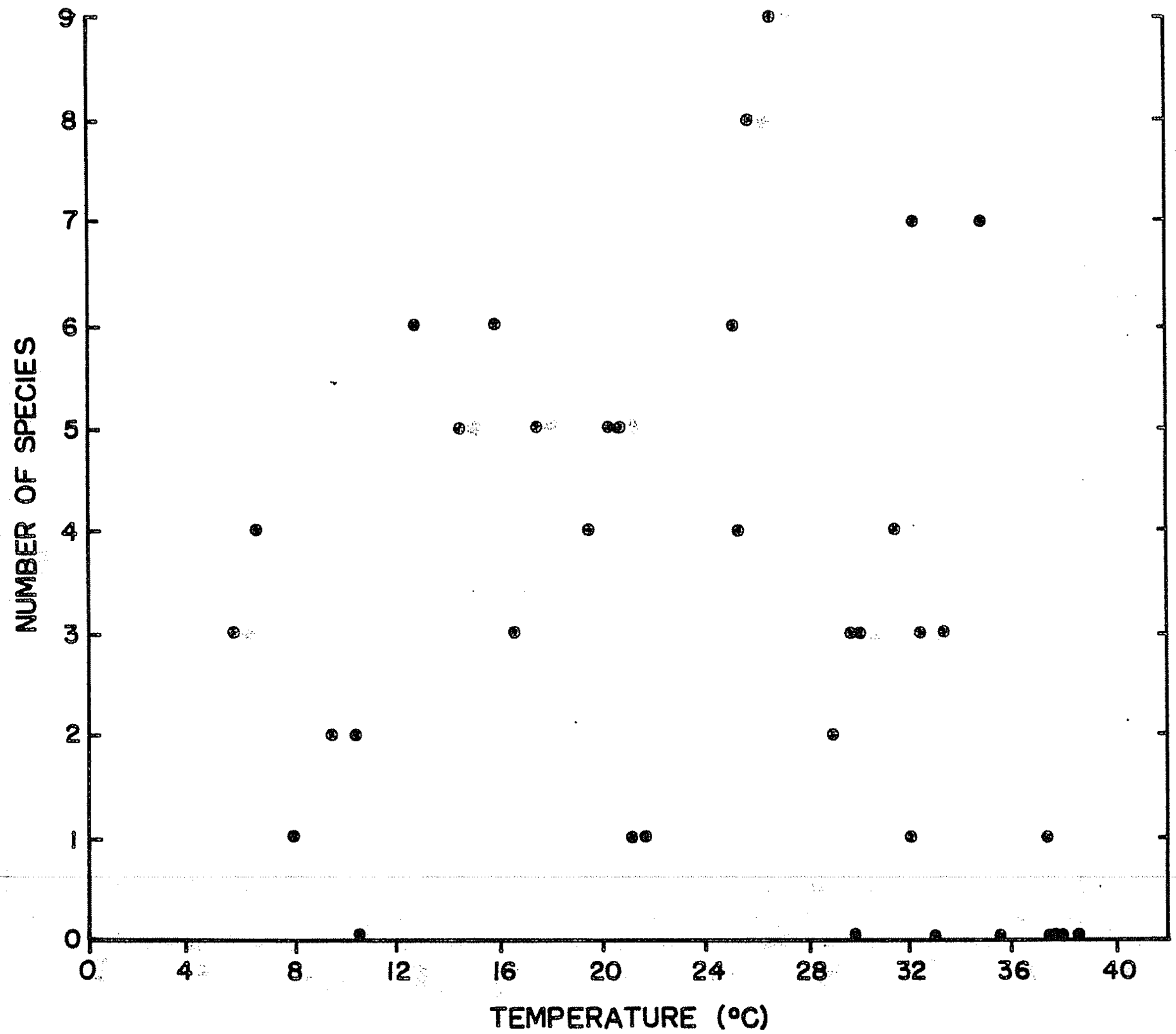


FIGURE V-4.8. Species Richness for Fishes Collected by Electrofishing at Different Temperatures (°C) in the Mouth of Four Mile Creek (November 1984-August 1985).
Source: Paller and Saul, 1986.

when the water temperature reached approximately 35°C, but returned immediately when water temperatures dropped as little as one degree.

V.4.2.3.4 Impingement

The objective of the impingement study was to provide estimates of the number of fish lost from the Savannah River fish community through impingement on the SRP cooling water intake screens.

Impingement of juvenile and adult fishes on the SRP cooling water intake screens was monitored between September 1983 and September 1985. Rates of impingement were influenced by a variety of factors including river water level, the volume of water pumped to the reactors and the D-Area pumphouse, water temperature in the intake canals, and fish species (and their densities) in the canals.

Between September 1983 and August 1984 (107 sampling days), a total of 1,938 fish, representing 50 species, were collected from the SRP intake screens (Table V-4.27). The number of fish impinged daily ranged from zero to 190, with an average of 18 fish/day. In addition to the total numbers, Table V-4.27 lists the relative abundance for all species impinged on the pumphouse screens from September 1983 to August 1984. The majority of the fish impinged on the screens were in the sunfish family (46.4%), but the most abundant species in the impinged collection was the threadfin shad (12.2%).

Generally, the number of fish impinged was lowest during the summer and early fall and highest in the spring (Figures V-4.9 and V-4.10; Table V-4.28). Higher impingement rates in the spring corresponded closely to elevated river levels. However, elevated river levels in August did not result in large numbers of impinged fish indicating that a combination of factors such as water temperature and fish migration patterns were involved in determining impingement rates.

In comparing relative rates of impingement between the intake canals, the 1G intake was found to have the highest number of impinged fish; a mean of 8.9 fish/10^6 m^3 (million cubic meters) of water (Paller & Osteen, 1985). The mean impingement rate at the 3G intake was 8.7 fish/10^6 m^3 and at the 5G intake, the mean impingement rate was 3.2 fish/10^6 m^3. The relative abundance of the dominant species impinged during this study at the 1G, 3G, and 5G pumphouses was compared to the relative abundance of fishes sampled by electrofishing in the 1G and 3G intake canals, and in the river in the vicinity of the 5G intake structure. The data indicated

TABLE V-4.27

Total Number and Relative Abundance of Fish Species Impinged at 1G, 3G, and 5G Pumphouses (September 1983-August 1984)

Taxa	Total	Percent Abundance
Bowfin	153	7.89
American eel	14	0.72
Blueback herring	80	4.13
American shad	41	2.12
Alosa sp.	1	0.05
Gizzard shad	73	3.77
Threadfin shad	236	12.18
Unid. clupeid	3	0.15
Eastern mudminnow	7	0.36
Redfin pickerel	38	1.96
Chain pickerel	23	1.19
Spottail shiner	30	1.55
Golden shiner	8	0.41
Carp	3	0.15
Pugnose minnow	2	0.10
Bannerfin shiner	4	0.21
Whitefin shiner	2	0.10
Notropis sp.	6	0.31
Cyprinidae spp.	2	0.10
Creek chubsucker	1	0.05
Lake chubsucker	5	0.26
Spotted sucker	4	0.21
Snail bullhead	1	0.05
White catfish	31	1.60
Yellow bullhead	3	0.15
Brown bullhead	2	0.10
Flat bullhead	22	1.14
Channel catfish	23	1.19
Unid. catfish	2	0.10
Tadpole madtom	2	0.10
Margined madtom	1	0.05
Speckled madtom	13	0.67
Unid. madtom	5	0.26
Pirate perch	20	1.03
Mosquitofish	4	0.21
Brook silverside	1	0.05
Striped bass	3	0.15
Flier	108	5.57

Source: Paller and Osteen, 1985.

TABLE V-4.27, Contd

Taxa	Total	Percent Abundance
Bluespotted sunfish	206	10.63
Redbreast sunfish	112	5.78
Green sunfish	3	0.15
Pumpkinseed	18	0.93
Warmouth	86	4.44
Bluegill	65	3.35
Dollar sunfish	60	3.10
Redear sunfish	20	1.03
Spotted sunfish	109	5.62
Mud sunfish	42	2.17
Lepomis sp.	12	0.62
Largemouth bass	9	0.46
White crappie	3	0.15
Black crappie	45	2.32
Unid. crappie	1	0.05
Swamp darter	1	0.05
Tesselated darter	2	0.10
Yellow perch	14	0.72
Blackbanded darter	8	0.41
Hogchoker	145	7.48
Total	1938	99.95

Source: Paller and Osteen, 1985.

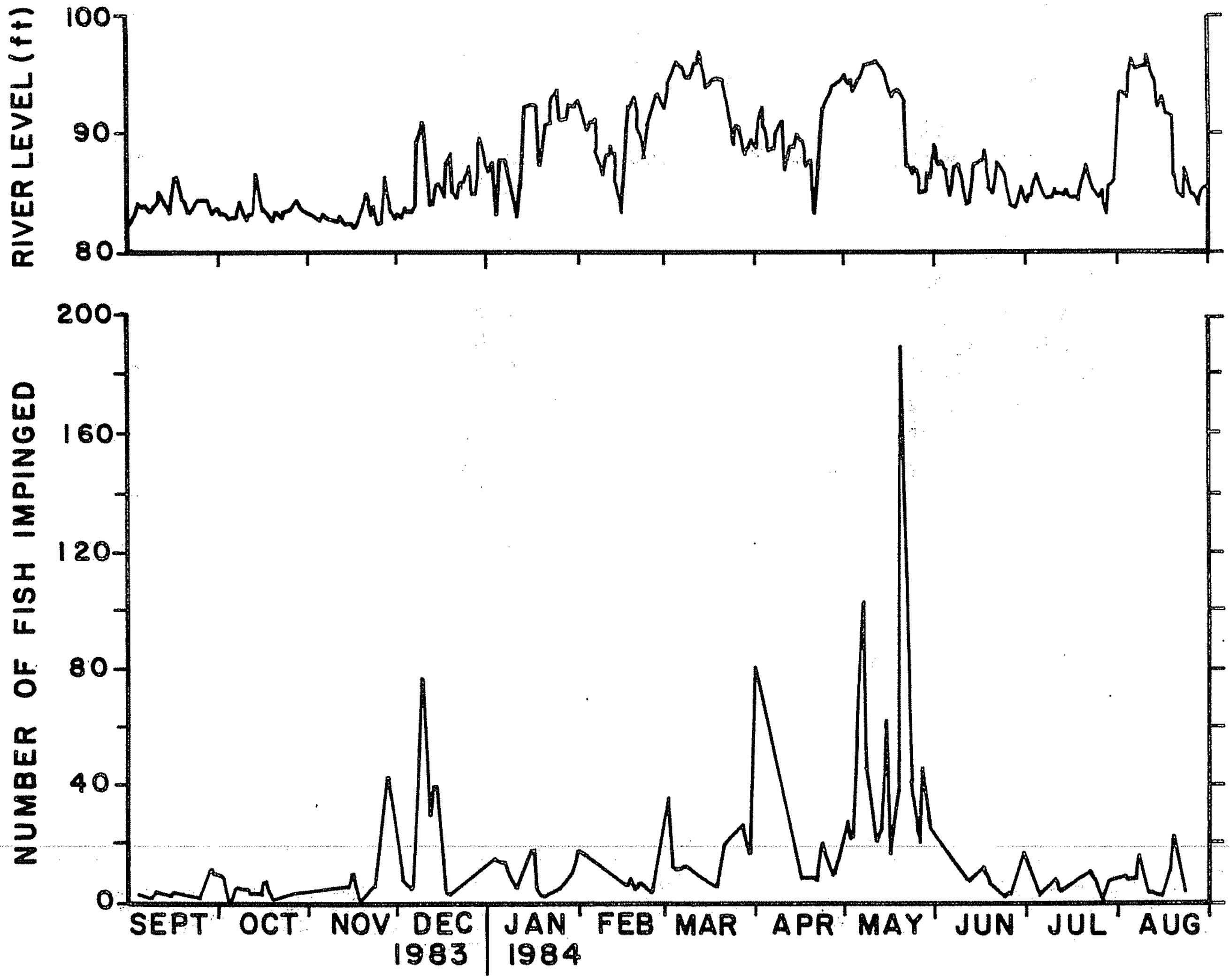


FIGURE V-4.9. Number of Fish Impinged at 1G, 3G, and 5G Pumphouses Compared to Savannah River Levels (September 1983-August 1984). Paller and Osteen, 1985.

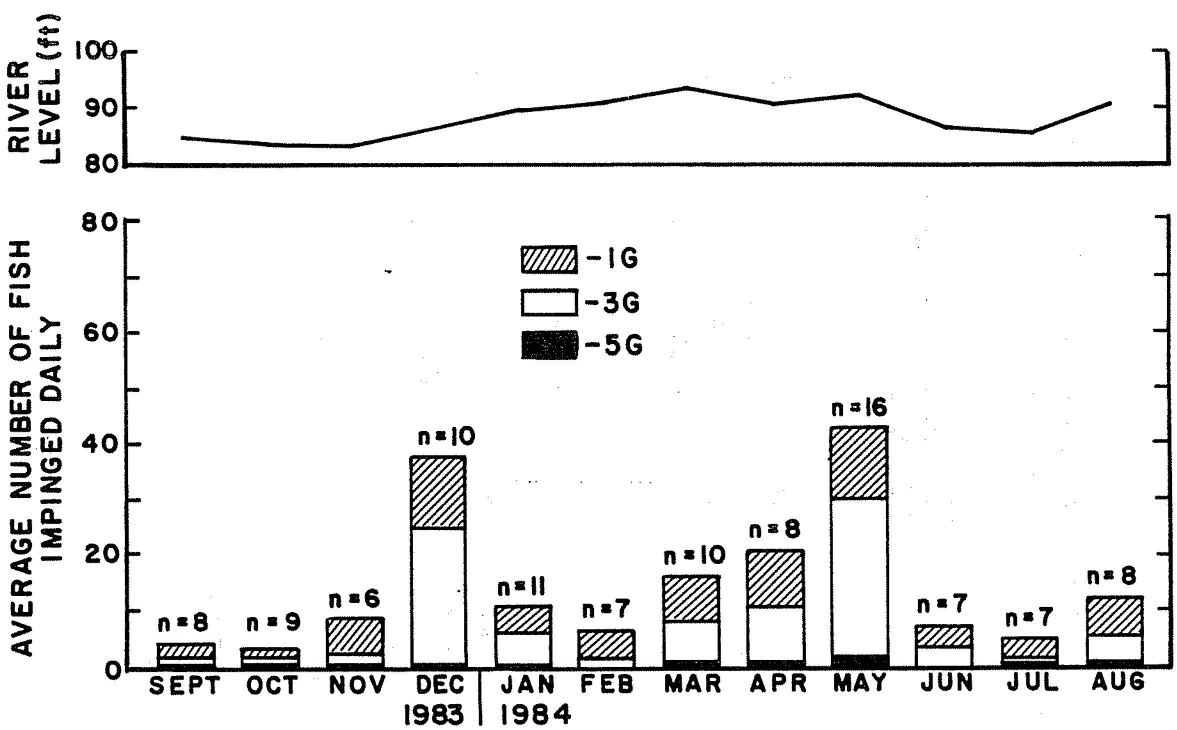


FIGURE V-4.10. Average Number of Fish Impinged at the 1G, 3G, and 5G Pumphouses Compared to Savannah River Water Levels (September 1983–August 1984).
Source: Paller and Osteen, 1985.

TABLE V-4.28

Number and Total Weight (g) of Fish Impinged by 1G, 3G, and 5G Pumphouses on 107 Sampling Dates (September 1983-August 1984)

Month		1G		3G		5G		Total	
		Number	Weight	Number	Weight	Number	Weight	Number	Weight
1983									
September	(8)*	19	790	10	186	4	35	33	1,011
October	(9)	15	1,089	6	516	6	231	27	1,836
November	(6)	52	6,106	12	274	1	6	65	6,386
December	(10)	132	4,424	244	8,598	2	6	378	12,928
1984									
January	(11)	47	812	64	1,680	2	10	113	2,502
February	(7)	36	1,018	8	74	0	0	44	1,092
March	(10)	80	1,941	71	1,258	9	181	160	3,380
April	(8)	80	2,972	78	1,839	6	46	164	4,857
May	(16)	285	13,253	456	9,946	25	137	766	23,336
June	(7)	24	2,860	24	1,205	1	21	49	4,086
July	(7)	25	1,216	7	608	1	5	33	1,829
August	(8)	29	1,107	36	845	8	98	73	2,050

* Number of sampling dates per month.

Source: Paller and Osteen, 1985.

that species vary considerably in their susceptibility to impingement, and the most abundant fish were not necessarily the most frequently impinged (Figure V-4.11).

Between September 1984 and September 1985 (97 sampling dates), a total of 745 fish representing 33 species were impinged on the SRP intake screens (Table V-4.29). The number of fish impinged daily ranged from zero to 99, with an average of 7.7 fish/day. In addition to the total numbers impinged, Table V-4.29 lists the relative abundance for all species impinged from September 1984 to September 1985. The majority of the fish collected were in the shad and herring family (53.7%). The most abundant species in the impingement collection, as in the previous sample year, was the threadfin shad (23.5%). During the two years prior to the 1984-1985 study, the sunfish family dominated the impingement collections. The shad/herring family became the most abundant species collected in the intake canals in 1984-1985, most likely due to the canal dredging that took place in this sample year. Dredging removes the submerged macrophytes that serve as excellent cover and food for many species of sunfish (Paller et al., 1986a).

The 1984-1985 seasonal trends for fish impingement were somewhat different than in 1983-1984. In 1984-1985, the number of fish impinged was lowest during the spring and fall and highest in the summer and winter (Figures V-4.12 and V-4.13; Table V-4.30). The high numbers of fish impinged in the summer of 1985 were not correlated with river elevations. This may have been related to the presence of large schools of shad, a member of the dominant family impinged that study year.

Impingement rates in the 1G, 3G, and 5G intakes were lower overall for the 1984-1985 sample year, probably because fish were less abundant in the intake canals due to low river levels and habitat alterations caused by dredging. As in 1983-1984, the 1G intake had the greatest number of fish impinged, a mean of 7.0 fish/10^6 m^3 (million cubic meters) of water, compared to a mean of 3.0 fish/10^6 m^3 at the 5G intake (Paller & Saul, 1986).

The relative abundance of the dominant species impinged during this study at the 1G, 3G, and 5G pumphouses was compared to the relative abundance of the fishes sampled by electrofishing in the 1G and 3G intake canals, and in the river in the vicinity of the 5G intake. As in 1983-1984, the data again indicated that species abundance and susceptibility were not closely associated and that the most abundant fishes did not necessarily appear in large numbers on the intake screens (Figure V-4.14). The dissimilarity between the abundant taxa collected by electrofishing and those impinged on the intake screens has been observed in other Savannah River studies (McFarlane et al., 1978; Paller et al., 1984; Paller and Osteen, 1985).

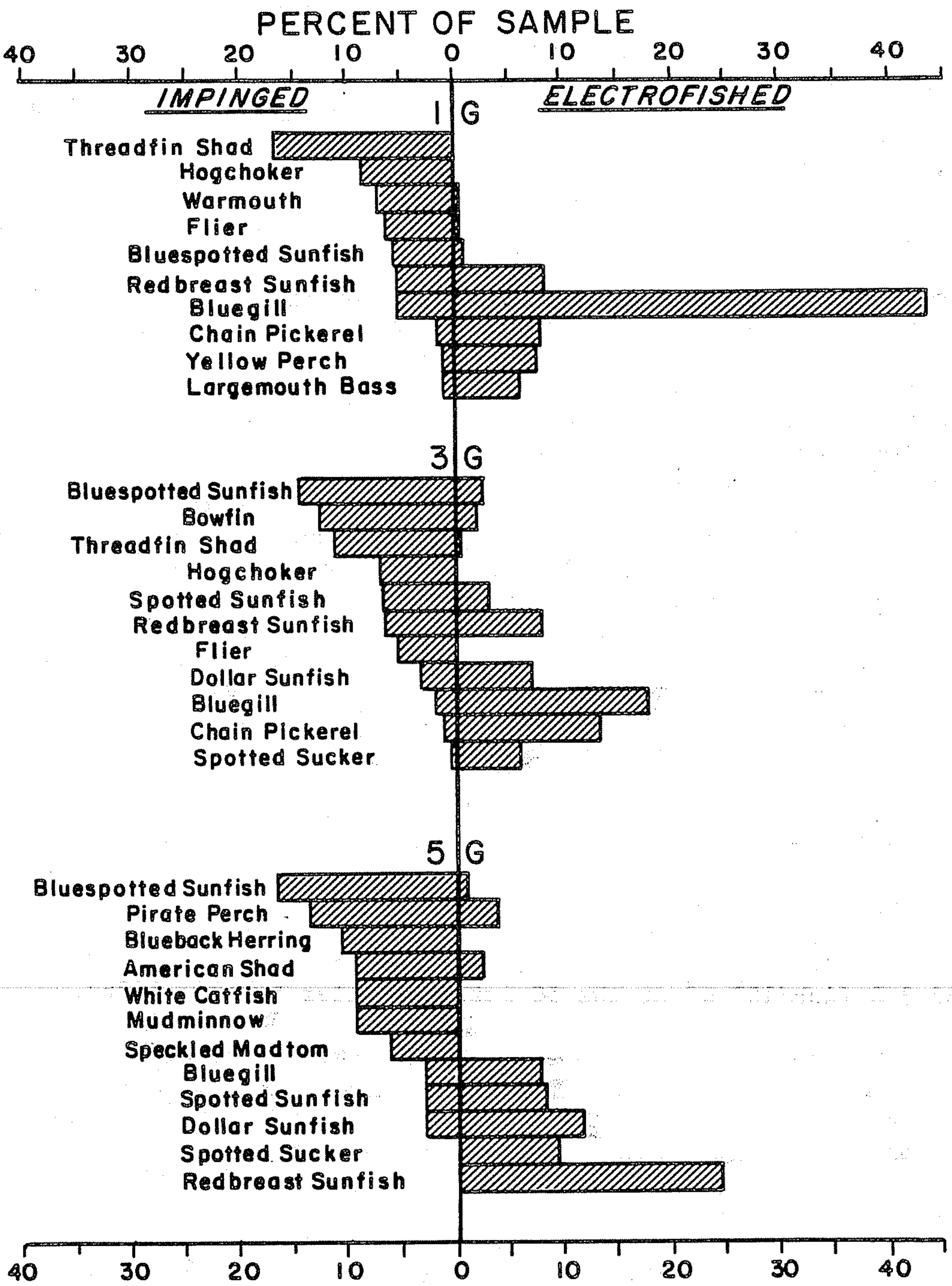


FIGURE V-4.11. Relative Number of Selected Fish Species Impinged at 1G, 3G, and 5G Pumphouses and Collected Near the Pumphouses by Electrofishing (September 1983–August 1984). Source: Paller and Osteen, 1985.

TABLE V-4.29

Total Number and Relative Abundance of Fish Species Impinged at 1G, 3G, and 5 G Pumphouses (September 1984–September 1985)

Taxa	Total	Percent Abundance
Bowfin	1	0.13
American eel	5	0.67
Blueback herring	40	5.36
Hickory shad	48	6.44
Gizzard shad	136	18.26
Threadfin shad	175	23.49
Unid. 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
Unid. 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
________ sp.	1	0.13
Unid. 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	2.41
Tesselated darter	1	0.13
Yellow perch	7	0.94
Blackbanded darter	1	0.13
Hogchocker	23	3.09
Unknown	1	0.13
Total	745	99.95

Source: Paller and Saul, 1986.

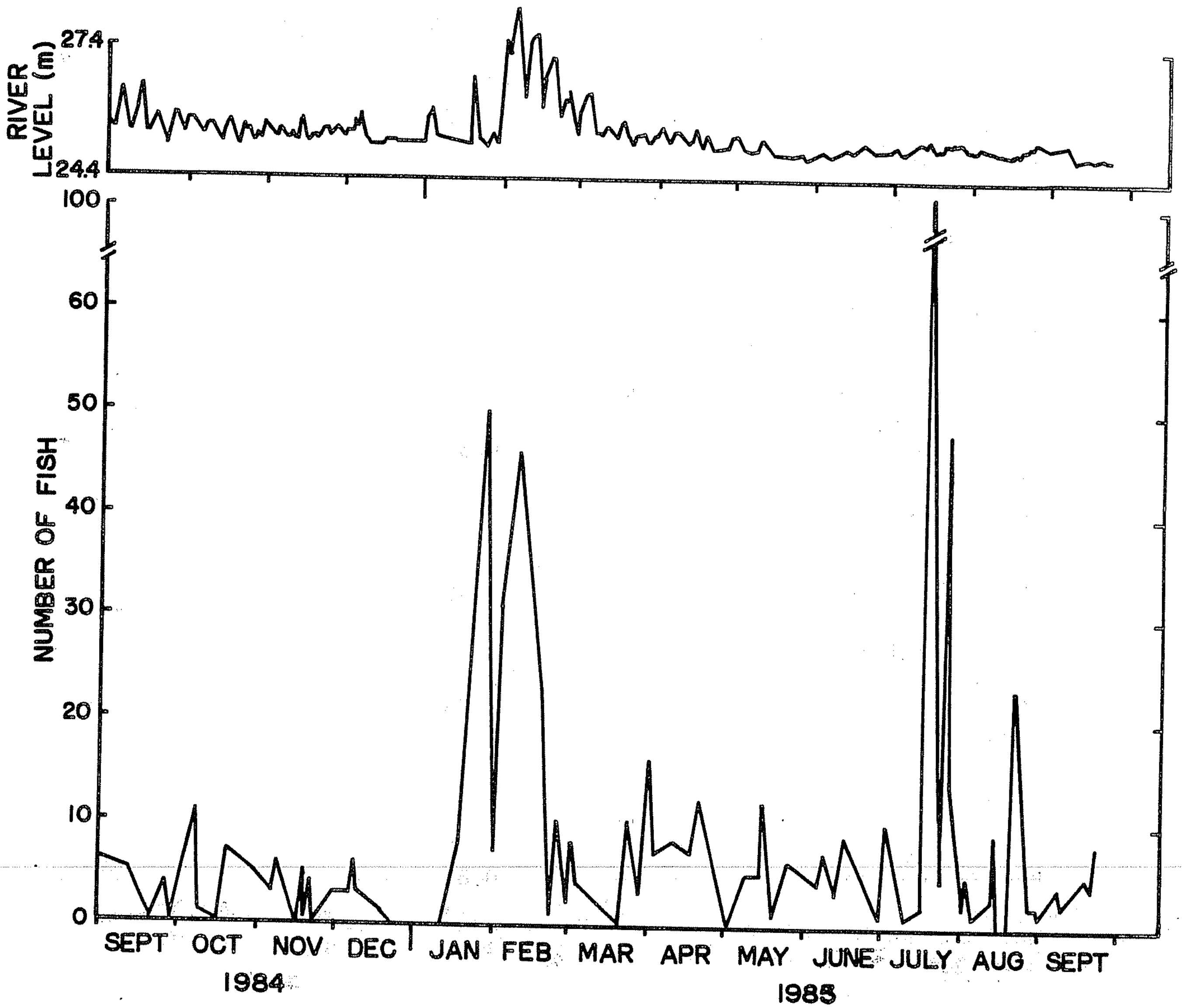


FIGURE V-4.12. **Number of Fish Impinged by the SRP Pumphouses in Relation to Savannah River Levels (September 1984-September 1985).** Source: Paller and Saul, 1986.

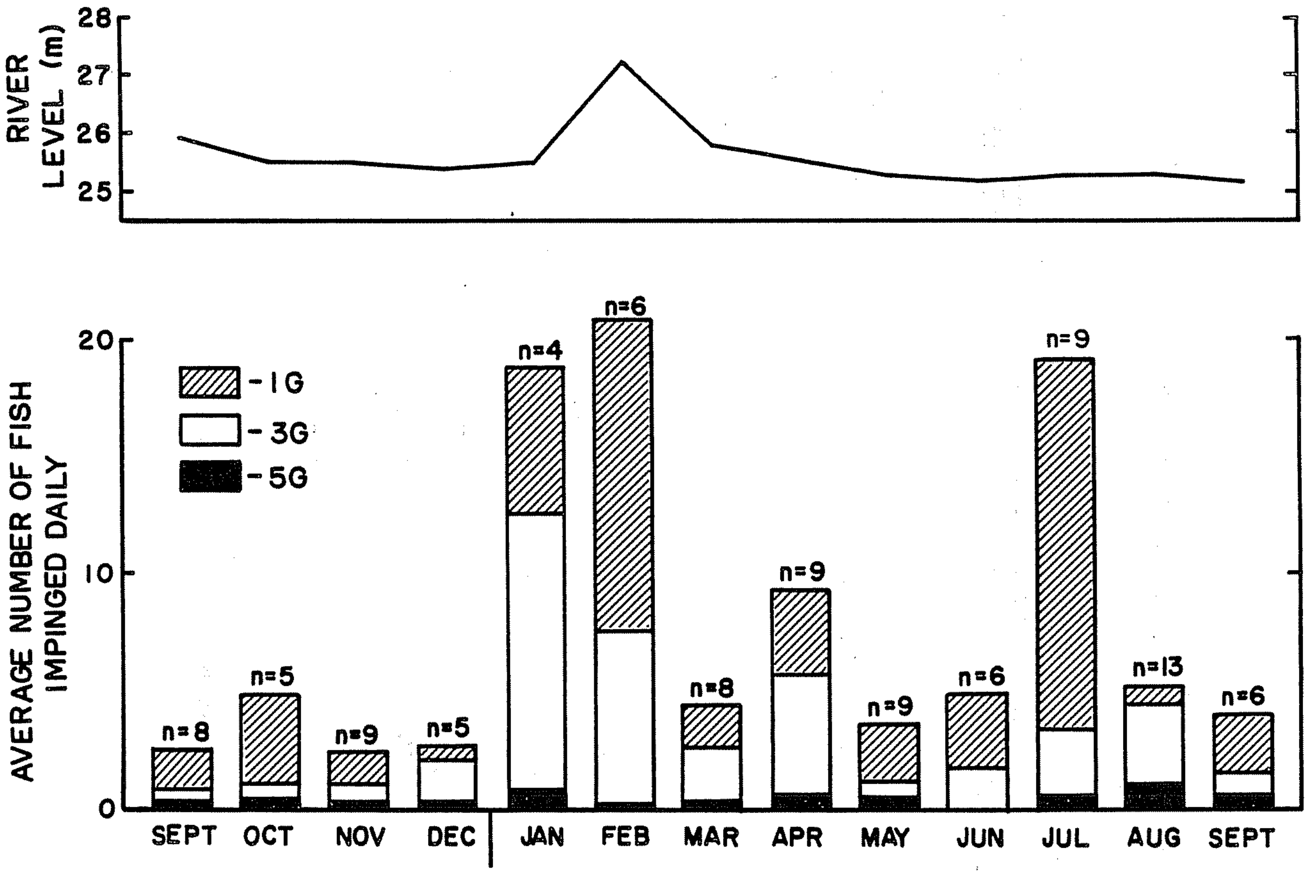


FIGURE V-4.13. Average Number of Fish Impinged Daily at the 1G, 3G, and 5G Pumphouses, and Mean River Levels September 1984-September 1985).
Source: Paller and Saul, 1986.

TABLE V-4.30

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	
		Number	Weight (g)	Number	Weight (g)	Number	Weight (g)	Number	Weight (g)
1984									
September	(8)*	14	923	4	124	2	216	20	1,263
October	(5)	19	655	3	1,026	2	8	24	1,689
November	(9)	13	1,323	6	129	2	31	21	1,483
December	(5)	3	66	9	479	1	14	13	559
1985									
January	(4)	25	1,491	47	426	3	8	75	1,925
February	(6)	80	4,608	44	1,787	1	4	125	6,399
March	(8)	14	849	18	702	2	461	34	2,012
April	(9)	33	4,361	45	3,410	5	535	83	8,306
May	(9)	12	1,028	22	1,735	4	1,173	38	3,936
June	(6)	19	4,109	10	2,228	0	0	29	6,337
July	(9)	158	1,219	28	5,539	5	44	191	6,802
August	(13)	12	358	43	1,311	13	54	68	1,723
September	(6)	15	1,477	6	358	3	967	24	2,802
Total		417	22,467	285	19,254	43	3,515	745	45,236

* Number of sampling dates per month.

Source: Paller and Saul, 1986.

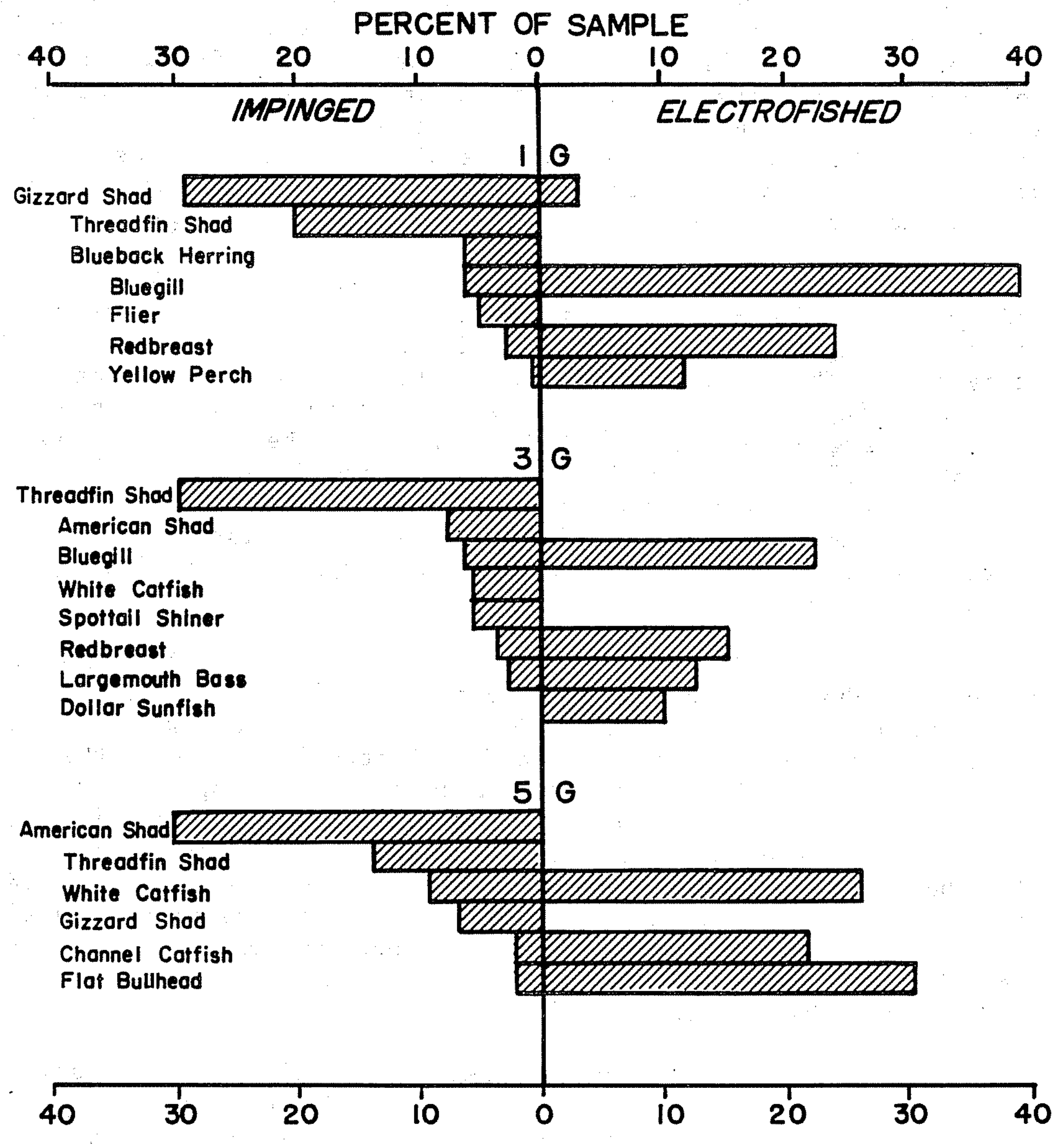


FIGURE V-4.14. Species Percent Composition for Fishes Impinged at the 1G, 3G, and 5G Pumphouses and Those Collected by Electrofishing in the Vicinity of the Pumphouses (September 1984-September 1985). Source: Paller and Saul, 1986.

V.4.2.4 Summary

A study of the juvenile and adult fish community in streams draining the SRP and in the Savannah River in the vicinity of the SRP was conducted over a two-year period (September 1983 - August 1985). The study included sample stations in the Savannah River, the SRP intake canals, and the major onsite creeks. The major objectives of this juvenile and adult fish study were to examine the abundance and distribution of fishes near the SRP in relation to thermal discharges into the river, creeks, and floodplain swamps, to determine the rate of impingement of adult and juvenile fishes on the intake screens at the three SRP pumphouses, and to utilize this information to assess impacts of cooling water intake and release on fish populations of the SRP.

In the 1983-1984 sampling year, approximately 12,160 adult and juvenile fishes representing 72 species were collected by electrofishing and hoopnetting at 26 sample stations in the SRP study area. The most abundant fishes (excluding minnows) taken by electrofishing were the 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%). The most abundant fishes taken by hoopnetting were the flat bullhead (29.2%), channel catfish (21.0%), redbreast sunfish (9.7%), white catfish (9.0%), black crappie (6.8%), longnose gar (5.6%), and bluegill (5.2%).

In the 1984-1985 sampling year, approximately 10,000 adult and juvenile fishes were collected by electrofishing and hoopnetting at 41 sampling stations in the SRP study area. 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 hoopnetting were the flat bullhead (38.0%), channel catfish (11.9%), bluegill (9.4%), white catfish (7.4%), black crappie (6.5%), and redbreast sunfish (5.5%). In comparing relative abundance estimates between the 1983-1984 and 1984-1985 sampling years, it should be noted that 15 new electrofishing sample stations were added in 1984-1985.

To evaluate habitat preferences, four habitats were sampled during the 1983-1984 sampling year: intake canals, the river, nonthermal creeks, and thermal creeks. The dominant species in the intake canals were the bluegill, black crappie, and chain pickerel. Redbreast sunfish, spotted sucker, channel catfish, and flat bullhead were dominant in the river and nonthermal creeks. In the thermal creeks, redbreast sunfish, largemouth bass, redear sunfish, channel catfish, and gar were the dominant species.

The number of species collected from each habitat in the study area was 44 in the river, 33 in the intake canals, 32 in the nonthermal creeks, and 27 in the thermal creeks. The relatively few species collected from the thermal creeks probably reflected fish avoidance of the heated effluents. Species numbers in the thermal creeks did not exhibit consistent seasonal cycles over the two study years. The only obvious trends were the low number of species in fall 1983 and spring 1985 collections. Species numbers exhibited a more consistent pattern in the nonthermal creeks, being highest in spring lowest in winter.

The study area was divided into five habitats in the 1984-1985 juvenile and adult fish study in order to evaluate habitat preferences. The habitat designations were the same as 1983-1984 except that the river habitat was designated nonthermal or thermal, with the South Carolina side of the river at the transects immediately downstream from Four Mile Creek and Beaver Dam Creek constituting the thermal river habitat. In 1984-1985, the dominant species in the intake canals were the bluegill, redbreast sunfish, and black crappie. The redbreast sunfish, spotted sunfish, spotted sucker, largemouth bass, channel catfish, white catfish, and flat bullhead were the dominant species at the nonthermal river sites. The dominant species in the nonthermal creeks were similar to the river species except that the catfishes were not as well represented. The thermal river and creek habitats differed from the nonthermal habitats in that they had a higher percentage (although often lower numbers) of channel catfish, white catfish, largemouth bass, and coastal shiner, and a lower percentage of flat bullhead. Exceptions occurred in the Pen Branch refuge areas and portions of Four Mile Creek where mosquitofish were the dominant, and sometimes only, species present.

In the overwintering study it was found that some species congregated in the thermal habitats during the winter months and some did not. During February and March of the 1983-1984 sampling year, C Reactor was shut down so Four Mile Creek was nonthermal during midwinter when the attractive effects of the heated discharge would have been greatest. Species that congregated in the thermal habitats in 1983-1984 were the redbreast sunfish, channel catfish, longnose and spotted gar, white catfish, and gizzard shad. Of the species studied, only the redear sunfish showed significantly lower condition (based on the condition coefficient) in the thermal creeks during winter as compared to the nonthermal creeks. There were no indications of abnormal rates of disease or parasitism in the thermal habitat. Species that did not congregate in the thermal habitats during the winter (and may have avoided the thermal areas) were the spotted sucker and flat bullhead. American eels also tended to exhibit lower catch rates in the thermal creeks in the winter.

In 1984-1985, many of the same species congregated in the thermal creeks as were observed in 1983-1984. Redear sunfish, channel catfish, longnose gar, black crappie, and gizzard shad congregated in moderately heated areas. In 1984-1985, fish appeared to congregate to the greatest extent in the thermal river habitat that was heated only 2 to 3°C above ambient temperatures. Several species, including the American eel, spotted sucker, and flat bullhead, avoided the thermal habitats. In 1984-1985, fish avoided Four Mile Creek, where temperatures occasionally exceeded 35°C. Of the species studied, only the gizzard shad and channel catfish showed significantly lower condition (based on the condition coefficient) in the thermal creeks during winter as compared to the nonthermal creeks. There were no indications of abnormal rates of disease or parasitism in the thermal habitat.

A total of 1,938 fish representing 50 species were collected from intake screens during the 1983-1984 impingement study. The majority of the fish impinged were sunfish and shad. The highest impingement rates occurred in May and December. The 3G intake canal had the highest impingement rate of 9.5 fish/day while the 1G intake canal had the highest number impinged by volume of water pumped ($8.9/10^6$ m^3).

A total of 745 fish representing 33 species were collected from intake screens during the 1984-1985 impingement study. The same species predominated in 1984-1985 as in 1983-1984 (the shad/herring group and the sunfishes). The 1G intake canal had the highest impingement rate of 7.0 fish/day. The numbers and weights of fish impinged during the 1985 study period were significantly lower than those impinged in the previous years of study, which may have been attributed to differences in the river level and canal habitat. The river levels were lower in the spawning season of 1985 than in 1984 when greater numbers of fishes were impinged on the intake screens. In addition, the spawning habitats in the 1G, 3G, and 5G canals were altered in the 1984-1985 season by extensive dredging. The removal of macrophyte beds was linked to the lower impingement rates in the canals in 1984-1985.

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. The data indicate that species abundance and susceptibility are not closely associated and that the most abundant fishes did not necessarily appear in large numbers on the intake screens.

In summary, results of the adult fish studies indicated that distributions and abundances of fish species in the Savannah River were not adversely impacted by SRP activities. In the SRP thermal creeks and swamps, most fish species were eliminated when water temperatures exceeded 35°C. At water temperatures of 30-35°C, reduced numbers of fish species were collected and the fish communities were dominated by thermally tolerant taxa, such as sunfish, largemouth bass, gar, and gizzard shad. Fish which overwinter in thermal streams may be subject to cold shock when the reactors are shut down, and to thermal shock when reactors are restarted. One such instance of thermal shock occurred in Four Mile Creek in late March 1984 shortly after restart of C Reactor, resulting in the death of many fish. While thermal effluents can eliminate fish populations, the mobility of fishes and the substantial populations of most taxa in unimpacted areas of the SRP allow for rapid invasion of thermal habitats once temperatures decline to tolerable levels. Results from the study indicated that a number of species congregate in thermal streams in winter. Several of these species showed lower condition factors than populations in nonthermal streams, possibly the result of temperature-induced increases in metabolic rate. However, there was no evidence during either year of the study of abnormal incidences of disease or parasitism of these taxa in the thermal streams during the winter months. Impingement of SRP water intake structures resulted in the loss of an average of 18 fish/day or less, which had an average total biomass (wet weight) of less than one-half kilogram. Shad, herring, and sunfish were the most commonly impinged taxa. These taxa were impinged at rates disproportionate to their populations (compared to other taxa). These losses are small compared to the large populations in the Savannah River and probably have no deleterious effects on the ecosystem.

V.4.3 Ichthyoplankton

V.4.3.1 Introduction

Because some of the streams on the SRP receive thermal effluents, there is concern about the effects of temperature increases on spawning success and larval fish distributions. Water temperatures can influence the reproductive success of fishes by affecting gonadal maturation, the onset of spawning, and the development rate of eggs and larvae (Nikolsky, 1963). Also, fish eggs and larvae that drift are vulnerable to entrainment into cooling water intakes or thermal plumes, which can result in injury or death to the eggs and larvae. Previous studies have shown that several of the SRP streams serve as spawning areas for many species of resident and migratory fishes (Paller, 1985). Fish larvae produced in these streams replenish resident stream populations or drift into the Savannah River to augment riverine and anadromous fish populations.

This section of the report discusses ichthyoplankton studies that were conducted during the 1983-1984 and 1984-1985 sampling years, the same sampling years during which the adult and juvenile fish studies were conducted. Ichthyoplankton collections were taken during the spawning season, February through July 1984, and February through July 1985.

One principal study investigated the distribution and abundance of ichthyoplankton (fish eggs and larvae) in the creeks and associated swamps that drain the SRP. The objectives of the study were (1) to determine the density, distribution, and species composition of ichthyoplankton in relation to habitat and temperature, and (2) to identify the effects of elevated temperatures of ichthyoplankton distribution, abundance, and the time of spawning. In 1985, two smaller sampling programs were also undertaken. A microhabitat study in Steel Creek was designed to assess the relative abundance of ichthyoplankton in three different habitat types and a gear comparison study was conducted to compare the efficiencies of four different gear types of capture ichthyoplankton.

The second principal study measured the distribution and abundance of ichthyoplankton in a 253.4 km section of the Savannah River (including SRP intake canals) and associated tributaries upstream and downstream from the SRP. This study was designed to provide information on the importance of the section of the river adjacent to the SRP for fish spawning relative to the reaches of river upstream and downstream from the SRP. As part of the Savannah River Study, diel fluctuations in ichthyoplankton densities in the Savannah River were examined over a 24-hour period, once during each of the two years.

The primary objectives of the river ichthyoplankton studies were (1) to assess spawning activity and ichthyoplankton distribution in SRP streams and swamps and the Savannah River upstream and downstream from the SRP in order to evaluate the possible impacts of existing and proposed thermal discharges; (2) to estimate entrainment of ichthyoplankton at SRP cooling water intakes and its impact on Savannah River fisheries; and (3) to characterize diurnal trends in ichthyoplankton distributions and densities in the Savannah River. Emphasis was placed on evaluating ichthyoplankton distribution in the mouth of Steel Creek, as compared to other similar creeks, because of the potential thermal impacts that would result in Steel Creek following the restart of L Reactor.

V.4.3.2 Materials and Methods

V.4.3.2.1 SRP Creek and Swamp Studies

The 1984 creek and swamp sampling program included 35 ichthyoplankton sampling stations on six creeks and in the SRP swamp (Figure V-4.15). The 1985 program included all the stations that were sampled in 1984 plus seven additional stations (Table V-4.31).

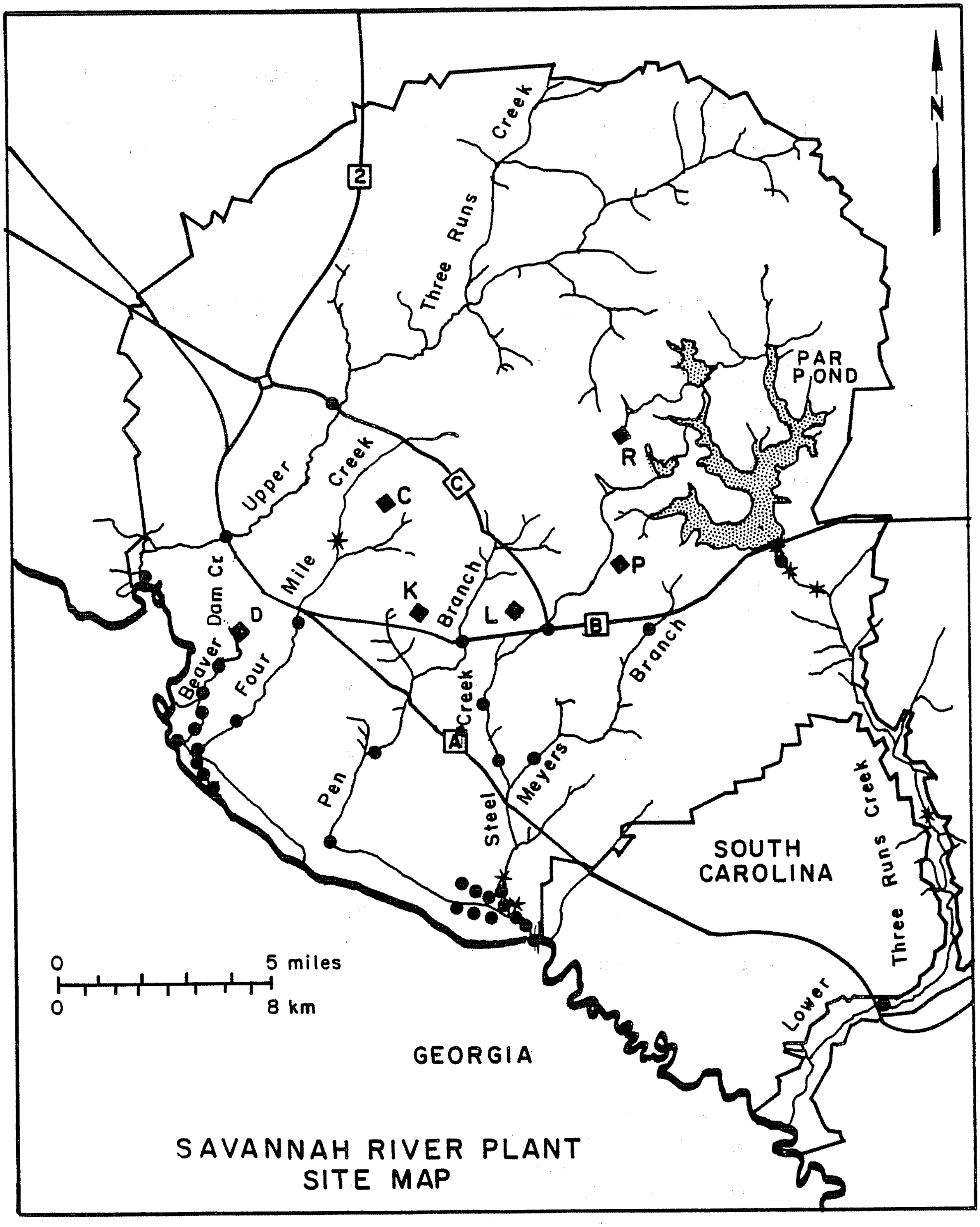


FIGURE V-4.15. A Map of the Savannah River Plant Indicating the Creeks Which Drain the Site and the Ichthyoplankton Sampling Sites (February-July 1985). Locations Marked with Stars were New Sampling Sites in 1985. Source: Paller et al., 1986a.

TABLE V-4.31

Location of the 1984 and 1985 Ichthyoplankton Sampling Sites in the Creeks and the Savannah River Swamp Which Drain the SRP and the Numbers Used to Identify them in Computer Analyses. The Sites are Listed from the Most Upstream Station to the Creek Mouth.

Sampling Site	Station Number Used in Computer Analyses
Upper Three Runs Creek	
Road C	1
Road A	2
Mouth	C157.2
Beaver Dam Creek	
Road A-12.2	5
Stream	6
Slough	7
Swamp	8
Mouth	C152.1
Four Mile Creek	
Road A-7 above C Reactor*	12
Road A	13
Road A-13	14
Four Mile swamp 1	15
Four Mile swamp 2	16
Four Mile swamp 3	17
Mouth	C150.6
Pen Branch	
Road B above K Reactor	20
Road A-13.2	21
Delta (at swamp boardwalk)	22
Steel Creek	
Road B	26
Road A-14	27
Road A-13.1	28
Cypress bridge*	29
Swamp above the islands	62
Swamp above the islands	31
Swamp between the islands	63
Swamp between the islands	32
Swamp between the islands	33

* New site in 1985.

Source: Paller et al., 1986a.

TABLE V-4.31, Contd

Sampling Site	Station Number Used in Computer Analyses
Steel Creek (contd)	
Swamp below the islands	34
Swamp below the islands	35
Swamp below the islands	64
Channel below the swamp	36
Channel below the swamp*	61
Mouth	C141.6
Meyers Branch	
Road B-6.2	39
Confluence with Steel Creek	40
Lower Three Runs Creek	
Spillway at Par Pond dam*,**	65
Road B	42
200 m below Road B*,**	66
Railroad trestle at Donoar Station*	67
Road A-18*	53
Road A (Route 125)	44
Mouth	C129.0

* New site in 1985.
** These three sites are sometimes combined under the term tailwater.

Source: Paller et al., 1986a.

The microhabitat and gear comparison studies conducted in 1985 will be discussed separately because the methods for each were different than for the main sampling program.

The creek and swamp samples were collected weekly during daylight hours at each sample station between March and July in 1984, and between February and July in 1985. In the 1985 study, additional diel samples were taken at six sampling stations in Steel Creek on March 22, April 24, May 23, and June 20. Diel sampling procedures were the same as for the regular weekly samples except that the diel samples were taken every 6 hours for 24 hours.

In the 1984 and 1985 creek and swamp sampling programs, most of the ichthyoplankton samples were collected using paired 0.5 m diameter 505 µ mesh circular plankton nets, mounted side by side in a common frame. Each of the paired 0.5 m plankton nets was approximately 2 m in length and fitted with a 1 L bottle at the cod end, which held organisms and detritus filtered from the water. Nets were set, towed or pushed depending upon depth, current velocity and quantity of submerged vegetation. Nets were set at locations where the current velocity exceeded approximately 20 cm/sec, depth exceeded approximately 0.5-1.0 m and there were few obstructions. Most samples were taken within 1 m of the surface since the water was generally shallow (<2 m). Exceptions were the creek mouths where depths sometimes exceeded 4 m. At these deeper creek mouth stations four samples were taken, two approximately 0.5 m below the surface and two approximately 0.5 m above the substrate. Nets were pushed or towed at stations where depths were sufficient for passage of the nets but current velocities inadequate to set the nets (<20 cm/sec). When towing, the nets were hung from the front of the boat on a short line and the motor operated in reverse to pull the nets through the water. When pushing, the nets were held in front of the boat and the boat directed forward. Pushing permitted the nets to be operated in slightly shallower water than towing. Collections were timed to allow approximately 50 m^3 of water to filter, or until 30 minutes had elapsed. A General Oceanics Model 2030 digital flow meter was placed in the center of the mouth of each net to record the volume of water filtered for each sample. In areas where shallow water, submerged vegetation, or slow flow precluded the use of the paired plankton nets, samples were collected either by pumping water through 505 µ mesh nets using a 833 L per minute trash pump (1984) or by setting paired, rectangular, 505 µ mesh ichthyoplankton drift nets (1985). Pumped samples were collected from a depth of approximately 0.5 - 1.0 m. Approximately 12.5 m^3 of water were filtered over a 15 minute period. Two replicates were taken at each station on each sampling date. Drift net samples were collected using a 30.5 x 45.7 mm drift net that was fitted with a General Oceanics Model 2030 digital reading flowmeter. Paired drift nets were used in the upper reaches of the streams, particularly during the June-August period to collect duplicate samples concurrently. The nets were anchored to the stream bed perpendicular to the current. Where only one net could be fished at a time, a second set usually was made after the first set was completed.

At the end of each collection, the nets were retrieved and rinsed to flush the contents into the collecting bottles. Buffered formalin was added to produce a final formalin concentration of 5%. Each bottle was then sealed and returned to the laboratory. Organisms were stained with 0.2 g/L Eosin red and 0.2 g/L Biebrich scarlet for easier separation from the detritus.

Other parameters measured concurrently with the ichthyoplankton collections were temperature, dissolved oxygen, pH, conductivity, alkalinity, and water velocity. Water temperature was measured with a Hydrolab Model VI, a Horiba Model U7, or a mercury thermometer. The mercury thermometer was used at stations where temperatures were high enough to impair instrument performance (>40°C). Dissolved oxygen, pH, and specific conductance were measured in the field using the Hydrolab Model VI or Horiba U7 water quality monitors. Alkalinity determinations were made in the laboratory using APHA method 403 for low alkalinity samples (APHA, 1980). Water quality measurements were taken approximately 0.5 m below the surface and, when depth exceeded approximately 1.5 m, 0.5 m above the bottom. (See Paller et al., 1986a for detailed methodologies.)

Water velocity was measured with a General Oceanics Model 2030 current meter or a General Oceanics remote reading flow meter. Readings were taken approximately 0.5 m below the surface.

Ichthyoplankton samples were examined under a stereomicroscope and identified to the lowest practical taxon using taxonomic keys by Geen et al. (1966), Mansuetti and Hardy (1967), Hogue et al. (1976), Jones et al. (1978), and Wang and Kernehan (1979). Identifications of particularly difficult or important taxa, such as the perch/darter complex, were verified by Darrel E. Snyder of the Larval Fish Laboratory at Colorado State University. Nomenclature throughout this report follows Robins et al. (1980).

In the following discussion of results of SRP creek and swamp ichthyoplankton studies, the category "unidentified clupeids) (Clupeidae) was comprised primarily by blueback herring and threadfin or gizzard shad. These larvae, while easily distinguishable with an attached yolk sac, are difficult to differentiate after the yolk sac has been absorbed or if the specimen is damaged.

Numerous species of the minnow family (Cyprinidae) occur in the creeks and swamps. These fishes are not only difficult to differentiate as adults, but also the larval forms of many species have not been described. For this study, the only taxonomic distinction made within this group was to place carp greater than 6 mm total length into a separate category. The category "unidentified larvae" included all larvae too damaged to identify reliably.

All collected fish eggs were assigned to one of the following categories: American shad, blueback herring, striped bass, yellow perch, darter, threadfin or gizzard shad, minnow, or "others." Further taxonomic differentiation was not practical.

A special sampling program was undertaken in 1985 in Steel Creek to assess the relative abundance of fish larvae and eggs in macrophyte beds, open channels, and the macrophyte bed/open channel interface. A 833 L/min trash pump was used to collect these samples because the nets were not effective in the weed beds. Samples were collected by pumping water into a 0.5 m diameter, 505 µ mesh circular plankton net held over the side of the boat. The opening of the net was suspended 5 to 10 cm above the water; the remainder of the net was submerged. The discharge pipe of the pump opened into the net approximately 25 cm below the water surface. This arrangement minimized turbulence and lessened the damage to fragile eggs and larvae. The intake hose was fitted with a 13 mm mesh hardware cloth cylinder to prevent entrainment of plant material into the pump.

Each sample was collected by filtering 4.2 m^3 of water during a 5 minute period. Samples were collected from weed beds by placing the intake hose directly into Ceratophyllum/ Polygonum beds. Macrophyte bed/open water interface samples were collected by using the intake hose in the center of the open channels between the macrophyte beds. Replicate samples were collected in four separate locations of each microhabitat on each sampling date. All samples were taken from a depth of approximately 0.3 to 0.8 m. Temperature, dissolved oxygen, pH, alkalinity, and conductivity readings were taken in each microhabitat on each sample date. Current velocity was measured at the open water sample sites. Samples were collected from March 16 to June 21, 1985. Day samples were collected weekly and night samples were collected biweekly.

The objective of the 1985 gear comparison study was to compare the efficiencies of set circular plankton nets, pushed plankton nets, set rectangular plankton nets (drift nets), and an 833 L/min trash pump to capture fish eggs and larvae. Samples were taken in the mouth of Steel Creek during daylight hours on April 30 and May 23, 1985. Both dates were divided into seven consecutive time periods. Duplicate samples using each technique were taken during each time period.

The set net collection efficiency was evaluated by suspending paired 0.5 m, 505 µ mesh circular plankton nets from a boom extending from the port side of an anchored boat. While the circular plankton nets were being fished off the port side, the rectangular set nets were arranged in a paired configuration similar to the circular nets and were fished from a boom extending from the starboard side. Both the circular and rectangular set nets were suspended approximately 1 m below the surface and approximately 50 m^3 of water was filtered through each net.

After retrieving the set nets, pump samples were taken by pumping water from a depth of approximately 0.5 to 1.0 m into a 0.5 m diameter, 505 µ mesh circular plankton net held over the side of the boat. The opening of the net was suspended 5 to 10 cm above the water; the remainder of the net was submerged. The discharge pipe of the pump opened into the net approximately 25 cm below the water surface. Samples were collected by filtering 12.5 m^3 of water during a 15 minute period.

Upon completion of the pump sampling, push net samples were taken by suspending paired 0.5 m, 505 µ mesh circular plankton nets beneath the bow of the boat while traveling against the current for a distance sufficient enough to filter approximately 50 m^3 of water. All samples were preserved and identified as described for the creek and swamp studies.

V.4.3.2.2 Savannah River and Associated Tributaries Studies

The 1984 river and tributary sampling program included 62 ichthyoplankton sampling stations. Of these 62 stations, 26 were river transects, 28 were creek transects, two were intake transects, and six were oxbows (Table V-4.32). The river transects were further divided into three categories for the purpose of providing a reference to the SRP area. The "upper farfield" section was upstream from the SRP and included river transects between RMs 187.1 and 166.6. The "nearfield" section, which was adjacent to the SRP, encompassed RM 166.6 to RM 128.9. The "lower farfield" section extended from RM 128.9 to RM 29.6. Transects in the upper farfield and lower farfield were at approximate 16 km (10 mi) intervals while the transects in the nearfield were more closely spaced to monitor phenomena associated with SRP activities. Creek sample stations were located in all three river study sections, with 6 in the upper farfield, 7 in the nearfield, and 15 in the lower farfield.

In the 1985 river and tributary sampling program, the number of sampling stations was reduced to 45 because collections were not made at the 1984 stations downstream of RM 89.3. Of these 45 stations, 21 were river transects, 17 were creek transects, two

TABLE V-4.32

Sampling Station Locations for the Savannah River Ichthyoplankton Monitoring Program (February-July 1984)

River Mile	Sampling Station Location
River Transect	
	Upper Farfield
187.1	River transect above Savannah River Plant
176.0	River transect above Savannah River Plant
166.6	River transect above Savannah River Plant
	Nearfield
157.3	Above 1G canal
157.0	Below 1G canal
155.4	Above 3G canal
155.2	Below 5G pumphouse
152.2	Above Beaver Dam Creek
152.0	Below Beaver Dam Creek
150.8	Above Four Mile Creek
150.4	Below Four Mile Creek
141.7	Above Steel Creek
141.5	Below Steel Creek
137.7	Recovery transect below Steel Creek
129.1	Above Lower Three Runs Creek
128.9	Below Lower Three Runs Creek
	Lower Farfield
120.0	River transect below Savannah River Plant
110.0	River transect below Savannah River Plant
97.5	River transect below Savannah River Plant
89.3	River transect below Savannah River Plant
79.9	River transect below Savannah River Plant
69.9	River transect below Savannah River Plant
60.0	River transect below Savannah River Plant
50.2	River transect below Savannah River Plant
40.2	River transect below Savannah River Plant
29.6	River transect below Savannah River Plant

Source: Paller et al., 1985.

TABLE V-4.32, Contd

River Mile	Sampling Station Location
Creek Transect	
183.3	Spirit Creek
180.1	Pine Creek
176.1	Hollow Creek
171.6	High Bank Creek
164.2	McBean Creek
162.2	Upper Boggy Gut
157.2	Upper Three Runs Creek*
152.1	Beaver Dam Creek*
150.6	Four Mile Creek*
141.6	Steel Creek*
141.3	Lower Boggy Gut
133.5	Sweetwater Creek
129.0	Lower Three Runs Creek*
126.5	Smith Lake Creek
109.0	The Gaul
97.6	Briar Creek
92.6	Buck Creek
88.6	Ware Creek
84.1	Pike Creek
78.4	Black Creek
64.2	Lake Parachuchia Outlet
51.1	Plank Creek
47.7	Seines Landing
44.8	Ebenezer Creek
43.2	Lockner's Creek
40.3	Coleman Lake
35.4	Meyers Lake
30.0	Collin Creek
Intake Transect	
157.1	1G Canal*
155.3	3G Canal*
Oxbows	
183.0	Fritz Cut
167.4	Unnamed
156.7	Unnamed
153.2	Unnamed
100.2	Miller's Old Lake
51.3	Unnamed

* Located on the Savannah River Plant.

Source: Paller et al., 1985.

were intake transects, and five were oxbows (Table V-4.33). The upper farfield and nearfield designations were the same in 1985 as in 1984, but the lower farfield section extended from RM 128.9 to RM 89.3, rather than to RM 29.6.

Each of the river transects was sampled near the South Carolina shore, in mid-river, and near the Georgia shore. The intake canal stations were sampled near both shores, and in mid-canal. Creeks and oxbows were sampled only in mid-channel within 20 m of the mouth. If the water depth exceeded 2 m, both surface and bottom samples were taken. All samples were taken in duplicate.

All stations were sampled weekly from early February through July during both years of study. Because ichthyoplankton abundance can vary within a short time frame (Paller et al., 1986b), all nearfield ichthyoplankton collections were taken on the same day to reduce the potential variation of ichthyoplankton densities between sample dates. Because of the distance involved, upper farfield and lower farfield areas of the river could not be sampled on the same day, but were sampled within two days of the nearfield sampling.

Ichthyoplankton collections were made from an anchored boat with two 0.5 diameter 505 μ mesh plankton nets mounted side by side in a common frame similar to the gear used for collecting creek and swamp ichthyoplankton. The collections were timed so that approximately 50 m^3 of water was filtered; 5 minute sets were usually adequate. For surface collections, the center of the net was maintained approximately 0.5 m below the surface. For bottom samples, the nets were weighted so that a sample was taken approximately 0.5 m above the substrate. A General Oceanics Model 2030 digital flow meter was placed in the center of the mouth of each net to record the volume of water filtered for each sample.

In the intake canals, the current velocity was too low for an adequate sample to be collected from an anchored boat. Instead, samples were collected by towing the nets for approximately three-fourths the length of the canal. The length of the tow was adjusted so that approximately 50 m^3 of water was filtered. A General Oceanics Model 2030 digital flow meter was placed in the center of the mouth of each net to record the volume of water filtered for each sample. Parallel surface tows were made close to each bank and down the center of the canal: a bottom collection was made down the center of the canal. Bottom collections were not made along the sides of the canal because the water was too shallow and the bottom topography was too variable.

Creeks and oxbows with adequate flow were sampled using set nets. Areas with low flow rates were sampled by towing the net. A few creeks were blocked by fallen trees and could only be sampled by setting the nets for a long period of time.

TABLE V-4.33

Sampling Station Locations for the Savannah River Ichthyoplankton Monitoring Program (February-July 1985)

River Mile	Sampling Station Location
River Transect	
	Upper Farfield
187.1	River transect above Savannah River Plant
176.0	River transect above Savannah River Plant
166.6	River transect above Savannah River Plant
	Nearfield
157.3	Above 1G canal
157.0	Below 1G canal
155.4	Above 3G canal
155.2	Below 5G pumphouse
152.2	Above Beaver Dam Creek
152.0	Below Beaver Dam Creek
150.8	Above Four Mile Creek
150.4	Below Four Mile Creek
145.7	Recovery transect below Four Mile Creek
141.7	Above Steel Creek
141.5	Below Steel Creek
137.7	Recovery transect below Steel Creek
129.1	Above Lower Three Runs Creek
128.9	Below Lower Three Runs Creek
	Lower Farfield
120.0	River transect below Savannah River Plant
110.0	River transect below Savannah River Plant
97.5	River transect below Savannah River Plant
89.3	River transect below Savannah River Plant
Creek Transect	
183.3	Spirit Creek
180.1	Pine Creek
176.1	Hollow Creek
171.6	High Bank Creek

* Located on the Savannah River Plant.

Source: Paller et al., 1986b.

TABLE V-4.33, Contd

River Mile	Sampling Station Location
Creek Transect (contd)	
164.2	McBean Creek
162.2	Upper Boggy Gut
126.5	Smith Lake Creek
109.0	The Gaul
97.6	Briar Creek
92.6	Buck Creek
Intake Transect	
157.1	1G Canal*
155.3	3G Canal*
Oxbows	
183.0	Fritz Cut
167.4	Unnamed
156.7	Unnamed
153.2	Unnamed
100.2	Miller's Old Lake

* Located on the Savannah River Plant.

Source: Paller et al., 1986b.

Samples were preserved and processed as described in Section V.4.3.2.1. Other parameters measured concurrently with ichthyoplankton collections were temperature, dissolved oxygen, pH, conductivity, alkalinity, and water velocity. (See Section V.4.3.2.1 for detailed methodologies.) The cross-sectional area of each creek mouth was calculated at the location where ichthyoplankton samples were taken, based on the width of the creek and depth measurements along a transect across the creek. Calculated cross-sectional areas were multiplied by water velocity measurements to determine the discharge (m^3/sec) from each creek on each sample date. Savannah River discharge data (m^3/sec) were taken from records collected at USGS gauging stations for the same dates that ichthyoplankton samples were collected. The number of ichthyoplankton transported past each river transect (no./sec) on each sample date was calculated by multiplying ichthyoplankton density at that transect (no./m^3) times river discharge.

V.4.3.3 Results and Discussion: SRP Creek and Swamp Ichthyoplankton Studies

V.4.3.3.1 Chemical and Physical Parameters

Although chemical and physical parameters were measured concurrently with ichthyoplankton collections at all sample stations during both years of study, only the results from the 1985 program were available for this report (Paller, 1985). Water temperature was measured with a Hydrolab Model VI, a Horiba Model U7, or a mercury thermometer. The mercury thermometer was used at stations where temperatures were high enough to impair instrument performance (>40°C). Dissolved oxygen, pH, and specific conductance were measured in the field using the Hydrolab Model VI or Horiba U7 water quality monitor. Alkalinity determinations were made in the laboratory using APHA method 403 for low alkalinity samples (APHA, 1980). Water quality measurements were taken approximately 0.5 m below the surface and, when depth exceeded approximately 1.5 m, 0.5 m above the bottom.

Water velocity was measured with a General Oceanics Model 2030 current meter or a General Oceanics remote reading flow meter. Readings were taken approximately 0.5 m below the surface.

Water temperatures in the study area were evaluated by calculating the mean temperature over all sample dates at each station (Table V-4.3) and mean temperature in each creek during each week of the study (Figures V-4.16 and V-4.17). These data were used to describe the basic thermal conditions and relative temperature differences between the streams. Because of its significance in this study, water temperature will be discussed in detail. Data for the other chemical and physical parameters are

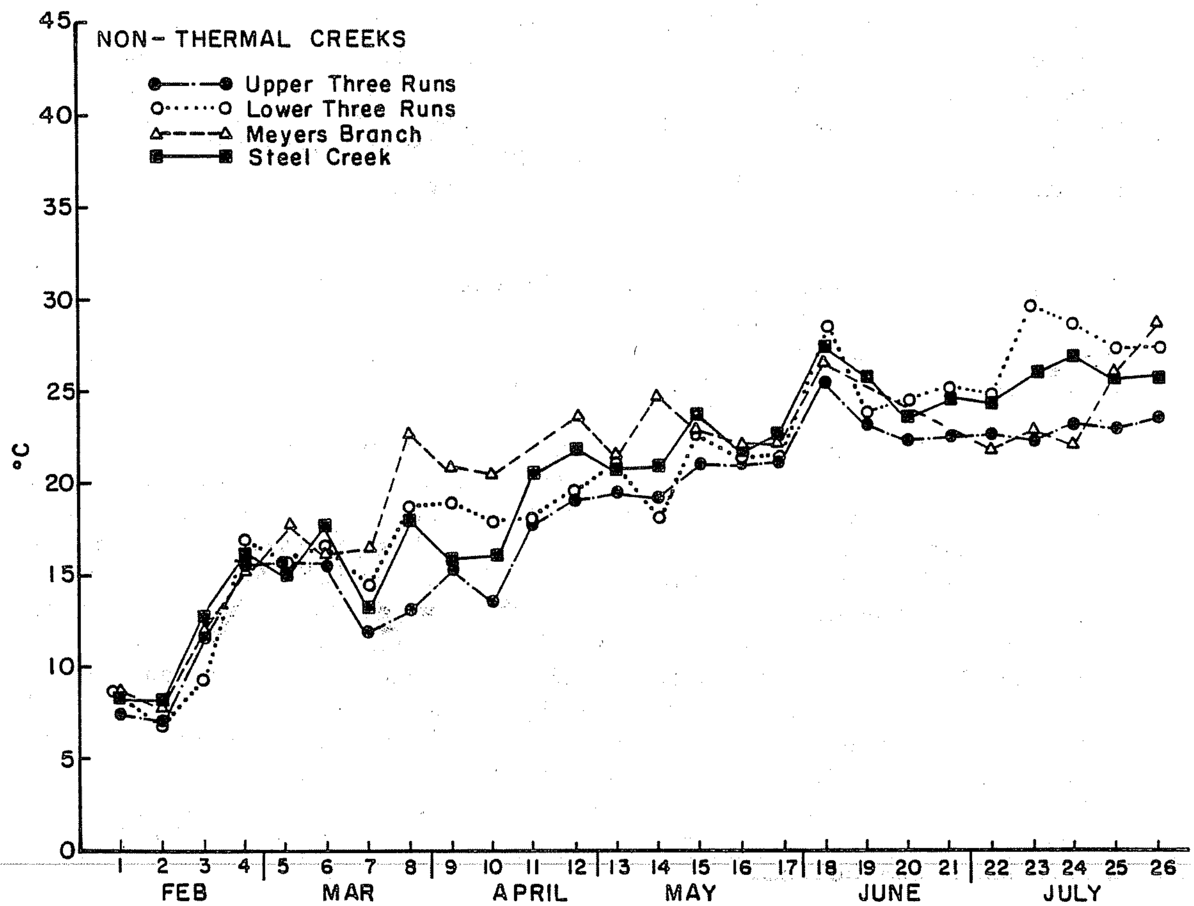


FIGURE V-4.16. Mean Temperatures of Upper Three Runs Creek, Lower Three Runs Creek, Steel Creek, and Meyers Branch for Each Week of the 1985 Ichthyoplankton Sampling Program (February-July 1985).
Source: Paller et al., 1986a

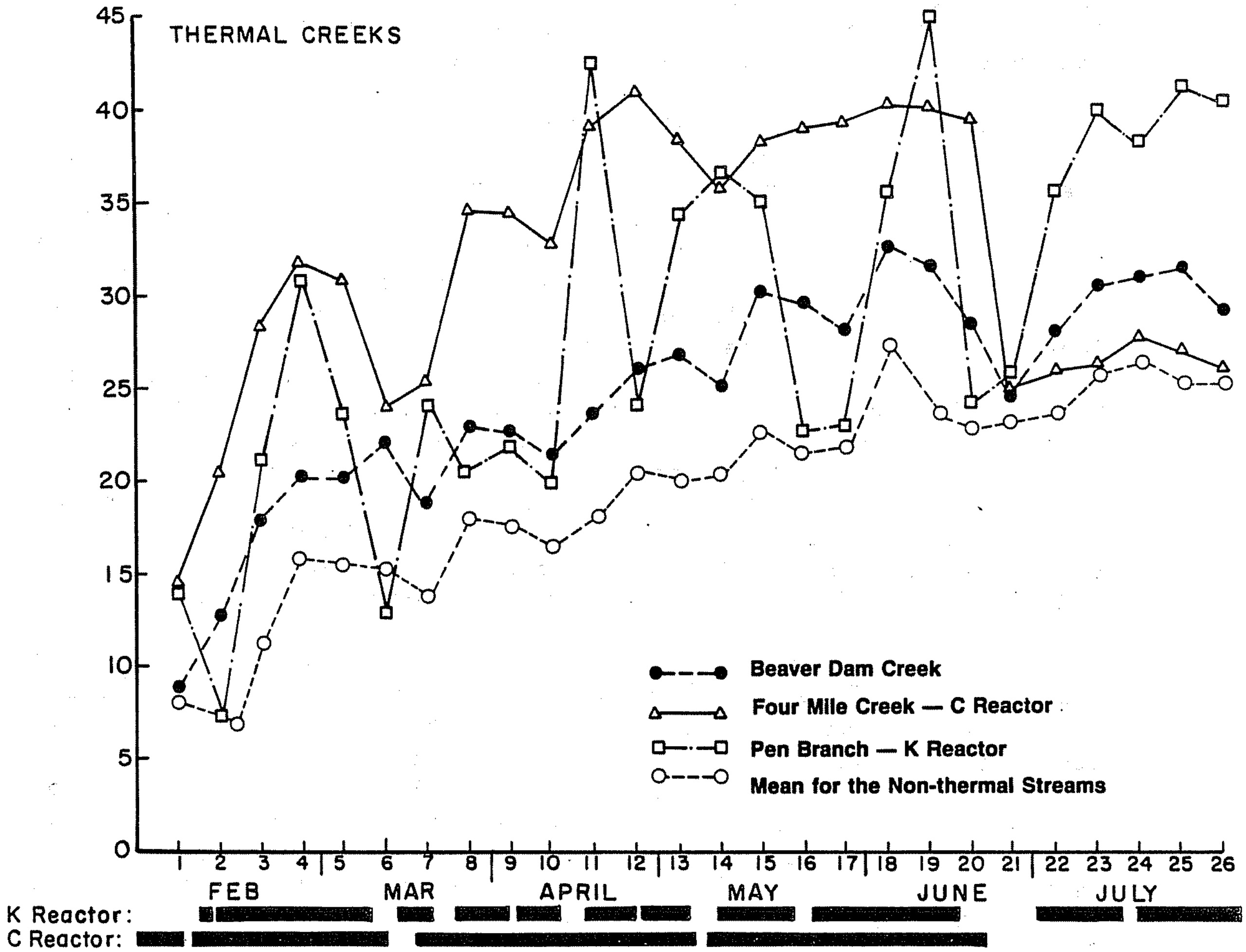


FIGURE V-4.17. Mean Temperatures of Beaver Dam Creek, Four Mile Creek, and Pen Branch for Each Week of the 1985 Ichthyoplankton Sampling Program (February-July 1985).
Source: Paller et al., 1986a

listed in Table V-4.34, and are summarized below. The highest water temperatures among the study sites were in Four Mile Creek and Pen Branch, both of which receive thermal effluents from SRP reactors. Temperatures at Road A in Four Mile Creek (closest to the C-Reactor outfall) averaged 39.4°C, and on one occasion measured as high as 57.6°C. Temperatures in the nonthermal section of Four Mile Creek above the C-Reactor outfall (at Road A-7) averaged approximately 19.5°C. Temperatures in the section of Pen Branch located upstream from K Reactor (Road B) averaged 19.8°C, while the thermally influenced downstream stations averaged 37.0°C and 35.1°C at Road A and the delta, respectively.

Beaver Dam Creek, which receives thermal discharge from a coal-fired power plant, was cooler than Four Mile Creek and Pen Branch. However, the average temperature in Beaver Dam Creek was 24.4°C, which was approximately 4°C warmer than the average temperatures in Steel Creek, Meyers Branch, Upper Three Runs Creek, and Lower Three Runs Creek. The only other stream that exhibited evidence of reactor-related warming during 1985 was Lower Three Runs Creek, which receives the overflow from Par Pond. Mean temperatures at sample stations in the upper reaches of Lower Three Runs Creek ranged from 22.3 to 27.2°C, compared to 19.5°C in Four Mile Creek at Road A-7 and 19.8°C in Pen Branch at Road B, while the three sample stations in the lower reaches of Upper Three Runs Creek ranged from 17.5°C to 18.1°C. Four sample stations in the upper reaches of Lower Three Runs Creek were located close to the Par Pond spillway. Par Pond receives heated effluents from P Reactor in addition to being heated by solar isolation.

Average dissolved oxygen concentrations exceeded 5 mg O_2/L at all sample stations. Five mg O_2/L is the minimum level generally considered necessary to support communities of desirable fishes (EPA, 1976). While average oxygen concentrations were within the acceptable range at all sample stations, lower values (minimum of 2.5 mg O_2/L) were occasionally observed in the Steel Creek swamp, which does not receive thermal discharge [except possibly during periods of river flooding (Shines & Tinney, 1983)], and at the sample stations downstream from the reactor outfalls in Four Mile Creek and Pen Branch.

The average pH at most sample stations was less than 7.0 and ranged from 5.8 to 8.0. Average alkalinities for all sample stations ranged from 3.5 to 35.6 mg $CaCO_3$/L and average conductivity ranged from 24.0 to 145.3 µS/cm. The alkalinity and conductivity of Upper Three Runs Creek differed from those of the other streams. Mean alkalinity values in Upper Three Runs Creek ranged from 3.5 to 3.8 mg $CaCO_3$/L compared to 7.1 to 35.6 mg $CaCO_3$/L in the other streams. Mean conductivity values ranged from 24.0 to 27.5 µS/cm in Upper Three Runs Creek and from 37.0 to 1345.3 µS/cm in the other creeks on the SRP.

TABLE V-4.34

Mean (and range) of Chemical and Physical Parameters Measured at Each Ichthyoplankton Sampling Site on the Savannah River Plant (February-July 1985)

Station	Temp. °C (min-max)	Dissolved Oxygen mg O_2/L (min-max)	pH (min-max)	Conductivity μS (min-max)	Alkalinity mg $CaCO_3$/L (min-max)	Current cm/sec (min-max)	Depth, m (min-max)
Upper Three Runs Creek							
Road C n = 27	18.0 (7.0-22.9)	8.0 (5.1-13.4)	5.8 (4.3-8.4)	27.5 (7.0-80.0)	3.8 (0.8-22.0)	41.5 (32.0-61.0)	1.1 (0.3-1.8)
Road A n = 27	18.0 (6.3-28.2)	7.8 (4.8-12.4)	6.1 (4.5-7.5)	25.8 (2.0-80.0)	3.5 (0.1-5.0)	62.5 (40.0-160.0)	1.1 (6.4-1.8)
Mouth n = 17	15.7 (8.0-23.5)	7.2 (5.2-9.1)	6.3 (5.2-6.9)	25.3 (17.0-32.0)	3.0 (1.0-4.3)	29.6 (20.0-41.0)	1.3 (0.6-3.3)
Beaver Dam Creek							
Road A-12.2 n = 25	25.6 (13.7-33.2)	6.9 (3.9-11.2)	6.5 (5.1-7.5)	98.5 (64.0-133.0)	16.5 (8.3-19.8)	78.2 (62.0-120.0)	1.1 (0.6-2.7)
Swamp n = 25	25.0 (9.1-33.0)	6.3 (4.6-10.1)	6.5 (5.4-7.3)	96.3 (52.0-131.0)	16.6 (12.8-19.5)	41.2 (22.0-86.0)	1.3 (0.9-1.8)
Slough n = 25	23.6 (5.4-32.1)	5.9 (3.7-10.6)	6.4 (5.4-7.3)	88.7 (14.0-128.0)	16.8 (12.5-18.8)	30.3 (5.0-45.0)	1.4 (0.6-2.4)
Swamp n = 25	23.0 (5.8-33.1)	6.2 (3.8-17.5)	6.3 (5.2-7.5)	86.7 (16.0-123.0)	16.4 (12.0-18.6)	74.6 (31.0-115.0)	1.4 (0.9-3.0)
Mouth n = 26	24.7 (15.5-34.0)	5.2 (4.0-7.2)	6.3 (4.9-7.6)	89.5 (82.0-98.0)	15.8 (11.8-18.5)	60.2 (23.0-88.0)	1.6 (0.9-3.0)
Four Mile Creek							
Road A-7 n = 18	19.5 (7.9-26.9)	7.8 (5.2-15.0)	6.3 (4.0-7.6)	71.7 (26.0-97.0)	7.1 (2.5-12.0)	16.1 (8.0-25.0)	0.9 (0.6-1.5)
Road A n = 26	39.4 (14.2-57.6)	6.1 (3.5-10.5)	6.9 (5.2-8.8)	72.1 (50.0-99.0)	14.3 (10.0-17.3)	119.7 (39.0-160.0)	1.1 (0.6-2.7)

Source: Paller et al., 1986a.

TABLE V-4.34, Contd

Station	Temp. °C (min-max)	Dissolved Oxygen mg O_2/L (min-max)	pH (min-max)	Conductivity µS (min-max)	Alkalinity mg $CaCO_3$/L (min-max)	Current cm/sec (min-max)	Depth, m (min-max)
Steel Creek (contd)							
Road A-13.1 n = 7	21.3 (9.9-23.3)	7.9 (5.6-11.3)	6.7 (5.8-7.6)	66.7 (25.0-86.0)	18.6 (13.5-22.5)	46.4 (10.0-100.0)	0.3 (0.3-0.3)
Cypress Bridge n = 26	19.8 (7.7-27.6)	7.3 (4.8-10.9)	6.5 (4.3-7.4)	64.7 (20.0-84.0)	18.8 (6.0-26.8)	40.2 (25.0-52.0)	0.6 (0.3-1.3)
Above Island 62 n = 2	12.2 (10.1-14.0)	6.5 (6.0-6.9)	6.1 (5.6-6.5)	37.0 (8.0-66.0)	13.4 (12.3-14.5)	-* -	0.8 (0.6-0.9)
Above Island 31 n = 24	20.1 (11.2-27.3)	5.8 (3.5-8.8)	6.3 (5.4-7.4)	67.2 (9.0-102.0)	19.6 (11.5-22.5)	26.8 (10.0-44.0)	0.9 (0.6-1.5)
Between Island 63 n = 5	15.5 (10.0-23.7)	6.4 (5.6-6.9)	6.2 (5.7-6.7)	49.3 (9.0-68.0)	15.8 (12.0-18.8)	24.0 (11.0-35.0)	1.0 (0.6-1.8)
Between Island 32 n = 25	20.3 (7.2-29.9)	5.9 (2.8-10.6)	6.1 (4.6-7.4)	67.3 (8.0-93.0)	20.0 (14.5-25.3)	20.3 (10.0-40.0)	1.0 (0.6-1.8)
Between Island 33 n = 25	19.8 (5.5-28.8)	5.3 (3.0-9.0)	6.3 (5.2-7.4)	74.9 (9.0-103.0)	19.1 (11.5-22.5)	28.0 (18.0-40.0)	1.2 (0.9-2.4)
Below Island 34 n = 25	19.3 (4.9-27.2)	5.9 (3.8-11.8)	6.2 (5.2-7.4)	71.7 (9.0-105.0)	19.0 (9.3-34.5)	14.4 (10.0-25.0)	1.2 (0.6-2.1)
Below Island 35 n = 26	19.4 (4.6-27.1)	5.8 (3.6-10.9)	6.2 (5.2-7.4)	76.3 (9.0-108.0)	18.2 (8.8-22.5)	25.5 (16.0-42.0)	1.2 (0.6-2.1)
Below Island 64	20.2 (10.1-27.1)	5.7 (3.8-9.1)	6.2 (5.2-7.4)	77.1 (8.0-109.0)	19.9 (11.5-48.0)	38.1 (16.0-56.0)	1.7 (0.9-2.4)

* Not measured.

Source: Paller et al., 1986a.

TABLE V-4.34, Contd

Station	Temp. °C (min-max)	Dissolved Oxygen mg O_2/L (min-max)	pH (min-max)	Conductivity µS (min-max)	Alkalinity mg $CaCO_3$/L (min-max)	Current cm/sec (min-max)	Depth, m (min-max)
Steel Creek (contd)							
Below Swamp 36 n = 27	19.2 (6.1-26.8)	9.8 (3.7-11.6)	6.2 (5.1-7.4)	77.2 (9.0-106.0)	10.0 (9.3-26.0)	71.0 (28.0-95.0)	1.9 (0.9-2.4)
Below Swamp 61 n = 26	19.4 (7.4-26.7)	5.7 (3.9-8.4)	6.5 (5.0-7.4)	77.4 (9.0-105.0)	19.7 (10.5-26.9)	73.8 (22.0-94.0)	1.7 (0.6-3.0)
Mouth n = 32	17.4 (6.0-25.7)	6.6 (3.9-10.4)	5.8 (4.1-7.0)	79.8 (52.0-108.0)	16.2 (8.0-22.7)	39.1 (10.0-60.0)	2.3 (1.5-4.3)
Meyers Branch							
Road B-6.2 n = 13	16.9 (7.4-24.0)	7.1 (4.3-11.3)	6.0 (4.1-7.7)	41.9 (14.0-60.0)	13.0 (5.5-20.3)	52.7 (10.0-150.0)	0.5 (0.3-0.9)
Steel Creek confluence n = 25	20.2 (7.8-28.5)	7.2 (5.2-11.4)	6.4 (3.9-7.6)	45.8 (2.0-81.0)	18.5 (7.0-23.0)	30.9 (18.0-63.0)	0.4 (0.3-0.6)
Lower Three Runs							
Spillway n = 11	27.2 (19.5-32.8)	6.6 (4.4-8.5)	7.1 (6.7-7.9)	72.2 (52.0-85.0)	15.4 (12.3-17.0)	31.0 (2.0-64.0)	0.4 (0.3-0.6)
Road B n = 25	22.3 (7.5-31.2)	7.1 (4.3-13.0)	6.4 (4.7-7.8)	68.9 (13.0-130.0)	20.3 (14.3-50.6)	53.8 (7.0-130.0)	0.6 (0.0-1.5)
Below Road B n = 17	25.4 (18.3-31.4)	6.5 (4.6-7.7)	6.4 (4.1-7.3)	79.9 (42.0-138.0)	18.0 (9.5-49.8)	0.6 (5.0-40.0)	(0.3-0.9)
Trestle n = 17	23.7 (15.0-30.7)	6.2 (4.2-7.7)	6.4 (4.1-7.5)	80.8 (34.0-123.0)	25.2 (13.8-48.0)	22.0 (10.0-60.0)	0.5 (0.3-0.9)

Source: Paller et al., 1986a.

TABLE V-4.34, Contd

Station	Temp. °C (min-max)	Dissolved Oxygen mg O_2/L (min-max)	pH (min-max)	Conductivity µS (min-max)	Alkalinity mg $CaCO_3$/L (min-max)	Current cm/sec (min-max)	Depth, m (min-max)
Four Mile Creek (contd)							
Road A-13 n = 22	34.5 (12.9-46.7)	5.2 (2.5-9.7)	6.9 (4.5-8.5)	79.3 (28.0-340.0)	15.7 (12.0-26.5)	69.1 (20.0-110.0)	1.1 (0.3-3.7)
Swamp 1 n = 22	33.4 (6.9-41.0)	6.2 (3.9-11.0)	6.7 (5.1-8.5)	71.4 (40.0-90.0)	14.8 (10.8-17.0)	27.4 (10.0-40.0)	1.8 (0.9-2.4)
Swamp 2 n = 22	33.2 (7.4-41.0)	6.1 (4.0-10.5)	6.6 (5.2-8.2)	72.7 (35.0-90.0)	14.7 (11.0-16.8)	31.7 (12.0-60.0)	2.1 (1.5-2.7)
Swamp 3 n = 22	32.3 (7.9-40.0)	5.8 (2.7-9.7)	6.5 (5.1-7.9)	73.1 (40.0-90.0)	15.0 (11.0-17.3)	31.8 (11.0-45.0)	1.6 (1.2-2.1)
Mouth n = 26	33.0 (11.0-39.5)	5.3 (3.6-7.0)	6.5 (5.7-7.4)	80.1 (42.0-94.0)	13.7 (9.3-22.7)	34.8 (12.0-62.0)	1.5 (0.9-4.0)
Pen Branch							
Road B n = 23	19.8 (7.3-25.7)	7.2 (5.9-8.8)	6.4 (4.4-8.5)	50.7 (10.0-88.0)	16.2 (6.0-25.3)	24.8 (10.0-40.0)	0.4 (0.3-0.6)
Road A-13.2 n = 26	37.0 (13.2-55.4)	5.2 (2.8-9.2)	6.6 (3.5-8.2)	103.0 (10.0-400.0)	17.5 (10.8-21.3)	118.4 (20.0-160.0)	1.6 (0.9-3.0)
Delta n = 11	35.1 (23.2-43.8)	7.3 (5.2-9.9)	8.0 (6.7-9.4)	145.3 (1.0-600.0)	17.5 (12.8-22.3)	21.4 (13.0-40.0)	0.3 (0.3-0.6)
Steel Creek							
Road B n = 12	17.4 (10.4-24.4)	7.1 (5.4-8.3)	6.0 (4.5-7.6)	57.4 (30.0-74.0)	14.8 (13.0-17.0)	49.3 (30.0-82.0)	0.5 (0.3-0.6)
Road A-14 n = 22	21.5 (10.0-34.2	6.3 (3.8-7.9)	6.4 (4.7-8.1)	68.0 (10.0-110.0)	17.4 (13.0-23.5)	50.2 (30.0-65.0)	0.4 (0.3-0.9)

Source: Paller et al., 1986a.

TABLE V-4.34, Contd

Station	Temp. °C (min-max)	Dissolved Oxygen mg O_2/L (min-max)	pH (min-max)	Conductivity µS (min-max)	Alkalinity mg $CaCO_3$/L (min-max)	Current cm/sec (min-max)	Depth, m (min-max)
Lower Three Runs (contd)							
Road A-13 n = 19	17.9 (6.6-27.2)	7.1 (5.4-10.5)	6.6 (4.8-7.6)	83.8 (4.0-130.0)	35.8 (18.0-55.5)	13.7 (6.0-40.0)	1.5 (0.9-2.1)
Road A n = 24	18.1 (5.2-24.5)	7.0 (4.9-11.3)	6.7 (5.5-7.8)	87.7 (22.0-123.0)	35.3 (8.8-48.0)	20.2 (10.0-110.0)	1.1 (0.6-2.4)
Mouth n = 20	17.5 (8.0-26.1)	7.3 (5.1-9.7)	6.1 (4.1-7.0)	92.0 (76.0-124.0)	32.6 (23.5-41.3)	26.5 (10.0-50.0)	1.4 (0.9-2.1)

Source: Paller et al., 1986a.

V.4.3.3.2 Ichthyoplankton Distribution

A total of 3,708 fish larvae and 448 fish eggs were collected from the SRP creeks and swamps between March 14 and July 31, 1984 (Table V-4.35; Appendix V-4.1). The relative scarcity of eggs in the collection reflects the fact that the eggs of most species of that fish reside near the SRP are either adhesive or deposited in nests (or other protected locations) and are not readily collected by sampling the water column. The majority of the eggs (77.2%) could not be identified but were probably those of minnows or suckers (Paller, 1985). Eggs from three of the most important anadromous species, blueback herring, American shad, and striped bass, were poorly represented in the collection from the creeks and swamps. Of these three, blueback herring were the best represented, with 13.2% of the total egg collection. American shad eggs totaled only 3.3% of the collection, and striped bass were represented by a single egg. The most abundant larvae were centrarchids (sunfish and bass), minnows, darters, spotted suckers, and brook silverside.

A total of 1,109 fish larvae and 710 fish eggs were collected from the SRP creeks and swamps between February and July 1985 (Table V-4.36). The most abundant larvae were darters, centrarchids (sunfish and bass), minnows, spotted suckers, and brook silverside. As in 1984, more than half of the eggs (56.3%) could not be unequivocally identified but were probably those of minnows and suckers (Paller et al., 1986a). The most abundant identifiable eggs were those of blueback herring and American shad. Again, striped bass were represented by only a single egg.

There were several similarities between the 1984 and 1985 ichthyoplankton collections from the creeks and swamps. Darters, minnows, and centrarchids were the most abundant larvae during both years of study; while blueback herring were the most abundant identifiable eggs. The number of taxa collected each year were fairly similar; 20 taxa during 1984 and 18 taxa during 1985. However, there were some differences in species composition. Darters comprised 12.0% of the ichthyoplankton larvae during 1984 and 31.3% during 1985; centrarchids (excluding crappie) comprised 38.8% of the larvae during 1984 and 16.9% during 1985. American shad, an important commercial and recreational species, comprised 3.3% of the eggs during 1984 and 15.4% during 1985.

To provide general information on the relationship between habitat and species composition, the sampling stations in the SRP creeks and swamps were partitioned into five basic habitat groups in 1985 (Table V-4.37). The "creek mouth" group included the five sampling stations at the mouths of the SRP creeks that enter the Savannah River. The "swamp" group included the 14 sampling stations in the swamps of Beaver Dam Creek, Four Mile Creek, Steel

TABLE V-4.35

Number and Percent Composition of Ichthyoplankton Collected from Seven Creeks and Swamp Areas on the Savannah River Plant (March 14-July 31, 1984)*

Taxa	Number	Percent
Larvae		
American shad	2	0.1
Gizzard and/or threadfin shad	83	2.2
Blueback herring	92	2.5
Unid. herring or shad	46	1.2
Spotted sucker	259	7.0
Unid. suckers	84	2.3
Pirate perch	46	1.2
Sunfish and/or bass	1,437	38.8
Crappie	381	10.3
Yellow perch	40	1.1
Darters	445	12.0
Mud minnow	5	0.1
Swamp fish	8	0.2
Minnows	512	13.8
Topminnow	3	0.1
Carp	6	0.2
Mosquitofish	4	0.1
Pickerel	3	0.1
Brook silverside	150	4.0
Catfish and/or bullhead	5	0.1
Needlefish	3	0.1
Unid. ichthyoplankton	94	2.5
Total	3,708	100.0
Eggs		
Blueback herring	59	13.2
American shad	15	3.3
Striped bass	1	0.2
Yellow perch	19	4.2
Minnow	8	1.8
Other**	346	77.2
Total	448	99.9

* Upper Three Runs, Beaver Dam, Four Mile, Pen Branch, Steel Creek, Meyers Branch, and Lower Three Runs creeks.
** Most were probably minnow and sucker eggs.

Source: Paller, 1985.

TABLE V-4.36

Number and Percent Composition of Ichthyoplankton Collected from Creek Mouth, Swamp and Creek Habitats on the Savannah River Plant (February - July 1985)

Taxa	Number	Percent
Larvae		
Unid. herring or shad	11	1.0
Blueback herring	23	2.1
American shad	9	0.8
Pickerel	2	0.2
Minnows	166	15.0
Carp	10	0.9
Unid. suckers	5	0.5
Spotted suckers	119	10.7
Catfish and/or bullhead	2	0.2
Swampfish	1	0.1
Pirate perch	1	0.1
Topminnow	2	0.2
Mosquitofish	5	0.5
Brook silverside	110	9.9
Sunfish and/or bass	187	16.9
Crappie	71	6.4
Yellow perch	6	0.5
Darters	347	31.3
Unid. larvae	30	2.7
Largemouth bass	2	0.2
Total	1,109	100.2
Eggs		
Blueback herring	183	25.8
American shad	109	15.4
Striped bass	1	0.1
Yellow perch	17	2.4
Unid. eggs	400	56.3
Total	710	100.0

Source: Paller et al., 1986a.

TABLE V-4.37

Number and Percent Composition of Ichthyoplankton Collected from Creek Mouth, Swamp and Creek Habitats on the Savannah River Plant (February-July 1985)

Taxa	Creek Mouth*		Swamp**		Creek†		Channel††		Tailwaters¶	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Unid. herring or shad	7	1.2	3	1.0	0	0.0	1	0.6	0	0.0
Blueback herring	116	19.1	44	14.6	0	0.0	45	27.1	1	0.3
American shad	87	14.3	6	2.0	2	0.5	23	13.9	0	0.0
Pickerel	1	0.2	0	0.0	1	0.2	0	0.0	0	0.0
Minnows	10	1.6	35	11.6	92	21.5	25	15.1	4	1.3
Carp	0	0.0	8	2.6	0	0.0	2	1.2	0	0.0
Unid. sucker	3	0.3	1	0.3	1	0.2	0	0.0	0	0.0
Spotted sucker	28	4.6	3	1.0	86	20.1	2	1.2	0	0.0
Catfish and/or bullhead	1	0.2	1	0.3	0	0.0	0	0.0	0	0.0
Swampfish	0	0.0	1	0.3	0	0.0	0	0.0	0	0.0
Pirate perch	0	0.0	0	0.0	0	0.0	1	0.6	0	0.0
Topminnow	1	0.2	1	0.3	0	0.0	0	0.0	0	0.0
Mosquitofish	0	0.0	2	0.7	1	0.2	0	0.0	2	0.6
Brook silverside	3	0.5	9	3.0	2	0.5	2	1.2	94	29.8
Striped bass	0	0.0	0	0.0	0	0.0	1	0.6	0	0.0
Sunfish and/or bass	25	4.1	68	22.5	36	8.4	15	9.0	43	13.7
Largemouth bass	0	0.0	2	0.7	0	0.0	0	0.0	0	0.0
Crappie	3	0.5	24	7.9	2	0.5	1	0.6	41	13.0
Yellow perch	6	1.0	1	0.3	9	2.1	4	2.4	3	1.0
Darters	68	11.2	63	20.9	161	37.7	34	20.5	21	6.7
Unid. ichthyoplankton	250	41.1	30	9.9	34	8.0	10	6.0	106	33.7
Total¶	609	100.1	302	99.9	427		166	100.0	315	100.1

* Upper Three Runs, Beaver Dam, Four Mile, Steel, and Lower Three Runs creeks.
** Swamp habitats were in Beaver Dam, Four Mile, Pen Branch, and Steel creek.
† Creek habitats were relatively narrow and well channelized with limited or no floodplain development and moderate currents. They were upstream from the swamp.
†† Lower Steel Creek channel.
¶ The three stations in the Par Pond tailwaters or Lower Three Runs Creek.

Source: Paller et al., 1986a.

Creek, and Pen Branch. The "creek" group included the 18 sampling stations above the river floodplain swamp in the upper reaches of Steel Creek, Meyers Branch, Pen Branch, Four Mile Creek, Upper Three Runs Creek, and Lower Three Runs Creek. Creek habitats were in relatively narrow, well-defined channels with little or no floodplain development. The "channel" group included the two stations in the Steel Creek channel below the Steel Creek swamp. The "tailwaters" group included the three stations just below the Par Pond spillway (refer to Table V-4.31 for station numbers of these sample sites).

The remainder of this section discusses ichthyoplankton distribution by individual creeks. For a comprehensive description of the morphological and hydrological characteristics of each creek monitored, see Section V.2 Study Sites.

V.4.3.3.2.1 Steel Creek

In 1984, there were 13 ichthyoplankton sampling stations in Steel Creek (Table V-4.31 and Figure V-4.15). The two stations farthest upstream (Station 26 and 27) were at Road B and Road A-14, approximately 15.5 km and 10.5 km, respectively, from the mouth of Steel Creek. Both stations were located in channelized portions of the stream. The next station (Station 28) was located approximately 300 m above the confluence of Steel Creek and Meyers Branch. The creek channel was more braided and marshy at this point. Eight stations (Stations 62, 31, 63, 32, 33, 34, 35, and 64) were located in the delta/swamp area (Figure V-4.18), one station (Station 36) was located in the main channel draining the delta/swamp, (300 m downstream from the swamp), and one station (Station C141.6) was located in the mouth of Steel Creek.

A total of 1,519 ichthyoplankters were collected from Steel Creek between March 14 and July 31, 1984. The predominant taxa were centrarchids, minnows, and darters (Table V-4.38). The taxonomic composition varied along the length of the creek, however. In the upper reaches of Steel Creek, minnows and darters comprised almost all of the ichthyoplankton (Table V-4.39). Downstream, in the swamp, there were considerably more taxa (16 compared to 3), and centrarchids, minnows, and darters dominated the collections. The increased diversity in the swamp was probably the result of a more varied habitat as well as the influx of riverine species which enter the swamp to spawn. The taxonomic composition in the mouth of Steel Creek was similar to that in the swamp except that the creek mouth had larger numbers of anadromous species.

From the data collected in Steel Creek (Figure V-4.19), it was determined that maximum spawning activity in Steel Creek occurred when the water temperatures ranged from 17 to 25°C. Temperatures

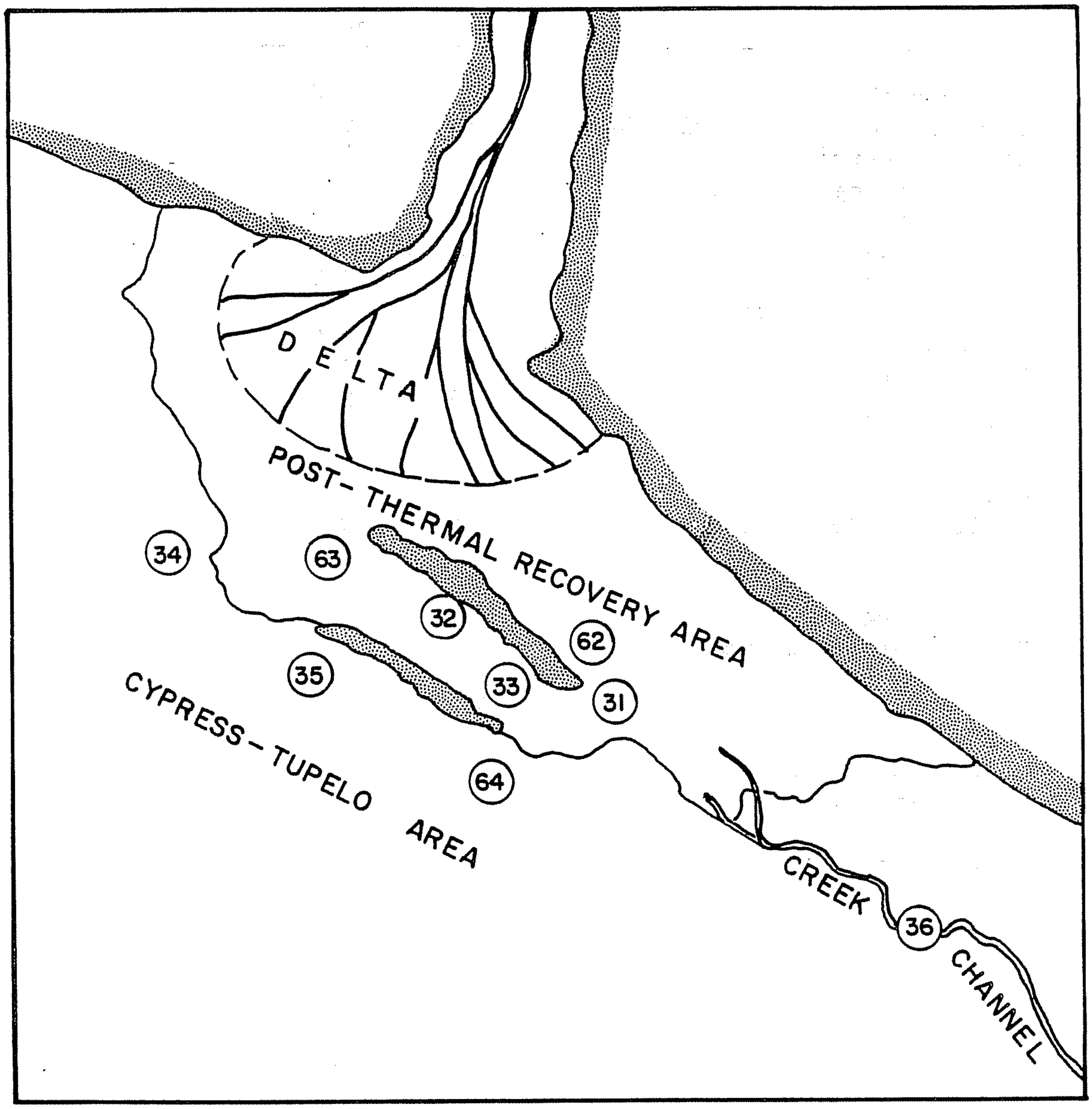


FIGURE V-4.18. The Steel Creek Delta Indicating the Location of the Ichthyoplankton Sampling Sites (February-July 1985)
Source: Paller et al., 1986a

TABLE V-4.38

Number of Percent Composition of Ichthyoplankton Collected from All Sites on Steel Creek (March 14-July 31, 1984)*

Taxa	Number	Percent
American shad	15	1.0
Gizzard and/or threadfin shad	12	0.8
Blueback herring	65	4.3
Unid. herring or shad	14	0.9
Spotted sucker	14	0.9
Unid. suckers	57	3.8
Pirate perch	42	2.8
Sunfish and/or bass	449	29.6
Crappie	34	2.2
Yellow perch	14	0.9
Darters	186	12.2
Mud minnow	5	0.3
Swamp fish	8	0.5
Minnows	420	25.7
Catfish and/or bullhead	4	0.3
Pickerel	2	0.1
Needlefish	2	0.1
Brook silverside	32	2.1
Unid. ichthyoplankton*	138	9.1
Total	1,519	99.5

* Principally eggs.

Source: Paller, 1985.

TABLE V-4.39

Number and Percent Composition of Ichthyoplankton Collected from the Mouth of Steel Creek, Steel Creek Swamp, and Upper Steel Creek (March 14-July 31, 1984)

Taxa	Creek Mouth*		Swamp**		Creek†	
	Number	Percent	Number	Percent	Number	Percent
American shad	15	2.1	0	0.0	0	0.0
Gizzard and/or threadfin shad	4	0.6	8	1.1	0	0.0
Blueback herring	63	8.7	2	0.3	0	0.0
Unid. herring or shad	10	1.4	4	0.6	0	0.0
Spotted sucker	0	0.0	14	1.9	0	0.0
Unid. sucker	7	1.0	50	6.9	0	0.0
Pirate perch	1	0.1	41	5.7	0	0.0
Sunfish and/or bass	236	32.6	213	29.4	0	0.0
Crappie	27	3.7	7	1.0	0	0.0
Yellow perch	1	0.1	10	1.4	3	4.6
Darters	70	9.7	94	13.0	22	33.8
Mud minnow	0	0.0	5	0.7	0	0.0
Swampfish	0	0.0	8	1.1	0	0.0
Minnows	275	38.0	106	14.6	39	60.0
Catfish and/or bullhead	0	0.0	4	0.6	0	0.0
Pickerel	0	0.0	2	0.3	0	0.0
Needlefish	0	0.0	2	0.3	0	0.0
Brook silverside	8	1.1	24	3.3	0	0.0
Unid. ichthyoplankton	7	1.0	130	18.0	1	1.5
Total	724	100.1	687	100.0	65	99.9

* One sampling station.
** Nine sampling stations.
† Three sampling stations above the confluence with Meyers Branch.

Source: Paller, 1985.

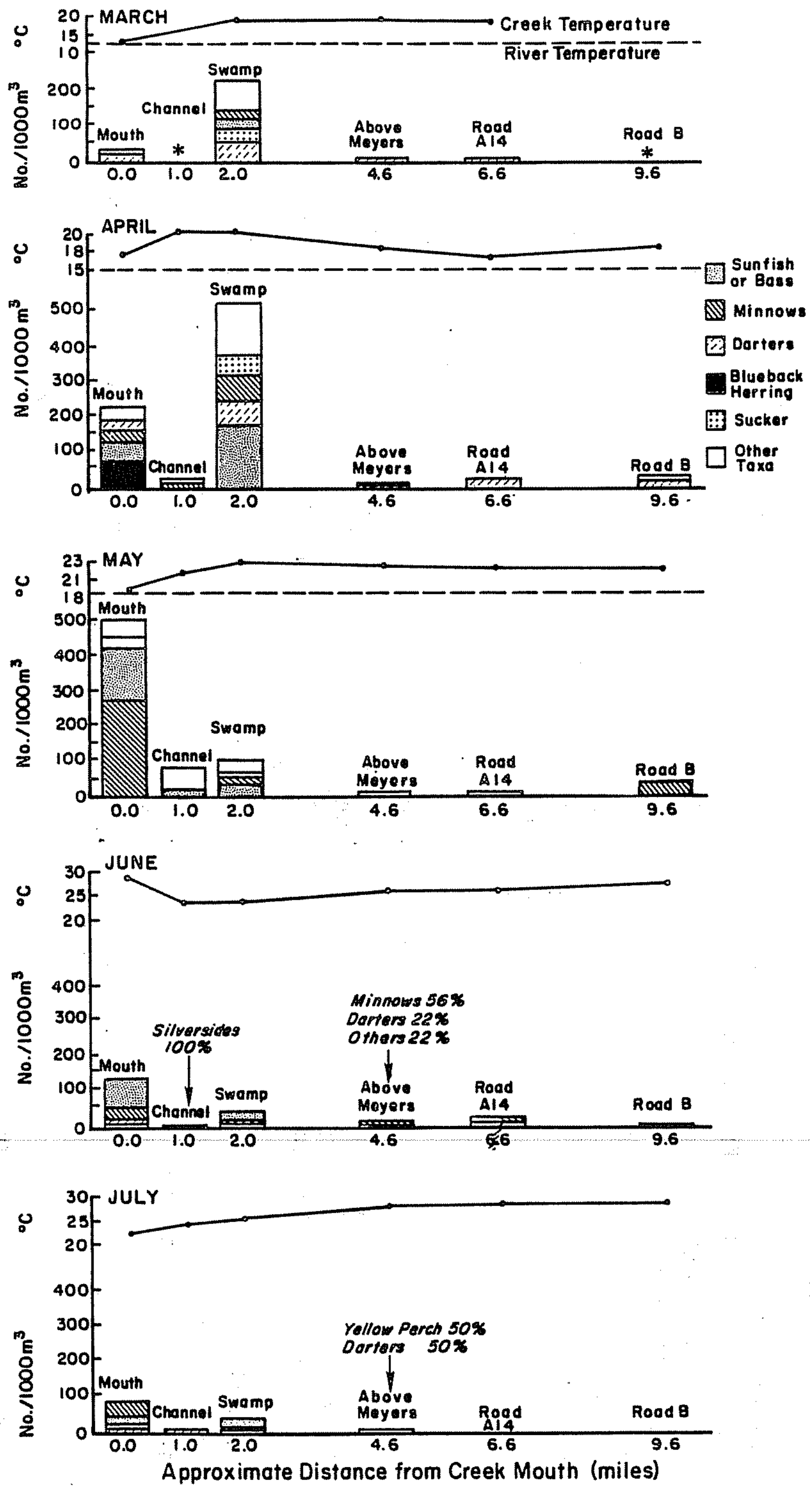


FIGURE V-4.19. Average Ichthyoplankton Density and Water Temperature at Six Sampling Stations Along Steel Creek (March-July 1984)
Source: Paller, 1985.

in the creek mouth were commonly several degrees cooler than in the upper portions of Steel Creek. As a result, the 17 to 25°C temperatures were reached earlier in the year in the swamp and nearby creek channel stations than in the creek mouth. The temperature differential between the creek mouth and swamp was attributed to solar heating of the relatively shallow water in the open canopy Steel Creek swamp, as well as the inflow of heated waters into the Steel Creek swamp from Pen Branch. The warming in the swamp was occasionally influenced by the inflow of cool water into the creek mouth from the Savannah River during high river levels.

The data collected from Steel Creek suggest that the swamp and creek mouth were the most important spawning areas in Steel Creek during 1984. The swamp appeared to be particularly important early in the spawning season, with the creek mouth becoming more important later in the season, as it warmed to temperatures suitable for spawning. Ichthyoplankton densities in the portion of Steel Creek between the swamp and the creek mouth were relatively low.

The relatively small number of ichthyoplankton collected from the sections of Steel Creek above the swamp suggests that this area was a spawning area only for resident populations. The ichthyoplankton from this region were typical creek taxa, such as darters and minnows.

Two sampling stations were added in Steel Creek in 1985; one at Cypress Bridge (Station 29) and one in the creek channel below the swamp (Station 16). The thirteen other sampling stations in Steel Creek were the same stations sampled in 1984 (Table V-4.31).

A total of 680 ichthyoplankters were collected from Steel Creek between February and July 1985. The dominant taxa were darters, blueback herring, minnows, American shad, and centrarchids (Table V-4.40; Figure V-4.20).

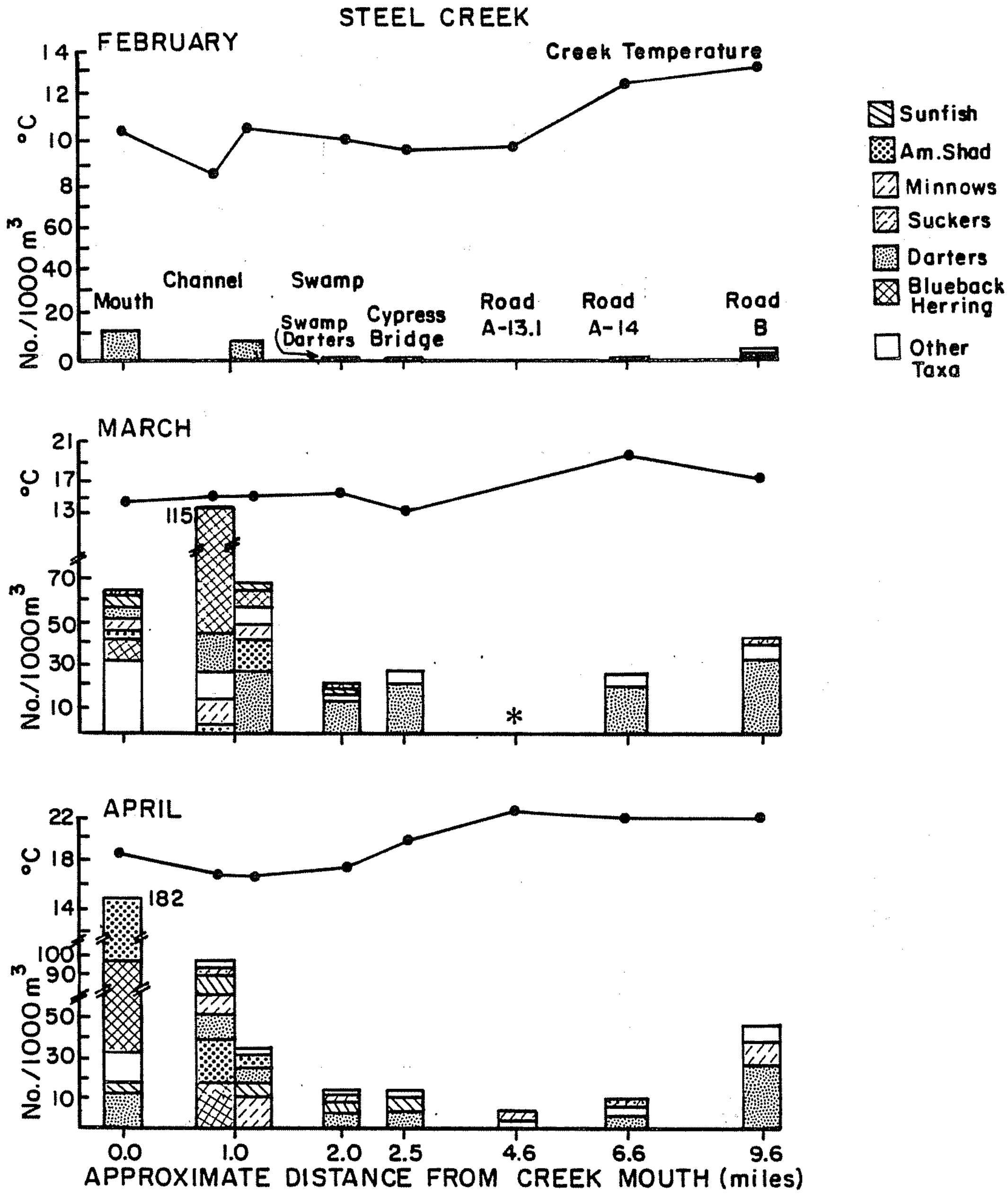
To assess ichthyoplankton occurrences along the length of the creek in 1985, the Steel Creek sampling stations were separated into four groups based on proximity to the river: upper creek, swamp, creek channel, and creek mouth. In the upper reaches of Steel Creek, minnows and darters comprised almost all of the ichthyoplankton (41.7 and 45.8%, respectively; Table V-4.41). Farther downstream in the swamp there were more taxa; darters (32.4%), centrarchids (32.4%), and minnows (13.5%) predominated. In the channel connecting the swamp to the creek mouth, the anadromous species were strongly represented. Blueback herring comprised 23.3% of the collection and American shad comprised 11.4%. Resident species, including darters (24.8%), minnows (18.8%), and centrarchids (9.4%), were also abundant. Anadromous species comprised the majority of the ichthyoplankton in the mouth of Steel Creek; American shad comprised 34.2% of the collection and blueback herring comprised 29.1%.

TABLE V-4.40

Number and Percent Composition of Ichthyoplankton Collected from All Sampling Sites on Steel Creek (February-July 1985)

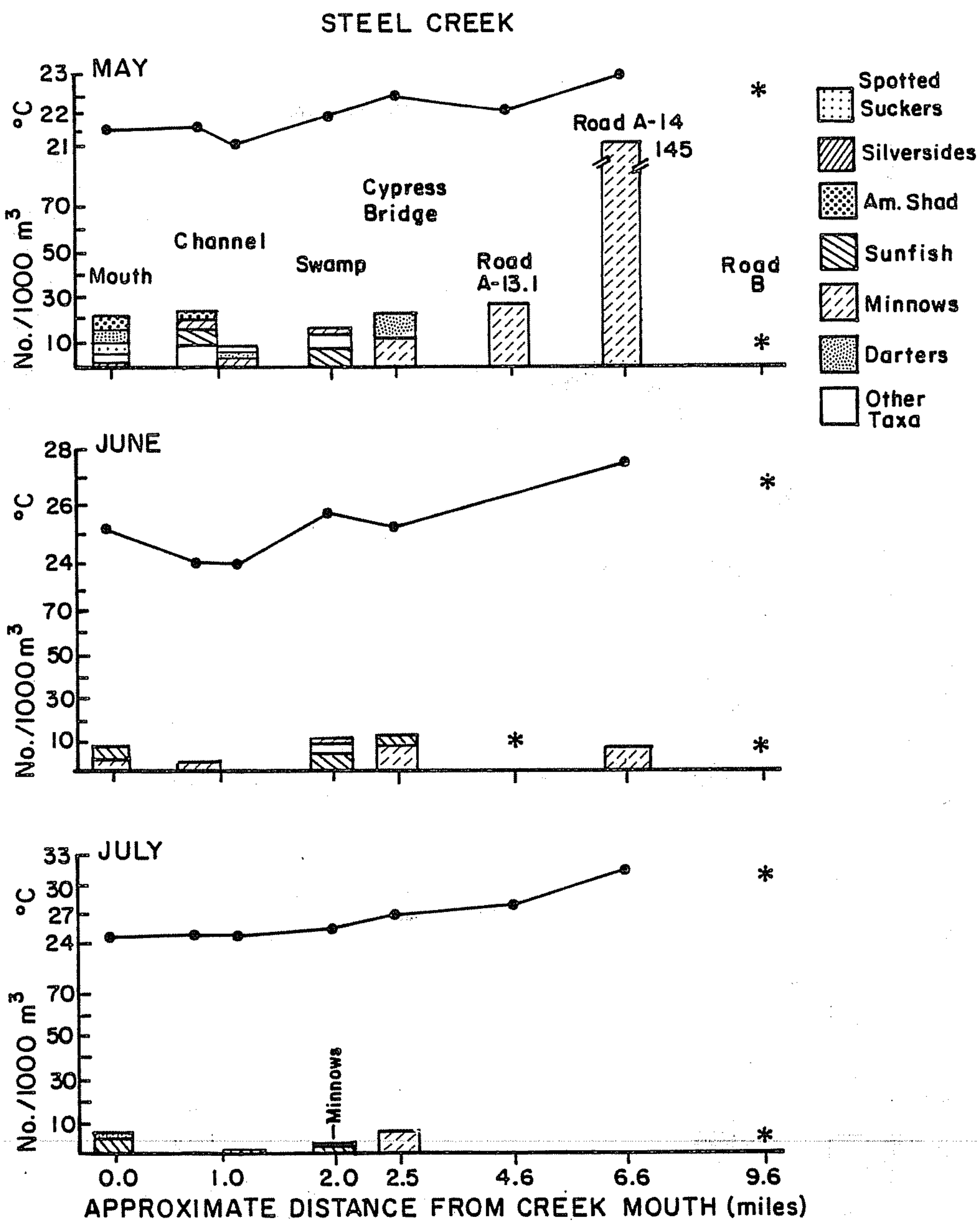
Taxa	Number	Percent
Unid. herring or shad	6	0.9
Blueback herring	116	17.1
American shad	103	15.1
Pickerel	1	0.1
Minnows	105	15.4
Carp	2	0.3
Spotted sucker	7	1.0
Unid. suckers	2	0.3
Catfish and/or bullhead	1	0.1
Swampfish	1	0.1
Pirate perch	1	0.1
Topminnow	1	0.1
Brook silverside	11	1.6
Striped bass	1	0.1
Sunfish and/or bass	79	11.6
Crappie	7	1.0
Yellow perch	11	1.6
Darters	170	25.0
Unid. ichthyoplankton	55	8.1
Total	680	100.0

Source: Paller et al., 1986a.



* Indicates no sample taken.

FIGURE V-4.20. Monthly Mean Water Temperature and Ichthyoplankton Density at Each Sampling Site on Steel Creek (February-July 1985)
Source: Paller et al., 1986a.



* Indicates no sample taken.

FIGURE V-4.20, Contd

TABLE V-4.41

Number and Percent Composition of Ichthyoplankton Collected from the Mouth of Steel Creek, Steel Creek Channel, Steel Creek Swamp, and Upper Steel Creek (February-July 1985)

Taxa	Creek Mouth*		Creek Channel**		Swamp†		Upper Creek††	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Unid. herring or shad	5	2.1	1	0.5	0	0.0	0	0.0
Blueback herring	68	29.1	45	22.3	3	2.0	0	0.0
American shad	80	34.2	23	11.4	0	0.0	0	0.0
Pickerel	0	0.0	1	0.5	0	0.0	0	0.0
Minnows	7	3.0	38	18.8	20	13.5	40	41.7
Carp	0	0.0	2	1.0	0	0.0	0	0.0
Spotted sucker	0	0.0	2	1.0	0	0.0	2	2.1
Unid. sucker	3	1.3	0	0.0	1	0.7	0	0.0
Catfish and/or bullhead	0	0.0	0	0.0	1	0.7	0	0.0
Swampfish	0	0.0	0	0.0	1	0.7	0	0.0
Pirate perch	0	0.0	1	0.5	0	0.7	0	0.0
Topminnow	0	0.0	0	0.0	1	0.7	0	0.0
Brook silverside	1	0.4	2	1.0	9	6.1	0	0.0
Striped bass	0	0.0	1	0.5	0	0.0	0	0.0
Sunfish and/or bass	12	5.1	19	9.4	48	32.4	0	0.0
Crappie	0	0.0	1	0.5	6	4.1	0	0.0
Yellow perch	0	0.0	4	2.0	2	1.4	5	5.2
Darters	28	12.0	50	24.8	48	32.4	44	45.8
Unid. ichthyoplankton	30	12.8	12	5.9	8	5.4	5	5.2
Total	234	100.0	202	100.1	148	100.1	96	100.0

* One sampling station.
** Two sampling stations.
† Eight sampling stations.
†† Four sampling stations.

Source: Paller et al., 1986a.

An analysis of mean ichthyoplankton densities over all sample dates in 1985 indicated that the densities were highest in the mouth of Steel Creek, but also fairly high in the Steel Creek channel and farther upstream at Road A-14 and Road B (Figure V-4.21). The species composition differed between these areas, with American shad, blueback herring, and darters predominating in the creek mouth and channel, and minnows and darters predominating farther upstream. These patterns differed somewhat from those observed during 1984, when densities were approximately as high in the swamp as in the creek mouth; and densities farther upstream were generally low (Paller, 1985). Furthermore, blueback herring and American shad comprised a much smaller percentage of the total catch in 1984 than in 1985.

The Steel Creek swamp has a diversity of habitats including different vegetation types, temperatures, water depth, and current velocities. To assess ichthyoplankton distributions in these varied habitats, eight ichthyoplankton sampling stations were established in the Steel Creek swamp (the 1984 and 1985 sampling stations were identical). Three stations (Stations 34, 35, and 64; Figure V-4.18) were located in a nonthermal cypress-tupelo swamp located downstream from the post-thermal recovery area. Three additional stations (Stations 32, 33, and 63) were located between two small islands in the post-thermal recovery area that had extensive submerged and emergent herbaceous and shrubby vegetation, but lacked a cypress-tupelo canopy. The two remaining sample stations (Stations 31 and 62) were located just downstream from the islands in the post-thermal recovery area. This area lacked the cypress-tupelo canopy, and had extensive sediment deposits that accumulated during previous periods of reactor operation (Figure V-4.18).

During March and the first half of April 1984, temperatures at Stations 63 and 32 (stations between the islands with reduced canopy in the post-thermal recovery area) were elevated approximately 2 to 6°C above ambient temperatures, probably due to thermal discharges from Pen Branch (Figure V-4.22). These thermal additions appeared to have raised temperatures enough to induce early spawning in the area between the islands before temperatures were high enough to permit active spawning elsewhere in the swamp (Figure V-4.23; Paller, 1985).

When temperatures reached levels suitable for spawning, habitat seemed to become a significant factor in ichthyoplankton distribution in 1984. For example, the stations between the islands (with reduced canopy) were in poorly defined channels that contained dense mats of submerged and emergent aquatic vegetation. This type of aquatic vegetation can support large numbers of fish larvae (Holland and Huston, 1984; Floyd et al., 1984), which may have been responsible for the high ichthyoplankton densities

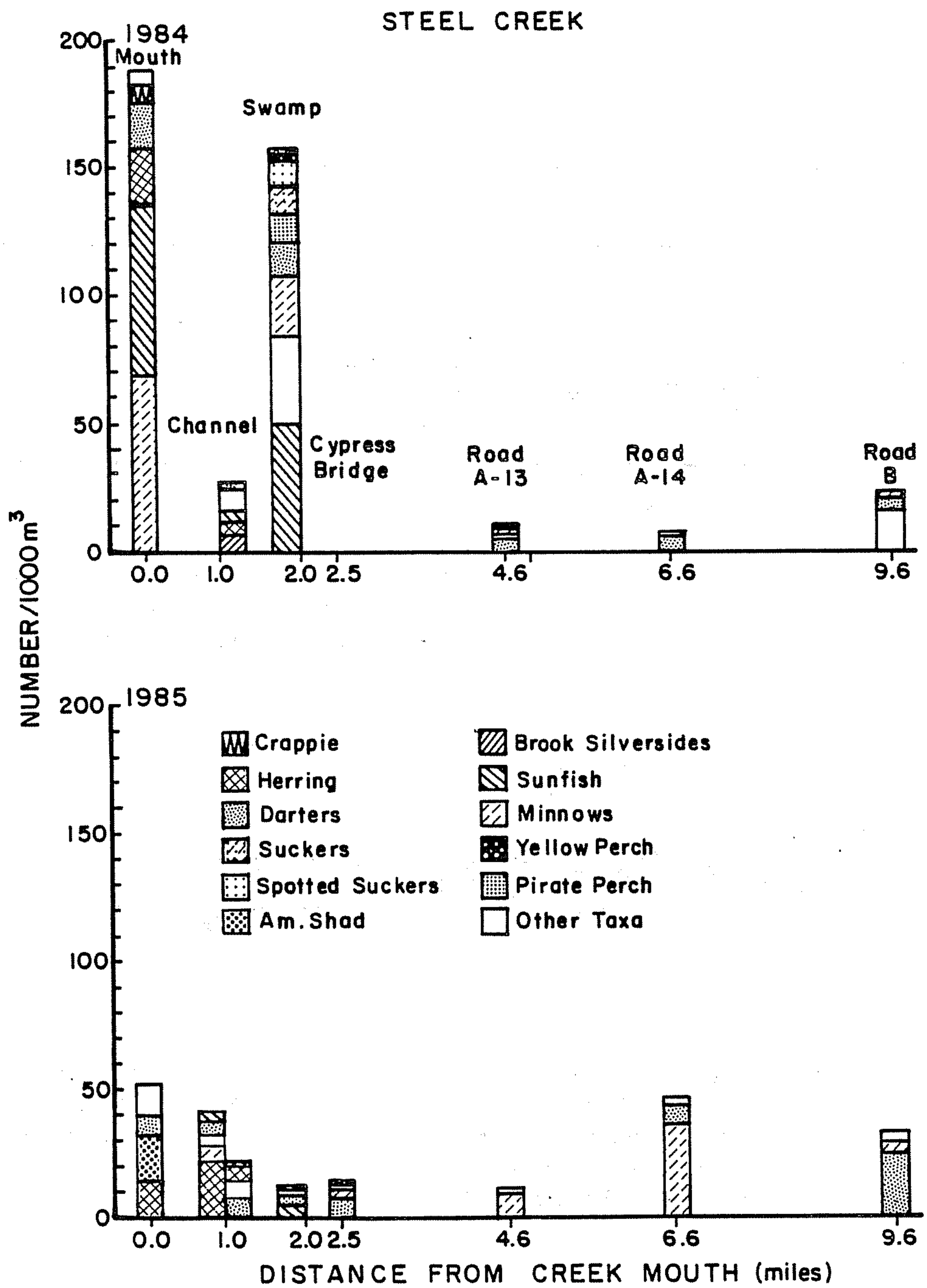


FIGURE V-4.21. Mean Ichthyoplankton Densities at Steel Creek Locations During the 1984 and 1985 Sampling Programs
Source: Paller et al., 1986a.

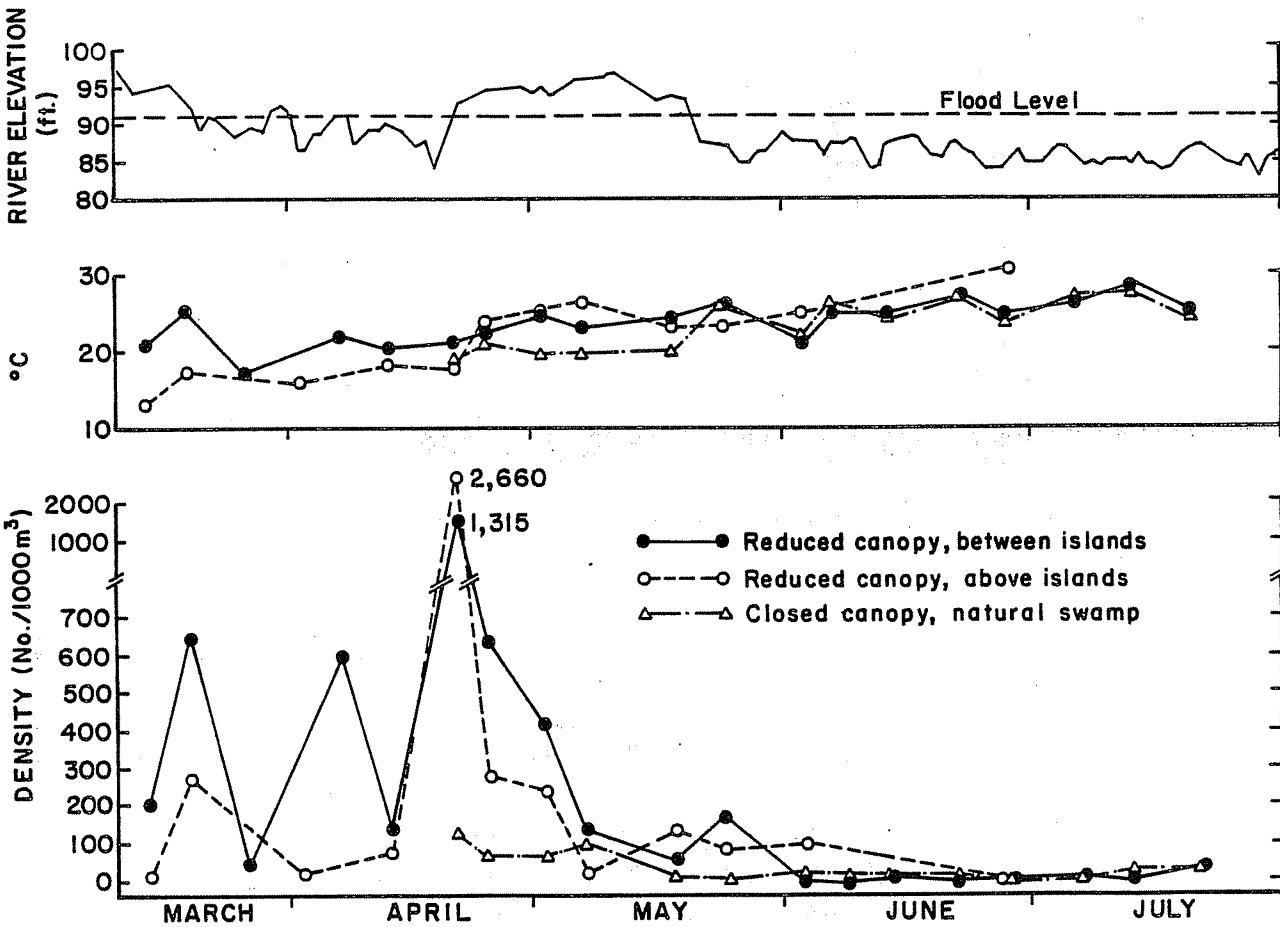


FIGURE V-4.22. A Comparison of the Ichthyoplankton Density in the Reduced Canopy and Natural Swamp Sites of the Steel Creek Swamp with Water Temperature and Savannah River Level (March-July 1984)
Source: Paller, 1985.

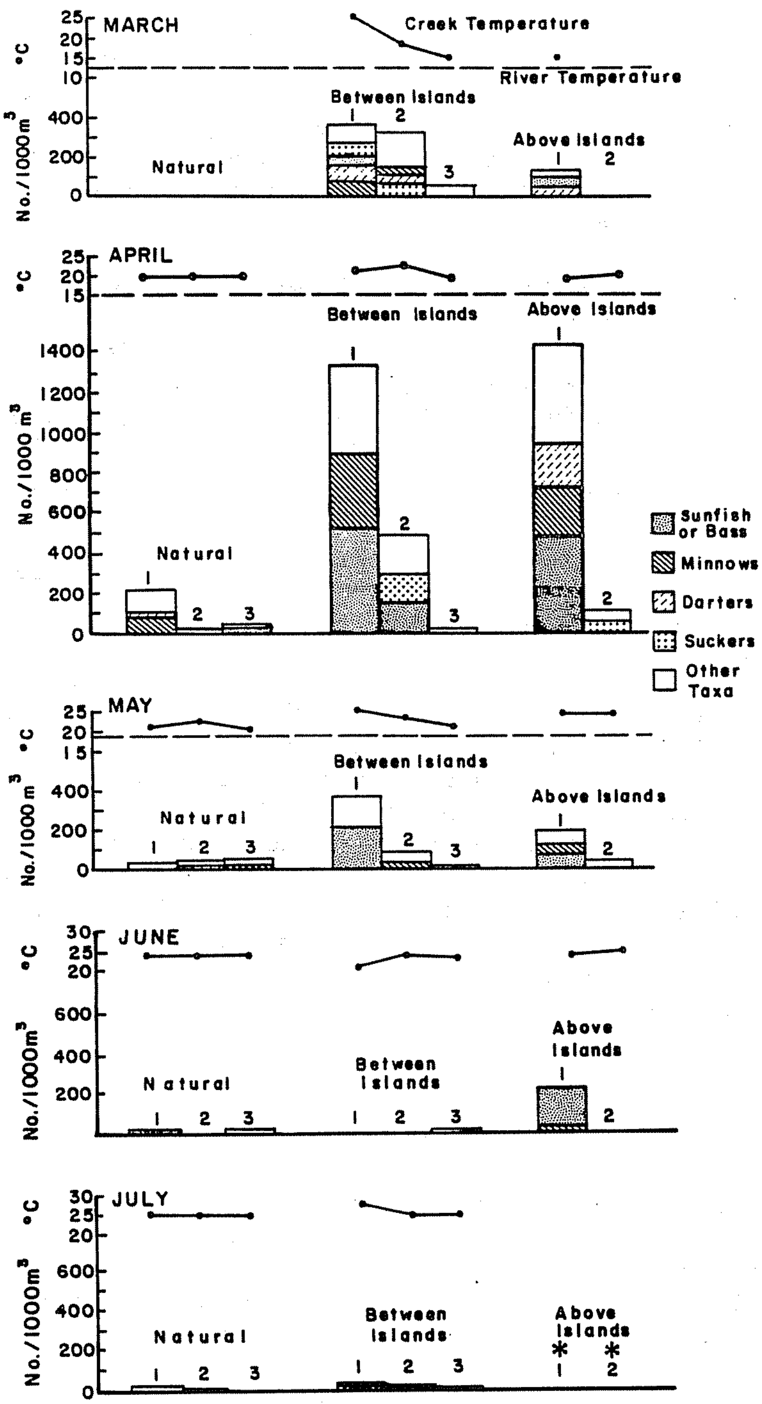


FIGURE V-4.23. Average Ichthyoplankton Density and Water Temperature at Eight Sampling Stations in the Steel Creek Swamp (March-July 1984) Source: Paller, 1985.

measured in 1984 at these stations. Aquatic macrophyte beds were far more extensive in the reduced canopy, post-thermal areas of the Steel Creek swamp than in the closed-canopy swamp. A scarcity of submerged and emergent vegetation may have been responsible for the relatively low ichthyoplankton densities observed in 1984 in the closed canopy swamp.

Average ichthyoplankton densities from February through July 1985 were fairly similar between, upstream, and downstream from the islands (Figure V-4.24). In contrast, the densities were much higher above and between the islands than downstream from the islands during 1984 (Paller, 1985). Densities were especially high at Stations 62 and 63 during 1984 (Figure V-4.25). These two stations were sampled infrequently during 1985 because low water levels made them inaccessible.

Much of the difference in ichthyoplankton densities between 1984 and 1985 could have been due to changes in the sampling methodology. During 1984, samples were occasionally collected in the Steel Creek swamp by towing plankton nets along the edges of macrophyte beds or by pumping water from submerged macrophyte beds with a 833 L/min pump. These procedures resulted in the capture of large numbers of larvae from the macrophyte beds. During 1985, all samples were taken by setting nets in the center of the channels in the swamp. The 1985 Microhabitat Study was conducted to quantify differences in larval fish abundance between macrophyte bed and open channel microhabitats in the Steel Creek swamp. The results of the microhabitat study are presented later in this report; however, they indicated that the macrophyte beds provided shelter and food for the developing larvae and, therefore, greater densities of larvae were collected there.

V.4.3.3.2.2 Meyers Branch

Two sample stations were located in Meyers Branch, a tributary of Steel Creek, for the 1984 and 1985 sample periods (Table V-4.31 and Figure V-4.15). One sample station (Station 39) was in the upper reaches of the tributary and the other (Station 40) was just upstream from the confluence with Steel Creek.

A total of 156 ichthyoplankters were collected from Meyers Branch in 1984, the majority of which were centrarchids and darters (Table V-4.42). Ichthyoplankton were generally more abundant at Station 39 in the upper reach of Meyers Branch than at Station 40 near the confluence with Steel Creek, especially during April (Figure V-4.26). The greater ichthyoplankton densities at the upstream station may have been due to several beaver dams located upstream from the collection site. The pools behind these dams provided favorable habitat for some species, particularly

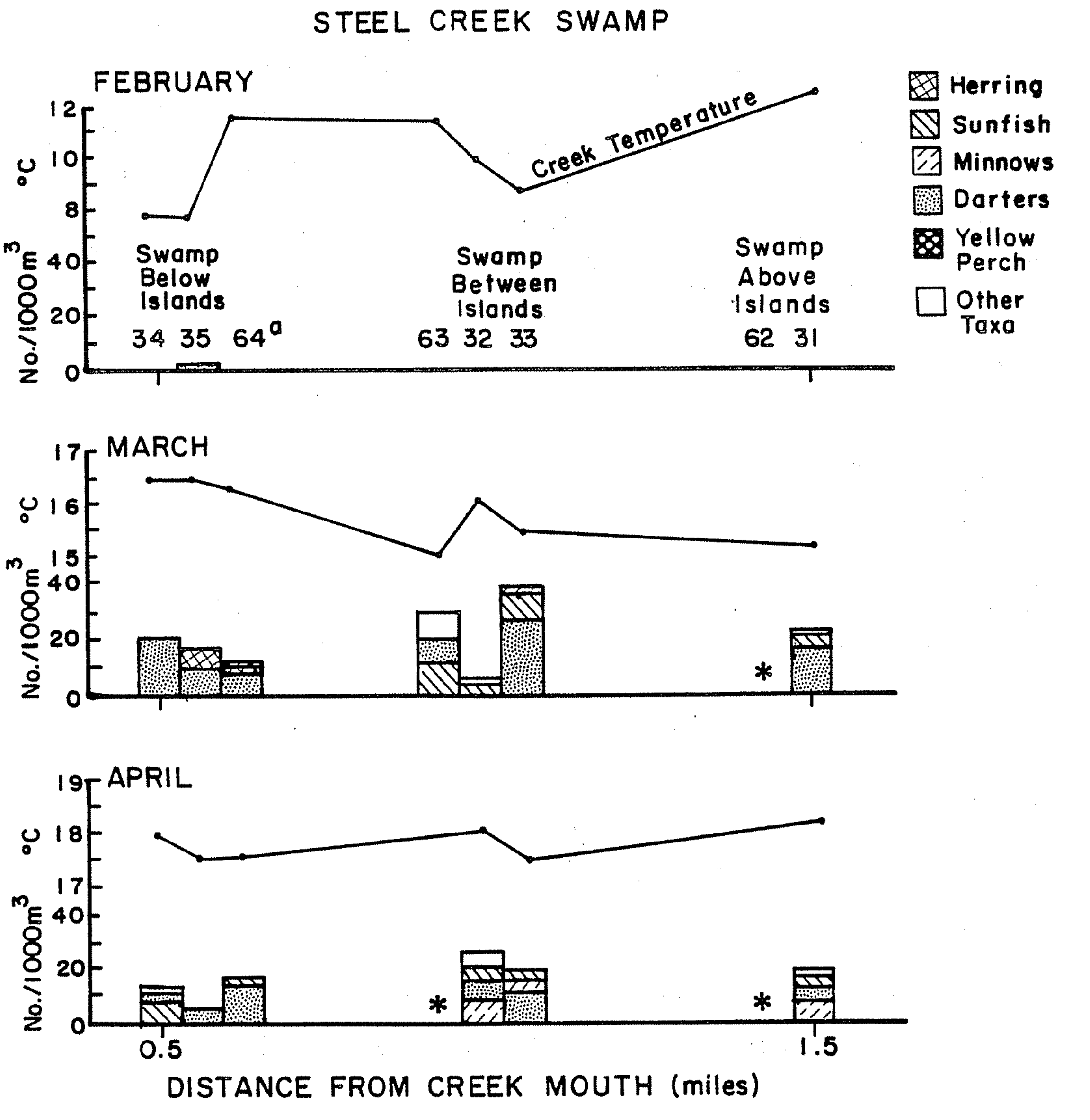
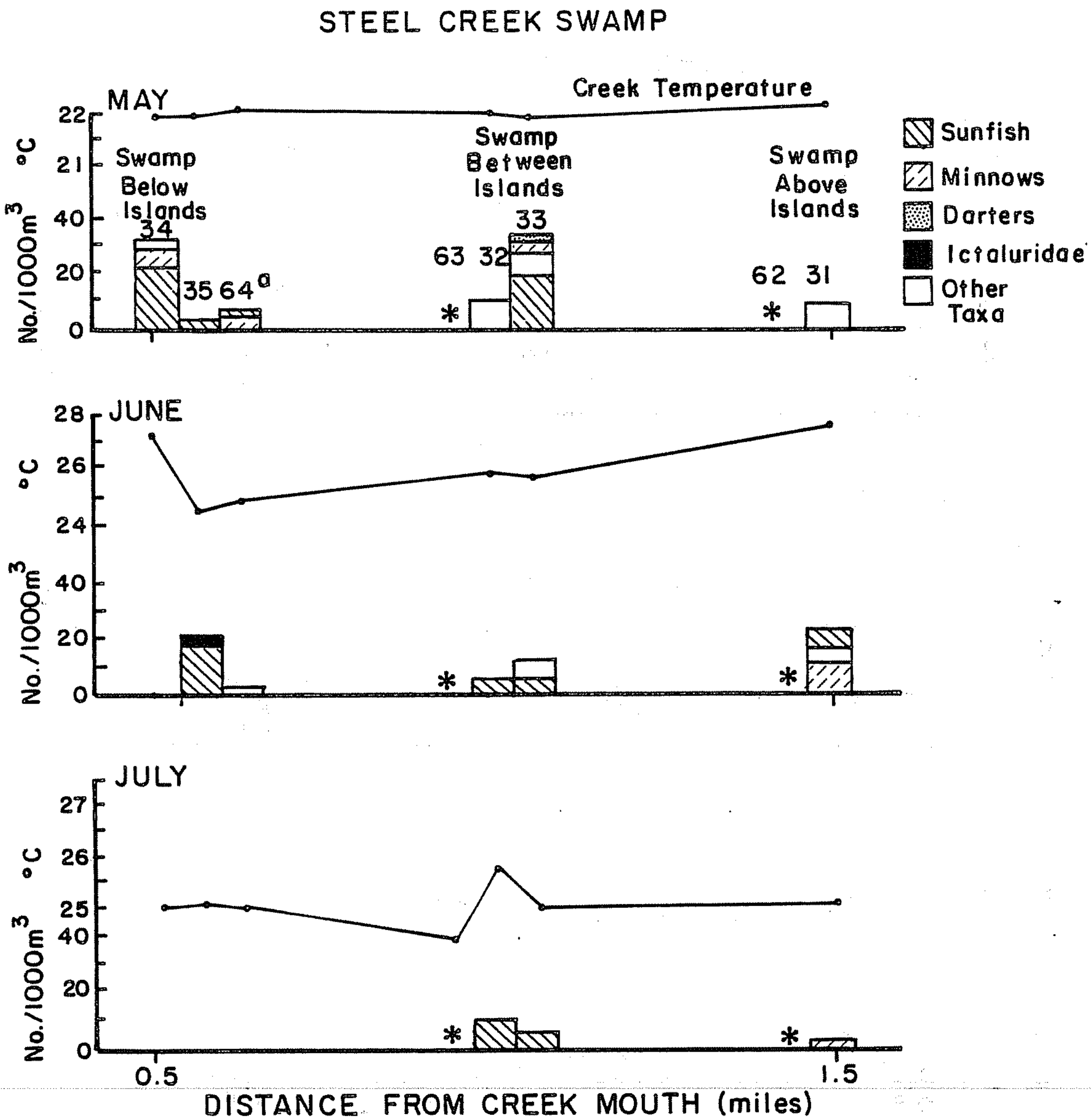


FIGURE V-4.24. Monthly Mean Water Temperature and Ichthyoplankton Density at Each Sampling Site in the Steel Creek Swamp (February-July 1985) Source: Paller et al., 1986a.



* Station numbers (see Figure V-4.21 for locations).
** Indicates no sample taken.

FIGURE V-4.24, Contd

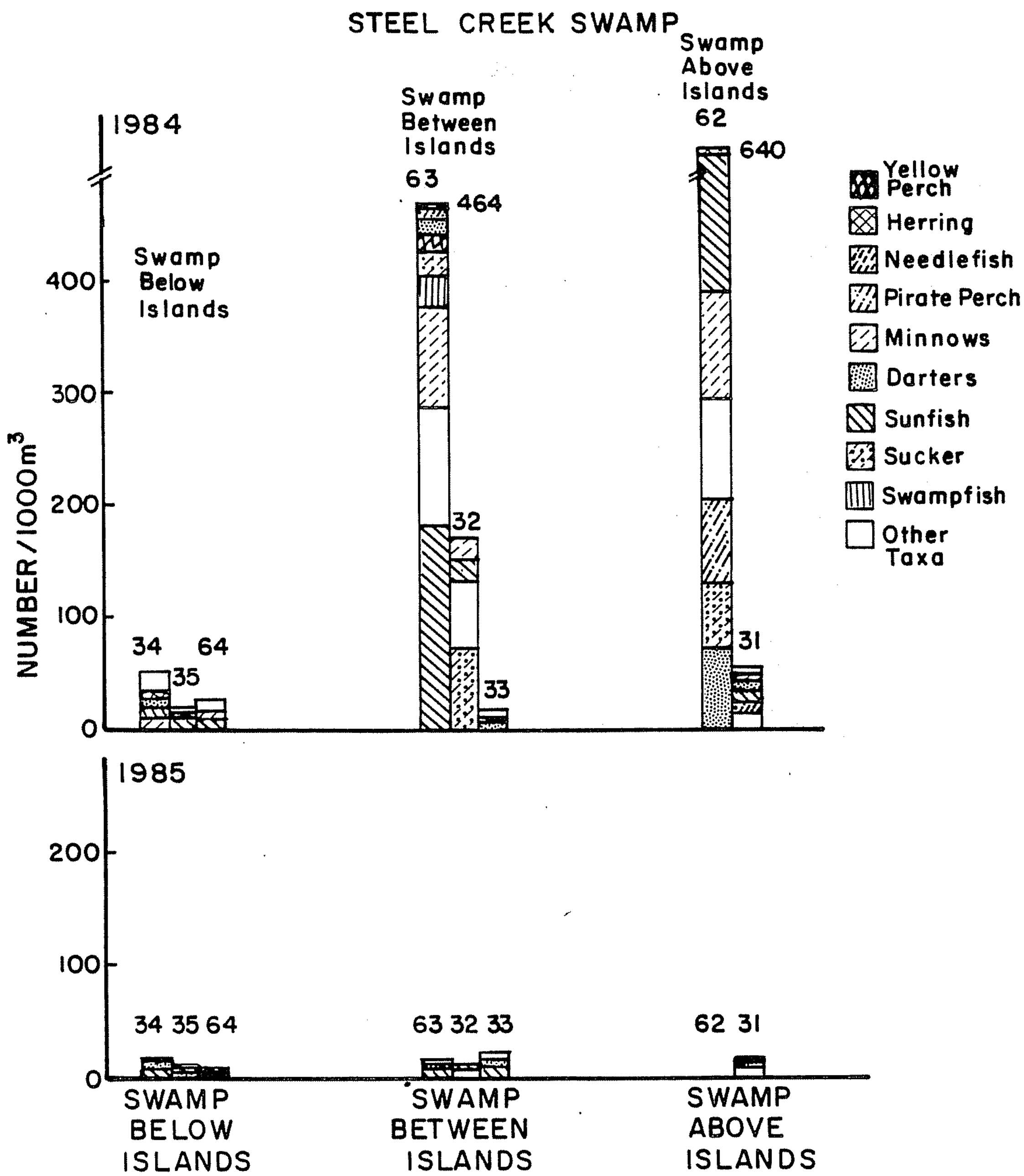


FIGURE V-4.25. Mean Ichthyoplankton Densities at Steel Creek Swamp Locations During the 1984 and 1985 Sampling Programs
Source: Paller et al., 1986a.

TABLE V-4.42

Number and Percent Composition of Ichthyoplankton Collected from Meyers Branch (March 14-July 31, 1984)

Taxa	Number	Percent
Gizzard and/or threadfin shad	3	1.9
Suckers	4	2.6
Sunfish and/or bass	66	42.3
Darters	45	28.8
Minnows	22	14.1
Brook silverside	1	0.6
Unid. ichthyoplankton	15	9.6
Total	156	99.9

Source: Paller, 1985.

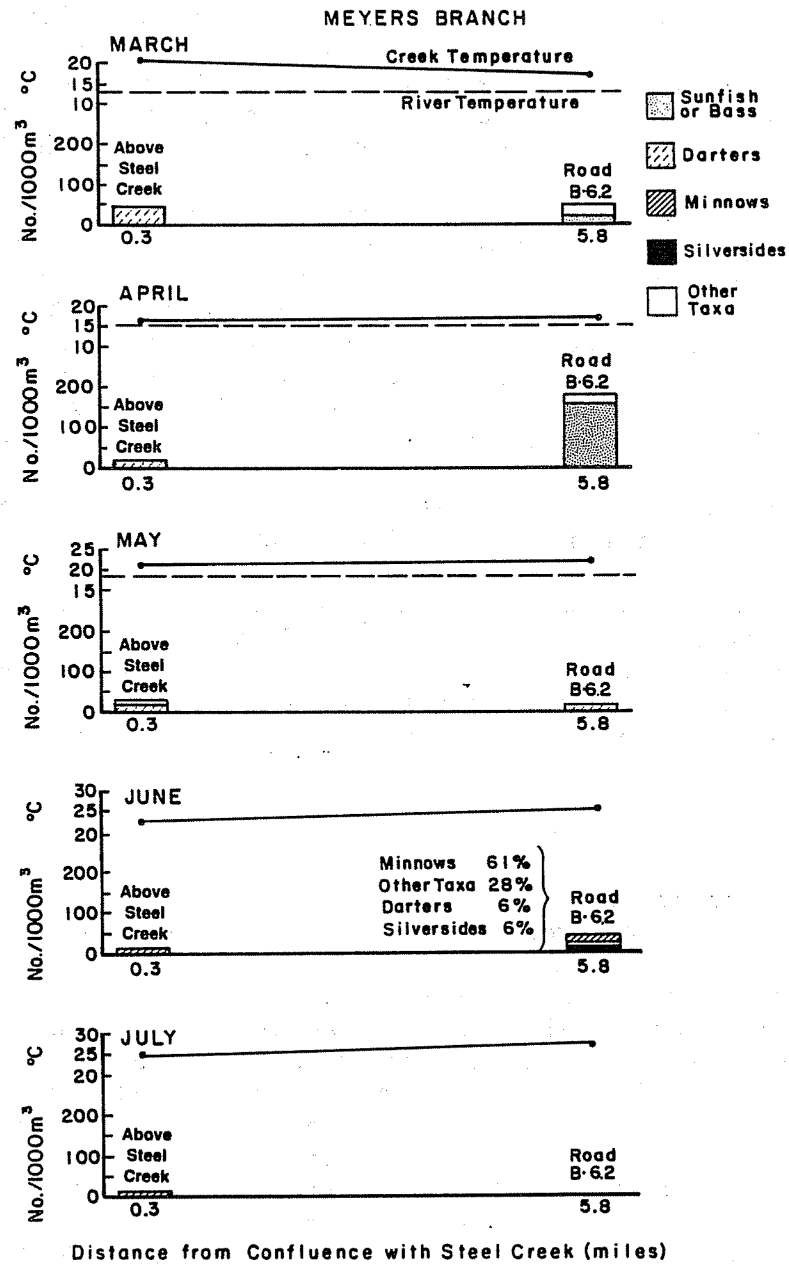


FIGURE V-4.26. Average Ichthyoplankton Density and Water Temperature at Two Sampling Stations in Meyers Branch (March-July 1984)
Source: Paller, 1985.

centrarchids, which were well-represented in the ichthyoplankton from the upstream Meyers Branch station (Paller, 1985). The relatively low number of ichthyoplankton collected from the station near the confluence with Steel Creek suggests that ichthyoplankton transport from Meyers Branch into Steel Creek was minimal.

In 1985, a total of 51 larvae and eggs were collected from Meyers Branch, most of which were darters and centrarchids (Table V-4.43). The first indications of reproductive activity appeared in March, with darter eggs and larvae being captured at both stations (Figure V-4.27). April was the main month of reproductive activity for most taxa. As was the case in 1984, total density was higher at the more upstream Station 39 during April. This was attributable primarily to higher densities of darter and sunfish eggs and larvae, a trend similar to that seen in 1984. In May, reproductive activity was higher at the more downstream Station 40. This trend was far less obvious during May 1984.

A comparison of annual results between 1984 and 1985 ichthyoplankton collections from Meyers Branch is shown in Figure V-4.28 and indicated that ichthyoplankton densities were greater during both years at the upstream station (Station 39) than at the station located near the confluence with Steel Creek (Station 40).

V.4.3.3.2.3 Pen Branch

Three sampling stations were located on Pen Branch for the 1984 and 1985 ichthyoplankton study (Table V-4.31 and Figure V-4.15). Station 20 was situated near Road B in the undisturbed headwaters upstream from the confluence with Indian Grave Branch. This station had a well-defined channel, a complete canopy, sand and gravel substrate, and moderate amounts of in-stream cover, such as log jams and leaf accumulations. The second station (Station 21) was located at Road A-13.2, approximately 7.0 km downstream from K Reactor. This station was characterized by greatly elevated temperatures (up to 40°C) and by greater depth and width, high current velocities, and sand and silt substrates. The third station (Station 22) was located in Pen Branch Delta, and was characterized by numerous standing dead cypress and tupelo trees, many braided channels, and large amounts of emergent vegetation. Temperatures were elevated at Station 22, but not to the extent that they were at Station 21 (Table V-4.34).

A total of 53 ichthyoplankters were collected from Pen Branch between March and July 1984 (Table V-4.44). Most of the minnows and darters were collected upstream from the reactor. With the exception of a few unidentifiable eggs, ichthyoplankton were absent from the site at Road A-13.2 where water temperatures reached as high as 49°C (Figure V-4.29). The eggs that were collected at Road A-13.2 probably drifted in from cooler refugia located in side

TABLE V-4.43

Number and Percent Composition of Ichthyoplankton Collected from Meyers Branch (February-July 1985)

Taxa	Number	Percent
Minnows	5	9.8
Spotted suckers	1	2.0
Sunfish and/or bass	20	39.2
Darters	23	45.1
Yellow perch	1	2.0
Unid. ichthyoplankton	1	2.0
Total	51	100.1

Source: Paller, 1986a.

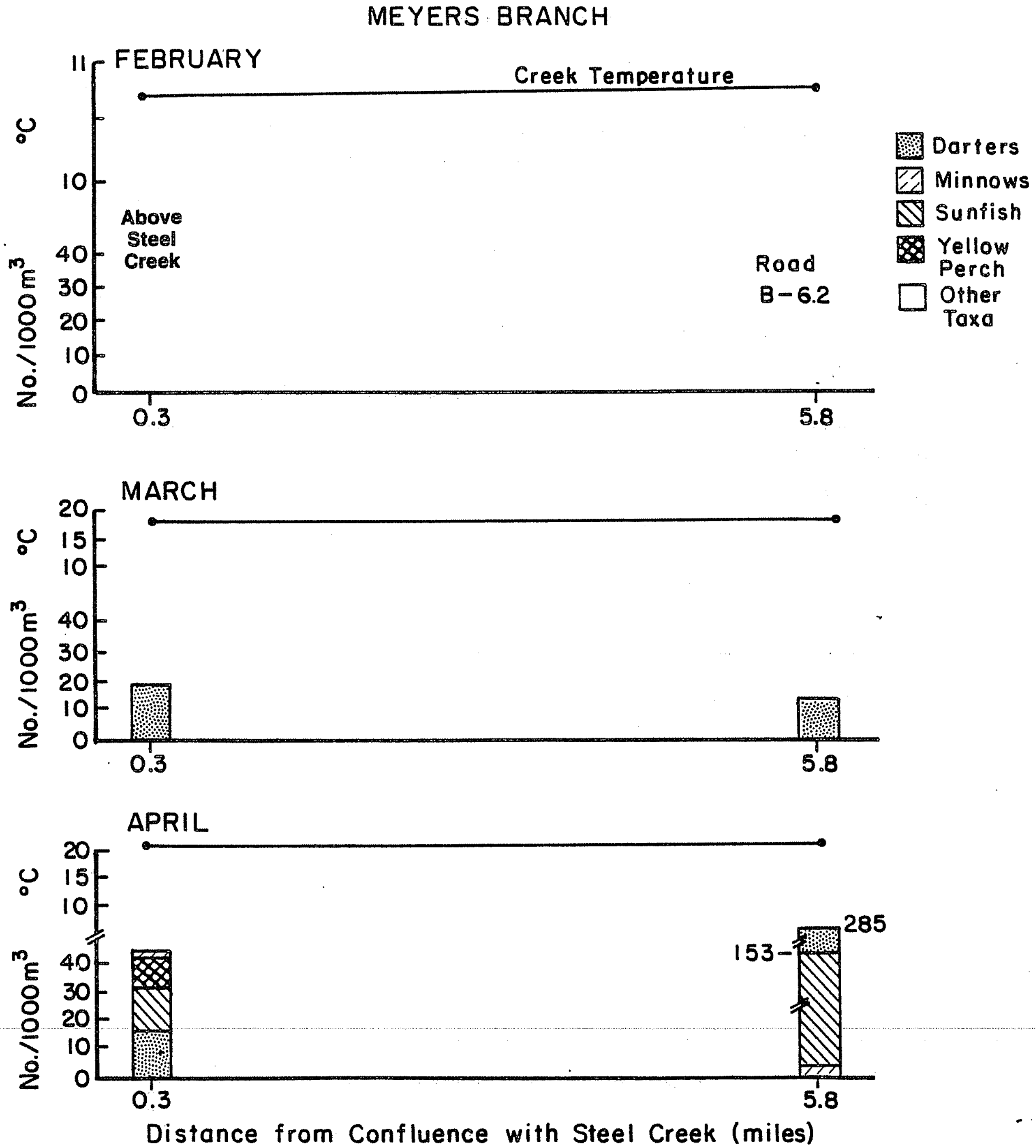


FIGURE V-4.27. **Average Ichthyoplankton Density and Monthly Mean Water Temperature at Two Stations in Meyers Branch (February-July 1985)**

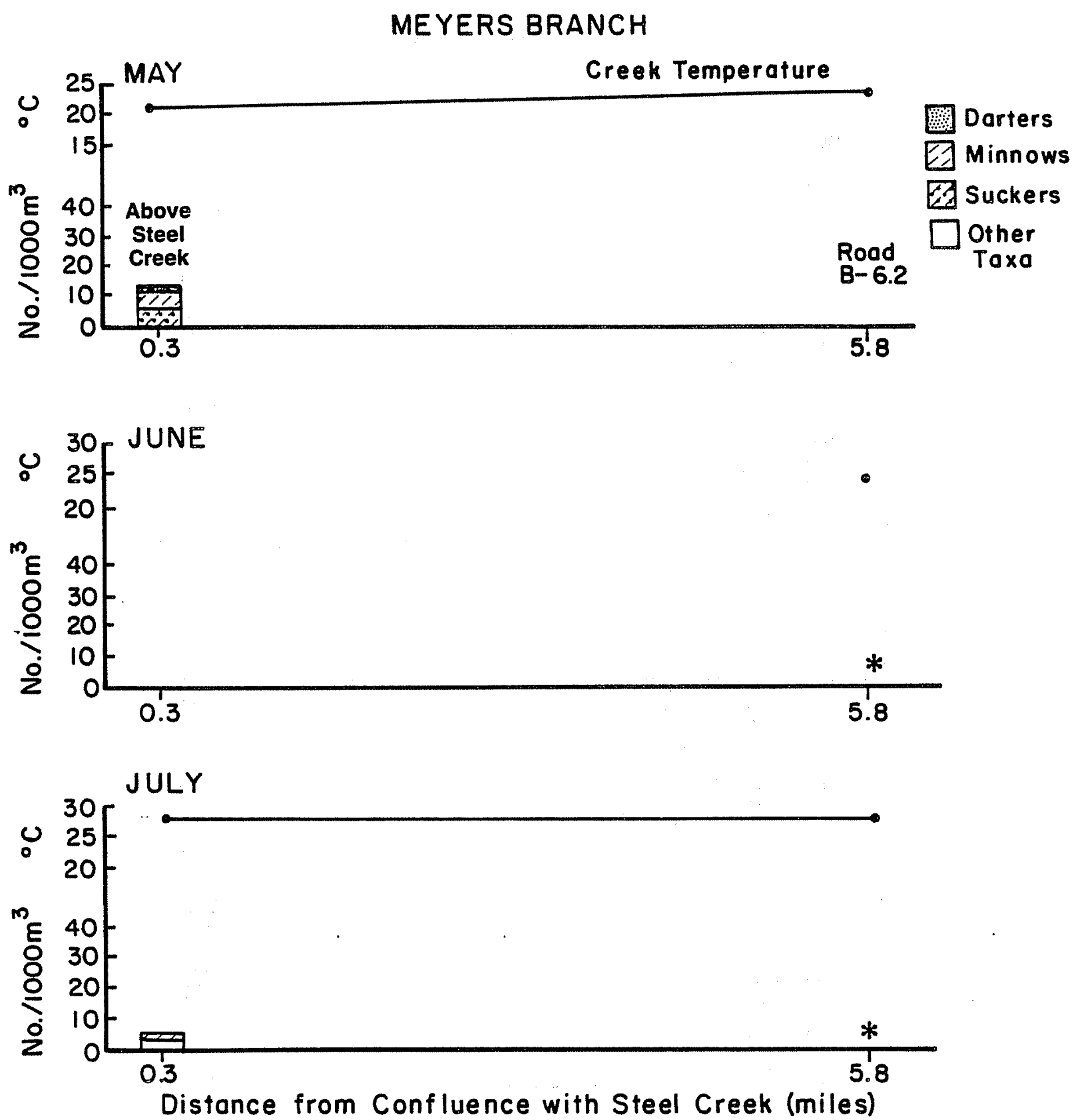


FIGURE V-4.27, Contd

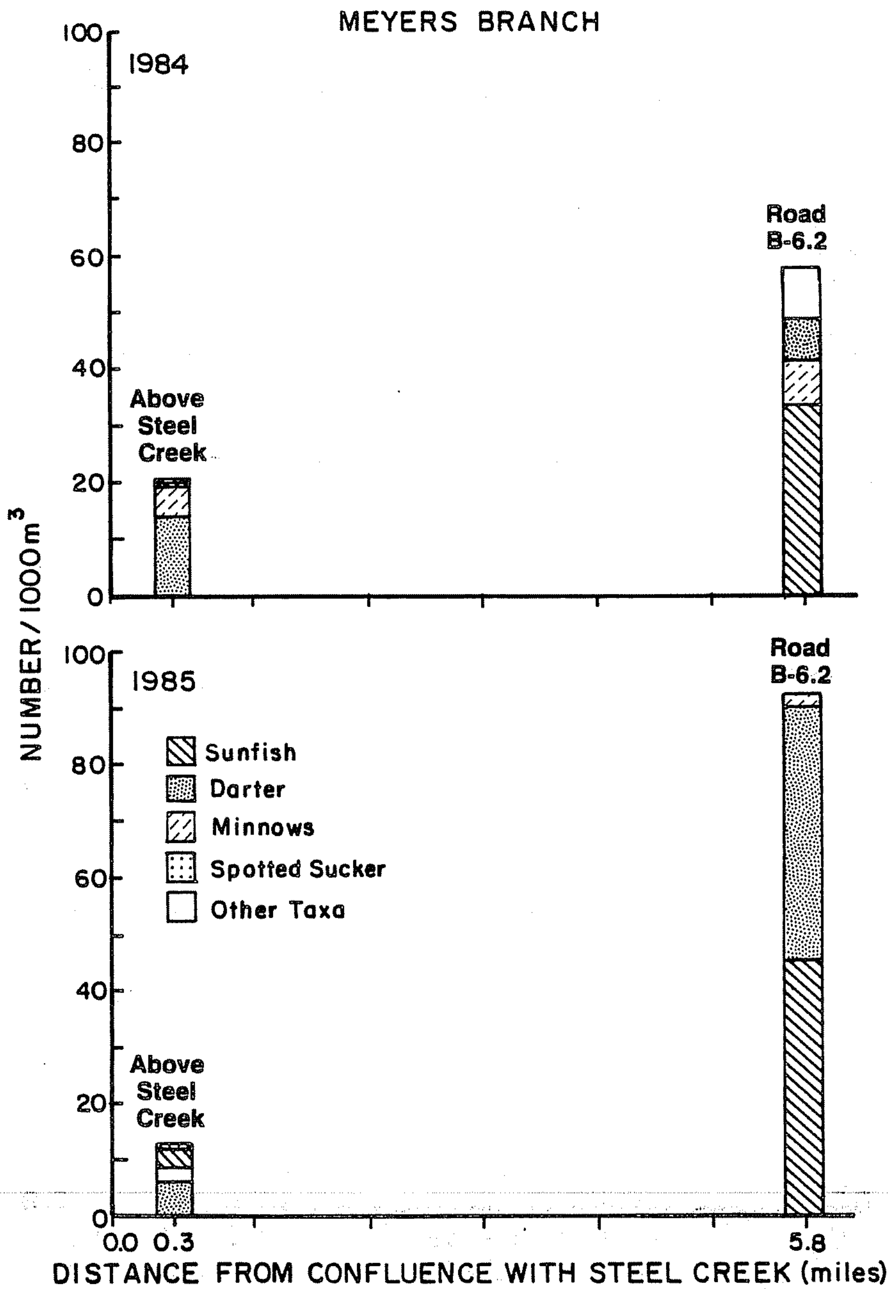


FIGURE V-4.28. Mean Ichthyoplankton Densities at Meyers Branch Locations During the 1984 and 1985 Sampling Programs
Source: Paller et al., 1986a.

TABLE V-4.44

Number and Percent Composition of Ichthyoplankton Collected from Pen Branch (March 14-July 31, 1984)

Taxa	Number	Percent
Suckers	4	7.5
Sunfish and/or bass	2	3.8
Darters	16	30.2
Swampfish	1	1.9
Minnows	19	35.8
Mosquitofish	3	5.7
Topminnow	1	1.9
Catfish and/or bullhead	1	1.9
Unid. ichthyoplankton	6	11.3
Total	53	100.0

Source: Paller, 1985.

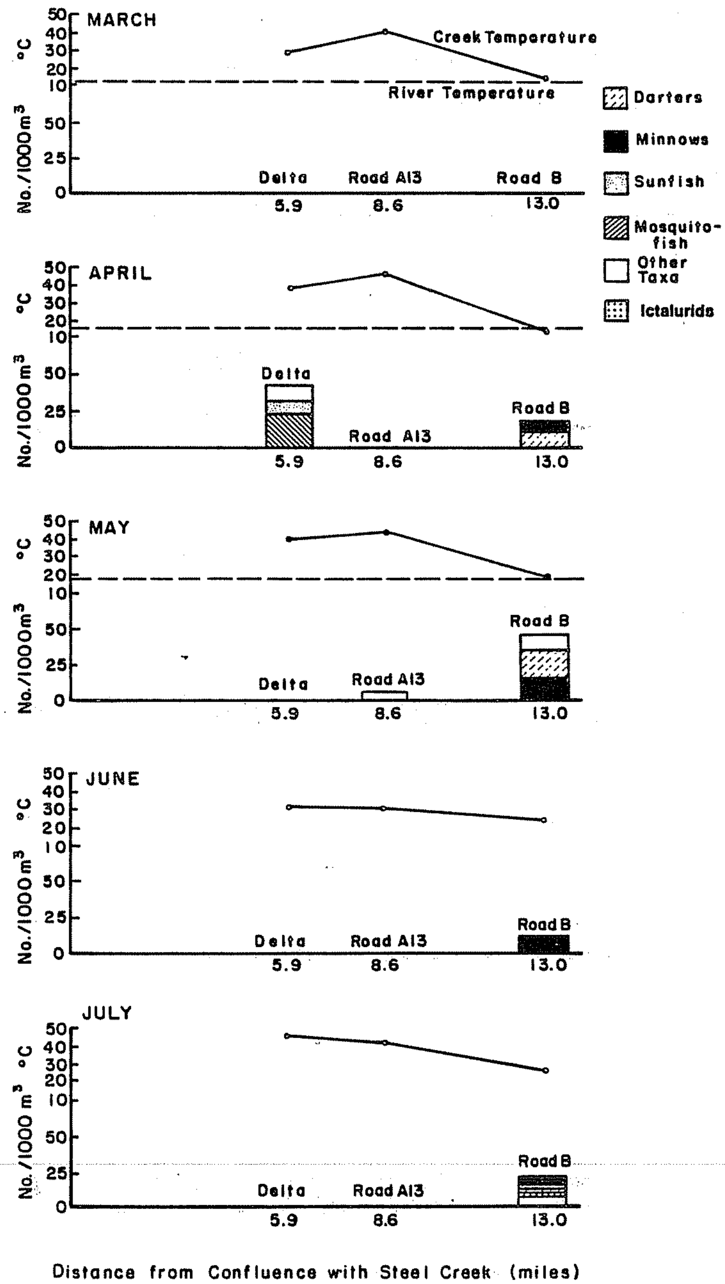


FIGURE V-4.29. Average Ichthyoplankton Density and Water Temperature at Three Sampling Stations Along Pen Branch (March-July 1984). Source: Paller, 1985.

channels and shallow pools off the main channel. The delta sampling station was somewhat cooler than the station at Road A-13.2, but temperatures still reached 45°C. The mosquitofish (Gambusia affinis) comprised the most abundant taxon collected at the delta sampling station in April 1984, the only month of reproductive activity at Station 22.

A total of 22 ichthyoplankters were collected from Pen Branch between February and July 1985 (Table V-4.45). The only place in Pen Branch where ichthyoplankton were consistently collected in 1985 was upstream from the reactor. In 1985, ichthyoplankton were never collected from the site at Road A-13.2 (Figure V-4.30).

V.4.3.3.2.4 Four Mile Creek

Six stations were sampled on Four Mile Creek during the 1983-1984 sampling program: one in the midreaches (at Road A approximately 8 km downstream from C Reactor), one at the inflow into the delta, three in the thermal swamp downstream from the delta, and one in the creek mouth (Table V-4.31 and Figure V-4.15). The three thermal swamp stations were grouped together in the following analysis because they had similar habitats and temperatures. One additional station was added to the sampling program in 1985 at Road A-7, which is located approximately 1.5 km upstream from C-Reactor outfall.

A total of 206 ichthyoplankters were collected from Four Mile Creek between March 14 and July 31, 1984. Centrarchids were the most abundant taxa, although brook silverside and blueback herring were also well-represented (Table V-4.46).

C Reactor was operating at full power throughout April and May (although it operated only intermittently during March). As a result, temperatures at Road A ranged from 33.9 to 50.1°C and temperatures at the inflow into the delta ranged from 30.1 to 44.8°C (Figure V-4.31). Ichthyoplankton were absent from these sites with the exception of some brook silverside eggs and unidentifiable eggs collected from the Road A sample site in May 1984. These eggs probably drifted into the channel of Four Mile Creek from cooler side-channel waters (Paller, 1985).

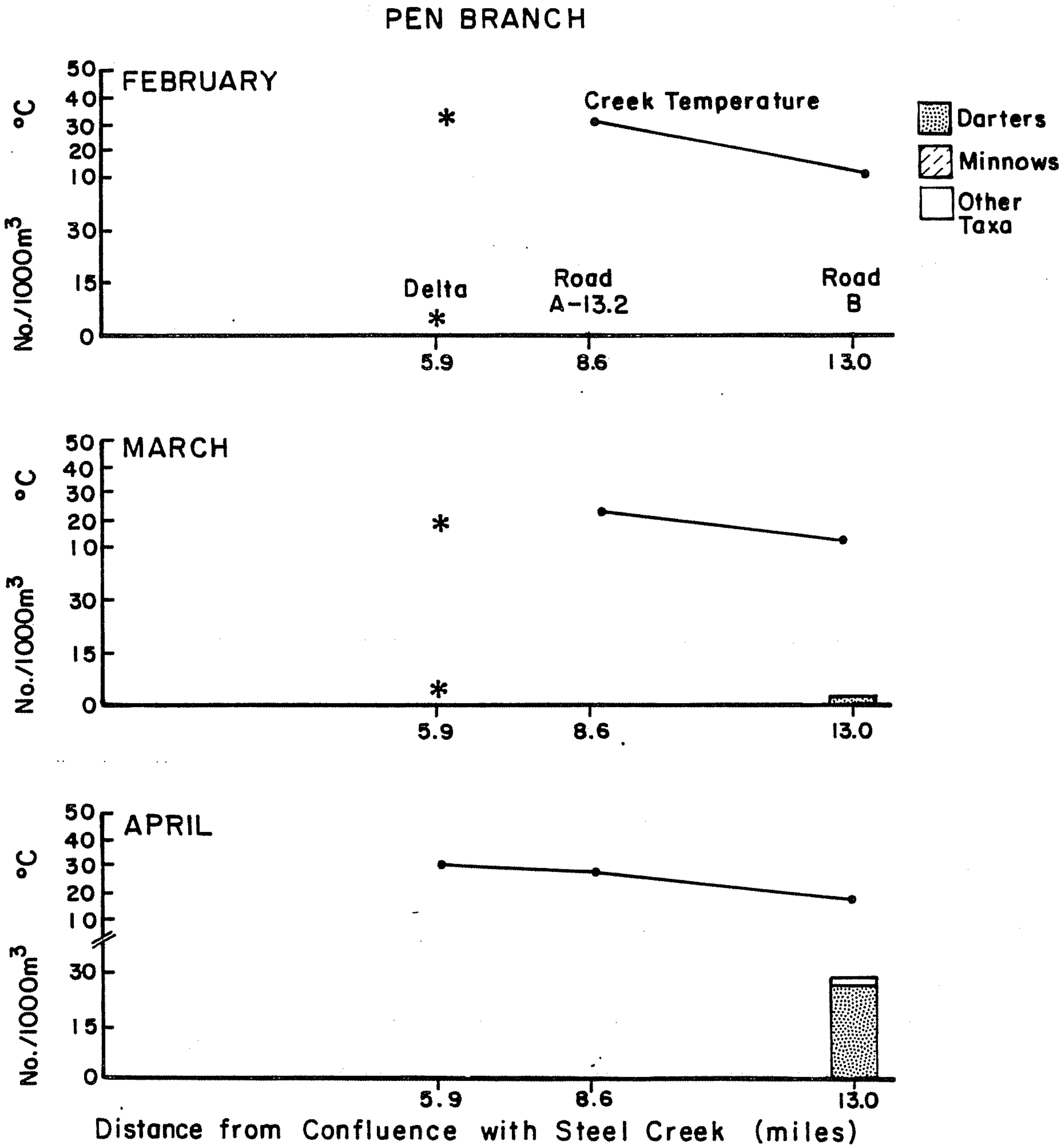
Temperatures in the Four Mile Creek thermal swamp and creek mouth ranged from 18 to 42°C, and were lower and much more variable than at the inflow into the Four Mile Creek Delta and at the Road A sample stations. The temperature variability in the thermal swamp was due to the intermittent intrusion of relatively cool river water during periods of high water in the Savannah River. During these periods, the river water displaced the thermal plume and created suitable habitats for fishes in areas that normally were

TABLE V-4.45

Number and Percent Composition of Ichthyoplankton Collected from Pen Branch (February-July 1985)

Taxa	Number	Percent
Minnows	10	45.5
Sunfish and/or bass	1	4.5
Darters	8	36.4
Yellow perch	1	4.5
Unid. ichthyoplankton	2	9.1
Total	22	100.0

Source: Paller et al., 1986a.



* Indicates no sample taken.

FIGURE V-4.30. Monthly Mean Water Temperature and Ichthyoplankton Density at Each Sampling Site on Pen Branch (February–July 1985)
Source: Paller et al., 1986a.

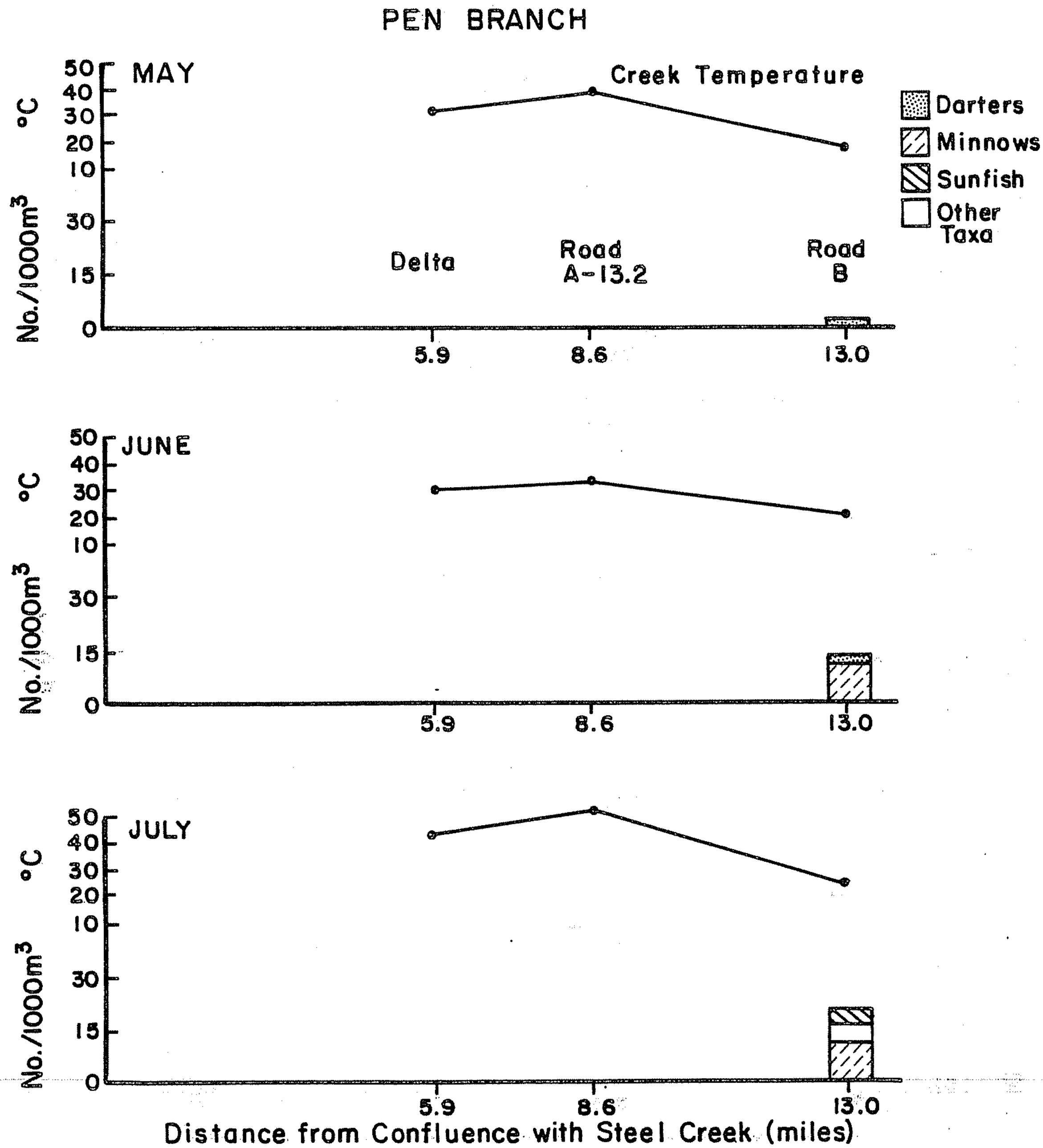


FIGURE V-4.30, Contd

TABLE V-4.46

Number and Percent Composition of Ichthyoplankton Collected from Four Mile Creek (March 14-July 31, 1984)

Taxa	Number	Percent
Gizzard and/or threadfin shad	16	7.8
Blueback herring	21	10.2
Unid. herring or shad	4	1.9
Sunfish and/or bass	66	32.0
Crappie	5	2.4
Yellow perch	1	0.5
Darters	2	1.0
Minnows	14	6.8
Carp	3	1.5
Brook silverside	28	13.6
Unid. ichthyoplankton*	46	22.3
Total	206	100.0

* Principally eggs.

Source: Paller, 1985.

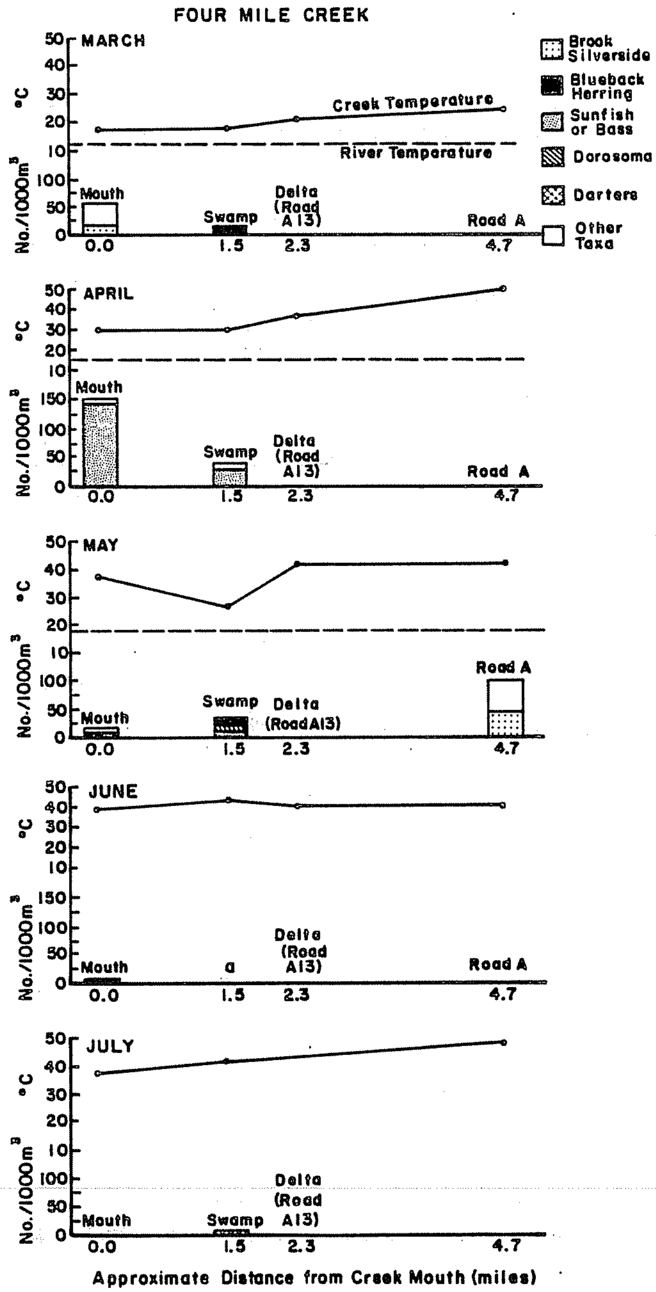


FIGURE V-4.31. Average Ichthyoplankton Density and Water Temperature at Four Sampling Stations Along Four Mile Creek (March-July 1984)
Source: Paller, 1985

hot. Most of the larvae collected from the Four Mile Creek thermal swamp during April and May were spawned during periods of high river water levels when the swamp was inundated with cool river water. These larvae were principally centrarchids, but also included blueback herring and threadfin or gizzard shad. Some larvae were also collected when temperatures were relatively high (37°C) in mid-April 1984. These larvae may have drifted into the main swamp channels from the cooler backwater areas (Paller, 1985).

A total of 174 ichthyoplankters were collected from Four Mile Creek between February and July 1985 (Table V-4.47). Unidentified ichthyoplankton (primarily eggs) were most common. Mean densities of ichthyoplankton upstream from C Reactor were generally low (<15/1,000 m^3), and most of the organisms collected were minnows or centrarchids (Figure V-4.32). Throughout the sampling period, ichthyoplankton were largely absent from the sample station near Road A where water temperatures sometimes exceeded 40°C when C Reactor was operating. Farther downstream in the delta, some cooling had occurred, but temperatures still remained near 40°C during much of the sampling period. Only in May were any eggs or larvae collected from the delta (i.e., Road A-13) station, and these were carp larvae.

Seasonal trends in ichthyoplankton density in Four Mile Creek swamp during 1985 (Figure V-4.32) were fairly consistent among the three stations. Highest ichthyoplankton densities were found during February and July, the only two months when temperatures averaged less than 30°C. However, some ichthyoplankton were collected from at least one swamp station during every month of sample collection. During February, darters, minnows, crappie, and sunfish were collected, while in July, the ichthyoplankton were all sunfish.

During April and June no larvae or eggs were collected from the mouth of Four Mile Creek (Figure V-4.32). Ichthyoplankton densities in the mouth of Four Mile Creek were greatest in May. Most of the ichthyoplankton collected during May were unidentifiable eggs, which were taken on a single sample date when C Reactor was briefly shut down and the water temperature was 27°C. These data suggest that fish began spawning in the creek mouth as soon as temperatures became tolerable (Paller et al., 1986a).

Except for the densities at the creek mouth, ichthyoplankton were less abundant in Four Mile Creek during 1985 than during 1984 (Figure V-4.33). The differences in the swamp and creek mouth ichthyoplankton densities were probably due to differences in the level of the Savannah River during these years. During the spring of 1984, the swamp was intermittently flooded by cool river water (Paller, 1985). Most of the larvae taken from the swamp during 1984 were collected when the swamp was flooded. Conversely, the

TABLE V-4.47

Number and Percent Composition of Ichthyoplankton Collected from Four Mile Creek (February-July 1985)

	Number	Percent
Blueback herring	3	1.7
Minnows	14	8.0
Carp	7	4.0
Mosquitofish	2	1.2
Brook silverside	2	1.2
Sunfish and/or bass	14	8.0
Crappie	3	1.7
Darters	6	3.4
Unid. ichthyoplankton	123	70.7
Total	174	99.9

Source: Paller et al., 1986a.

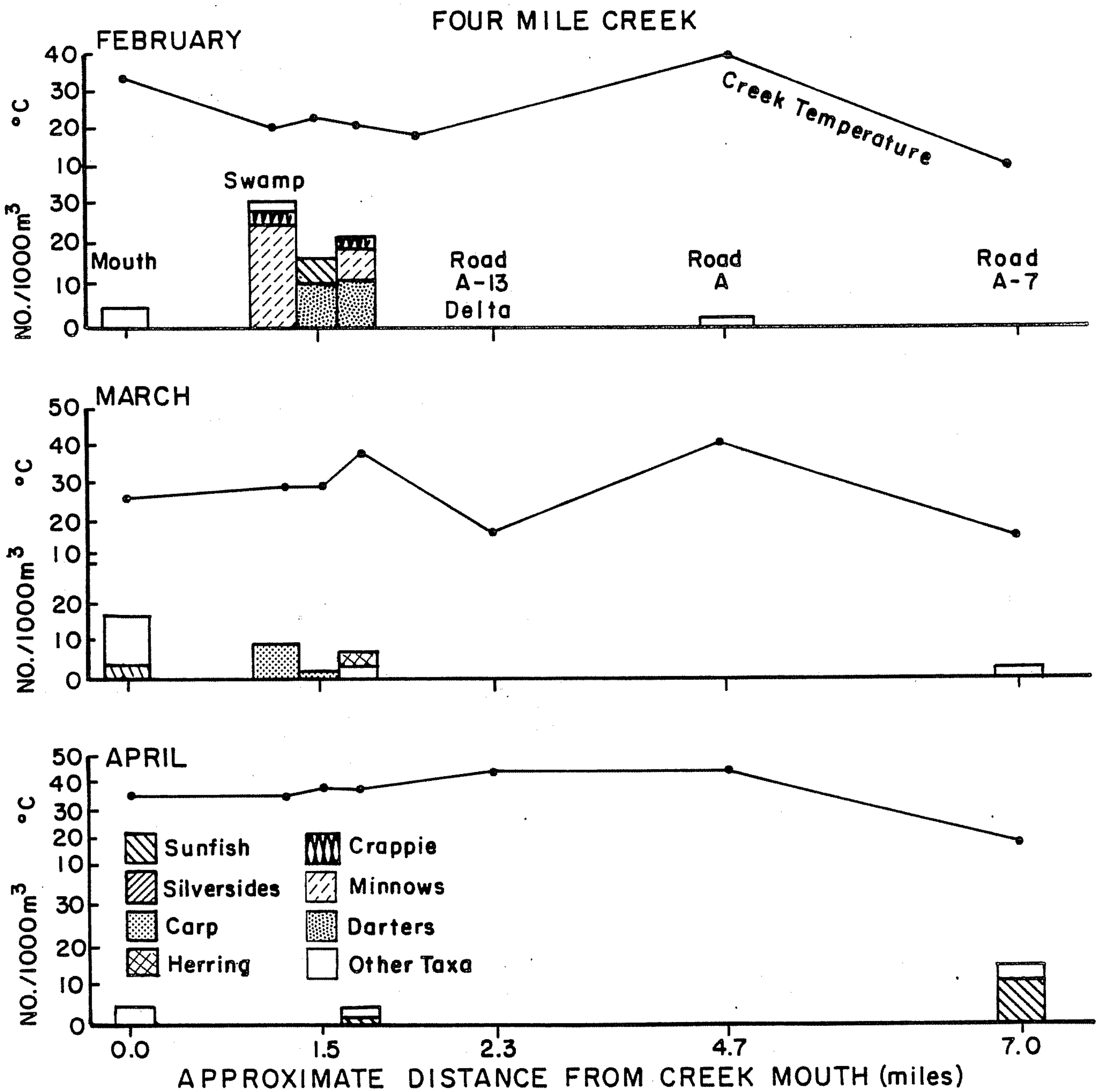


FIGURE V-4.32. Monthly Mean Water Temperature and Ichthyoplankton Density at Each Sampling Site in Four Mile Creek (February–July 1985)
Source: Paller et al., 1986a.

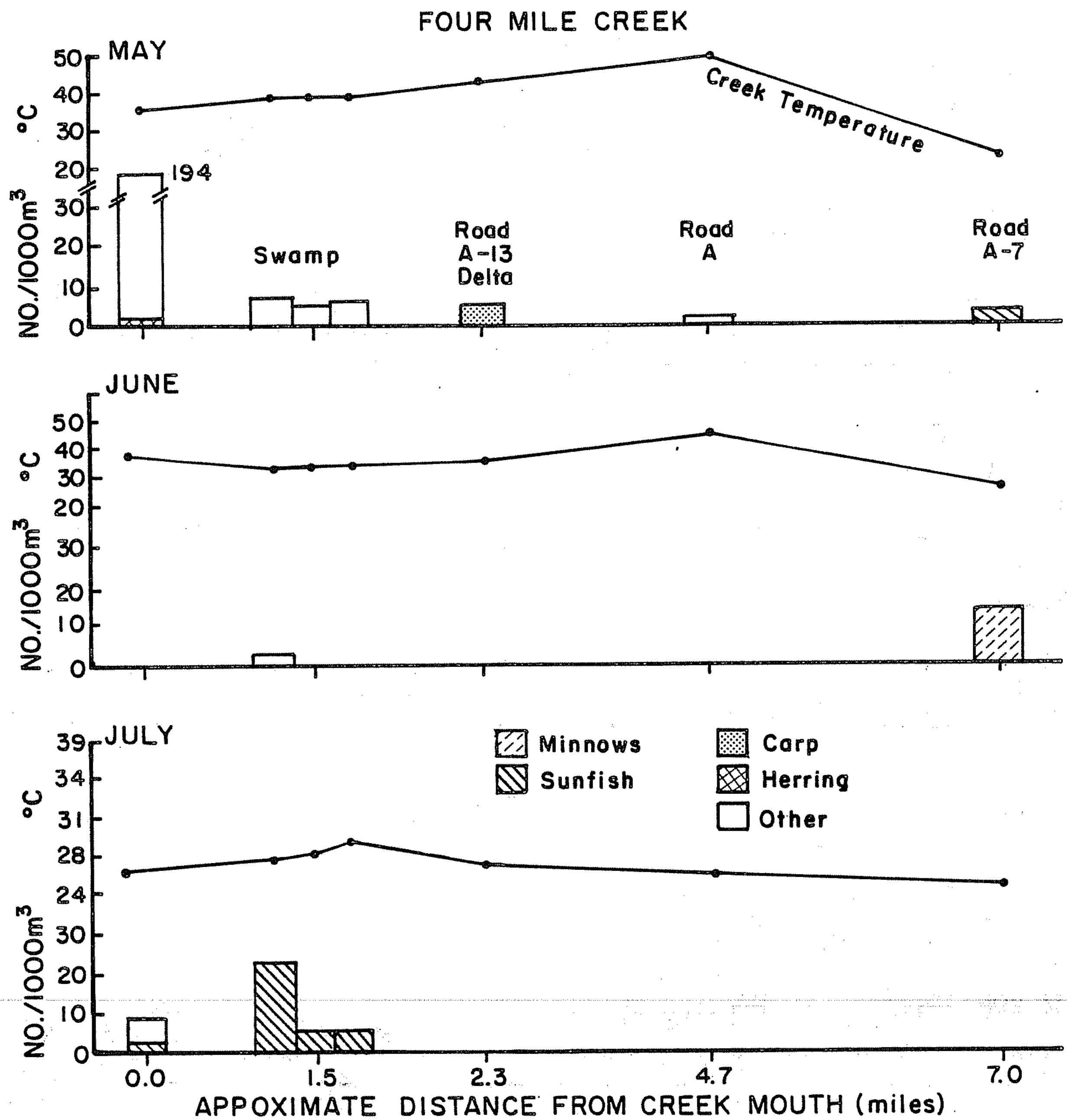
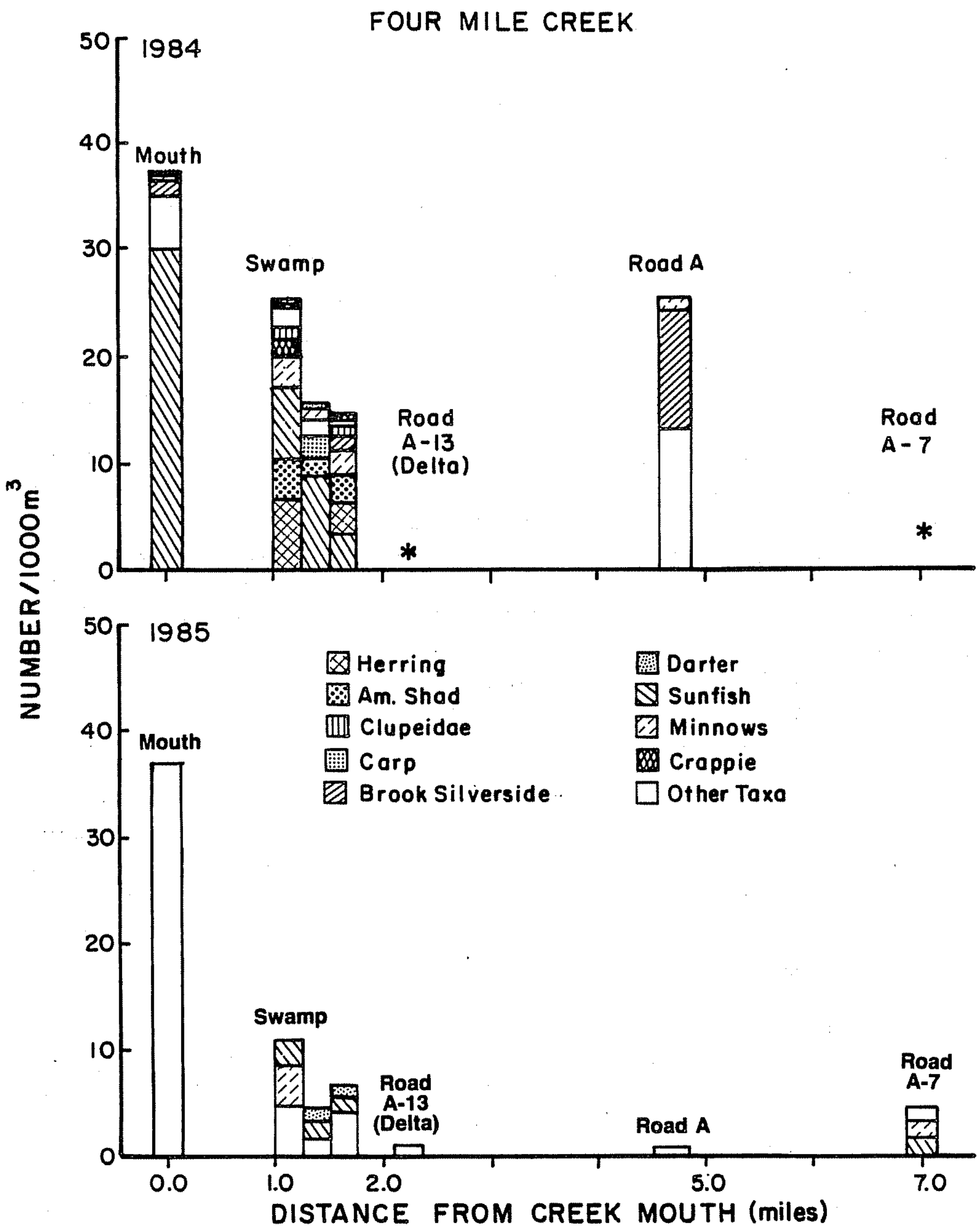


FIGURE V-4.32, Contd



* Indicates no sample taken.

FIGURE V-4.33. Total Ichthyoplankton Densities at Four Mile Creek Locations During the 1984 and 1985 Sampling Programs
Source: Paller et al., 1986a.

Savannah River generally remained below flood stage during 1985, and relatively few ichthyoplankton were collected from Four Mile Creek.

V.4.3.3.2.5 Beaver Dam Creek

Beaver Dam Creek begins in D Area and flows south, parallel to Four Mile Creek, to the Savannah River. Beaver Dam Creek receives thermal effluent from the coal-fired power station in D Area and formerly received nonthermal effluent water from the heavy water production facility.

In 1984 and 1985, there were five ichthyoplankton sampling stations in Beaver Dam Creek (Table V-4.31 and Figure V-4.15). The uppermost (Station 5) was located just below D Area (near Road A-12.2) in a deeply channelized (mean depth of 1.1 m) reach with very abrupt banks and a substrate of shifting sand, fly ash, organic ooze, and occasional clay outcroppings. Station 6 was in a narrow, vegetation-lined channel flowing through the upper flood-plain. Station 7 was farther downstream in a broad slough with large amounts of submerged and emergent vegetation. The last swamp station (Station 8) was approximately 0.6 km from the river in a swampy channel lined by willows (Salix sp.) and a few cypress. The remaining station (Station C152.1) was located in the creek mouth.

From March through July 1984, water temperatures in Beaver Dam Creek (Figure V-4.34) were not as high as in Pen Branch or Four Mile Creek (Figures V-4.29 and V-4.31, respectively). The upper reaches of Beaver Dam Creek (Road A-12) averaged approximately 7°C warmer than the Savannah River, while the swamp station averaged approximately 4°C warmer.

In general, temperatures in Beaver Dam Creek decreased from Road A-12 to the lowermost swamp station due to gradual downstream cooling. However, temperatures increased at the mouth, probably due to an influx of heated water through a channel connecting Four Mile Creek with Beaver Dam Creek.

A total of 334 ichthyoplankters were collected from Beaver Dam Creek between March 14 and July 31, 1984. The dominant taxa were centrarchids. Other taxa present in relatively large numbers were crappie, threadfin and gizzard shad, minnows, and darters (Table V-4.48). Figure V-4.34 illustrates the relationship between average ichthyoplankton densities and water temperature in Beaver Dam Creek.

In 1985, as in 1984, water temperatures in Beaver Dam Creek were not as high as in Four Mile Creek or Pen Branch. The highest average monthly water temperature in Beaver Dam Creek was 32.5°C at Station 6 which was recorded during July 1985 (Figure V-4.35).

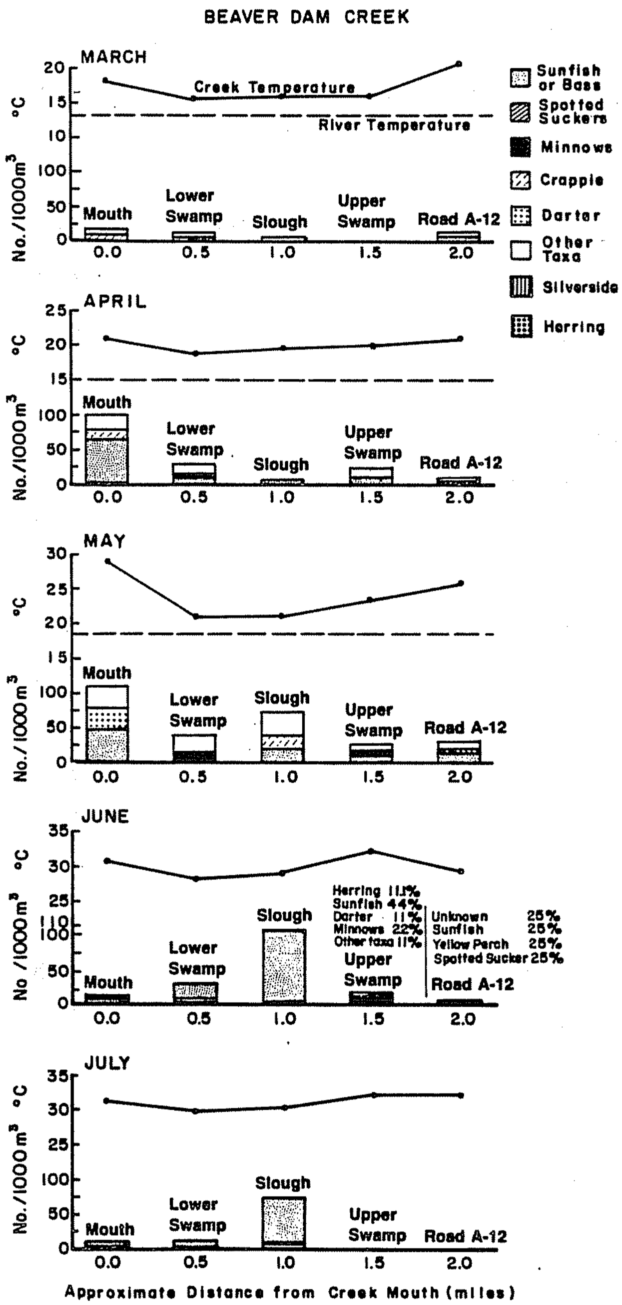


FIGURE V-4.34. Average Ichthyoplankton Density and Water Temperature at Five Sampling Stations Along Beaver Dam Creek (March-July 1984)

Source: Paller, 1985.

TABLE V-4.48

Number and Percent Composition of Ichthyoplankton Collected from Beaver Dam Creek (March 14–July 31, 1984)

Taxa	Number	Percent
American shad	1	0.3
Striped bass	1	0.3
Gizzard and/or threadfin shad	19	5.7
Blueback herring	9	2.7
Unid. herring or shad	5	1.5
Spotted sucker	4	1.2
Pirate perch	3	0.9
Sunfish and/or bass	177	53.0
Crappie	25	7.5
Yellow perch	1	0.3
Darters	21	6.3
Minnows	19	5.7
Topminnow	2	0.6
Carp	1	0.3
Brook silverside	11	3.3
Unid. ichthyoplankton	35	10.5
Total	334	100.1

Source: Paller, 1985.

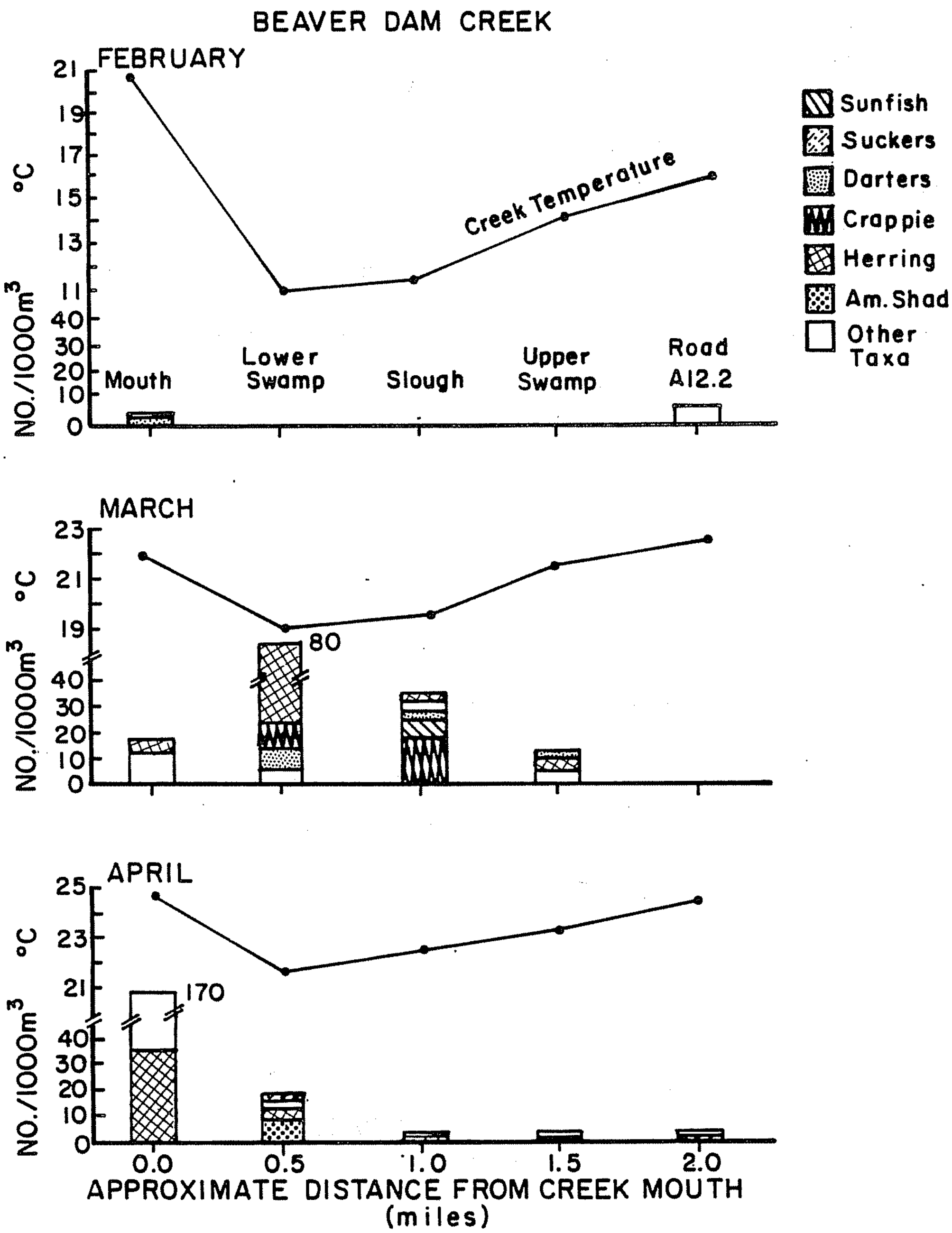


FIGURE V-4.35. Monthly Mean Water Temperature and Ichthyoplankton Density at Each Sampling Site on Beaver Dam Creek (February–July 1985)
Source: Paller et al., 1986a.

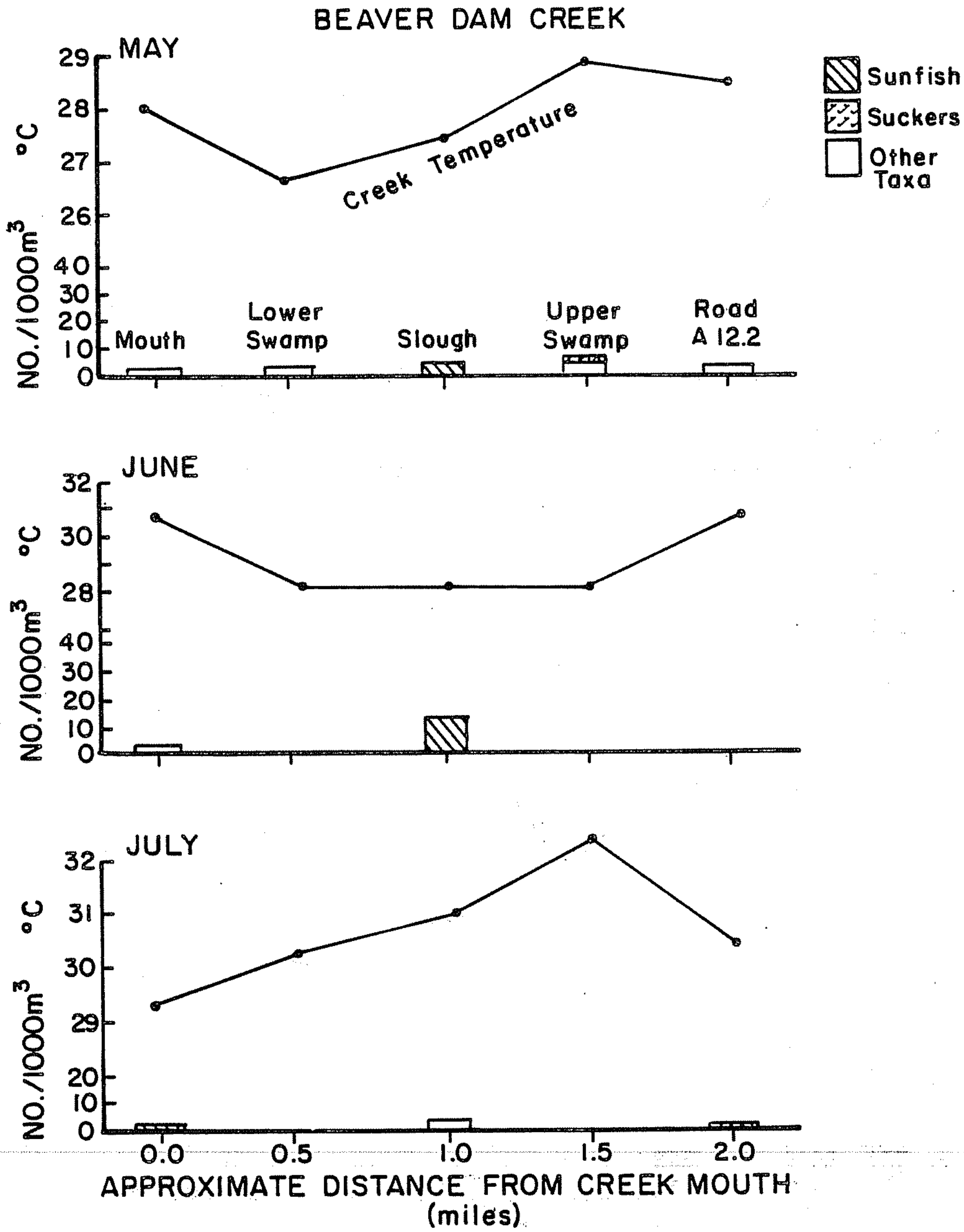


FIGURE V-4.35, Contd

A total of 253 ichthyoplankters were collected from Beaver Dam Creek between February and July 1985. The most abundant species was blueback herring (Table V-4.49). Centrarchids, which dominated the ichthyoplankton collections in Beaver Dam Creek in 1984, comprised only a small percentage of ichthyoplankton collected in 1985.

A comparison of the average ichthyoplankton densities in Beaver Dam Creek during 1984 and 1985 (Figure V-4.36) indicated that most of the spawning activity occurred in the creek mouth and downstream stations during both years (Paller, 1985).

V.4.3.3.2.6 Lower Three Runs Creek

In 1984, there were three sampling stations on Lower Three Runs Creek (Table V-4.31 and Figure V-4.15). The first station was in a pool in the Par Pond tailwaters (Station 42). The depth and flow rate at this station were governed by overflow from Par Pond. The second sampling station (Station 44) was located near Road A, approximately two-thirds of the distance from Par Pond to the Savannah River. The third station sampled in 1984 was in the mouth of Lower Three Runs (Station C129.0).

A total of 1,483 ichthyoplankters were collected from Lower Three Runs Creek between March and July 1984 (Table V-4.50). The vast majority were collected in the tailwater pool below Par Pond at Road B where ichthyoplankton densities averaged 625/1,000 m^3 compared to 14/1,000 m^3 at Road A and 24/1,000 m^3 in the creek mouth (Figure V-4.37). Most of the larvae collected in the tail-water pool were sunfish/bass, crappie, and yellow perch. These larvae probably originated in Par Pond and entered Lower Three Runs via the Par Pond overflow (Paller, 1985). The low ichthyoplankton densities at Road A, approximately 22.5 km downstream from the Par Pond tailwaters, suggested that few of the larvae in the tailwaters were transported that far downstream. During June, when the creek mouth station showed the highest density, sunfish/bass dominated the catch.

In the 1985 ichthyoplankton study there were seven sampling stations on Lower Three Runs. Three of the stations (Stations 65, 42, and 66) were located upstream, in the Par Pond tailwaters. The habitat at the third station (Station 66) was more representative of Lower Three Runs Creek than Stations 65 and 42 (upstream from Station 66), both of which were modified by Par Pond construction and Par Pond discharges. The three other sampling stations were located at the railroad trestle (Station 67), Road A-18 (Station 53), and at Road A (Station 44). The sample station farthest down-stream was located in the creek mouth.

TABLE V-4.49

Number and Percent Composition of Ichthyoplankton Collected from Beaver Dam Creek (February-July 1985)

Taxa	Number	Percent
Unid. herring or shad	3	1.2
Blueback herring	74	29.2
American shad	7	2.8
Pickerel	1	0.4
Minnows	2	0.8
Carp	1	0.4
Spotted sucker	5	2.0
Catfish and/or bullhead	1	0.4
Topminnow	1	0.4
Mosquitofish	1	0.4
Sunfish and/or bass	13	5.1
Crappie	16	6.3
Darters	9	3.6
Yellow perch	1	0.4
Unid. ichthyoplankton	118	46.6
Total	253	100.0

Source: Paller et al., 1986a.

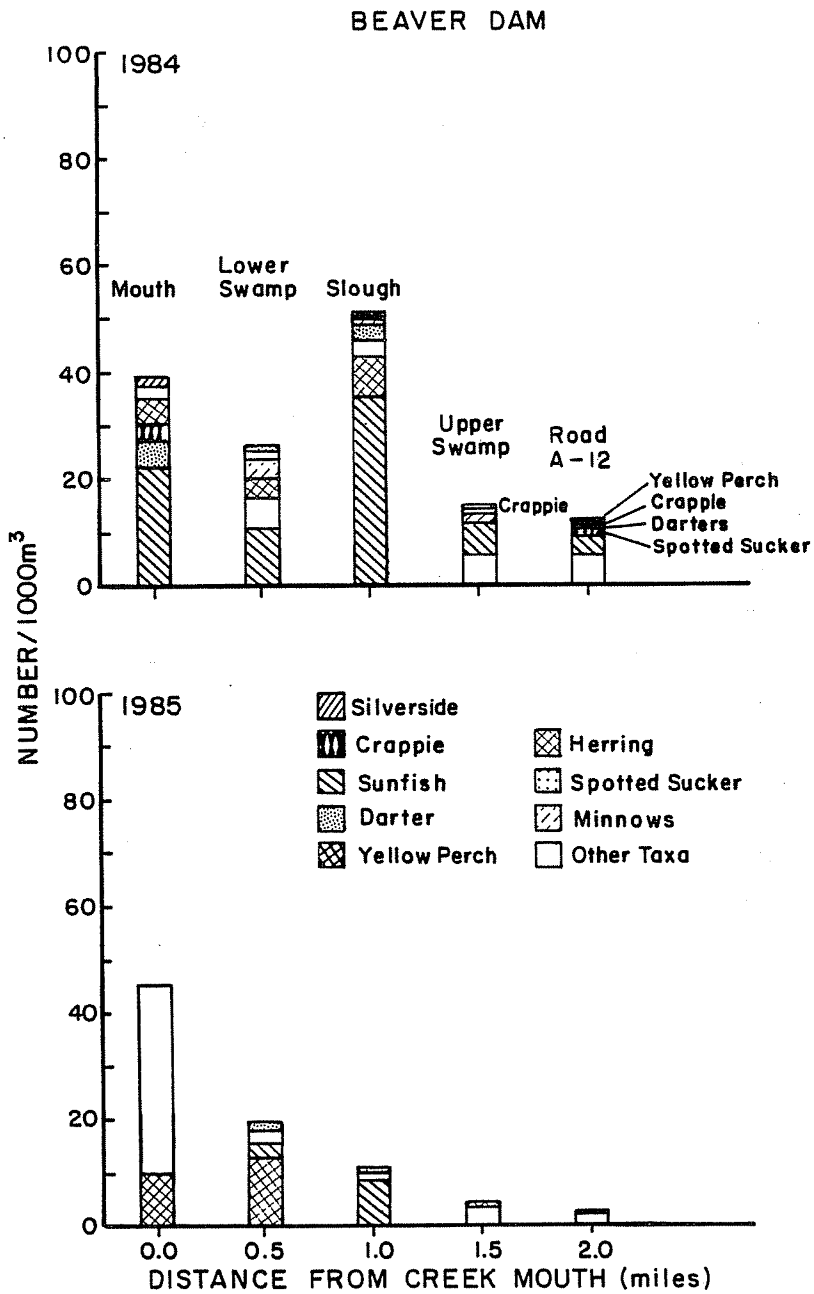


FIGURE V-4.36. Total Ichthyoplankton Densities at Beaver Dam Creek Locations During the 1984 and 1985 Sampling Programs
Source: Paller et al., 1986a

TABLE V-4.50

Number and Percent Composition of Ichthyoplankton Collected from Lower Three Runs Creek (March 14-July 31, 1984)

Taxa	Number	Percent
American shad	1	0.1
Gizzard and/or threadfin shad	23	1.6
Blueback herring	20	1.3
Unid. herring or shad	16	1.1
Spotted sucker	7	0.5
Unid. suckers	15	1.0
Sunfish and/or bass	671	45.2
Crappie	266	17.9
Yellow perch	29	2.0
Darters	160	10.8
Minnows	24	1.6
Mosquitofish	1	0.1
Brook silverside	78	5.3
Unid. ichthyoplankton*	172	11.6
Total	1,483	100.1

* Principally eggs.

Source: Paller, 1985.

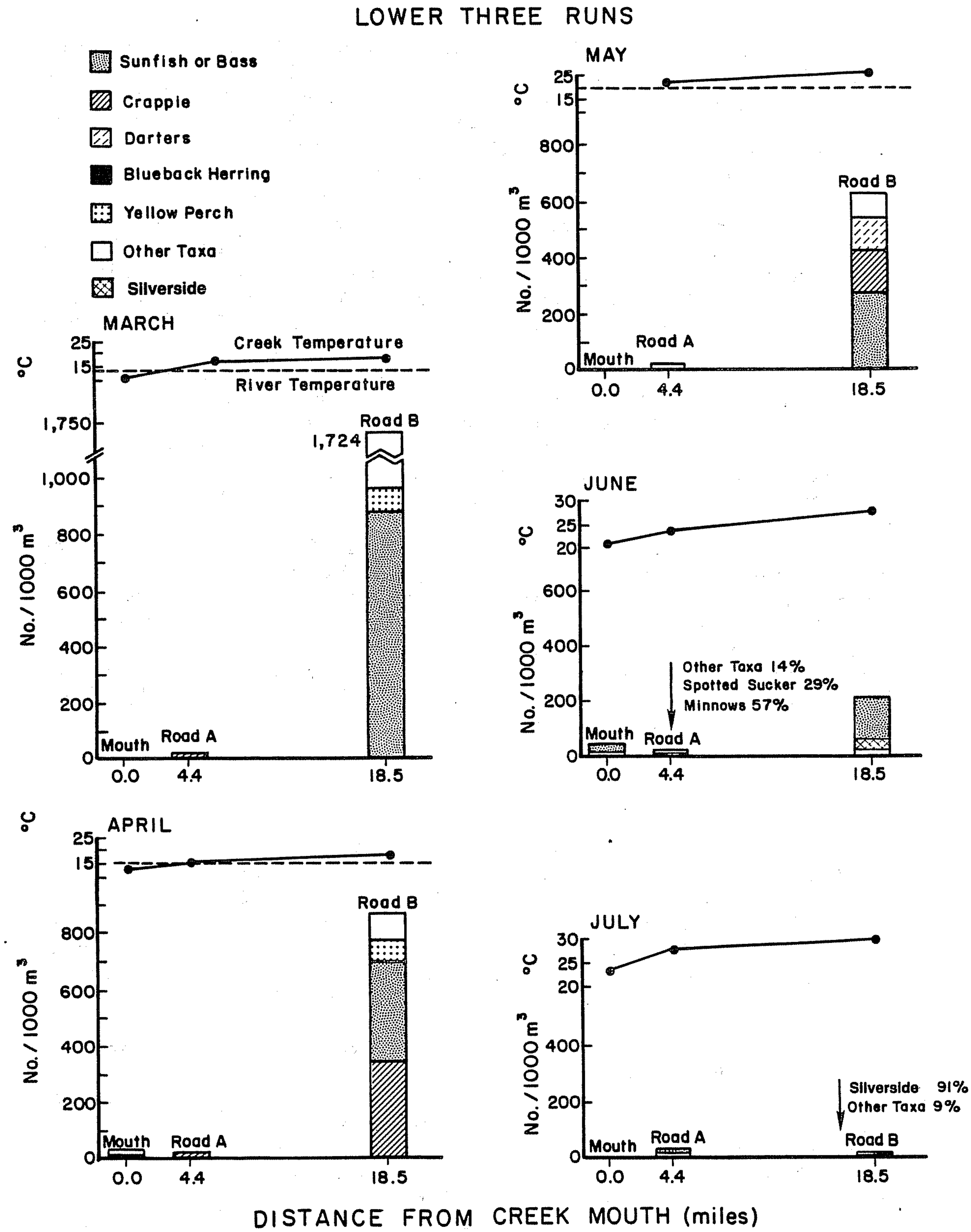


FIGURE V-4.37. Average Ichthyoplankton Density and Water Temperature at Three Sampling Stations Along Lower Three Runs Creek (March-July 1984)
Source: Paller, 1985.

A total of 446 ichthyoplankters were collected from Lower Three Runs between February and July 1985 (Table V-4.51). Most of the ichthyoplankton from Lower Three Runs Creek were collected at the three tailwater sample stations in the Par Pond tailwaters (Figure V-4.38). As in 1984, the ichthyoplankton collected at this site appear to have originated in Par Pond and entered Lower Three Runs Creek via the Par Pond spillway. During February, minnows and darters numerically dominated the tailwater samples, and as the season progressed, crappie, sunfish/bass, and silversides became relatively more important. The exception was in June, when minnows were the most abundant ichthyoplankters. In contrast, minnow eggs or larvae were not collected in May and July. Densities were consistently low at the station located approximately 50 m below Road B, indicating that few of the ichthyoplankton conveyed from Par Pond to Lower Three Runs Creek were transported farther than approximately 400-500 m downstream from the Par Pond dam. Ichthyoplankton densities at the four sample stations downstream from the Par Pond tailwater stations were low to moderate (0 to 70/1,000 m^3), and consisted primarily of darters, sunfish, and suckers.

Comparisons between the 1984 and 1985 data indicate that ichthyoplankton densities were fairly similar in the lower half of Lower Three Runs Creek during both years (Figure V-4.39). However, densities in the Par Pond tailwaters were approximately five times higher during 1984 than 1985. The higher densities in the tailwaters during 1984 were probably due to greater discharges from Par Pond into Lower Three Runs Creek in 1984, as observed by field personnel (Paller et al., 1986a).

V.4.3.3.2.7 Upper Three Runs Creek

Upper Three Runs Creek does not receive thermal effluent and is the largest Savannah River tributary on the SRP. Upper Three Runs had three sampling stations located on it for the 1984 and 1985 ichthyoplankton studies (Table V-4.31 and Figure V-4.15). The station farthest upstream (Station 1) was near Road C, a second station (Station 2) was downstream at Road B, and the last station (Station C1572) was in the mouth of Upper Three Runs Creek.

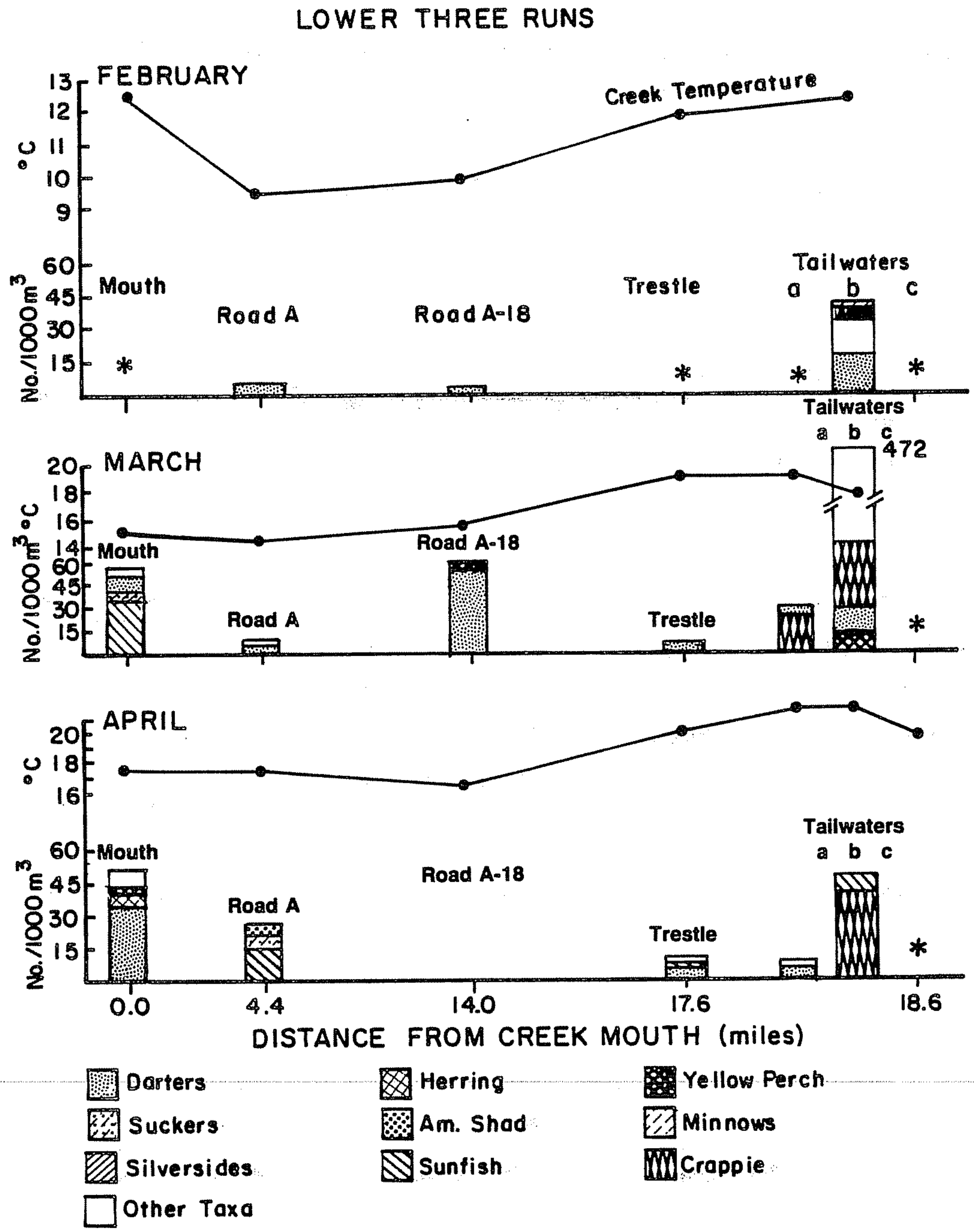
In 1984, a total of 358 ichthyoplankters were collected from Upper Three Runs Creek between March 14 and July 31, 1984 (Table V-4.52). The predominant taxa were spotted suckers and crappie. Spotted suckers were particularly dominant at the stations near Road A and C (Stations 1 and 2) where they comprised almost all of the ichthyoplankton catch (Figure V-4.40). Spotted suckers were most abundant during the middle of the study period (i.e., April-June). At the creek mouth station, crappie dominated the ichthyoplankton in May. Overall, ichthyoplankton densities in Upper Three Runs Creek (mean of 29/1,000 m^3) were similar to those in other undisturbed SRP creeks sampled during the same period.

TABLE V-4.51

Number and Percent Composition of Ichthyoplankton Collected from Lower Three Runs Creek (February-July 1985)

Taxa	Number	Percent
Blueback herring	5	1.1
American shad	2	0.4
Minnows	26	5.8
Spotted sucker	5	1.1
Sucker	1	0.2
Mosquitofish	2	0.4
Brook silverside	96	21.6
Sunfish and/or bass	57	12.8
Crappie	46	10.3
Yellow perch	7	1.6
Darters	84	18.9
Unid. ichthyoplankton	115	25.8
Total	446	100.0

Source: Paller et al., 1986a.



* Indicates no sample taken.

FIGURE V-4.38. Monthly Mean Water Temperatures and Ichthyoplankton Density at Each Sampling Site in Lower Three Runs Creek (A is sample station 200 m below Road B; B is pool at Road B; C is station at base of Par Pond spillway; February–July 1985)
Source: Paller et al., 1986a.

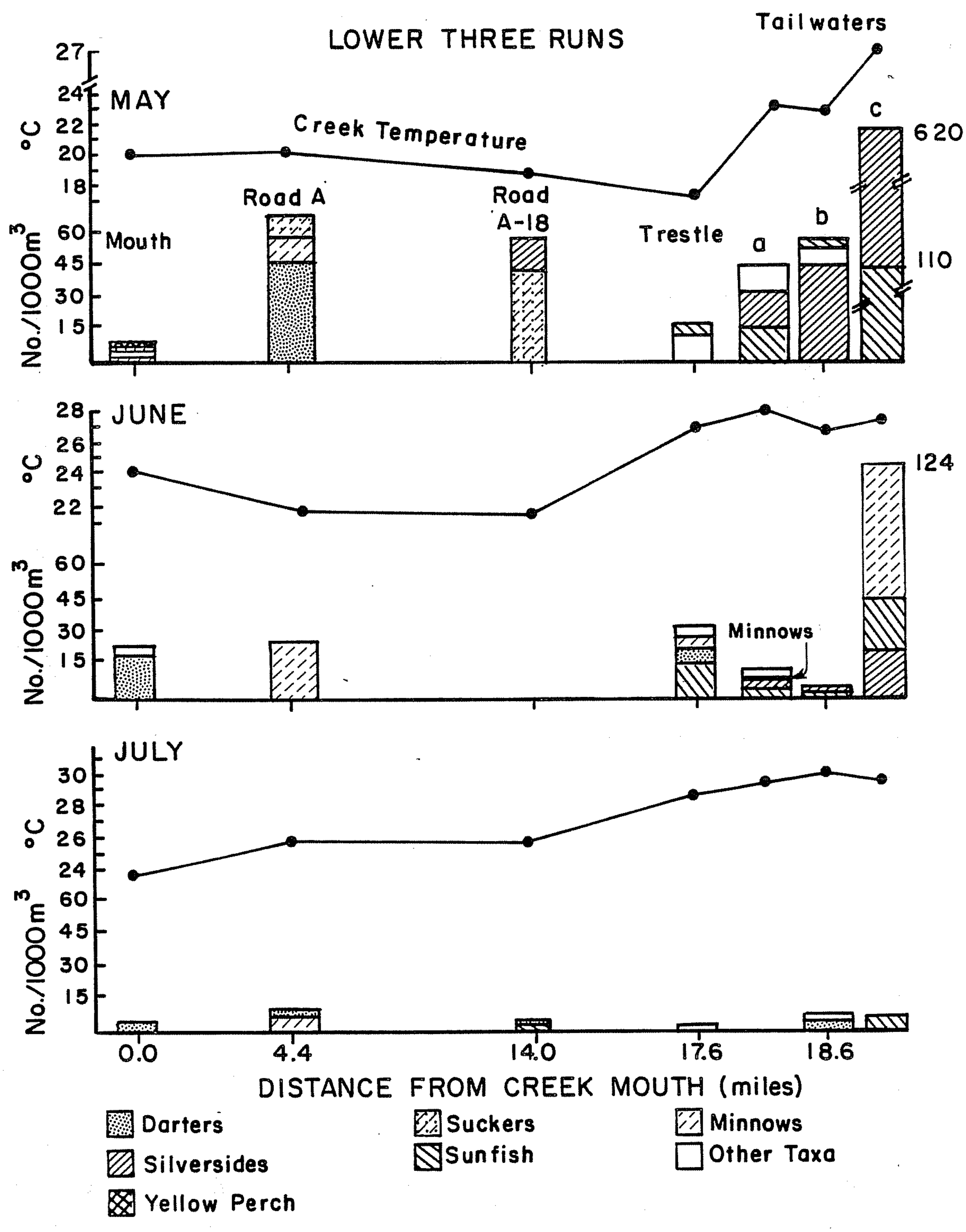


FIGURE V-4.38, Contd

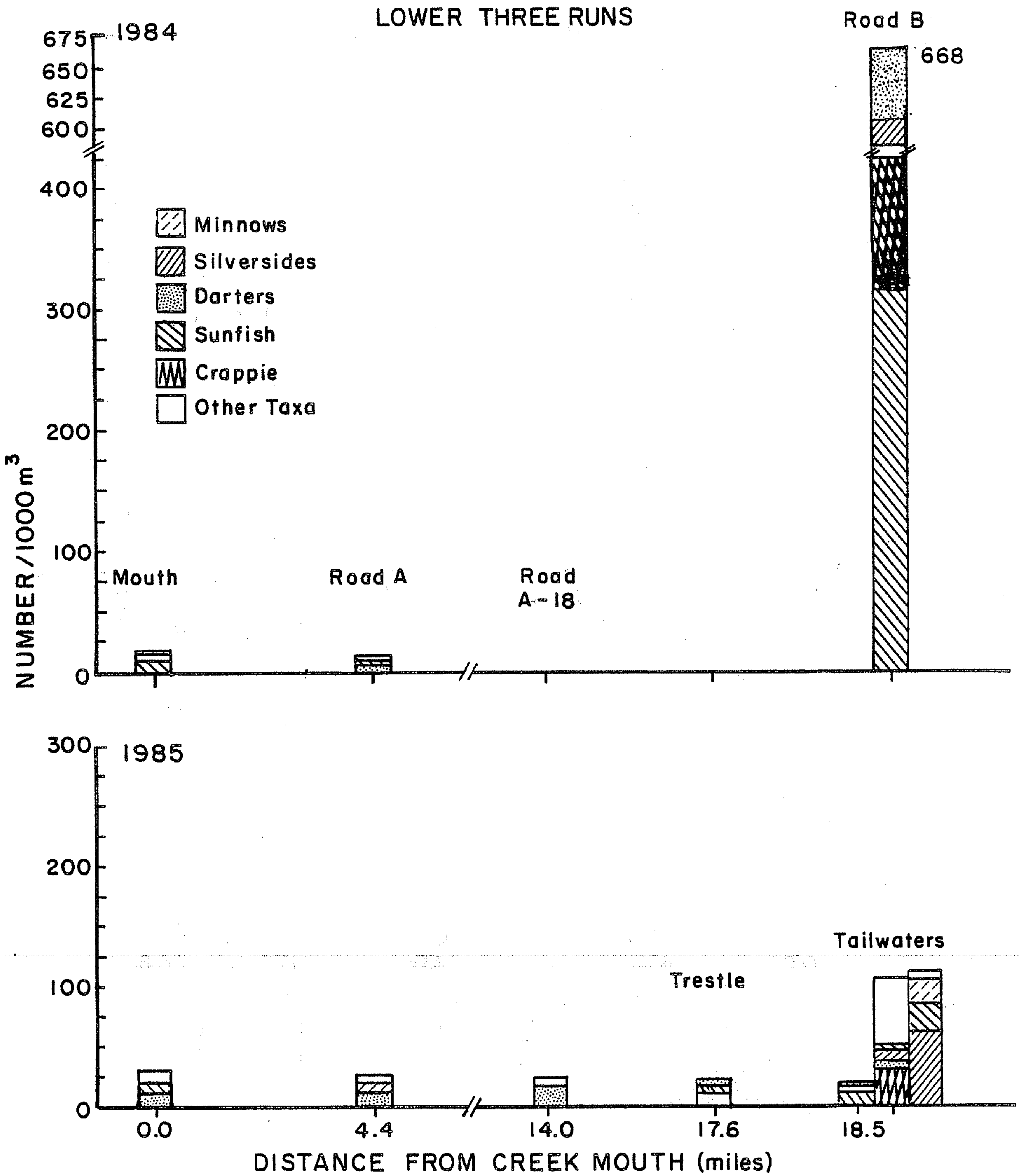


FIGURE V-4.39. Total Ichthyoplankton Densities at Lower Three Runs Locations During the 1984 and 1985 Sampling Programs
Source: Paller et al., 1986a

TABLE V-4.52

Number and Percent Composition of Ichthyoplankton Collected from Upper Three Runs Creek (March 14-June 3, 1984)

Taxa	Number	Percent
Gizzard and/or threadfin shad	12	3.4
Blueback herring	4	1.1
Unid. herring or shad	4	1.1
Spotted sucker	234	65.4
Unid. suckers	3	0.8
Sunfish and/or bass	4	1.1
Crappie	51	14.2
Yellow perch	2	0.6
Darters	20	5.6
Minnows	17	4.7
Carp	2	0.6
Unid. ichthyoplankton	5	1.4
Total	358	100.0

Source: Paller, 1985.

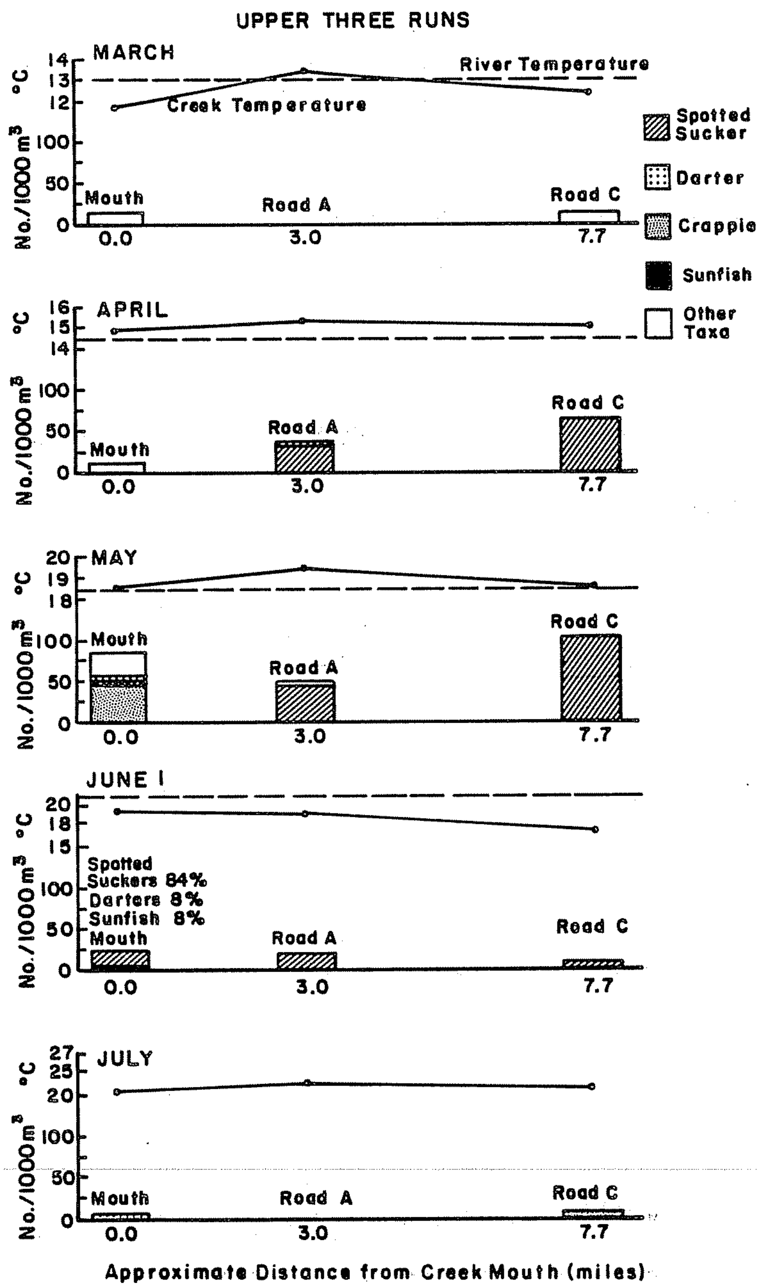


FIGURE V-4.40. Average Ichthyoplankton Density and Water Temperature at Three Sampling Stations Along Upper Three Runs Creek (March-July 1984)
Source: Paller, 1985.

In 1985, a total of 193 ichthyoplankters were collected from Upper Three Runs Creek between February and July 1985 (Table V-4.53). Spotted suckers dominated the ichthyoplankton collection in 1985 (Figure V-4.41) as they did in 1984. Darters were also important, comprising 24.4% of the ichthyoplankton collected during 1985. In 1984, darters constituted only 5.6% of the ichthyoplankton. As was the case in 1984, suckers were most well-represented during the April-June period. The mean density of ichthyoplankton from all sample stations in Upper Three Runs in 1985 was lower than in 1984. Mean density over all sample dates in 1984 was 29/1,000 m^3 in the creek mouth, 69/1,000 m^3 near Road A, and 60/1,000 m^3 near Road C (Figure V-4.42). Comparable values for 1985 were 38/1,000 m^3, 23/1,000 m^3, and 21/1,000 m^3, respectively.

V.4.3.3.3 Temperature Effects

The relationship between temperature and ichthyoplankton density during 1985 was determined by plotting the mean density at each sample station on each date against temperature (Figure V-4.43). Some very high densities that distorted the scales used in Figure V-4.42 were omitted from the plot. Their omission in no way alters the interpretation of the data (Paller et al., 1986a).

Larval densities in the creeks and swamps were generally highest (greater than 100 organisms/1,000 m^3) at temperatures ranging from 10 to 26°C. With few exceptions, there were no larvae collected at water temperatures above 35°C. In Four Mile Creek, unidentified eggs and larvae were collected in densities as high as 40 organisms/1,000 m^3 at approximately 45°C. These eggs and larvae were almost certainly transported from cooler backwaters or tributaries and were probably dead when they were collected (Paller et al., 1986a). The same may have been true for other blueback herring collected from Four Mile Creek at temperatures between 37 and 38°C.

The temperature/density relationships are summarized for the major taxonomic groups in Figure V-4.44. Of the anadromous species, almost all blueback herring were collected at temperatures between 9 and 26°C, while most American shad were collected at temperatures between 9 and 20°C. At temperatures from 27 to 35°C, centrarchids, darters, and minnows comprised most of the identifiable ichthyoplankton. Very few ichthyoplankters were collected at temperatures above 35°C.

V.4.3.3.4 Microhabitat Study

Three habitats were sampled for ichthyoplankton densities in the Steel Creek swamp (Figure V-4.45): macrophyte beds, open channels, and the macrophyte bed/open channel interface. From

TABLE V-4.53

Number and Percent Composition of Ichthyoplankton Collected from Upper Three Runs Creek (February-July 1985)

Taxa	Number	Percent
Blueback herring	10	5.2
American shad	9	4.7
Unid. clupeid	2	1.0
Minnows	4	2.1
Unid. suckers	1	0.5
Spotted sucker	101	52.3
Sucker	1	0.5
Sunfish and/or bass	2	1.0
Crappie	2	1.0
Darters	47	24.4
Unid. ichthyoplankton	14	7.3
Total	193	100.0

Source: Paller et al., 1986a.

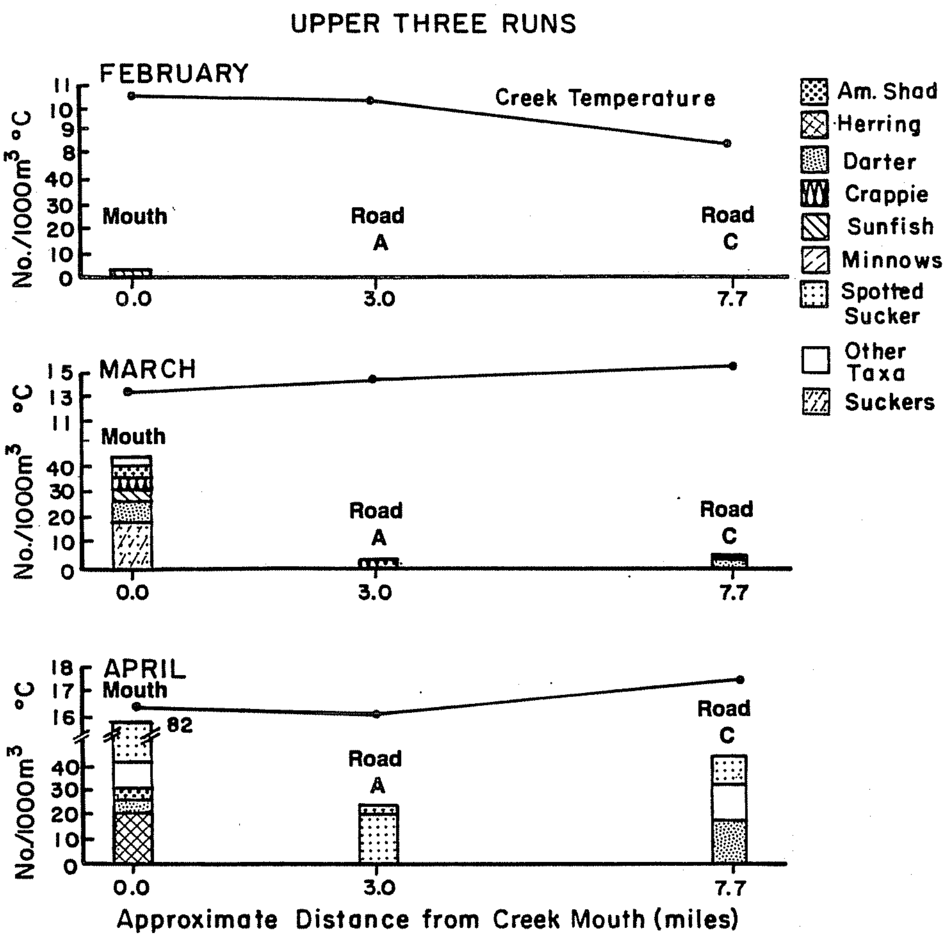


FIGURE V-4.41. Monthly Mean Water Temperature and Ichthyoplankton Density at Each Sampling Site on Upper Three Runs Creek (February-July 1985)
Source: Paller et al., 1986a.

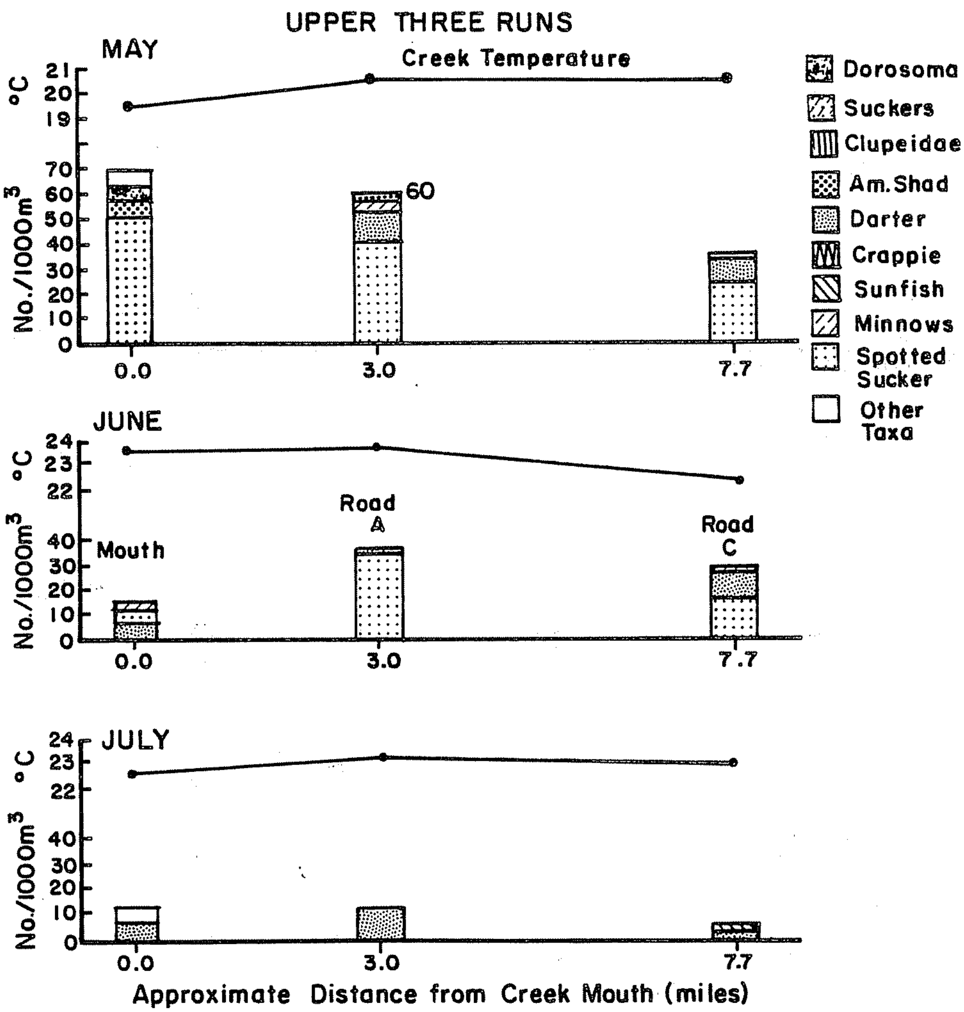


FIGURE V-4.41, Contd

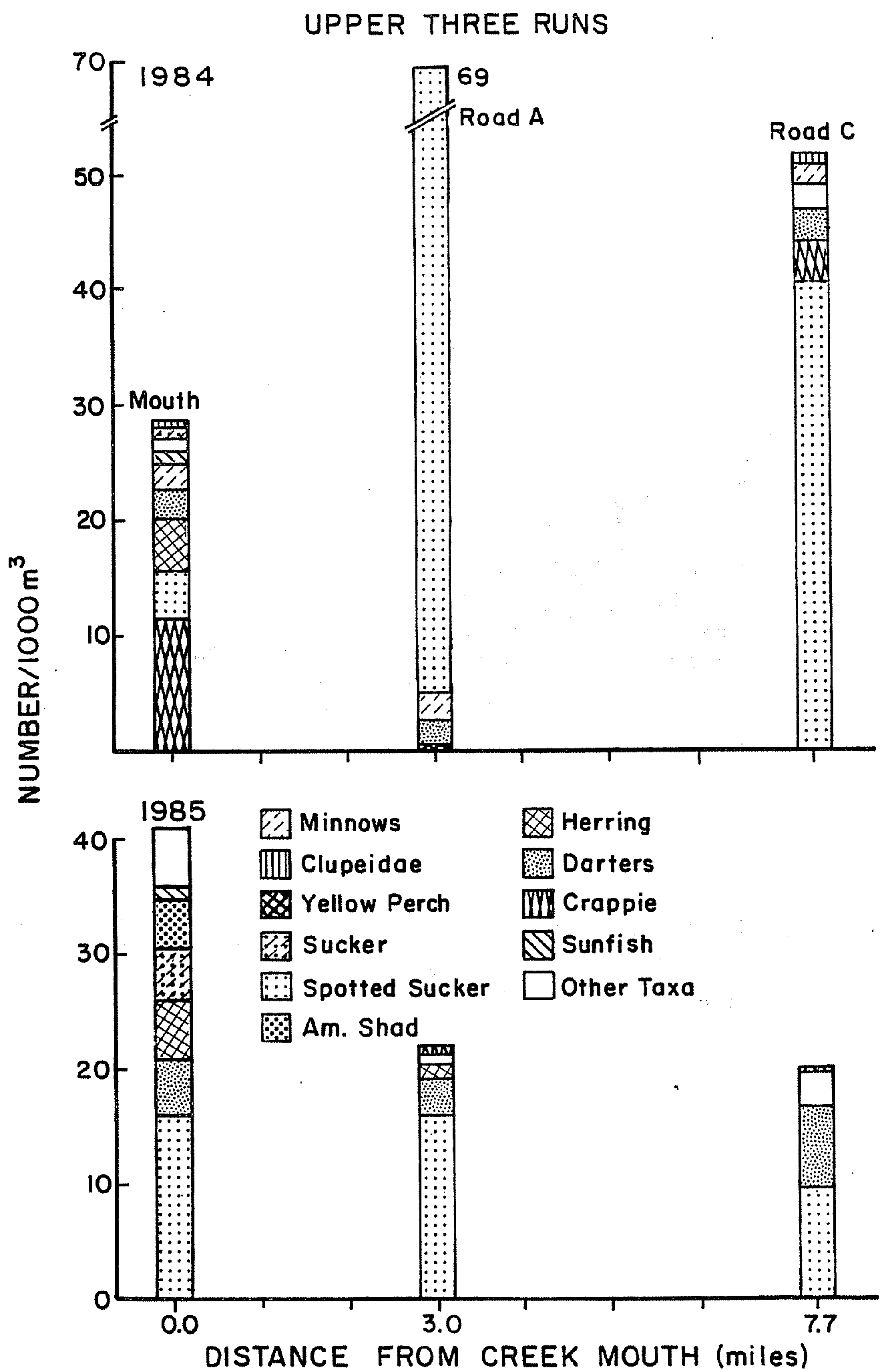


FIGURE V-4.42. Total Ichthyoplankton Densities at Upper Three Runs Creek Locations During the 1984 and 1985 Sampling Programs
Source: Paller et al., 1986a

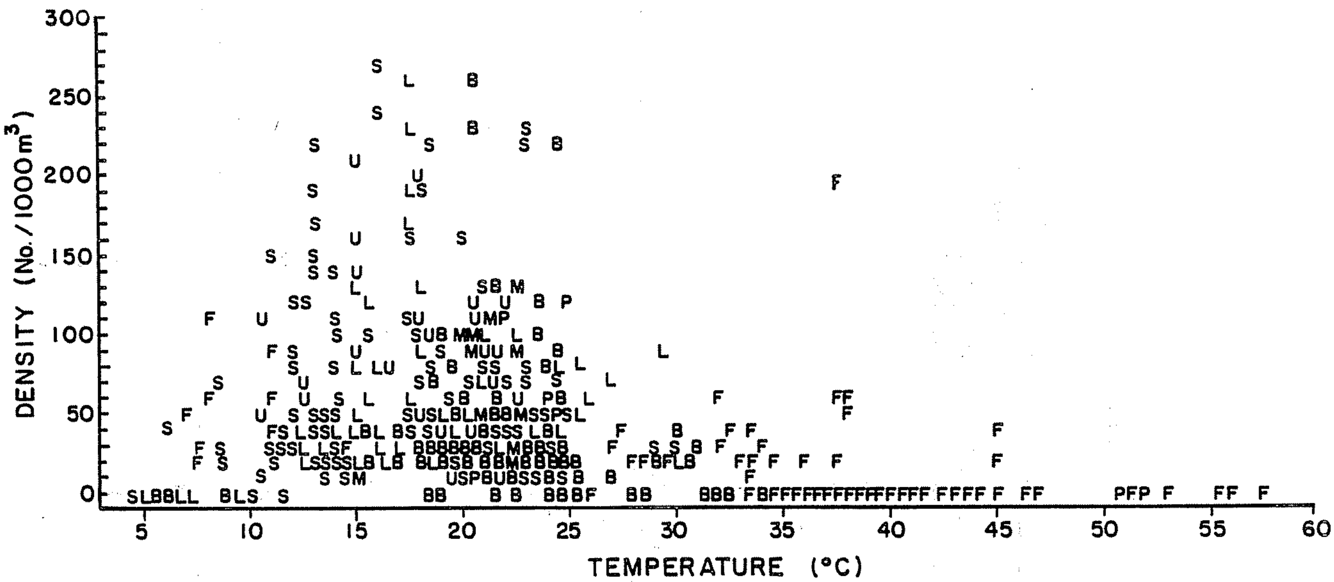


FIGURE V-4.43. Ichthyoplankton Density Versus Temperature at the Time of Sampling in the SRP Creeks and Swamps (February–July 1985)

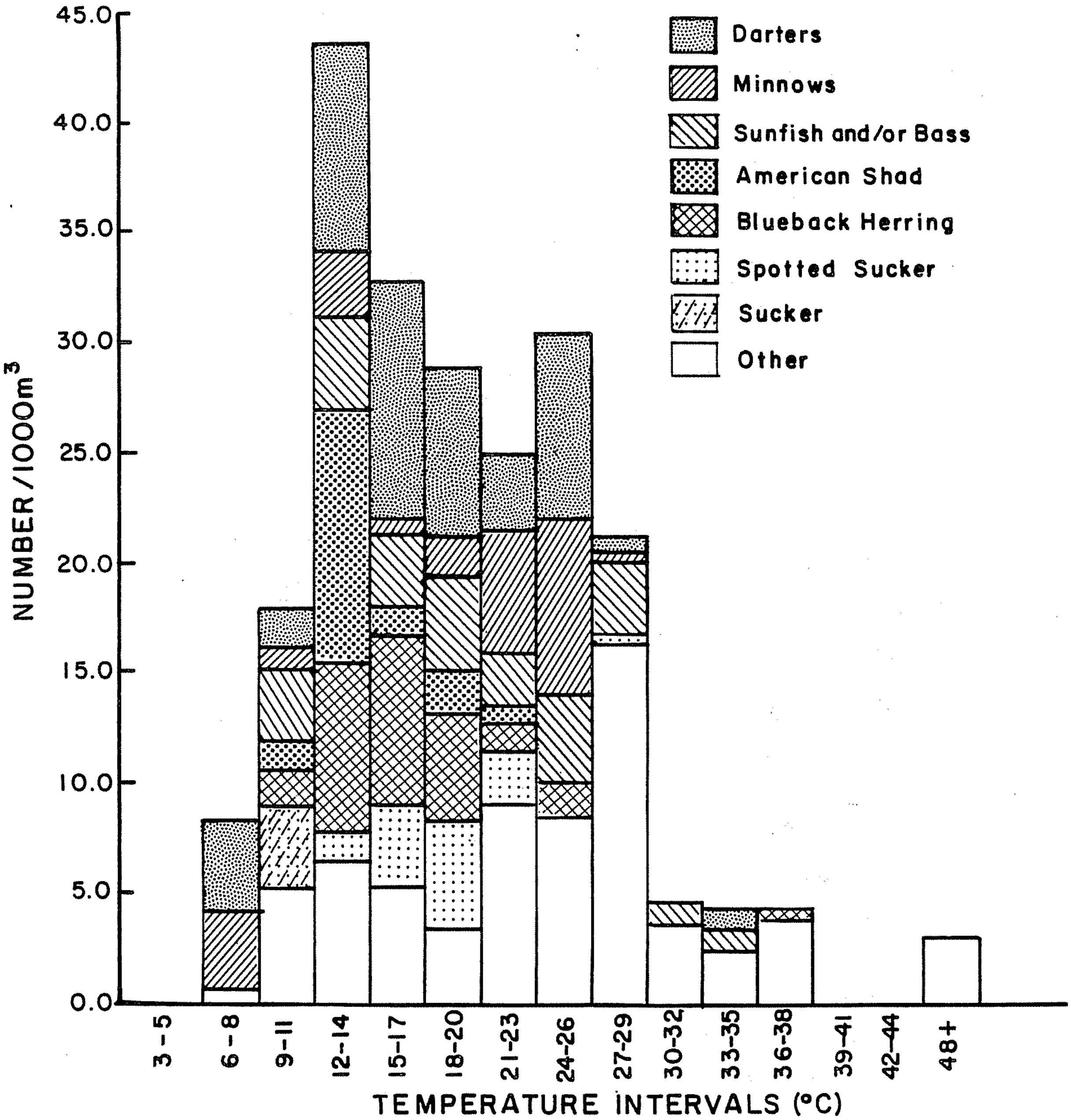


FIGURE V-4.44. The Density of Ichthyoplankton Larvae Collected at Different Temperature Intervals (February–July 1985)
Source: Paller et al., 1986a.

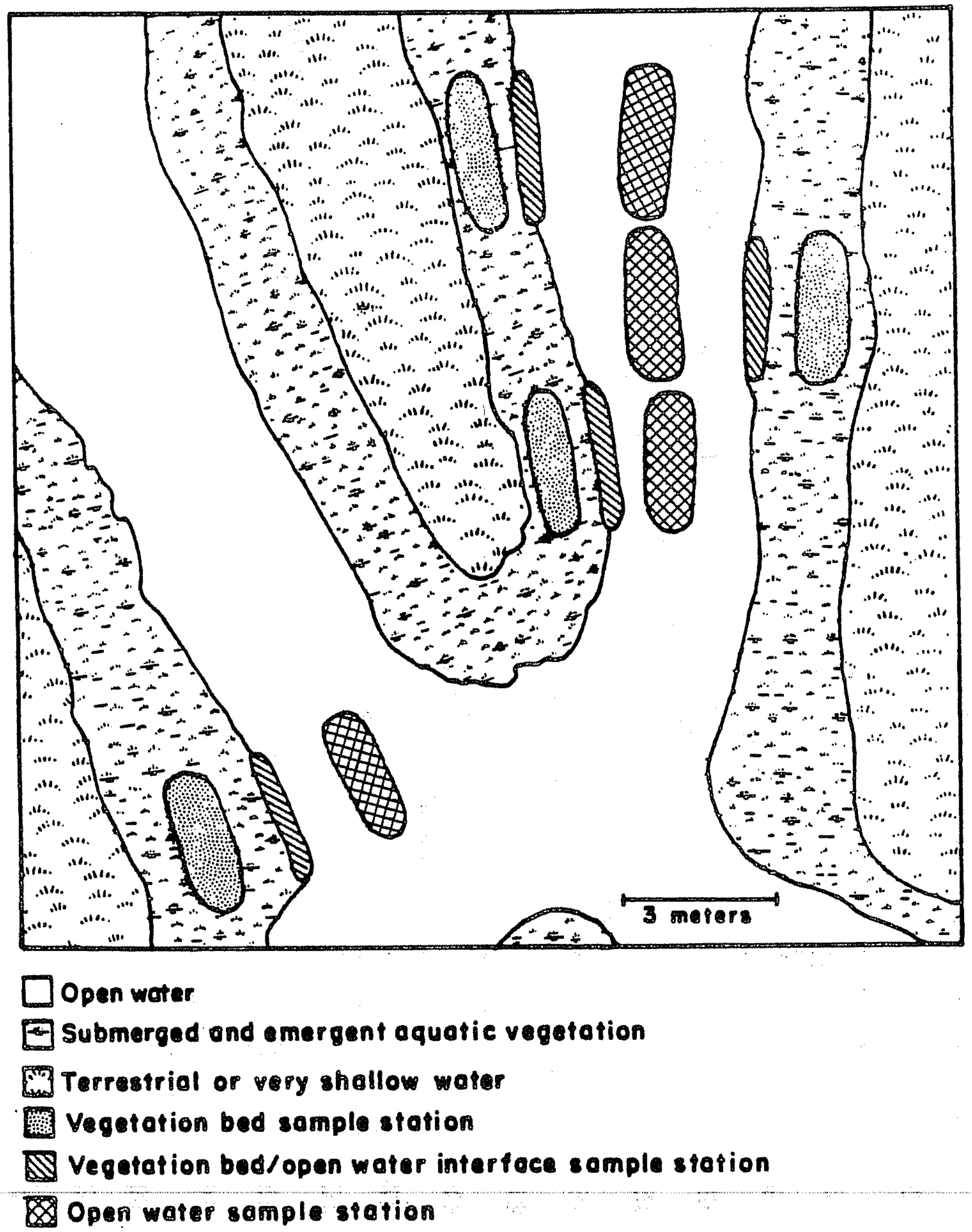


FIGURE V-4.45. Map of the Area in Steel Creek Swamp Sampled for the Microhabitat Study Indicating the Location of Each Sample Area (February-July 1985)
Source: Paller et al., 1986a.

March 16 to June 21, 1985, daytime samples (0600 to 1800 hr) were taken at weekly intervals and nighttime samples (1800 to 0600 hr) were taken at biweekly intervals. Four duplicate samples were taken in each habitat on each sample date. All samples were taken by pumping and filtering 12.5 m^3 of water.

A total of 5,367 fish were collected: 3,175 from daytime sampling and 2,192 from nighttime sampling (Tables V-4.54 and V-4.55). Five different lifestages were collected: eggs, pro-larvae (yolk-sac larvae), larvae, juveniles, and adults. Only small species such as mosquitofish, swampfish, and pirate perch were collected as adults.

The distribution of the five lifestages differed among the three habitats. All of the identified fishes collected from the open channel during both day and night were larvae or pro-larvae (Tables V-4.54 and V-4.55). In contrast, eggs, pro-larvae, larvae, and juveniles were all collected from the macrophyte bed/open channel interface, with larvae predominanting.

All five lifestages were collected from the macrophyte beds, with larvae predominating the collections. Many of the fish larvae were unrecognizable due to damage caused by passage through the pump. Based on a comparison of "unidentifiable taxa" to "total ichthyoplankton," one-third to one-half of the ichthyoplankton larvae may have been damaged beyond recognition. The dominant, identifiable larvae, pro-larvae, and eggs were minnows, chub-suckers, unidentified sunfish, sunfish (Lepomis spp.), and darters. The relative abundance of these taxa varied, depending on habitat and time of day.

Relative abundance of identified ichthyoplankton are presented in Table V-4.56. Chubsuckers were found in the greatest abundance in the macrophyte bed habitat, comprising 24.7% of the total catch during the day and 25.7% during the night. In the macrophyte bed/open channel interface, chubsuckers were less abundant, comprising only 11.6% of the catch during the day and 5.5% at night. Chubsuckers were least abundant in the open channel, comprising only 4.1% of the catch during the night; only one was caught during the day.

Like the chubsuckers, unidentified sunfishes were more abundant in the macrophyte bed habitat than the other habitats. The percent abundance of unidentified sunfish in the macrophyte beds was 37.9% during the day and 34.5% during the night. In the interface habitat, the percent abundance of sunfishes was 27.9% during the day and 22.0% during the night. In the open channel, the percent abundance was zero percent during the day and 10.8% during the night. While mainly associated with the macrophyte bed/open channel interface and in the open channel than the chubsuckers.

TABLE V-4.54

Ichthyoplankton Catch During the Day in Open Channel, Channel/Week Bed Interface and Weed Bed Habitats (February-July 1985)

Species	Open Channel				Channel/Weed Bed Interface				Weed Bed				
	E*	P	L	J	E	P	L	J	E	P	L	J	A
Gar	0	0	0	0	0	0	0	0	0	0	6	0	0
Pickerel	0	0	0	0	0	0	0	0	0	0	2	0	0
Unid. minnow	0	0	1	0	0	2	54	0	0	4	335	0	0
Chubsucker	0	0	1	0	2	0	15	0	0	1	313	0	0
Madtom	0	0	0	0	0	0	0	3	0	0	0	2	0
Swampfish	0	0	0	0	0	0	0	0	0	0	10	3	6
Pirate perch	0	0	0	0	0	0	1	2	0	0	13	30	2
Topminnow	0	0	0	0	0	0	0	0	0	0	2	0	0
Mosquitofish	0	0	0	0	0	0	0	0	0	0	3	2	0
Brook silverside	0	0	0	0	2	0	0	0	0	0	8	0	0
Sunfish and/or bass	0	0	0	0	0	0	41	1	4	3	474	2	0
Sunfish (*Lepomis* spp.)	0	0	4	0	0	0	11	0	0	0	16	2	0
Sunfish (*Elassoma* spp.)	0	0	0	0	0	0	0	0	0	0	9	6	4
Largemouth bass	0	0	0	0	0	0	0	0	0	0	12	0	0
Crappie	0	0	0	0	0	0	0	0	0	1	47	0	0
Darter (*Etheostoma* sp.)	0	0	0	0	2	0	17	0	2	3	5	0	1
Unidentifiable taxa	0	0	10	0	11	0	83	0	9	1	1,569	0	0
Total ichthyoplankton	0	0	16	0	17	2	222	6	15	13	2,824	47	13

Source: Paller et al., 1986a.

TABLE V-4.55

Ichthyoplankton Catch at Night in Open Channel, Channel/Week Bed Interface and Weed Bed Habitats (February-July 1985)

Species	Open Channel				Channel/Weed Bed Interface				Weed Bed				
	E*	P	L	J	E	P	L	J	E	P	L	J	A
Pickerel	0	0	0	0	0	0	0	0	0	0	0	1	1
Unid. minnow	0	0	19	0	0	1	23	0	2	6	265	0	0
Chubsucker	0	0	3	0	0	1	6	0	0	0	312	0	0
Madtom	0	0	1	0	0	0	0	1	0	0	0	1	2
Swampfish	0	0	0	0	0	0	0	0	0	0	1	5	5
Pirate perch	0	0	2	0	0	0	2	0	0	0	21	60	3
Topminnow	0	0	0	0	0	0	0	0	0	0	5	1	0
Mosquitofish	0	0	0	0	0	0	0	0	0	0	2	4	0
Brook silverside	0	0	2	0	0	0	0	0	0	0	40	0	0
Sunfish and/or bass	0	0	8	0	1	0	27	0	1	1	417	20	0
Sunfish (*Lepomis* spp.)	0	0	32	0	0	0	46	0	0	0	100	0	0
Sunfish (*Elassoma* spp.)	0	0	0	0	0	0	0	0	0	0	14	13	1
Crappie	0	0	0	0	0	0	0	0	0	0	4	0	0
Darter (*Etheostoma* sp.)	0	3	4	0	1	6	13	0	2	3	4	0	0
Unidentifiable taxa	0	2	63	0	12	0	52	0	6	4	492	0	0
Total ichthyoplankton	0	5	134	0	14	8	169	1	11	13	1,695	105	37

* Fisd life stage. E = egg; P = pro-larvae (yolk-sac larvae); L = larvae; J = juvenile; and A = adult.

Source: Paller et al., 1986a.

TABLE V-4.56

Relative Abundance and Mean Catch Per Unit Effort of Identified Ichthyoplankton Collected from Open Channel (C), Channel/Macrophyte Bed Interface (E), and Macrophyte Bed (W) Habitats (February-July 1985)

	Day						Night					
	C		E		W		C		E		W	
Species*	Percent	CPUE	Percent	CPUE	Percent	CPUE	Percent	CPUE	Percent	CPUE	Percent	CPUE
Gar	0.0	0.00	0.0	0.00	0.5	0.10	0.0	0.00	0.0	0.00	0.0	0.00
Pickerel	0.0	0.00	0.0	0.00	0.2	0.03	0.0	0.00	0.0	0.00	0.0	0.00
Unid. minnow	16.7	0.02	38.1	0.93	26.7	5.65	25.7	0.79	18.9	1.00	22.5	11.38
Chubsucker	16.7	0.02	11.6	0.28	24.7	5.23	4.1	0.13	5.5	0.29	25.7	13.00
Madtom	0.0	0.00	0.0	0.00	0.0	0.00	1.4	0.04	0.0	0.00	0.0	0.00
Swampfish	0.0	0.00	0.0	0.00	0.8	0.17	0.0	0.00	0.0	0.00	0.1	0.04
Pirate perch	0.0	0.00	0.7	0.02	1.0	0.22	2.7	0.08	1.6	0.08	1.7	0.88
Topminnow	0.0	0.00	0.0	0.00	0.2	0.03	0.0	0.00	0.0	0.00	0.4	0.21
Brook silverside	0.0	0.00	1.4	0.03	0.6	0.13	2.7	0.08	0.0	0.00	3.3	1.67
Unid. sunfish	0.0	0.00	27.9	0.68	37.9	8.02	10.8	0.33	22.0	1.17	34.5	17.46
Sunfish												
(Lepomis spp.)	66.7	0.07	7.5	0.18	1.3	0.27	43.2	1.33	36.2	1.92	8.2	4.17
(Elassoma spp.)	0.0	0.00	0.0	0.00	0.7	0.15	0.0	0.00	0.0	0.00	1.2	0.58
Largemouth bass	0.0	0.00	0.0	0.00	0.9	0.20	0.0	0.00	0.0	0.00	0.0	0.00
Crappie	0.0	0.00	0.0	0.00	3.8	0.80	0.0	0.00	0.0	0.00	0.3	0.17
Darter												
(Etheostoma spp.)	0.0	0.00	12.9	0.32	0.8	0.17	9.5	0.29	15.7	0.83	2.3	1.08
Totals	100.1	0.11	100.1	2.44	100.1	21.17	100.1	3.07	99.9	5.29	100.2	50.64
Total number of fish identified*	6		147		1,273		74		127		1,217	

* Only those individuals are included in discussions in the text. C = open channel; E = channel/macrophyte bed interface; W = macrophyte bed.

Source: Paller et al., 1986a.

Minnows were collected in their greatest abundance in the macrophyte beds; however, they were also well-represented in the macrophyte bed/open channel interface and in the open channel. The abundance of minnows in the open channel was second only to that of Lepomis spp., and together, these two taxa comprised 68.4% of the drift taken from the open channel at night. Darters were also an important component of the open channel fauna at night, comprising 9.5% of the catch. No darters were caught in the open channel during the day.

Most of the taxa exhibited marked differences in their relative and absolute abundances between the macrophyte bed and open channel habitats. Virtually all taxa had highest CPUE in the macrophyte beds, and lowest CPUE in the open channel habitat. The dominant taxa in the macrophyte bed habitat at night were unidentified sunfish (34.5%), chubsuckers (25.7%), and unidentified minnows (32.5%). The dominant taxa in the open channel at night were Lepomis spp. (43.2%), unidentified minnows (25.7%), unidentified sunfish (10.8%), and darters (9.5%). The only taxa that maintained the same proportional abundance in both the macrophyte bed and open channel habitats were the minnows. The dominant taxa in the macrophyte beds during the day (chubsuckers, unidentified sunfishes, and minnows) were also the dominant taxa in the macrophyte beds at night.

These results indicate that regardless of adult habitat preferences, larvae of virtually all species seek out macrophyte beds. As such, thermal discharges that reduce or eliminate macrophyte growth may be very detrimental to the fish communities of SRP creeks. At the same time, post-thermal Steel Creek, where macrophyte growth has been enhanced by destruction of the tree canopy, has extensive vegetated areas for larval development.

V.4.3.3.5 Diel Distribution

To assess ichthyoplankton distributions over a 24 hr period, diel samples were taken at four sample stations (Stations 32, 33, 35, and 64) in the Steel Creek swamp and two sample stations (Stations 36 and 31) in the channel connecting the swamp to the creek mouth (Figure V-4.18). Each station was sampled at 6 hr intervals over a 24 hr period on March 22, April 24, May 23, and June 20, 1985. Diel sampling procedures were the same as those for the regular weekly samples (see Section V.4.3.2.1).

Average densities over all sample dates and stations were 25 organisms/1,000 m^3 between 0600 to 1200 hr, 17/1,000 m^3 between 1200 to 1800 hr, 195/1,000 m^3 between 1800 to 2400 hr, and 576/1,000 m^3 between 2400 to 0600 hr. The trend of low densities from 0600 to 1800 hr, higher densities from 1800 to 2400 hr, and extremely high densities from 2400 to 0600 hr was observed at all sample stations except Station 35, where the highest density occurred during the 1800 to 2400 hr period. Nearly all species were more abundant at night, especially Lepomis spp., unidentified sunfishes, and minnows (Figure V-4.46).

In summary, diurnal samples taken in the Steel Creek swamp showed that larval densities in the open channels were approximately 18 times higher during the night than during the day. Larvae entering the open channels at night probably came from the weed beds where larvae were concentrated in high densities, as seen in the microhabitat study (see Section V.4.3.3.4). These results indicate that the potential for entrainment of larvae via cooling water intake is higher at night, at least in areas with macrophyte beds. The small differences in densities during daylight hours would indicate that time of day is not a large source of variation in sampling design.

V.4.3.3.6 Gear Comparison Study

The gear comparison study was conducted on April 30 and May 23, 1985. Four sampling methods were evaluated: stationary set 30.5 x 45.7 cm rectangular plankton nets, stationary set 0.5 m diameter circular plankton nets, pushed 0.5 diameter plankton nets, and pumping through a plankton net with a 833 L/min pump. Methodologies are discussed in greater detail in Section V.4.3.2.1.

Six taxa were collected during this study: American shad, darters, minnows, silversides, sunfishes, and blueback herring (Table V-4.57). The stationary rectangular plankton nets captured all six taxa. The stationary circular plankton nets captured all the taxa except blueback herring and silversides. The pumped ichthyoplankton sampling method captured American shad, darters, and minnows. The pushed plankton nets captured the silversides as well as the taxa collected by pumping.

Mean densities of ichthyoplankton collected for the four methods were 39.6 organisms/1,000 m^3 for the rectangular net, 28.7/1,000 m^3 for the pumped collections, and 19.7/1,000 m^3 for the pushed plankton net. A statistical analysis of the gear comparison study, designed to test for differences in ichthyoplankton density, revealed no significant differences between the four methods of collection that were tested (Paller et al., 1986a).

V.4.3.4 Summary: SRP Creek and Swamp Ichthyoplankton Studies

Weekly ichthyoplankton collections were made in the SRP creeks and swamp at 35 sample stations in 1984 and 42 sample stations in 1985. The creeks that were sampled included Upper Three Runs

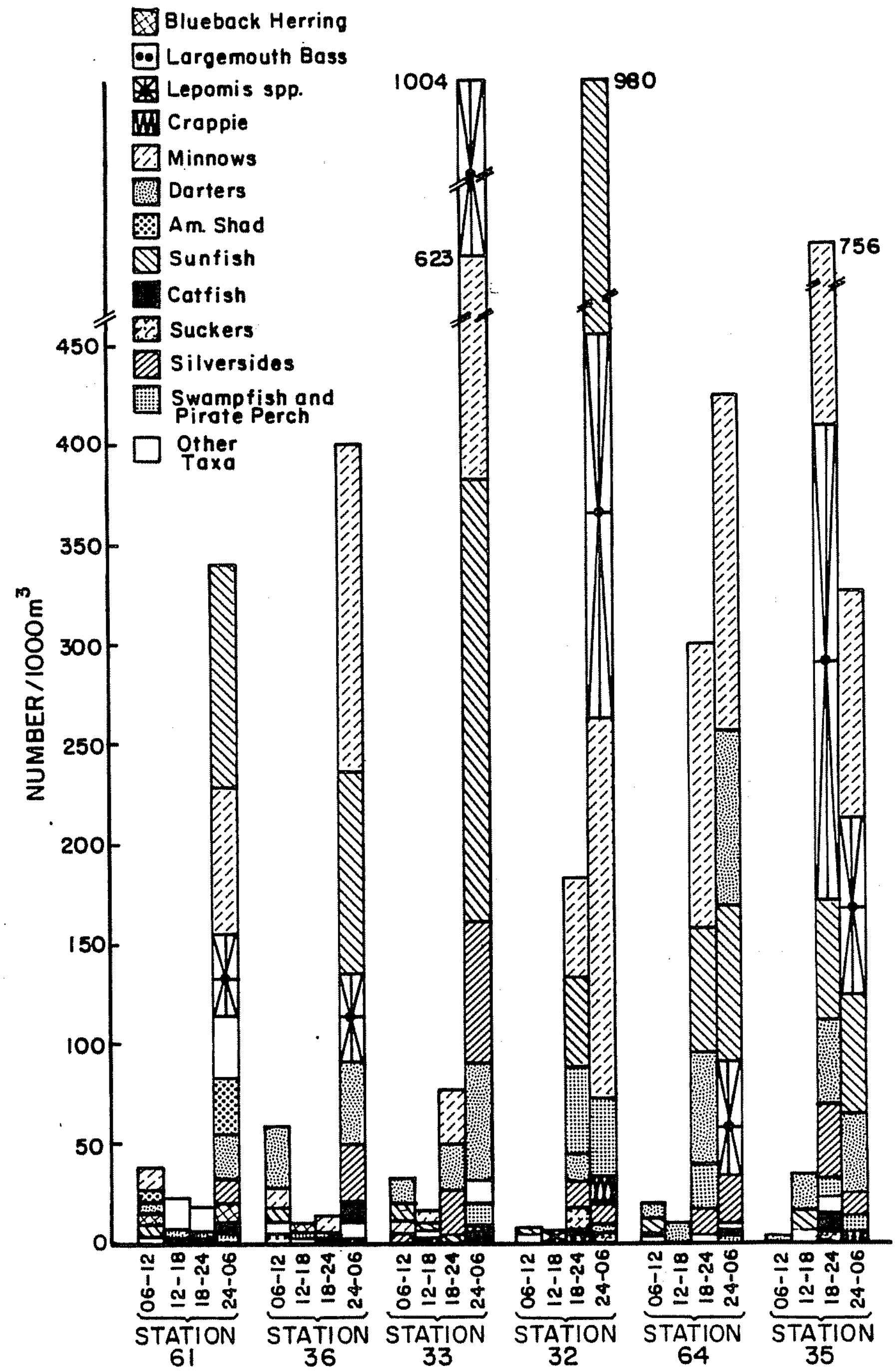


FIGURE V-4.46. **Densities of Individual Taxa Collected at Six Stations in Steel Creek During the Diel Study (February-July 1985)**

TABLE V-4.57

Numbers of Ichthyoplankton Collected by Pump, Stationary, or Towed Net Sets in the Gear Comparison Study (1985)

Date	Species	Stage*	Capture Method** P	TP	SP	SR	Totals
4/30/85	American shad	E	6	6	12	17	41
		L	1	7	0	3	11
	Darters	E	2	1	2	4	8
		L	6	5	11	8	30
	Unknown	E	1	1	3	1	6
		L	2	0	0	3	5
	Minnows	E	0	0	0	0	0
		L	1	1	1	1	4
	Silverside	E	0	0	0	0	0
		L	0	1	0	2	3
	Sunfish	E	0	0	0	0	0
		L	0	0	1	2	3
	Blueback herring	E	0	0	0	0	0
		L	0	0	0	0	0
5/23/85	American shad	E	0	1	4	1	6
		L	0	0	3	0	3
	Darters	E	0	0	1	0	1
		L	2	0	4	2	8
	Unknown	E	2	4	0	1	7
		L	1	0	1	0	2
	Minnows	E	0	0	0	0	0
		L	0	0	1	0	1
	Silverside	E	0	0	0	0	0
		L	0	0	0	0	0
	Sunfish	E	0	0	0	0	0
		L	0	0	0	1	1
	Blueback herring	E	0	0	0	1	1
		L	0	0	0	0	0

* E refers to egg stage and L refers to larval stage.
** P refers to pumped net, TP refers to towed plankton net, SP refers to stationary plankton net, and SR refers to stationary rectangular net.

* Source; Paller et al., 1986a.

Creek, Beaver Dam Creek, Four Mile Creek, Pen Branch, Steel Creek, Meyers Branch, and Lower Three Runs Creek. Sample stations were located in the upper and lower reaches of each stream and encompassed a variety of habitats and thermal regimes.

In 1984, 3,708 fish larvae and 448 fish eggs, representing at least 21 taxa, were collected from March 14 through July 31. The dominant taxa were sunfishes and bass (centrarchids; 38.8%), minnows (13.8%), darters (12.0%), and crappie (10.3%). Two of the three significant anadromous species in the SRP study area (blueback herring and American shad) were relatively well represented in the mouth of Steel Creek, but were collected in relatively low densities in the other locations within the study area. American shad were collected only in the mouth of Steel Creek and accounted for 2.1% of the ichthyoplankton that were collected. Blueback herring showed a similar pattern, but was collected in greater numbers. This species constituted 8.7% of the ichthyoplankton collected in the creek mouth, but only 0.3% in the swamp. Striped bass were represented only by a single egg in both the 1984 and 1985 collections. The period of maximum spawning for most of the species in the creeks and swamps was April through May. Sunfish, however, continued spawning at moderate levels through July.

In 1985, 1,109 fish larvae and 710 fish eggs were collected from February through July. The most abundant larvae were darters (31.3%), centrarchids (16.9%), minnows (15.0%), spotted suckers (19.7%), and brook silversides (9.9%). The most common identifiable eggs were those of blueback herring (25.8%) and American shad (15.4%). Unidentifiable eggs comprised 56.3% of the collection in 1985.

Ichthyoplankton densities were highly variable at all locations during the 1984 study period. In the post-thermal Steel Creek swamp, ichthyoplankton densities were relatively high in March and April (averaging 218 organisms/1,000 m^3 and 510/1,000 m^3, respectively) and declined through July. This area experienced canopy tree kill from reactor discharge, which resulted in an open canopy, and had developed extensive submerged and emergent macrophyte beds. The water temperature was slightly elevated by thermal discharges from Pen Branch and from solar insulation. Ichthyoplankton densities in the mouth of Steel Creek were relatively high in April and highest in May (averaging 226/1,000 m^3 and 449/1,000 m^3, respectively). The data collected from Steel Creek suggest that the swamp and creek mouth were the most important spawning areas in Steel Creek during 1984. Most of the spawning in Steel Creek occurred between temperatures of approximately 17 to 25°C.

Except for a few sampling dates in 1984, ichthyoplankton were absent from the upper reaches of Four Mile Creek and Pen Branch, both of which were characterized by high water temperatures due to reactor discharges. The few larvae and eggs that were collected from the upper reaches of these streams were probably washed into the sample areas from tributaries and other cool water refugia outside the main creek channels. Higher ichthyoplankton densities were observed in the cooler swamps of Four Mile Creek and Pen Branch, particularly when these areas were inundated by flood waters from the Savannah River.

Beaver Dam Creek, which receives thermal effluents from the coal-fired power plant in D Area, averaged approximately 7°C warmer than the Savannah River. In general, temperatures decreased from the uppermost reaches of the creek (at the D-Area effluent outfalls) to the swamp station, due to gradual downstream cooling. However, temperatures increased at the mouth. This increase was probably due to an influx of heated water through a channel connecting Four Mile Creek to Beaver Dam Creek at a point approximately 100 m from the mouth of Beaver Dam Creek (see Figure V-4.15). In the upper reaches of the creek, ichthyoplankton densities were low. They were also low or moderate in the lower swampy reaches and in the mouth of Beaver Dam Creek.

Ichthyoplankton densities in Meyers Branch were generally higher in the upper reaches of the creek (averaging 58/1,000 m^3) where beaver dams provided habitat more favorable to some species of fish, than at the sampling station near the confluence with Steel Creek (averaging 20/1,000 m^3). In Upper Three Runs, ichthyoplankton densities (averaging 29/1,000 m^3) were similar to other undisturbed SRP creeks.

Ichthyoplankton densities in Lower Three Runs were low in the downstream reaches of the creek (averaging 24/1,000 m^3 in the creek mouth) and highest (averaging 625/1,000 m^3) in the upstream reach just downstream from the tailwaters of Par Pond. The high densities in the tailwaters were probably due to ichthyoplankton transported over the spillway from Par Pond as well as from spawning in the Par Pond tailwaters.

In the 1985 sample period, ichthyoplankton densities were again highly variable. Mean densities over all sample dates were 28/1,000 m^3 in Upper Three Runs Creek, 24/1,000 m^3 in Steel Creek, 39/1,000 m^3 in Meyers Branch, and 52/1,000 m^3 in Lower Three Runs Creek. The high average density in Lower Three Runs Creek was partially due to the transport of larvae into this stream from the Par Pond spillway. The mean density in Four Mile Creek and Pen Branch, the two streams receiving reactor effluent, was 13/1,000 m^3 and 4/1,000 m^3, respectively. These values were significantly lower than the densities in the other nonthermal streams. Beaver

Dam Creek, where the mean density was 21/1,000 m^3, was not significantly lower than the nonthermal creeks.

The 1985 analysis of the relationship between ichthyoplankton density and temperature revealed that most species in SRP waters will spawn at temperatures from 12 to 26°C. Ichthyoplankton densities decreased above 26°C and ichthyoplankton were largely absent at temperatures above 35°C. The taxa most abundant at high temperatures were centrarchids and, to a lesser extent, minnows and darters. The anadromous species were collected at lower temperatures: American shad reached maximum densities at 9 to 20°C and blueback herring reached maximum densities at 9 to 26°C.

The anadromous species, American shad and blueback herring, were mainly located in the creek mouths, which indicated the importance of the creek mouths in the life cycles of these species. In the SRP creeks, densities of anadromous species were highest in the mouth of Steel Creek during both years of the study. The importance of the creek mouths as spawning areas for anadromous species may be partly dependent on river level. The numbers of American shad and blueback herring collected from the creek mouths were much higher during 1985, when the Savannah River levels remained below flood stage, than during 1984, when the floodplain was inundated during much of the spring. During low water years, potential spawning areas on the floodplain are unavailable. At these times, anadromous species may use the creek mouths more heavily for spawning.

The influence of microhabitat on ichthyoplankton distribution was examined in the Steel Creek swamp. Fish larvae were collected from macrophyte beds, open water habitats, and the interface between the macrophyte beds and open water to compare relative densities. Most taxa exhibited marked differences in their relative abundance between the macrophyte beds and the open channel habitats. Larvae, in general, were caught in the greatest abundance in the macrophyte bed habitat. The higher catch in the macrophyte beds may have been due to shelter seeking behavior by the larvae, the presence of zooplankton forage for the larvae in the macrophyte beds, and the deposition of eggs in the macrophyte beds by spawning adult fishes. The abundance of fish larvae in the macrophyte beds indicated that macrophyte beds contributed to the reproduction of many of the fishes in the SRP streams and swamps.

Diel samples taken in the Steel Creek swamp showed that larval densities in the open channels were approximately 18 times higher during the night than during the day. Larvae entering the open channels at night probably came from the macrophyte beds where larvae were concentrated in large numbers. Their movement into the channels at night is probably a response to reduced light with a corresponding increase in movement and feeding activity.

V.4.3.5 Results and Discussion: Savannah River and Associated Tributaries Studies

In the 1984 sampling period a total of 24,289 fish larvae and 4,756 fish eggs were collected from the Savannah River, the Savannah River oxbows, selected Savannah River tributaries, and SRP intake canals (Table V-4.58). Dominant ichthyoplankton taxa (eggs and larvae, combined) included gizzard and/or threadfin shad (21.0%), crappie (15.3%), unidentified clupeids (14.4%), Lepomis (12.4%), and minnows (11.1%). Clupeids (including American shad, blueback herring, gizzard and/or threadfin shad, and unidentified clupeids), comprised 41.6% of all the larvae and 59.8% of all the eggs collected from the entire study area. Other important larval taxa were sunfish (17.3%), crappie (15.3%), and minnows (11.1%). Two taxa comprised the majority of the egg collection: American shad (51.3%) and striped bass (24.1%). It should be noted that both American shad and striped bass produce drifting eggs that have a higher probability of capture by ichthyoplankton nets than the adhesive or demersal eggs of most other fish species found in the SRP area.

In the 1985 sample period a total of 19,926 fish larvae and 15,749 fish eggs were collected from the Savannah River, the Savannah River oxbows, selected Savannah River tributaries, and SRP intake canals (Table V-4.59). The dominant taxa were gizzard and threadfin shad (35.5%), sunfishes (unidentified sunfish and Lepomis spp.; 13.2%), unidentified cluepids (12.6%), spotted sucker (10.7%), carp (5.6%), and blueback herring (5.4%). The dominant eggs were those of the American shad (73.0%) and of the striped bass (7.2%).

V.4.3.5.1 Creek Mouth Ichthyoplankton

This section presents an evaluation of the importance of the major creek mouths on the SRP as spawning areas within the Savannah River drainage by comparing their ichthyoplankton density, taxonomic composition, time of ichthyoplankton appearance, and number of ichthyoplankton transported into the river to other Savannah River tributaries. While these were important measures of the value of each creek as a spawning area, they did not take into account larval mortality or the importance of each creek as nursery areas for juvenile fish.

As described om Section V.4.3.2.2, ichthyoplankton were collected from 28 creek mouths in 1984. In 1985, the number of creeks that were sampled was reduced to 14, with 11 creeks eliminated from the lower farfield region (those creeks below RM 89.3), one from the nearfield (due to low discharge) and two from the upper farfield (due to low discharge).

TABLE V-4.58

Ichthyoplankton Taxa Collected from the Savannah River, Tributaries, Oxbows, and the Savannah River Plant Intake Canals (February-July 1984)*

Taxa	Number	Percent
Larvae		
American shad	196	0.7
Blueback herring	1,574	5.7
Gizzard and/or threadfin shad	5,800	21.0
Unid. clupeids	3,987	14.4
Striped bass	199	0.7
Spotted sucker	913	3.3
Unid. suckers	163	0.6
Pirate perch	60	0.2
Yellow perch	223	0.8
Darter	887	3.2
Sunfish (genus Lepomis)	3,437	12.4
Unid. sunfish	1,361	4.9
Crappie	4,236	15.3
Largemouth bass	13	<0.1
Mud minnow	1	<0.1
Swampfish	8	<0.1
Minnow (family Cyprinidae)	3,060	11.1
Carp	690	2.5
Mosquitofish	2	<0.1
Topminnow	4	<0.1
Needlefish	9	<0.1
Brook silverside	92	0.3
Catfish and/or bullhead	7	<0.1
Pickerel	34	0.1
Sturgeon	9	<0.1
Gar	8	<0.1
Bowfin	2	<0.1
Unid. larvae	670	2.4
Total	27,643	99.6
Eggs		
American shad	2,520	51.3
Blueback herring	191	3.9
Gizzard and/or threadfin shad	225	4.6
Striped bass	1,182	24.1
Yellow perch	63	1.3
Minnow	27	0.6
Other eggs	708	14.4
Total	4,916	100.2

* Study area was between RM 29.6 and 187.1 and included 2 intake canals, the mouths of 28 tributary creeks, and 6 oxbows.

Source: Paller et al., 1985.

TABLE V-4.59

Ichthyoplankton Taxa Collected from the Savannah River, Tributaries, Oxbows, and the Savannah River Plant Intake Canals (February-July 1985)

Taxa	Number	Percent
Larvae		
Sturgeon	6	<0.1
Gar	1	<0.1
Unid. Clupeidae	2,522	12.7
Blueback herring	1,076	5.4
American shad	361	1.8
Gizzard and/or threadfin shad	7,070	35.5
Mudminnow	1	<0.1
Pickerel	8	0.1
Needlefish	2	<0.1
Minnow (family Cyprinidae)	856	4.3
Carp	1,109	5.6
Unid. suckers	111	0.6
Spotted sucker	2,142	10.7
Catfish and/or bullhead	3	<0.1
Swampfish	1	<0.1
Pirate perch	17	0.1
Topminnow	4	<0.1
Mosquitofish	7	<0.1
Brook silverside	144	0.7
Striped bass	134	0.7
Unid. sunfish	298	1.5
Sunfish (*Lepomis*)	2,337	11.7
Crappie	373	1.9
Darter	675	3.4
Yellow perch	387	1.9
Unid. larvae	281	1.4
Total	19,926	100.0
Eggs		
Blueback herring	491	3.1
American shad	11,494	73.0
Gizzard and/or threadfin shad	339	2.2
Minnow	39	0.2
Striped bass	1,132	7.2
Yellow perch	48	0.3
Other eggs	2,206	14.0
Total	15,749	100.0

Source: Paller et al., 1986a.

The 28 creeks sampled during 1984 ranged from small intermittent streams to major tributaries. Discharge rates from most of the creeks were highly variable. The mean temperature also varied among the creeks (Table V-4.60). Four of the creeks (Lockner's, Ebenezer, Lake Parachuchia Outlet, and Hollow) occasionally experienced very low (<1.0 mg/L) oxygen levels. This generally occurred during June and July when the spawning season was nearly over (Paller et al., 1985).

The 14 creeks sampled during 1985 also ranged in size, discharge rate, and mean temperature. In the nonthermal creeks, the mean temperatures varied from 8.0 to 19.3°C (Table V-4.61), while the mean temperatures in the thermal creeks were considerably higher: Four Mile Creek had a mean temperature of 32.7°C, which was 13 to 16°C above the average temperature in most of the other creeks, and Beaver Dam Creek had a mean temperature of 25.7°C, which was approximately 7°C above most of the other creeks. The average oxygen concentrations remained above 5.0 mg/L (the minimum level recommended by the EPA for a sustainable fish community) in all streams, although lower concentrations were observed on isolated dates in most streams.

A total of 5,379 larvae and 363 eggs were collected from all creek mouths combined during 1984 (Table V-4.62). The greatest densities of ichthyoplankton were from Steel Creek (871/1,000 m^3), Briar Creek (858/1,000 m^3), and Lake Parachuchia Outlet (856/1,000 m^3). The majority of the eggs collected in 1984 were from Steel Creek and Spirit Creek.

A total of 1,511 fish larvae and 539 fish eggs were collected from the creek mouths during 1985 (Table V-4.63). Most of the eggs taken from Four Mile Creek were collected on May 7, 1985 when C Reactor was shut down and the creek temperature had dropped to 26.8°C. These data indicated that fish moved into the mouth of this creek and spawned when temperatures were suitable (Paller et al., 1986b). The eggs collected from Four Mile Creek and Beaver Dam Creek could not be positively identified. The eggs collected from Steel Creek were primarily those of American shad (44.1%) and blueback herring (35.8%). Steel Creek also produced large numbers of blueback herring eggs in 1984 (Paller et al., 1985) and in 1983 (Paller et al., 1984), indicating that it was a regular spawning area for this species.

The average density for all creek mouths sampled in 1984, including those located downstream of RM 89.3), was 85.4/1,000 m^3. The average ichthyoplankton density in the creek mouths sampled during 1984 ranged from 5.0/1,000 m^3 in Upper Boggy Gut to 232.5/1,000 m^3 in Seine's Landing (Table V-4.63).

TABLE V-4.60

Chemical Parameters (mean and range) in the Mouths of Selected Savannah River Tributaries (February-July 1984)

Creek (RM)	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µ mhos)	Alkalinity (mg/L)	pH
Collin (30.0)	18.5 (7.4-27.5)	6.7 (4.4-10.3)	66.4 (41.0-96.0)	1.48 (3.3-20.5)	6.1 (5.1-8.5)
Meyers Lake (35.4)	18.6 (7.4-28.5)	6.0 (3.2-8.7)	63.5 (41.0-91.0)	13.5 (2.6-19.3)	5.9 (4.9-8.3)
Coleman Lake (40.3)	18.2 (7.3-27.0)	6.1 (3.1-8.8)	65.4 (26.0-89.0)	15.4 (3.3-20.8)	5.9 (5.0-7.1)
Lockner's (43.2)	16.9 (6.5-20.5)	3.6 (0.1-8.4)	56.3 (20.0-85.0)	5.1 (0.0-17.5)	4.6 (3.5-6.9)
Ebenezer (44.8)	18.3 (7.0-26.1)	3.1 (0.0-8.0)	53.3 (42.0-84.0)	4.8 (0.0-18.0)	4.2 (3.0-6.9)
Seines Landing (47.7)	15.8 (5.9-25.5)	5.0 (2.0-7.6)	60.1 (48.0-87.0)	7.3 (0.0-18.3)	4.9 (4.2-7.0)
Plank (51.1)	16.9 (7.4-24.2)	6.5 (3.0-8.7)	66.4 (50.0-100.0)	16.6 (13.0-22.5)	5.5 (4.8-7.1)
Lake Parachuchia (64.2)	17.9 (6.4-27.0)	5.8 (0.5-8.9)	67.2 (42.0-100.0)	15.9 (9.0-22.5)	6.0 (4.9-7.8)
Black (78.4)	14.7 (8.0-23.9)	7.8 (4.7-9.9)	69.6 (52.0-140.0)	23.2 (11.5-65.3)	6.6 (6.3-6.8)
Pike (84.1)	17.6 (6.5-27.5)	6.2 (3.2-9.6)	81.8 (40.0-170.0)	23.4 (11.5-56.3)	6.2 (5.1-7.2)
Ware (88.6)	21.3 (16.5-27.5)	6.9 (5.9-8.5)	69.3 (50.0-81.0)	19.1 (17.3-20.5)	6.5 (5.8-6.9)
Buck (92.6)	17.1 (5.6-26.8)	6.3 (3.7-10.0)	84.4 (54.0-194.0)	22.9 (8.8-80.0)	5.9 (1.1-7.2)
Briar (97.6)	17.6 (5.2-25.2)	6.7 (4.3-9.5)	67.9 (42.0-101.0)	17.0 (10.0-24.8)	6.1 (5.2-7.0)
The Gaul (109.0)	15.0 (5.9-20.6)	6.2 (3.2-9.0)	61.7 (40.0-78.0)	14.1 (3.8-24.8)	5.9 (5.1-6.9)
Smith Lake (126.5)	16.9 (5.6-25.8)	6.8 (2.9-9.6)	61.7 (36.0-120.0)	18.9 (11.5-29.0)	6.2 (5.3-7.6)
Lower Three Runs (129.0)*	18.0 (5.0-24.2)	6.9 (5.1-8.4)	78.1 (41.0-130.0)	24.1 (11.8-29.3)	6.3 (5.5-7.5)
Sweetwater (133.5)	16.5 (7.1-24.5)	7.5 (4.7-9.8)	69.6 (45.0-120.0)	15.4 (11.5-19.8)	4.9 (3.6-7.6)
Lower Boggy Gut (141.3)	16.1 (11.4-25.4)	6.7 (5.0-7.6)	45.3 (38.0-60.0)	9.5 (9.5-9.5)	6.1 (6.1-6.1)
Steel (141.6)	17.8 (5.2-25.5)	6.6 (3.8-10.4)	60.7 (44.0-86.0)	14.1 (10.5-17.9)	5.6 (4.3-7.0)
Four Mile (150.6)	30.7 (6.0-39.9)	5.3 (3.5-9.4)	71.8 (50.0-145.0)	11.6 (6.0-15.8)	6.7 (5.9-8.1)
Beaver Dam (152.1)	25.1 (12.0-32.0)	5.1 (3.3-8.2)	73.4 (40.0-92.0)	13.1 (3.8-2.8)	6.4 (5.5-7.2)
Upper Three Runs (157.2)	16.4 (6.2-23.5)	6.9 (4.5-9.7)	37.9 (10.0-100.0)	5.9 (1.0-16.8)	5.6 (4.4-7.2)
Upper Boggy Gut (162.2)	12.4 (6.6-20.5)	6.8 (4.0-9.0)	59.3 (46.0-90.0)	14.6 (9.4-19.3)	4.9 (7.3-7.4)
McBean (164.2)	18.0 (5.5-26.9)	6.4 (3.9-8.9)	65.2 (47.0-100.0)	17.3 (11.9-21.5)	6.2 (3.6-8.6)
High Bank (171.9)	12.7 (7.5-20.0)	6.5 (2.0-10.5)	64.4 (55.0-100.0)	15.7 (12.8-18.5)	6.4 (5.5-7.1)
Hollow (176.1)	16.7 (4.4-26.0)	7.0 (0.8-10.4)	39.1 (13.0-130.0)	5.7 (1.5-13.6)	5.5 (6.1-6.8)
Pine (180.1)	16.6 (16.5-16.6)	6.3 (6.3-6.3)	51.0 (50.0-52.0)	13.3 (13.3-13.3)	6.5 (9.6-8.2)
Spirit (183.3)	16.3 (4.9-27.2)	6.5 (1.6-9.0)	48.6 (24.0-140.0)	8.0 (2.8-8.0)	5.9 (5.2-8.1)

* Underscores indicate creeks draining the SRP.

Source: Paller et al., 1985.

TABLE V-4.61

Chemical Parameters (mean and range) in the Mouths of Selected Savannah River Tributaries (February-July 1985)

Creek (RM)	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)†	Alkalinity ($mgCaCO_3/L$)	pH	Number of Dates Sampled
Buck (92.6)	19.2 (6.3-28.1)	5.9 (3.0-9.2)	157.7 (67.0-260.0)	47.3 (6.3-74.5)	6.7 (4.7-8.3)	23
Briar (97.6)	19.3 (5.2-30.5)	7.1 (5.2-9.4)	95.4 (51.0-134.0)	23.3 (5.8-29.0)	6.6 (5.2-7.9)	26
The Gaul (109.0)	10.9 (4.0-17.8)	5.9 (5.5-6.5)	69.6 (63.0-78.0)	13.0 (8.3-17.0)	4.9 (3.9-6.2)	3
Smith Lake (126.5)	17.6 (6.0-27.0)	6.1 (3.5-9.7)	93.5 (28.0-178.0)	31.9 (15.8-52.8)	6.5 (3.7-8.6)	26
Lower Three Runs (129.0)*	18.3 (8.0-26.1)	7.2 (5.4-9.7)	93.9 (64.0-124.0)	33.6 (20.5-43.0)	6.4 (4.1-7.3)	23
Sweetwater (133.5)	17.1 (7.0-25.3)	6.1 (4.6-10.5)	66.0 (33.0-84.0)	19.0 (13.0-24.3)	6.3 (4.2-7.3)	20
Steel (141.6)	19.1 (6.0-27.0)	6.5 (2.7-10.4)	80.6 (34.0-108.0)	18.7 (8.0-23.5)	6.2 (4.2-7.3)	26
Four Mile (150.6)	32.7 (11.0-40.5)	5.6 (3.6-8.3)	79.2 (42.0-94.0)	14.0 (9.3-22.7)	6.6 (5.7-7.5)	25
Beaver Dam (152.1)	25.7 (15.5-33.0)	5.4 (4.0-7.2)	88.5 (24.0-125.0)	16.3 (11.8-18.5)	6.4 (4.9-7.6)	25
Upper Three Runs (157.2)	17.0 (8.0-24.9)	7.3 (5.2-9.3)	23.8 (17.0-61.0)	3.5 (1.0-6.0)	6.3 (5.2-7.6)	25
Upper Boggy Gut (162.2)	8.0 (8.0-8.0)	6.9 (6.8-6.9)	56.0 (40.0-72.0)**	16.0 (16.0-16.0)	6.1 (6.0-6.1)	1
McBean (164.2)	19.1 (6.5-28.1)	6.7 (3.6-9.6)	53.9 (45.0-66.0)	17.9 (11.0-21.3)	6.6 (4.7-9.3)	24
Hollow (176.1)	18.1 (6.6-26.2)	7.2 (3.1-10.2)	18.3 (11.0-80.0)	3.9 (0.3-39.0)	6.1 (4.8-9.0)	26
Spirit (183.3)	18.9 (6.0-28.0)	6.6 (4.4-10.6)	45.7 (29.0-64.0)	5.6 (2.3-18.3)	6.2 (5.0-8.3)	26

* Underscores indicate creeks draining the SRP.
** This large conductivity range on a single sample date was due to top/bottom differences.
† Equivalent to µmho used in earlier reports.

Source: Paller et al., 1986b.

TABLE V-4.62

Ichthyoplankton Abundance in Savannah River Tributaries Located Between RM 30.0 and 183.3 (February-July 1984)

Creek	(RM)	Mean Discharge (m^3/sec)	Number Dates Sampled	Larvae	Eggs	Taxa	Mean Density (no./1,000 m^3)	Max. Density (no./1,000 m^3)	Ichthyoplankton Transported x 10^6
Collin	(30.0)	20.6	26	282	1	11	43.3	307.6	23.2
Meyers Lake	(35.4)	11.6	26	266	0	12	43.4	323.1	18.0
Coleman Lake	(40.3)	23.7	26	435	0	13	64.4	292.6	95.5
Lockner's	(43.2)	0.4	21	264	0	14	225.8	3,690.8	<0.1
Ebenezer	(44.8)	8.4	26	313	0	13	60.3	604.7	21.8
Seines Landing	(47.7)	0.0*	15	319	1	11	232.5	781.2	0.0
Plank	(51.1)	4.7	12	154	1	10	110.0	363.2	3.5
Lake Parachuchia	(64.2)	27.7	26	822	34	12	182.6	622.1	102.4
Black	(78.4)	4.8	4	31	0	7	52.7	134.9	0.9
Pike	(84.1)	11.0	21	128	3	11	59.4	416.3	5.1
Ware	(88.6)	0.0*	3	47	0	6	190.6	461.9	0.0
Buck	(92.6)	3.3	25	204	2	12	68.8	668.2	1.7
Briar	(97.6)	62.4	26	853	5	12	157.7	612.2	142.7
The Gaul	(109.0)	2.2	9	56	0	7	83.0	747.2	0.2
Smith Lake	(126.5)	24.3	26	242	0	13	50.8	257.0	26.4
Lower Three Runs	(129.0)	1.0	14	27	1	7	14.1	106.3	0.3
Sweetwater	(133.5)	9.1	19	48	5	11	18.1	75.0	2.3
Lower Buggy Gut	(141.3)	5.2	2	36	0	6	133.2	303.5	0.8
Steel	(141.6)	16.3	26	801	70	14	172.5	1,288.2	53.0
Four Mile	(150.6)	3.0	18	38	12	6	45.5	547.6	3.9
Beaver Dam	(152.1)	2.1	17	115	4	10	39.9	149.7	0.9
Upper Three Runs	(157.2)	9.2	23	113	4	12	24.6	211.3	10.3
Upper Boggy Gut	(162.2)	5.8	7	6	0	4	5.0	18.1	0.5
McBean	(164.2)	2.1	13	22	7	10	22.6	112.1	0.7
High Bank	(171.6)	0.0*	3	14	0	4	39.1	81.3	0.0
Hollow	(176.1)	2.7	24	115	29	10	44.5	278.0	0.2
Pine	(180.1)	0.0*	1	5	0	2	93.1	93.1	0.0
Spirit	(183.3)	2.8	17	59	184	10	113.1	1,786.2	5.4
Total				5,379	363				

* Although some of the small creeks had no discharge, when sampled they had ichthyoplankton. Larvae in these creeks were not transported into the river with creek discharge.

Source: Paller et al., 1985.

TABLE V-4.63

Ichthyoplankton Abundance in Savannah River Tributaries Located Between RM 89.3 and 187.1 (February-July 1985)

Creek	(RM)	Mean Discharge (m^3/sec)	Number Dates Sampled	Larvae	Eggs	Taxa	Mean Density (no/1,000 m^3)	Ichthyoplankton Transported (millions)
Buck	(92.6)	0.0	23	314	0	8	129.7	0.0
Briar	(97.6)	15.1	26	82	12	10	21.0	2.2
The Gaul	(109.0)	0.0	3	1	0	1	11.5	0.0
Smith Lake	(126.5)	3.7	26	714	2	11	212.0	0.2
Lower Three Runs	(129.0)	1.2	23	67	8	7	28.4	0.5
Sweetwater	(133.5)	1.2	20	7	0	4	6.1	0.0
Steel	(141.6)	8.5	26	71	179	8	53.0	5.2
Four Mile	(150.6)	1.2	25	6	113	4	373.3	0.7
Beaver Dam	(152.1)	3.8	25	17	136	9	44.0	4.3
Upper Three Runs	(157.2)	2.8	25	73	18	8	41.3	1.0
Upper Boggy Gut	(162.2)	0.0	1	0	0	0	0.0	0.0
McBean	(164.2)	1.3	24	39	9	7	28.7	0.5
Hollow	(176.1)	2.4	26	111	32	6	48.3	2.1
Spirit	(183.3)	1.5	26	9	30	6	69.7	0.7
Total				1,511	539			

Source: Paller et al., 1986b.

The average density for all creek mouths sampled during 1985 was 64.6/1,000 m^3. This was less than the average for 1983 (99.9/1,000 m^3) or for 1984 (66.2/1,000 m^3) for those creeks upstream from RM 89.3. The differences observed between years may have been related to differences in spawning success or creek discharges. Reduced discharges in a creek could result in fewer larvae being carried from the sheltered creek backwaters and adjacent swamps into the main creek channels, where all sampling occurred.

Average monthly ichthyoplankton densities in 1984 were consistently higher in the creek mouths than in the river (Figure V-4.47). The higher densities in the creeks may have been related to slightly higher temperatures which could have stimulated spawning (Nikolsky, 1963). However, water level may have also been a factor since fishes can spawn in areas of the floodplain which have been inundated by the river. River elevation was relatively low during late March and throughout April, when the difference between densities in the creek mouths and river was greatest, so many of the spawning sites in the floodplain were unavailable during these months. Consequently, spawning in the creek mouths may have been greater than what would be expected when flooding was prevalent. During May, when the Savannah River was above flood level, ichthyoplankton densities were more similar between the creek mouths and river (Figure V-4.47). Taxa that appeared to utilize the creek mouths most during 1984 were blueback herring, gizzard and threadfin shad, other clupeids, centrarchids, and crappie. In contrast, American shad and striped bass densities were generally higher in the river than in the creek mouths (Table V-4.64), primarily in May.

During 1985, the average monthly ichthyoplankton densities were higher in the creek mouths than in the river during March and July (Figure V-4.48). The relatively high mean density in the creeks during March was due to an abundance of American shad, darters, blueback herring, and other species, which may have spawned earlier in the creek because of slightly higher temperatures. The relatively high mean density in the creek mouths during July was due primarily to sunfish spawning. When river densities were higher than creek mouth densities (April-June), they were due primarily to an abundance of American shad ichthyoplankton, which were more abundant during 1985 than during 1984. American shad often deposit their eggs in and near the main channel of large rivers (Jones et al., 1978; Leggett, 1976), although they sometimes spawn in the lower reaches of tributary creeks. They are not known to utilize floodplain habitats for spawning. Densities of American shad eggs and larvae should be less dependent on river levels than those taxa (e.g., crappie, minnows, and blueback herring) which utilize floodplain habitats to spawn. Dominant taxa in the creek mouths in 1985 were blueback herring, sunfish, American shad, and darters (Table V-4.65).

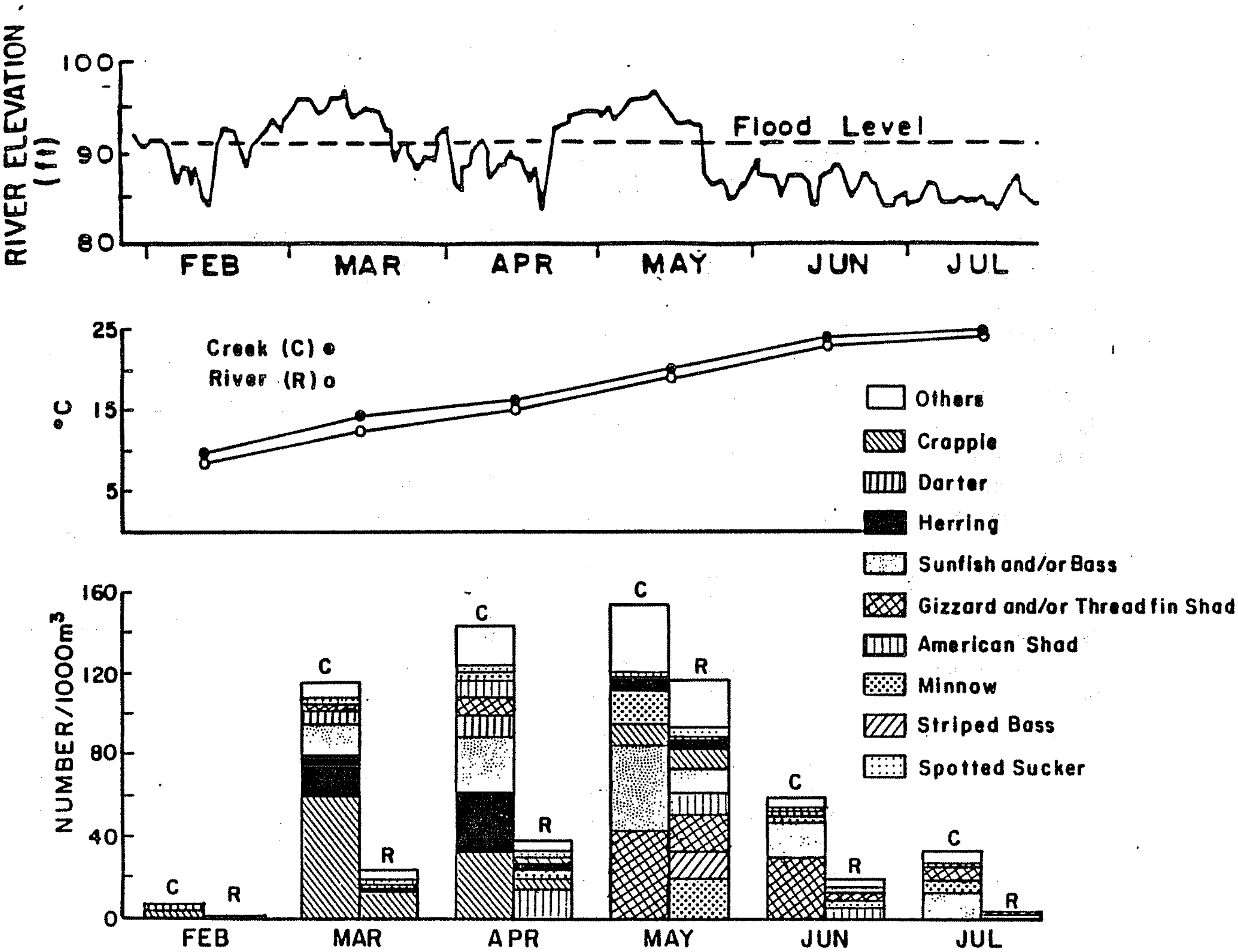


FIGURE V-4.47. Comparison of Average Monthly Ichthyoplankton Density and Water Temperature in the Savannah River and 26 of its Tributaries (February–July 1984)
Source: Paller et al., 1985

TABLE V-4.64

Percent Abundance and Average Density (no./1,000 m^3) of Fish Larvae and Eggs Collected from the Savannah River Tributaries, Oxbows, and SRP Intake Canals (February-July 1984)

Taxa	River*		Creeks**		Oxbows†		Intake Canals††	
	Percent	Density	Percent	Density	Percent	Density	Percent	Density
American shad	14.0	5.2	2.1	4.9	0.2	0.5	0.4	0.2
Blueback herring	4.5	1.6	8.0	8.4	4.6	9.4	12.6	5.6
Gizzard and/or threadfin shad	10.8	3.9	14.3	11.8	42.2	85.9	11.6	5.0
Unid. clupeid	7.6	2.6	14.6	11.4	21.4	48.8	24.2	10.0
Striped bass	3.0	2.9	<0.1	<0.1	0.2	0.4	3.2	1.5
Spotted sucker	4.3	1.7	0.7	0.6	0.3	0.6	5.9	2.5
Unid. sucker	0.7	0.3	0.6	2.0	<0.1	<0.1	0.1	<0.1
Pirate perch	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Yellow perch	1.1	0.4	0.6	0.4	0.3	0.6	2.1	0.9
Darter	2.7	1.0	5.7	4.7	0.4	0.8	2.0	0.8
Sunfish (Lepomis)	6.9	2.6	12.8	11.0	19.0	43.2	1.5	0.7
Unid. sunfish	4.0	1.4	7.4	6.2	2.3	6.0	1.5	0.7
Crappie	13.5	4.7	20.5	15.0	3.7	7.6	24.1	10.5
Largemouth bass	0.0	0.0	<0.1	<0.1	<0.1	<0.1	0.0	0.0
Mudminnow	<0.1	<0.1	0.0	0.0	0.0	0.0	0.0	0.0
Swampfish	<0.1	<0.1	0.0	0.0	0.0	0.0	0.0	0.0
Minnow (Cyprinid)	13.5	5.2	7.4	6.0	1.2	2.2	6.5	2.7
Carp	3.2	1.1	1.2	0.8	0.3	0.6	2.0	0.9
Mosquitofish	<0.1	<0.1	0.0	0.0	<0.1	<0.1	0.0	0.0
Topminnow	<0.1	<0.1	<0.1	<0.1	0.0	0.0	0.0	0.0
Needlefish	0.1	<0.1	0.0	0.0	0.0	0.0	0.0	0.0
Silverside	0.2	0.1	0.8	0.7	0.1	0.2	0.0	0.0
Catfish and/or bullhead	<0.1	<0.1	<0.1	<0.1	0.0	0.0	0.0	0.0
Pickerel	0.1	<0.1	0.1	0.1	<0.1	<0.1	0.3	0.1
Sturgeon	<0.1	<0.1	0.0	0.0	0.0	0.0	0.0	0.0
Gar	<0.1	<0.1	<0.1	<0.1	0.0	0.0	0.1	<0.1
Bowfin	<0.1	<0.1	<0.1	<0.1	0.0	0.0	0.0	0.0
Unid. larvae	1.5	0.6	2.0	1.7	3.6	9.4	1.2	0.5
Unid. eggs	3.5	1.3	1.1	0.8	0.1	0.2	0.4	0.2
Total	99.9	36.7	100.0	86.6	99.9	216.4	99.8	42.8
Total number	18,267		6,159		7,235		978	

* Twenty-six transects between RM 29.6 and 187.1.
** Mouths of 28 tributary creeks.
† Six oxbows.
†† 1G (RM 157.1) and 3G (RM 155.3) intake canals.

Source: Paller et al., 1985.

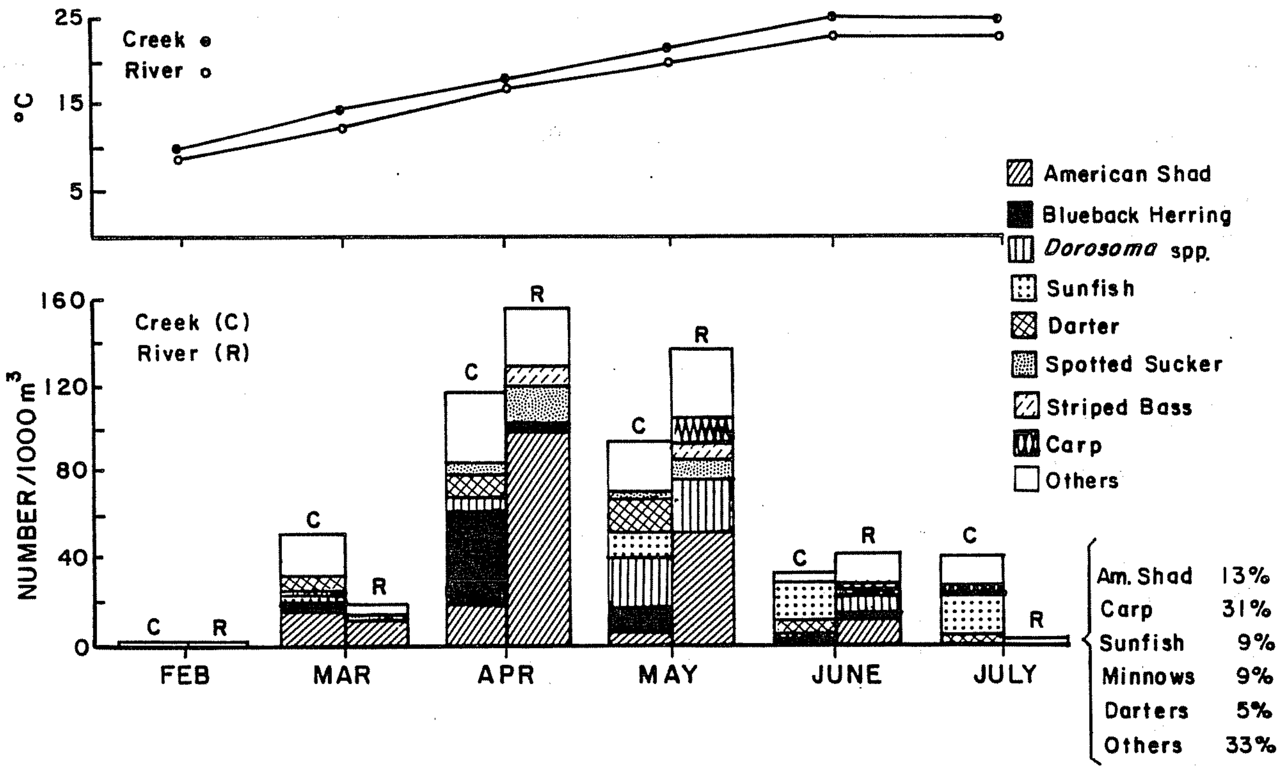


FIGURE V-4.48. Average Monthly Ichthyoplankton Density (no./1,000 m³) and Taxonomic Composition, and Mean Monthly Temperatures (°C) for the Savannah River (R) and Tributary Creeks (C) (February-July 1985). Source: Paller et al., 1986b.

TABLE V-4.65

Percent Abundance and Average Density (no./1,000 m^3) of Fish Larvae and Eggs Collected from the Savannah River Tributaries, Oxbows, and the Savannah River Canals (February-July 1985)

	River*		Creeks**		Oxbows†		Intake Canals††	
Taxa	Percent Abundance	Density	Percent Abundance	Density	Percent Abundance	Density	Percent Abundance	Density
Sturgeon	<0.1	<0.1	0.0	0.0	0.0	0.0	0.0	0.0
Gar	0.0	0.0	0.0	0.0	0.0	0.0	0.2	<0.1
Unid. Clupeidae	3.3	2.2	8.3	3.9	14.9	65.5	10.1	5.0
Blueback herring	2.2	1.4	19.3	10.2	5.9	27.6	3.5	1.0
American shad	50.8	37.8	13.0	10.3	0.7	3.4	1.7	1.4
Gizzard and/or threadfin shad	9.9	7.1	6.5	4.2	47.6	221.6	18.5	12.0
Mudminnow	0.0	0.0	<0.1	<0.1	0.0	0.0	0.0	0.0
Pickerel	<0.1	<0.1	0.2	0.1	0.0	0.0	0.2	<0.1
Needlefish	<0.1	<0.1	0.0	0.0	0.0	0.0	0.0	0.0
Minnow (Cyprinidae)	3.7	2.2	1.2	0.5	<0.1	0.1	3.1	1.3
Carp	4.6	3.1	0.0	0.0	<0.1	0.2	9.1	6.5
Unid. sucker	0.4	0.3	0.5	0.5	0.0	0.0	0.3	0.3
Spotted sucker	8.1	8.4	0.0	9.1	<0.1	0.2	41.7	23.4
Catfish and/or			14.1					
bullhead	<0.1	<0.1	<0.1	<0.1	0.0	0.0	<0.1	0.2
Swampfish	<0.1	<0.1	0.0	0.0	0.0	0.0	<0.1	<0.1
Pirate perch	0.1	0.1	<0.1	<0.1	0.0	0.0	0.0	0.6
Topminnow	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.0	0.0
Mosquitofish	<0.1	<0.1	0.0	0.0	<0.1	0.2	0.0	0.0
Brook silverside	0.1	<0.1	3.9	2.5	0.2	0.6	0.4	0.1
Striped bass	5.4	3.7	0.1	<0.1	0.1	0.2	5.6	1.8
Unid. sunfish	0.3	0.3	1.8	0.9	1.8	8.8	0.3	0.2
Sunfish (<u>Lepomis</u>)	0.7	0.4	11.4	5.6	18.9	87.7	0.2	0.2
Crappie	0.3	0.2	0.9	0.5	2.8	14.5	0.5	0.1
Darter	0.7	1.0	12.1	7.0	2.5	11.5	3.0	1.0
Yellow perch	0.2	0.1	0.8	0.4	3.6	18.4	0.0	0.1
Unid. larvae	9.2	6.4	14.3	8.9	1.0	4.8	1.8	1.5
Unid. eggs								
Total	99.9	74.8	100.0	64.6	100.1	465.4	100.2	56.7
Number larvae and eggs collected	22,698		2,050		10,322		605	

* Twenty-one transects between RM 89.3 and 187.1.
** Mouths of 17 tributary creeks.
† Five oxbows.
†† 1G (RM 157.1) and 3G (RM 155.3) intake canals.

Source: Paller et al., 1986b.

The number of ichthyoplankton transported from creeks to the river during February through July 1984 ranged from approximately 0.0 for several of the smaller creeks to 142.7 million for Briar Creek (Table V-4.62). With the exception of Steel Creek, all creeks with total transport numbers in excess of 20.0 million were in the lower farfield. Steel Creek, which transported 53.0 million ichthyoplankton into the river, had the fourth highest transport value for all creeks and the highest transport value for any creek in the nearfield and the upper farfield. All of the creeks with high transport numbers were large and had relatively high discharges. These factors, rather than high ichthyoplankton densities, were primarily responsible for the high transport numbers (Paller et al., 1985). Conversely, small creeks such as Lockner's and Seine's Landing had high densities but low transport numbers because of their low discharge rates.

The average number of ichthyoplankton transported from the creeks into the river varied dramatically during the 1985 sampling period. The creeks with the greatest transport of ichthyoplankters were Steel Creek (5.2 million), Beaver Dam Creek (4.3 million), Briar Creek (2.2 million), and Hollow Creek (2.1 million; Table V-4.63). Approximately 88.0% of the ichthyoplankton from Beaver Dam Creek consisted of eggs from species such as blueback herring, minnows, sunfishes, and others that deposit their eggs on the creek bottom. Once scoured from the bottom, these nonpelagic eggs have a poor survival rate, whereas the eggs from American shad (nearly half the eggs transported from Steel Creek were those of American shad) are well adapted for pelagic transport in river currents (Jones et al., 1978; Leggett, 1976).

All the creeks with high transport numbers in 1985 had relatively high discharges (Table V-4.63). As in 1984, a few creeks, such as Smith Lake Creek and Buck Creek, had high ichthyoplankton densities but low transport numbers because of their low discharge rates.

To determine the relative contribution of ichthyoplankton from each creek to the total Savannah River ichthyoplankton count, the numbers of ichthyoplankton transported from each creek were compared to the numbers of ichthyoplankton transported by the Savannah River. From the 1984 study, it was concluded that the largest contributor to river ichthyoplankton was Briar Creek (RM 110.0), with an estimated 143.0 million ichthyoplankters transported, compared to 470.0 million at the river transect just downstream from Briar Creek. Thus, the ichthyoplankton transported from this lower farfield creek increased river ichthyoplankton levels by an estimated 70.0% or more (Figure V-4.49). Lake Parachuchia Outlet (RM 64.2) also made large ichthyoplankton contributions to the river (102.0 million), as did Coleman Lake (RM 40.3; 95.0 million). Other creeks which made substantial ichthyoplankton contributions

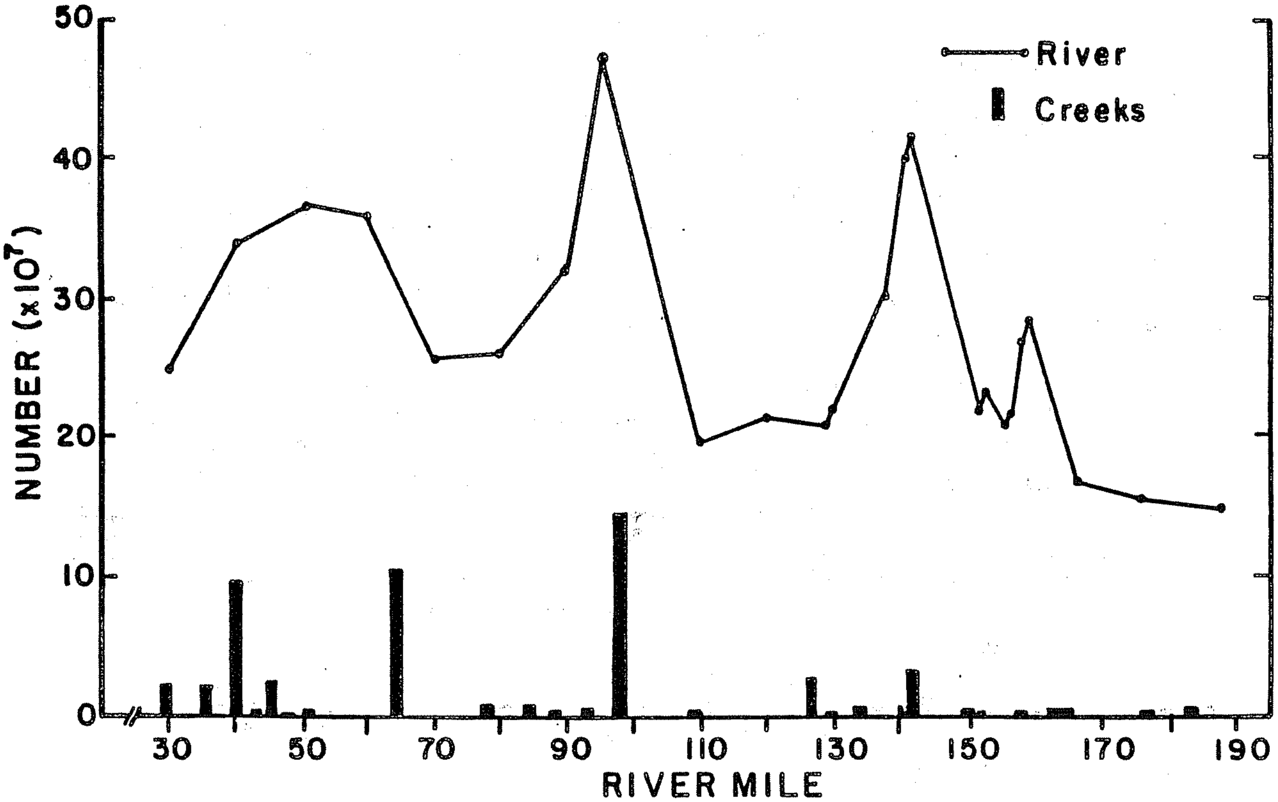


FIGURE V-4.49. Total Number of Fish Larvae and Eggs Transported Past Transects in the Savannah River and from the Mouths of Selected Savannah River Tributaries (February-July 1984).
Source: Paller et al., 1985

to the river were Collins (RM 30.0), Meyers Lake (RM 35.4), Ebenezer (RM 44.8), Smith Lake (RM 126.5), and Steel Creek (RM 141.6). Steel Creek, which contributed 53.0 million ichthyoplankton, increased river ichthyoplankton densities immediately below the creek by an estimated 15.0%.

From the 1985 study, it was concluded that, of the tributaries sampled, Steel Creek was the largest contributor of ichthyoplankton to the river, with an estimated 5.2 million ichthyoplankters transported. The ichthyoplankton transported from Steel Creek increased river ichthyoplankton levels by an estimated 2.4%, after comparing the creek's 5.2 million to the 212.8 million ichthyoplankters counted at the river transect just downstream from Steel Creek (Paller et al., 1986b). Similar comparisons for the other creeks exhibiting relatively high transport during 1985, Beaver Dam Creek, Briar Creek, and Hollow Creek, indicated that these creeks increased river ichthyoplankton levels by an estimated 3.5%, 1.4%, and 1.5%, respectively (Paller et al., 1986b). In general, creek transport to the river during 1985 was very low compared to previous years (Paller et al., 1986b).

When making comparisons between 1984 and 1985, it should be noted again that the 1985 sampling program did not include any stations downstream of RM 89.3. This is significant because five of the creeks that contributed large numbers of ichthyoplankton to the river in 1984 (Lake Parachuchia Outlet, Ebenezer, Coleman Lake, Meyer's Lake, and Collins) were not sampled in 1985. In addition, numbers of ichthyoplankton transported from two major contributors in 1984, Briar Creek and Steel Creek, had diminished considerably in 1985. The reduced ichthyoplankton transport during 1985 was probably a function of decreased creek discharges and possibly of decreased spawning activity. Decreased creek discharges would tend to result in larvae remaining in the creeks rather than being passively transported into the river. If the larvae remained in sheltered backwaters, densities would appear lower in the creeks because only larvae in the open channels would be sampled. However, the lower larval densities observed in the creeks during 1985 might have been a reasonable indication of decreased spawning, especially because water levels were low during the 1985 spawning season and many species spawn most successfully when flood waters inundate terrestrial areas (Paller et al., 1986b).

Calculations of the transport of ichthyoplankton from the creeks to the Savannah River can provide a useful indication of the contribution of various creeks to the total river ichthyoplankton densities. However, the significance of the calculated transport values of ichthyoplankton from any creek should be interpreted cautiously for several reasons. First, due to the variability in ichthyoplankton densities and the difficulties in determining river and creek discharges (see Section V.3.2.2), transport numbers should be regarded at only approximations. Second, the most important function of the creeks for fish populations may be to serve as nursery areas rather than spawning areas. As nursery areas, the creeks may provide habitat where larval fishes can grow to less vulnerable sizes before entering the river. Finally, it is difficult to evaluate the significance of a localized 8 to 10% increase or decrease in ichthyoplankton on a river fish community because biological communities are able to compensate for population losses and because density dependent mortality increases with abundance (Odum, 1971; Goodyear, 1980).

The impacts of cooling water effluents on fish spawning habitats in the creek mouths on the SRP was an important consideration of this two-year study. Of particular concern were the potential impacts on spawning areas in Steel Creek that would result from the restart of L Reactor.

In the mouth of Steel Creek, ichthyoplankton densities were low, except in late February and again from late April through May, when densities peaked at 1,288.2 organisms/1,000 m^3 (Figure V-4.50). These very high densities were primarily due to large numbers of sunfishes and unidentified cyprinids. Although moderate ichthyoplankton densities were observed through July, the peaks were lower than in earlier months, which indicated that most spawning had been completed. The major species collected during 1984 were unidentified cyprinids, sunfishes, darters, and blueback herring.

The taxonomic composition of the ichthyoplankton in Steel Creek differed somewhat from the other creeks. Steel Creek had the highest percentage of cyprinids and the third highest percentage of darters of any creek sampled during 1984 (Tables V-4.66, V-4.67, and V-4.68). Cyprinids and darters are abundant in the dense aquatic vegetation in areas of the Steel Creek swamp that are recovering from former reactor impact (Paller, 1985). Furthermore, more blueback herring ichthyoplankton were collected from Steel Creek than any other creek in the upper farfield and nearfield.

Ichthyoplankton were first collected in the mouth of Steel Creek in the 1985 study in early February (Figure V-4.51). Densities steadily increased throughout February and March and peaked in early April (it should be noted that the high densities in Steel Creek depicted in Figure V-4.51 are due primarily to a single large collection; Paller et al., 1986b). As in 1984, the densities of ichthyoplankton were relatively low in July, indicating that most of the spawning in Steel Creek was over.

Compared to the other creek mouths sampled in 1985, Steel Creek was again somewhat of an anomaly in taxonomic composition of ichthyoplankton. Steel Creek again had the highest percentage of

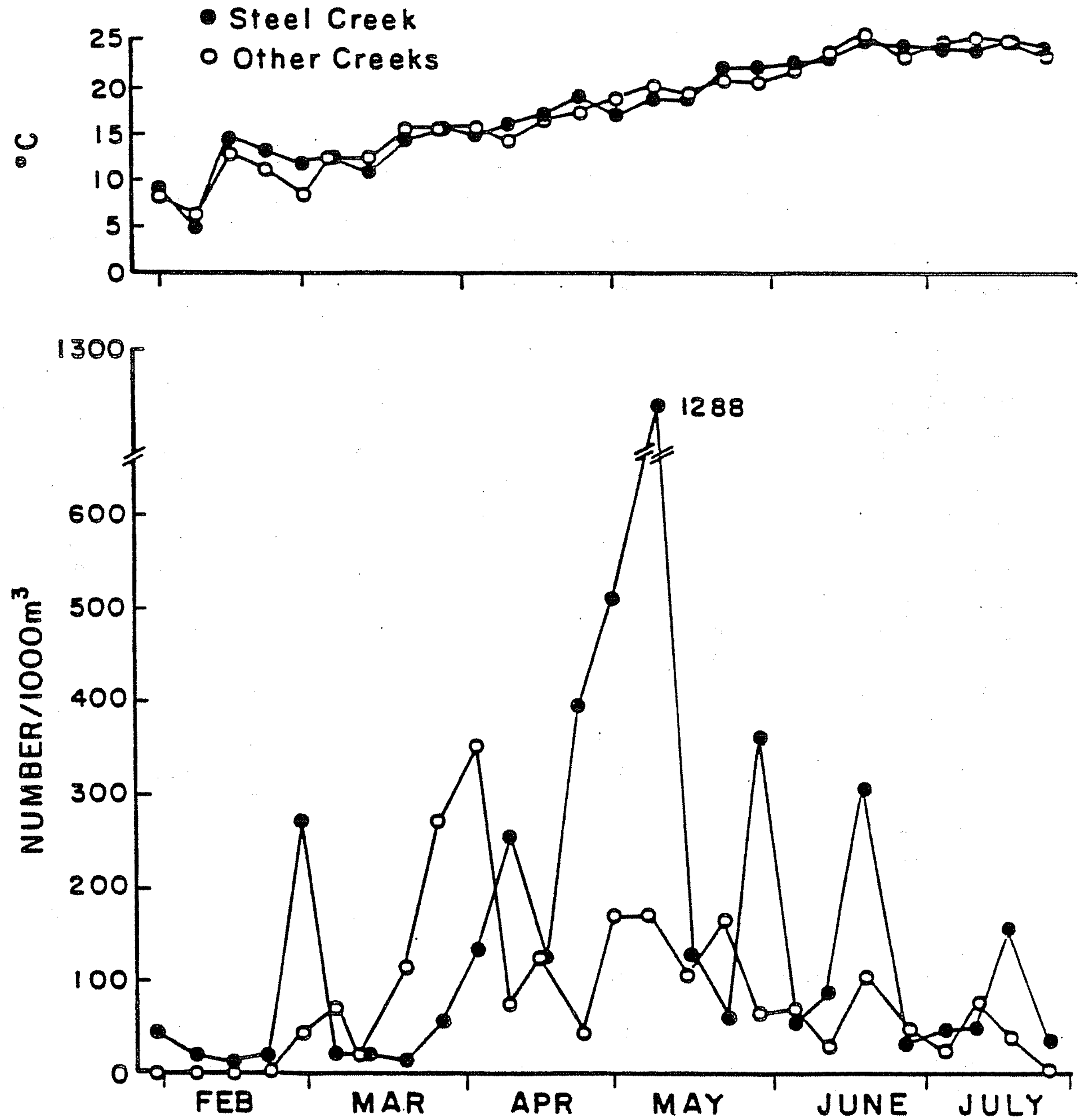


FIGURE V-4.50. Mean Ichthyoplankton Density and Temperature in Steel Creek and All Other Savannah River Tributaries Sampled During February-July 1984
Source: Paller et al., 1985

TABLE V-4.66

Percent Abundance of Ichthyoplankton in the Nearfield Creeks of the Savannah River (February-July 1984)

Taxa	Lower Three Runs (129.0)	Sweet-water (133.5)	Lower Boggy Gut (141.3)	Steel Creek (141.6)	Four Mile Creek (150.6)	Beaver Dam Creek (152.1)	Upper Three Runs (157.2)
American shad	3.6	5.7	0.0	2.2	4.0	0.8	0.9
Blueback herring	7.1	0.0	0.0	6.9	0.0	4.2	3.4
Gizzard and/or threadfin shad	3.6	7.5	0.0	0.5	0.0	0.0	13.7
Unid. clupeid	0.0	1.9	0.0	1.1	0.0	1.7	3.4
Striped bass	0.0	1.9	0.0	0.0	0.0	0.8	0.0
Spotted sucker	14.3	9.4	0.0	0.0	0.0	0.8	12.8
Unid. sucker	0.0	0.0	0.0	0.8	0.0	0.0	2.6
Pirate perch	0.0	1.9	0.0	0.1	0.0	0.0	0.0
Yellow perch	0.0	7.5	0.0	0.2	0.0	0.0	0.9
Darter	7.1	1.9	19.4	17.7	0.0	10.1	10.3
Sunfish (Lepomis)	42.9	13.2	63.9	17.5	30.0	46.2	2.6
Unid. sunfish	0.0	3.8	2.8	9.8	30.0	19.3	2.6
Crappie	0.0	7.5	8.3	3.1	2.0	8.4	37.6
Minnoe (Cyprinidae)	17.9	24.5	2.8	37.8	2.0	0.8	6.8
Largemouth bass	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Carp	0.0	0.0	2.8	0.0	0.0	0.0	1.7
Topminnow	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brook silverside	0.0	7.5	0.0	0.9	8.0	4.2	0.0
Catfish and/or bullhead	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pickerel	0.0	1.9	0.0	0.1	0.0	0.0	0.0
Gar	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bowfin	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unid. ichthyoplankton	3.6	3.8	0.0	1.1	24.0*	2.5	0.9
Total percent	100.1	99.9	100.0	100.0	100.1	99.8	99.9
Total fish	28	53	36	871	50	119	117
Total samples	14	19	2	26	18	17	23

* Primarily eggs.

Source: Paller et al., 1985.

TABLE V-4.67

Percent Abundance of Ichthyoplankton in the Lower Farfield Creeks of the Savannah River (February-July 1984)

Taxa	Collin (30.0)	Meyers Lake (35.4)	Coleman Lake (40.3)	Lockner's (43.2)	Ebenezer (44.8)	Seines Landing (47.7)	Plank (51.1)
American shad	0.0	6.4	1.2	1.9	0.0	2.8	0.0
Blueback herring	1.8	9.4	3.0	3.4	0.3	28.8	3.2
Gizzard and/or threadfin shad	6.4	4.9	5.8	0.4	0.3	22.2	14.2
Unid. clupeid	11.4	10.6	8.7	3.4	0.3	15.7	27.7
Striped bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spotted sucker	0.0	0.0	0.0	0.0	0.0	0.0	0.6
Unid. sucker	0.4	0.0	0.9	2.3	1.9	1.3	0.0
Pirate perch	0.4	0.0	0.0	0.4	0.0	0.0	0.0
Yellow perch	0.0	0.8	0.7	0.8	0.3	0.0	0.0
Darter	1.4	1.5	0.9	18.9	6.1	10.0	1.3
Sunfish (Lepomis)	16.3	18.1	25.8	15.2	1.3	3.4	16.1
Unid. sunfish	24.0	3.4	8.7	33.0	10.9	5.9	10.3
Crappie	32.5	27.1	38.9	17.0	76.7	7.2	20.6
Minnow (Cyprinidae)	2.8	1.5	0.0	0.4	0.0	0.6	1.9
Largemouth bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carp	1.8	13.5	0.2	0.0	0.0	0.0	0.0
Topminnow	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Brook silverside	0.0	0.0	0.2	1.5	0.0	0.9	0.6
Catfish and/or bullhead	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Pickerel	0.0	0.4	0.5	0.4	0.0	0.0	0.0
Gar	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bowfin	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unid. ichthyoplankton	1.1	2.6	3.9	1.1	0.6	1.2	3.2
Total percent	100.3	100.2	100.3	100.1	99.9	100.0	99.7
Total number	283	266	435	264	313	320	155
Total samples	26	26	26	21	26	15	12

Source: Paller et al., 1985.

TABLE V-4.67, Contd

Taxa	Parachuchia (64.2)	Black (78.4)	Pike (84.1)	Ware (88.6)	Buck (92.6)	Briar (97.6)	Gaul (109.0)	Smith Lake (126.5)
American shad	0.7	0.0	3.8	0.0	18.4	0.6	0.0	0.4
Blueback herring	7.8	0.0	29.0	4.3	13.6	4.8	0.0	10.7
Gizzard and/or threadfin shad	17.4	9.7	3.8	2.1	18.9	28.6	5.4	21.9
Unid. clupeid	17.3	3.2	7.6	19.2	26.2	43.8	3.4	21.9
Striped bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spotted sucker	0.0	0.0	0.8	0.0	0.5	0.2	7.1	0.8
Unid. sucker	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pirate perch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Yellow perch	1.4	6.5	0.0	0.0	0.0	0.6	0.0	0.4
Darter	0.6	0.0	3.8	0.0	1.9	1.5	1.8	2.5
Sunfish (Lepomis)	12.7	32.3	19.1	19.2	5.8	2.9	0.0	10.7
Unid. sunfish	1.1	25.8	2.3	21.3	0.0	1.0	1.8	1.7
Crappie	31.3	9.7	24.4	8.5	7.8	8.7	67.9	18.2
Minnow (Cyprinidae)	3.6	0.0	2.3	0.0	2.4	1.9	8.9	2.5
Largemouth bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carp	0.7	0.0	0.8	0.0	1.0	1.6	0.0	0.0
Topminnow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brook silverside	0.6	12.9	0.0	0.0	1.0	0.0	0.0	0.5
Catfish and/or bullhead	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pickerel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Gar	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
Bowfin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unid. ichthyoplankton	4.5	0.0	2.3	25.5	2.0	3.7	3.6	5.4
Total percent	100.1	100.1	100.1	100.1	100.0	99.9	99.9	98.0
Total number	856	31	131	47	206	858	56	242
Total samples	26	4	21	3	25	26	9	26

Source: Paller et al., 1985.

TABLE V-4.68

Percent Abundance of Ichthyoplankton in the Upper Farfield Creeks of the Savannah River (February-July 1984)

Taxa	Upper Boggy Gut (162.2)	McBean (164.2)	High Bank (171.9)	Hollow (176.1)	Pine (180.1)	Spirit (183.3)
American shad	0.0	13.8	0.0	3.8	0.0	1.3
Blueback herring	0.0	10.3	0.0	17.7	0.0	18.1
Gizzard and/or threadfin shad	0.0	13.8	7.1	33.1	80.0	66.0
Unid. clupeid	0.0	3.4	0.0	10.0	20.0	5.0
Striped bass	0.0	0.0	0.0	0.0	0.0	0.0
Spotted sucker	0.0	3.4	0.0	4.6	0.0	0.4
Unid. sucker	0.0	0.0	0.0	0.0	0.0	0.0
Pirate perch	0.0	0.0	0.0	0.0	0.0	0.0
Yellow perch	16.7	0.0	0.0	0.0	0.0	0.4
Darter	16.7	3.4	7.1	5.4	0.0	0.8
Sunfish (*Lepomis*)	33.3	31.0	7.1	0.0	0.0	2.9
Unid. sunfish	0.0	0.0	78.6	1.5	0.0	0.0
Crappie	33.3	13.8	0.0	10.0	0.0	0.0
Minnow (Cyprinidae)	0.0	3.4	0.0	6.2	0.0	1.3
Largemouth bass	0.0	0.0	0.0	0.0	0.0	0.0
Carp	0.0	0.0	0.0	0.8	0.0	1.3
Topminnow	0.0	0.0	0.0	0.0	0.0	0.0
Brook silverside	0.0	3.4	0.0	0.0	0.0	0.0
Catfish and/or bullhead	0.0	0.0	0.0	0.0	0.0	0.0
Pickerel	0.0	0.0	0.0	0.0	0.0	0.0
Gar	0.0	0.0	0.0	0.0	0.0	0.0
Bowfin	0.0	0.0	0.0	0.0	0.0	0.0
Unid. ichthyoplankton	0.0	0.0	0.0	6.9	0.0	2.3
Total percent	100.0	99.7	99.9	100.0	100.0	99.8
Total number	6	29	14	130	5	238
Total samples	7	13	3	24	1	17

Source: Paller et al., 1985.

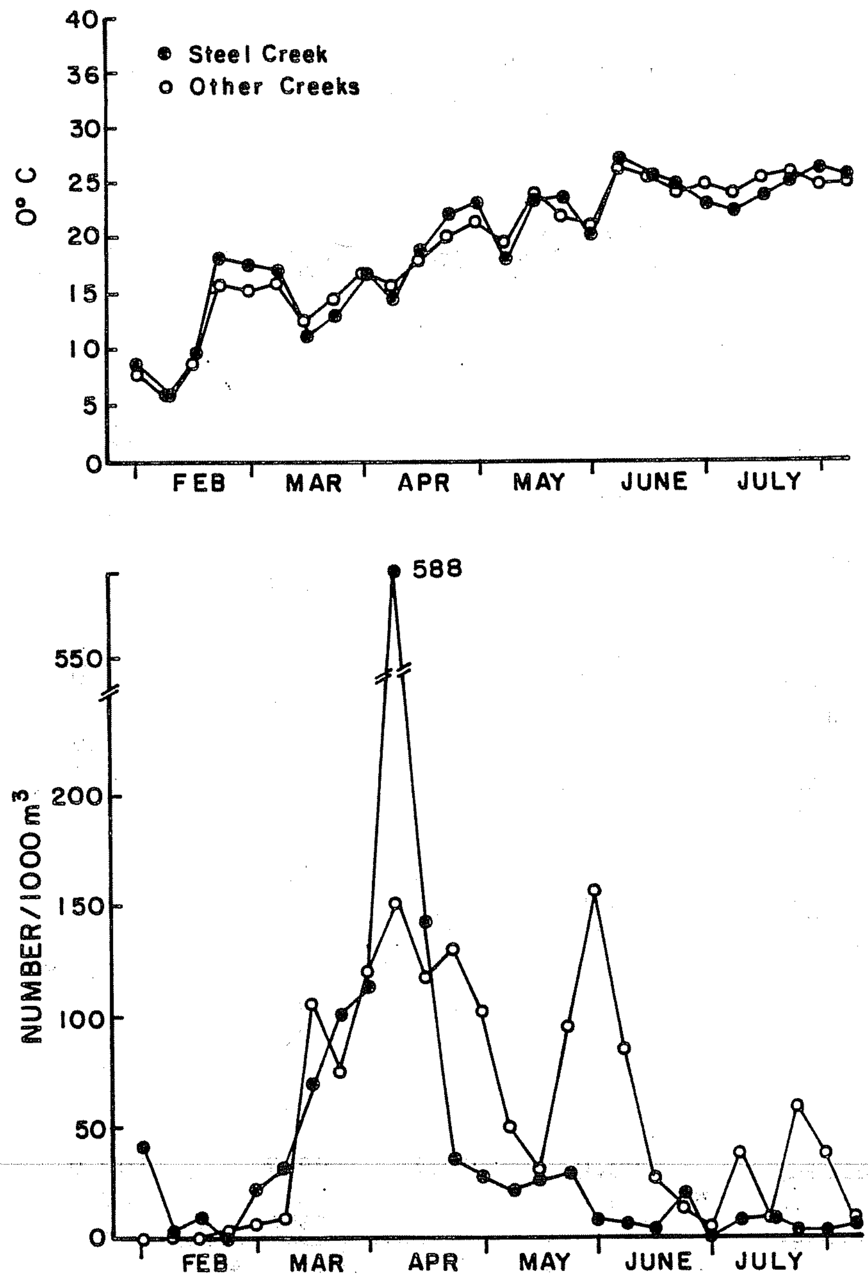


FIGURE V-4.51. Mean Ichthyoplankton Density (no./1,000 m^3) and Temperature (°C) of Steel Creek and Other Nonthermal (all creeks except Four Mile Creek and Beaver Dam Creek) Savannah River Tributary Creeks (February–July 1985)
Source: Paller et al., 1986b.

blueback herring of any creek sampled in 1985. It also had the highest percentage of American shad of any creek sampled (Tables V-4.69, V-4.70, and V-4.71).

These high densities during both years of the study indicate that Steel Creek is an important producer of blueback herring. Only Seine's Landing and Lake Parachuchia Outlet (lower farfield creeks) exported more blueback herring ichthyoplankton than Steel Creek. The lower reaches of Steel Creek also serve as a spawning area for American shad. Although American shad have been collected from the mouth of Steel Creek during previous years, they were more abundant by far during 1985. There was no indication that striped bass utilize the lower reaches of Steel Creek for spawning.

Ichthyoplankton were first collected from the mouth of Four Mile Creek in late February 1984 (Figure V-4.52). Throughout the study period, densities were low, with peaks occurring in mid-April and a small one in May. Apart from these peaks, densities in Four Mile Creek were low or ichthyoplankton were absent. During two periods, late February through late March, and mid-April through mid-May, samples were not taken in Four Mile Creek due to high river levels. At these times river water was flowing into Four Mile Creek and sampling the creek mouth would have provided no information on spawning activity in the creek (Paller et al., 1985).

Temperatures in the mouth of Four Mile Creek in 1984 exceeded the average temperature in the other creeks by as much as 15°C (Figure V-4.52). The extremely low numbers of ichthyoplankton collected in Four Mile Creek during June and July have been attributed to creek temperatures as high as 40°C. Early spawning was not observed in Four Mile Creek despite its elevated temperature, possibly because of extreme temperature variability which repelled spawning fishes or disrupted spawning cycles (Paller et al., 1985).

The dominant ichthyoplankton in the mouth of Four Mile Creek in 1984 were sunfish larvae and brook silverside. Sunfish were also predominant in several of the other creeks sampled including Lower Boggy Gut, Beaver Dam Creek, High Bank Creek, and Black Creek (Tables V-4.66, V-4.67, and V-4.68).

In 1985, ichthyoplankton were first collected from the mouth of Four Mile Creek in mid-February 1985 (Figure V-4.53). Densities were low until mid-March when a temporary drop in temperature (due to C-Reactor shutdown) was followed by an increase in ichthyoplankton densities. When C Reactor began operating again, temperatures rapidly climbed to approximately 33°C and ichthyoplankton densities declined to zero. The other two density peaks shown in Figure V-4.53 occurred during C-Reactor shutdown. In early July 1985, when the last density peak occurred, C Reactor was placed on

TABLE V-4.69

Percent Abundance of Ichthyoplankton in the Nearfield Creeks of the Savannah River (February-July 1985)

Taxa	Lower Three Runs Creek (129.0)	Sweet-water (133.5)	Steel Creek (141.6)	Four Mile Creek (150.6)	Beaver Dam Creek (152.1)	Upper Three Runs Creek (157.2)
Gar	-	-	-	-	-	-
Unid. Clupeidae	1.3	-	1.6	-	-	-
Blueback herring	8.0	-	27.2	1.7	20.3	12.1
American shad	-	-	33.2	-	1.3	6.6
Gizzard and/or threadfin shad	-	-	-	-	-	2.2
Pickerel	-	-	-	-	0.7	-
Minnow (Cyprinidae)	1.3	-	4.0	-	2.6	1.1
Carp	-	-	-	-	-	-
Unid. sucker	6.7	-	0.4	-	-	5.5
Spotted sucker	1.3	14.3	1.2	-	-	44.0
Catfish and/or bullhead	-	-	-	-	0.7	-
Pirate perch	-	-	-	-	-	-
Topminnow	-	-	-	-	0.7	-
Brook silverside	-	-	0.4	0.8	-	-
Striped bass	-	-	-	-	-	-
Unid. sunfish	20.0	14.3	3.6	-	0.7	2.2
Sunfish (*Lepomis*)	-	14.3	1.2	1.7	1.3	-
Crappie	6.7	-	-	0.8	-	1.1
Darter	41.3	28.6	12.0	-	2.0	14.3
Yellow perch	4.0	28.6	2.0	-	2.6	-
Unid. larvae	4.0	-	0.8	1.7	0.7	-
Other eggs	5.3	-	12.4	93.3	66.7	11.0
Total percent	99.9	100.1	100.0	100.0	100.3	100.1
Total larvae and eggs	75	7	250	119	153	91
Total number of sample dates	23	20	26	25	25	25

Source: Paller et al., 1986b.

TABLE V-4.70

Percent Abundance of Ichthyoplankton in the Lower Farfield Creeks of the Savannah River (February-July 1985)

Taxa	Buck (92.6)	Briar (97.6)	The Gaul (109.0)	Smith Lake (126.5)
Gar	-	-	-	-
Unid. Clupeidae	12.4	11.7	-	16.1
Blueback herring	26.1	10.6	-	19.8
American shad	30.3	3.2	-	8.7
Gizzard and/or threadfin shad	2.2	2.1	-	18.7
Mudminnow	-	-	-	0.1
Pickerel	-	-	-	0.3
Minnow (Cyprinidae)	-	1.1	-	-
Carp	0.3	4.3	-	-
Unid. sucker	-	-	-	-
Spotted sucker	-	4.3	-	0.1
Catfish and/or bullhead	-	-	-	-
Pirate perch	-	-	-	-
Topminnow	-	-	-	-
Brook silverside	1.9	1.1	-	12.4
Striped bass	-	2.1	-	-
Unid. sunfish	0.3	5.3	-	0.3
Unid.sunfish (*Lepomis*)	23.2	2.1	-	20.7
Largemouth bass	-	-	-	-
Crappie	-	-	-	1.5
Darter	1.3	41.5	-	0.6
Yellow perch	0.3	-	-	0.1
Unid. larvae	1.6	1.1	100.0	0.5
Other eggs	-	9.6	-	-
Total percent	99.9	100.1	100.0	99.9
Total larvae and eggs	314	94	1	716
Total number of sample dates	23	26	3	26

Source: Paller et al., 1986b.

TABLE V-4.71

Percent Abundance of Ichthyoplankton in the Upper Farfield the Creeks of Savannah River (February-July 1985)

Taxa	McBean (164.2)	Hollow (176.1)	Spirit (183.3)
Gar	-	-	-
Unid. Clupeidae	-	-	-
Blueback herring	20.8	16.8	25.6
American shad	16.7	4.9	-
Gizzard and/or threadfin shad	2.1	2.8	46.2
Mudminnow	-	-	-
Pickerel	-	-	-
Minnow (Cyprinidae)	4.2	-	2.6
Carp	-	-	-
Unid. sucker	-	-	-
Spotted sucker	-	2.1	10.3
Catfish and/or bullhead	-	-	-
Pirate perch	-	-	-
Topminnow	-	-	-
Brook silverside	4.2	-	7.7
Striped bass	-	-	-
Unid. sunfish	-	-	-
Unid. sunfish (*Lepomis*)	4.2	-	-
Crappie	-	-	-
Darter	45.8	69.2	2.6
Yellow perch	-	1.4	-
Unid. larvae	2.1	2.1	-
Other eggs	-	0.7	5.1
Total percent	100.1	100.0	100.1
Total larvae and eggs	48	143	39
Total number of sample dates	24	26	26

Source: Paller et al., 1986b.

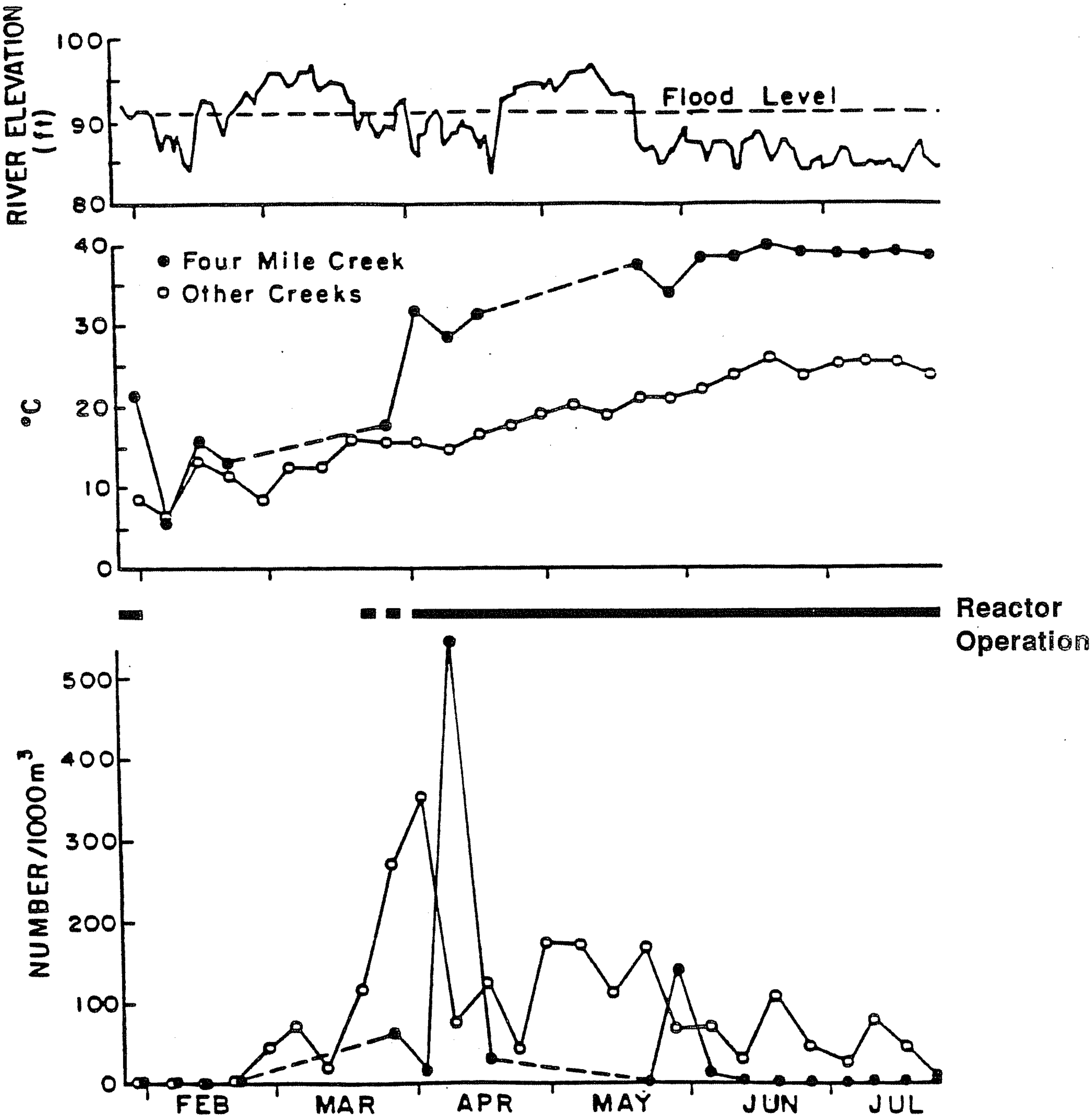


FIGURE V-4.52. Mean Ichthyoplankton Density and Temperature in Four Mile Creek and Other Savannah River Tributaries Sampled During February-July 1984

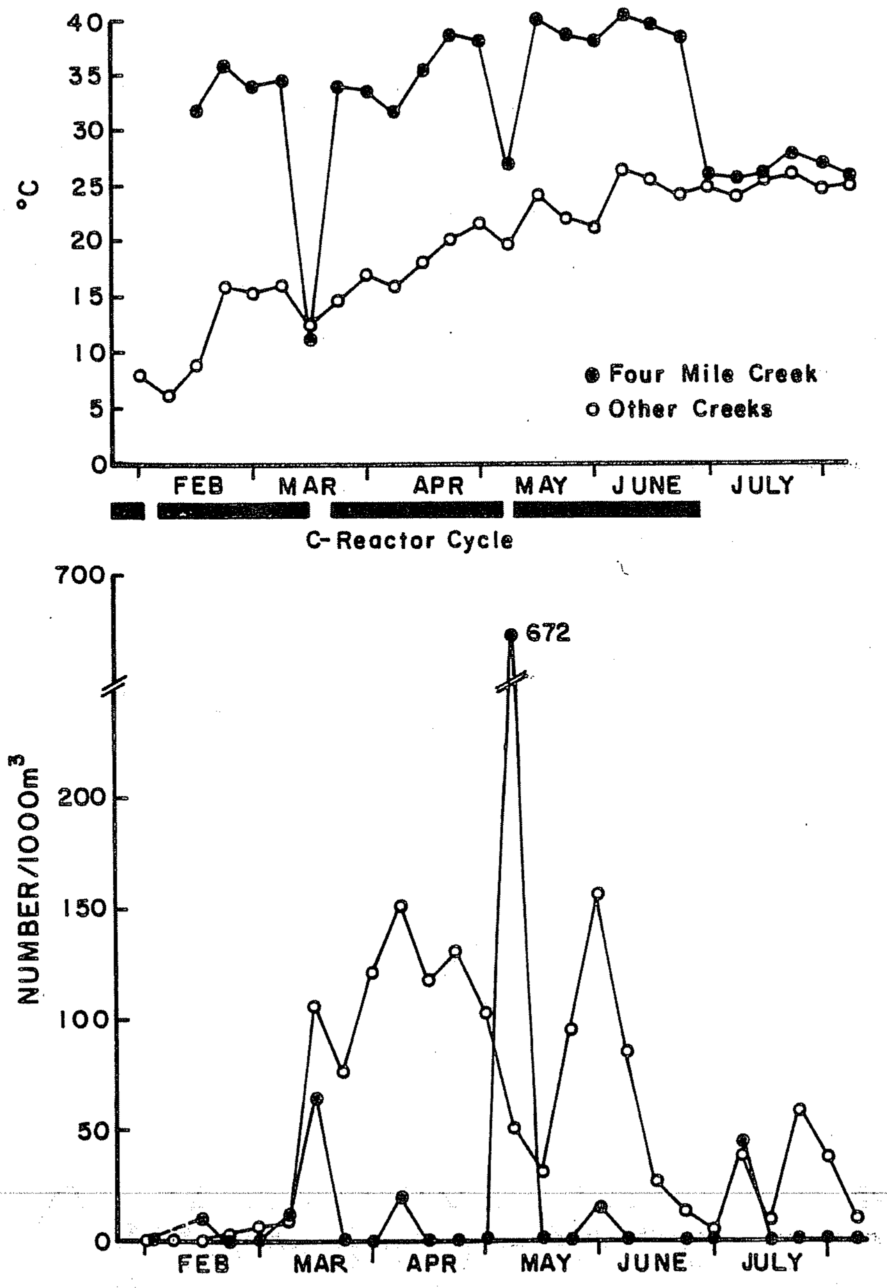


FIGURE V-4.53. Mean Ichthyoplankton Density (No./1000 m^3) and Temperature (°C) of Four Mile Creek and the Nonthermal (all creeks except Steel Creek and Beaver Dam Creek) Savannah River Tributary Creeks (February-July 1985) standby and did not discharge thermal effluent for the rest of the study period. These data suggest that ichthyoplankton were largely absent from the mouth of Four Mile Creek when the reactor was operating and water temperatures were high, but that fish rapidly moved into Four Mile Creek and began spawning as soon as the reactor shut down. This general pattern of low or zero densities, contrasted by a few brief peaks, was also observed in Four Mile Creek in 1984 (Paller et al., 1985).

Most of the ichthyoplankton collected from the mouth of Four Mile Creek in 1985 were unidentified eggs (Table V-4.69) from a single large collection (May 7, 1985). Other taxa found in Four Mile Creek were blueback herring, brook silverside, unidentified sunfish, and crappie (Table V-4.69). The abundance of fish eggs in the Four Mile Creek collection may have been due to the relatively high current velocities in this stream, or to the shortage of submerged vegetation, leaf accumulations, or other substrates that many fishes use to attach or shelter eggs (Breder & Rosen, 1966). These materials are generally scoured out of Four Mile Creek by high water velocities from C-Reactor discharges.

In 1984, ichthyoplankton were first collected from the mouth of Beaver Dam Creek, in low densities in February (Figure V-4.54). During the latter weeks of April, densities increased. Sampling was often interrupted in Beaver Dam Creek in 1984 due to high river levels. At these times river water was flowing into Beaver Dam Creek and sampling the creek mouth would have provided no information on spawning activity in the creek.

Temperatures at the mouth of Beaver Dam Creek were approximately 7°C above the average temperature of the other creeks. The greatest temperature differences occurred during May, June, and July when Beaver Dam Creek temperatures averaged 28 to 32°C, compared to average temperatures of 22 to 26°C in the other creeks. Ichthyoplankton densities were lower in the mouth of Beaver Dam Creek than in the other creek mouths during June and July, possibly indicating that spawning was reduced due to the higher temperatures.

In 1985, ichthyoplankton in the mouth of Beaver Dam Creek were first collected in early February 1985 (Figure V-4.55). The seasonal distribution of ichthyoplankton densities was similar to that of Steel Creek; densities peaked in April and were low the rest of the study period, despite the differences in temperature between the creeks. The major taxa in the mouth of Beaver Dam Creek were blueback herring and unidentified eggs (Table V-4.69). As in Four Mile Creek, the abundance of eggs could have been due to strong currents that may have dislodged eggs from the spawning areas, making them more vulnerable to collection.

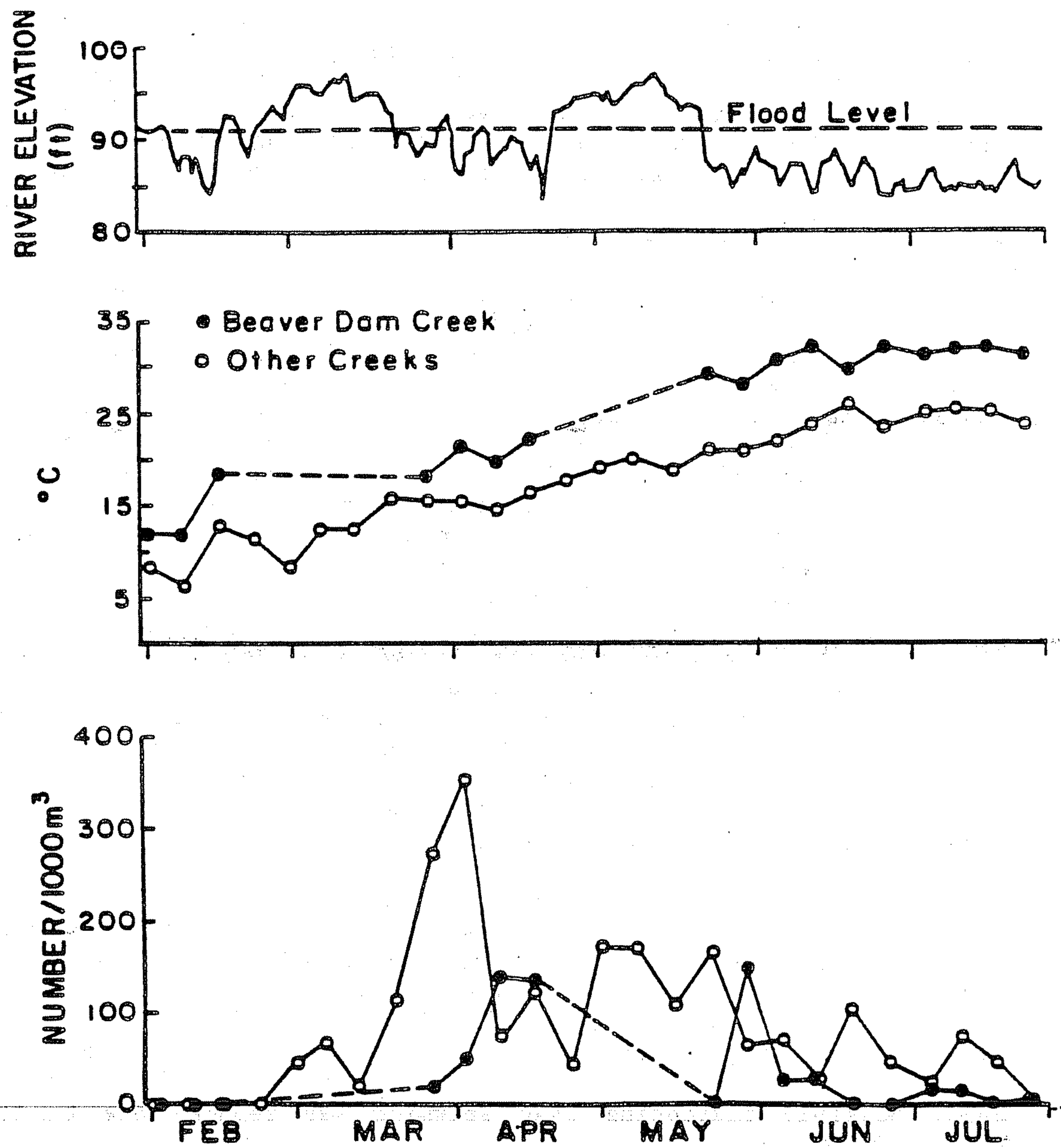


FIGURE V-4.54. **Mean Ichthyoplankton Density and Temperature in Beaver Dam Creek and all Other Savannah River Tributaries Sampled During February–July 1985**

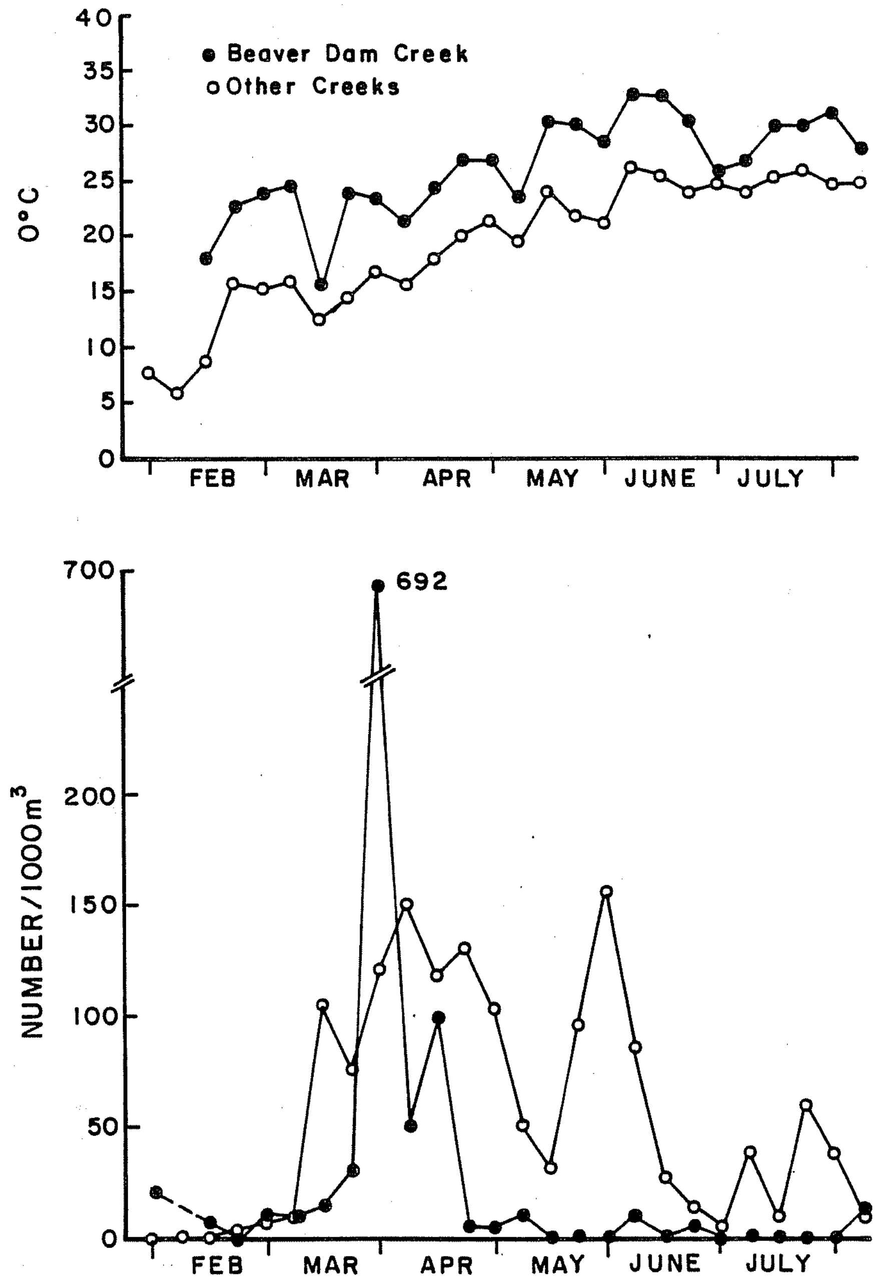


FIGURE V-4.55. Mean Ichthyoplankton Density (no./1,000 m^3) and Temperature (°C) of Beaver Dam Creek and the Nonthermal (all creeks except Four Mile Creek and Steel Creek) Savannah River Tributary Creeks (February–July 1985)
Source: Paller et al., 1986b.

Temperature trends at the mouth of Beaver Dam Creek were similar to those observed in 1984. Throughout the sample period, Beaver Dam Creek was approximately 1 to 8°C above the average temperature of the other creeks. There was some evidence of early spawning in Beaver Dam Creek due to elevated water temperatures early in the year (Figure V-4.55). There were also indications that spawning may have been reduced in Beaver Dam Creek during May, June, and July when temperatures were highest (as high as 33°C). Average densities in Beaver Dam Creek in June and July were considerably lower than the average densities in the mouths of other creeks during these months (Paller et al., 1986b). This decline in densities during June and July was also observed in 1984.

V.4.3.5.2 River Ichthyoplankton

During 1984, data collected at the 26 transects on the Savannah River between RM 29.6 and 187.1 indicated that the ichthyoplankton assemblage was numerically dominated by American shad (14.0%), gizzard and/or threadfin shad (10.8%), crappie (13.5%), and minnows (13.5%), with blueback herring, unidentified clupeids, Lepomis spp., spotted suckers, and striped bass also well-represented (Table V-4.64). In the SRP intake canals, crappie (24.1%), unidentified clupeids (24.2%), gizzard or threadfin shad (11.6%), and blueback herring (12.6%), and to a lesser extent, striped bass, spotted suckers, and minnows were the most abundant taxa (Table V-4.64). Comparing the two habitats, American shad and minnows were considerably more abundant in the river, while blueback herring, unidentified clupeids, and crappie were more abundant in the intake canals (Table V-4.64).

In 1984, ichthyoplankton were collected in small numbers in February at all transects except those in the upper farfield. Mean densities ranged from 0.0 ichthyoplankters/1,000 m^3 to 6.2/1,000 m^3. Some of the ichthyoplankton collected below RM 141.7 during February were probably transported from Steel Creek at RM 141.6. It is possible that the high densities observed in Steel Creek in February were the result of early spawning induced by thermal discharges from the SRP (Paller et al., 1985). Ichthyoplankton densities in the nearfield and lower farfield were significantly higher than in the upper farfield during February. The absence of spawning in the upper farfield may have been related to temperature, which was slightly lower in the upper farfield (mean of 8.7°C) than in the nearfield and lower farfield (means of 9.4°C; Table V-4.72).

Ichthyoplankton densities increased during March, ranging from a mean of 2.1/1,000 m^3 to 62.0/1,000 m^3. This increase was associated with rising temperatures which averaged 12.9°C over the entire study area during March. Spatial trends in ichthyoplankton density

TABLE V-4.72

Mean Ichthyoplankton Densities (no./1,000 m^3) and Temperatures (°C) in the Savannah River During February 1984

River Mile	Temp. (°C)	American Shad	Blue back Herring	Striped Bass	Other Shad*	Unid. Cyprinids	Sunfish	Crappie	Total Ichthyo-plankton**
				Lower Farfield					
29.6	9.6	0.2	0.0	0.0	0.0	0.0	0.0	0.7	1.3
40.2	9.4	0.5	0.0	0.0	0.0	0.0	0.0	2.3	5.3
50.2	9.6	0.0	0.0	0.0	0.0	0.0	0.8	2.2	3.1
60.0	9.4	0.0	0.0	0.0	0.0	0.0	0.6	3.9	6.2
69.9	9.2	0.0	0.0	0.0	0.0	0.0	0.4	0.9	4.4
79.9	9.2	0.0	0.0	0.0	0.0	0.0	0.0	1.7	3.0
89.3	9.5	0.0	0.0	0.0	0.0	0.0	0.0	0.8	2.0
97.5	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.0
110.0	9.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.0
120.0	8.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2
				Nearfield					
128.9	9.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0
129.1	9.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8
137.7	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9
141.5	9.4	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2.9
141.7	9.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
150.4	9.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
150.8	9.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
152.0	9.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
152.2	9.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
155.2	9.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
155.3	9.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
155.4	9.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
157.0	9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3
157.1	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
157.3	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				Upper Farfield					
166.6	8.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
176.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
187.1	8.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

* Gizzard and threadfin shad.
** Totals include taxa shown plus not shown.

Source: Paller et al., 1985.

were similar to those in February with lowest densities in the upper farfield, intermediate densities in the nearfield, and highest densities in the lower farfield. Again, the increase in ichthyoplankton density downstream was correlated with an overall increase in temperature downstream (Paller et al., 1985). Mean temperature increased from 11.2°C at RM 187.1 to 14.5°C at RM 29.6 (Table V-4.73).

Ichthyoplankton densities averaged 37.7 ichthyoplankters/1,000 m^3 throughout the entire study area during April, indicating a 40.0% increase in spawning activity from March. This increase was associated with water temperatures which increased from a mean of 12.9°C during March to 15.3°C during April. Mean density was highest in the nearfield, intermediate in the lower farfield, and lowest in the upper farfield. The increase in densities from March at the nearfield transects was associated with the presence of large numbers of American shad eggs. Ichthyoplankton transported from Steel Creek (RM 141.6) may also have contributed to the increase in densities in the nearfield (Paller et al., 1985). At RM 141.7, just upstream from Steel Creek, ichthyoplankton densities were 56.6/1,000 m^3, compared to 76.9/1,000 m^3 at the river transect just downstream from Steel Creek (RM 141.5; Table V-4.74).

Ichthyoplankton densities attained their highest levels during May, ranging from a mean of 37.2 ichthyoplankters/1,000 m^3 at RM 89.3 to 237.1/1,000 m^3 at RM 141.7. Temperatures ranged from 17.0 to 20.7°C, increasing in a downstream direction (Table V-4.75). Ichthyoplankton densities were highest in the nearfield due to an abundance of striped bass ichthyoplankton. American shad ichthyoplankton, which dominated the nearfield collections during April, were also abundant during May.

Spawning activity declined in June, with mean densities ranging from 50.3 ichthyoplankters/1,000 m^3 at RM 141.7 to 1.2/1,000 m^3 at RM 29.6 (Table V-4.76). During June, densities averaged 30.2/1,000 m^3 in the upper farfield, 24.3/1,000 m^3 in the nearfield, and 9.6/1,000 m^3 in the lower farfield. Compared to trends observed in the February through April collection period, densities in June were significantly greater in the upper farfield than in the lower farfield and nearfield, indicating that spawning activity was declining in the lower reaches of the Savannah River study area, but was continuing in the upper reaches of the study area. River temperatures averaged 24.2°C in the lower farfield, 22.7°C in the nearfield, and 20.8°C in the upper farfield during June (Table V-4.76).

Spawning activity in the river was low during July. Mean ichthyoplankton densities ranged from 0.0/1,000 m^3 at RM 152.0 to 8.5/1,000 m^3 at RM 60.0 (Table V-4.77). As in June, densities were significantly higher in the upper farfield than in the nearfield and lower farfield.

TABLE V-4.73

Mean Ichthyoplankton Densities (no./1,000 m³) and Temperatures (°C) in the Savannah River During March 1984

River Mile	Temp. (°C)	American Shad	Blue-back Herring	Striped Bass	Other Shad*	Unid. Cyprinids	Sunfish	Crappie	Total Ichthyo-plankton**
				Lower Farfield					
29.6	14.5	1.7	1.7	0.0	0.0	1.4	9.2	25.0	52.6
40.2	14.5	2.6	2.9	0.0	0.6	0.0	3.7	36.6	51.4
50.2	14.5	2.3	2.3	0.0	0.0	0.3	1.3	13.2	25.8
60.0	14.1	1.5	10.3	0.0	0.0	0.0	1.1	42.1	62.0†
69.9	13.8	1.4	3.1	0.0	0.0	2.4	1.9	16.2	32.1††
79.9	13.8	2.2	6.7	0.0	0.0	0.0	0.6	13.2	30.7
89.3	14.1	2.7	3.4	0.0	0.0	0.3	0.8	11.0	31.4
97.5	13.9	5.5	15.8	0.0	0.7	0.0	0.0	11.0	43.0
110.0	13.2	0.9	4.3	0.0	0.8	0.3	0.0	8.5	27.0
120.0	13.1	2.3	2.2	0.0	0.0	1.5	0.2	3.0	22.5
				Nearfield					
128.9	13.1	1.1	1.1	0.0	0.0	0.0	0.2	6.7	21.6
129.1	13.1	1.1	1.3	0.0	0.0	2.9	0.3	6.0	17.5
137.7	12.8	0.6	0.3	0.0	0.0	0.7	0.7	10.9	19.5
141.5	12.6	0.7	0.9	0.0	0.0	0.0	0.3	14.7	22.2
141.7	12.4	1.8	0.0	0.0	0.0	0.0	0.0	21.9	32.0
150.4	12.5	0.0	1.1	0.0	0.0	0.0	0.8	18.4	25.4
150.8	12.4	0.3	0.0	0.0	0.3	0.4	0.4	16.8	23.2
152.0	12.5	0.0	0.0	0.0	0.0	0.0	1.5	14.3	17.7
152.2	12.5	0.3	0.0	0.0	0.0	0.0	1.3	9.5	12.9
155.2	12.3	0.3	0.0	0.0	0.0	0.0	0.0	15.2	16.4
155.3	12.5	0.0	1.7	0.0	0.0	0.0	0.6	41.2	54.3¶
155.4	12.3	0.3	0.7	0.0	0.0	0.0	0.9	15.8	20.4
157.0	11.7	0.0	0.0	0.0	0.0	0.0	0.7	18.7	22.8
157.1	12.4	0.0	0.0	0.0	0.0	0.0	0.7	31.6	37.0
157.3	11.4	0.9	0.6	0.0	0.0	0.3	0.0	19.9	22.7
				Upper Farfield					
166.6	11.7	0.4	0.0	0.0	0.0	0.0	0.0	3.1	5.3
176.0	11.5	0.2	0.0	0.0	0.0	0.0	0.0	1.5	2.4
187.1	11.2	0.0	0.0	0.0	0.0	0.0	0.4	1.0	2.1

* Gizzard and threadfin shad.
** Totals include taxa shown plus taxa not shown.
† Significantly different ($p \leq 0.0019$) from RM 50.2.
†† Significantly different ($p \leq 0.0019$) from RM 60.0.
¶ Significantly different ($p \leq 0.0019$) from RM 155.2

Source: Paller et al., 1985.

TABLE V-4.74

Mean Ichthyoplankton Densities (no./1,000 m^3) and Temperatures (°C) in the Savannah River During April 1984

River Mile	Temp. (°C)	American Shad	Blue-back Herring	Striped Bass	Other Shad*	Unid. Cyprinids	Sunfish	Crappie	Total Ichthyo-plankton**
					Lower Farfield				
29.6	17.1	5.4	0.4	0.0	1.5	2.0	6.5	2.3	22.9
40.2	16.6	5.2	1.0	0.0	1.3	4.0	8.7	8.1	37.9
50.2	16.4	6.2	2.1	0.0	0.6	8.5	4.2	6.5	33.9
60.0	16.5	4.7	2.8	0.0	0.0	4.6	1.2	8.9	26.5
69.9	16.2	3.1	0.9	0.0	2.0	14.1	3.3	5.6	42.6
79.9	16.1	3.8	3.2	0.0	0.9	9.2	0.0	2.3	25.7
89.3	15.9	15.6	2.4	0.0	0.3	19.6	2.8	0.4	51.3†
97.5	15.7	23.0	5.5	0.0	1.2	6.0	0.7	1.9	50.4
110.0	16.0	20.8	2.4	0.0	0.0	9.2	0.5	3.3	45.3
120.0	15.8	21.8	1.4	0.0	0.0	12.4	0.6	2.0	49.4
					Nearfield				
128.9	15.8	13.7	1.1	0.0	1.4	5.9	2.4	3.1	35.7
129.1	15.8	13.6	0.6	0.0	0.0	5.6	1.7	4.7	35.4
137.7	15.5	27.6	2.0	0.0	0.0	6.2	4.5	6.8	61.6††
141.5	15.5	24.0	5.1	0.0	1.8	6.6	6.7	15.3	76.9
141.7	15.4	32.0	0.9	0.0	0.0	4.3	7.1	5.8	56.6
150.4	15.2	7.6	2.9	0.0	0.0	0.7	4.5	5.8	31.2
150.8	14.9	6.4	1.5	0.0	0.0	0.6	1.3	6.2	29.7
152.0	14.8	11.6	2.3	0.0	0.0	0.0	1.5	8.9	32.9
152.2	14.7	20.0	0.6	0.0	0.0	0.3	0.0	7.0	45.0
155.2	14.3	24.8	1.7	0.0	0.6	0.6	0.0	5.1	43.3
155.3	14.6	0.0	1.6	0.0	0.0	1.1	0.0	11.1	23.3
155.4	14.4	14.9	0.3	0.0	0.3	0.3	0.0	8.4	35.5
157.0	14.4	25.4	1.4	0.0	0.6	0.7	0.9	5.2	57.5
157.1	14.7	0.0	6.1	0.0	0.0	0.6	1.0	10.6	25.3¶
157.3	14.4	20.8	1.6	0.0	0.3	0.0	2.1	5.9	48.5
					Upper Farfield				
166.6	14.4	3.2	2.9	0.0	0.6	0.2	0.0	0.0	15.4¶¶
176.0	14.1	2.1	0.5	0.0	0.5	1.9	0.7	0.0	10.3
187.1	13.9	0.0	0.0	0.0	0.4	0.8	0.0	0.3	5.1

* Gizzard and threadfin shad.
** Totals include taxa shown taxa plus not shown.
† Significantly different (p <0.0019) from RM 79.9.
†† Significantly different (p <0.0019) from RM 129.1.
¶ Significantly different (p <0.0019) from RM 157.0.
¶¶ Significantly different (p <0.0019) from RM 157.3.

Source: Paller et al., 1985.

TABLE V-4.75

Mean Ichthyoplankton Densities (no./1,000 m^3) and Temperatures (°C) in the Savannah River During May 1984

River Mile	Temp. (°C)	American Shad	Blue-back Herring	Striped Bass	Other Shad*	Unid. Cyprinids	Sunfish	Crappie	Total Ichthyo-plankton**
					Lower Farfield				
29.6	20.7	0.0	1.6	0.0	10.7	1.8	32.0	4.1	62.7
40.2	20.5	0.2	1.3	0.0	13.1	1.3	32.8	5.3	75.6
50.2	20.3	1.5	1.1	0.0	15.9	6.3	55.4	8.0	107.7
60.0	20.5	1.3	2.0	0.0	22.8	4.9	23.4	8.5	81.5
69.9	20.3	0.3	1.4	0.0	18.6	2.1	11.1	9.4	58.2
79.9	19.9	2.1	5.6	0.0	20.9	3.4	5.9	6.8	72.5
89.3	19.8	2.6	0.4	3.0	8.9	1.1	10.3	2.5	37.2
97.5	19.8	8.3	4.3	3.6	56.7	10.6	17.3	15.8	145.3†
110.0	19.8	21.6	1.2	8.0	4.7	18.1	20.8	10.8	102.6
120.0	19.8	6.4	5.9	21.1	12.8	17.3	13.7	14.8	108.9
					Nearfield				
128.9	19.6	5.7	3.0	17.0	8.7	28.1	13.8	8.2	108.3
129.1	19.5	11.1	3.0	15.9	6.3	32.1	23.6	5.6	116.5
137.7	19.1	7.8	4.0	32.2	7.6	42.0	21.9	6.7	157.6
141.5	18.8	13.9	6.5	16.4	9.4	62.7	41.5	10.7	194.6
141.7	18.8	15.0	4.3	68.4	12.2	55.2	38.6	11.0	237.1
150.4	18.7	8.1	13.1	34.9	18.7	24.5	6.9	11.7	158.9
150.8	18.6	20.9	13.9	26.8	22.5	22.1	6.6	11.5	150.1
152.0	18.6	14.6	6.1	10.5	23.6	20.9	4.6	13.5	122.8
152.2	18.6	24.3	5.0	13.7	16.9	22.9	2.8	9.1	131.1
155.2	18.7	4.7	8.5	32.1	17.0	16.4	2.4	8.3	118.5
155.3	18.9	1.1	30.5	8.2	21.8	11.1	2.3	14.5	132.3
155.4	18.7	5.2	4.5	31.6	17.9	18.9	3.0	11.4	127.2
157.0	18.5	19.1	6.4	20.3	16.1	22.8	6.6	12.5	145.0
157.1	19.0	0.3	17.1	7.1	24.8	8.6	6.3	20.1	144.2
157.3	18.2	33.4	11.5	15.8	15.6	30.9	3.8	3.3	158.5
					Upper Farfield				
166.6	18.1	10.6	10.9	0.0	30.2	23.7	0.9	3.0	102.4
176.0	17.6	15.9	3.1	0.0	28.3	26.0	3.0	0.4	100.0
187.1	17.0	18.3	0.6	0.3	10.1	24.4	3.3	1.3	86.0

* Gizzard and threadfin shad.
** Totals include taxa shown taxa plus not shown.
† Significantly different ($p < 0.0019$) from RM 79.9.

Source: Paller et al., 1985.

TABLE V-4.76

Mean Ichthyoplankton Densities (no./1,000 m³) and Temperatures (°C) in the Savannah River During June 1984

River Mile	Temp. (°C)	American Shad	Blue-back Herring	Striped Bass	Other Shad*	Unid. Cyprinids	Sunfish	Crappie	Total Ichthyo-plankton**
Lower Farfield									
29.6	25.2	0.0	0.0	0.0	0.0	0.0	0.6	0.0	1.2
40.2	24.6	0.0	0.0	0.0	0.0	0.4	3.5	0.0	5.7
50.2	24.6	0.7	0.3	0.0	0.4	0.7	3.8	0.0	10.2
60.0	24.4	0.8	0.0	0.0	0.3	0.8	1.9	0.0	8.1
69.9	24.3	0.3	0.0	0.0	0.0	0.6	0.7	0.0	3.0
79.9	24.0	1.0	0.0	0.0	0.3	0.8	2.9	0.3	9.9†
89.3	23.6	2.4	0.0	0.0	1.5	0.5	1.4	0.0	7.6
97.5	23.7	1.0	0.0	0.0	0.5	0.6	2.2	0.0	10.3
110.0	23.7	19.8	0.0	0.0	0.3	0.6	2.6	0.0	26.8
120.0	23.4	3.9	0.0	0.0	0.4	1.5	1.9	0.0	13.1
Nearfield									
128.9	23.0	1.5	0.0	2.6	0.4	1.6	1.4	0.0	11.5
129.1	22.9	5.0	0.0	0.4	0.4	1.9	1.8	0.4	16.6
137.7	22.5	12.9	0.0	1.6	0.7	1.7	7.6	0.8	31.5
141.5	22.5	5.4	0.0	1.6	0.0	2.8	4.4	0.0	22.7
141.7	22.5	19.2	0.0	6.9	0.6	4.4	10.6	0.0	50.3
150.4	23.9	0.7	0.0	0.0	1.1	2.4	2.1	0.0	12.0††
150.8	23.2	4.7	0.0	0.0	0.9	2.9	0.8	0.0	15.5
152.0	23.3	7.6	0.5	0.3	1.4	2.5	0.7	0.0	19.5
152.2	22.9	12.8	0.0	0.0	1.3	4.0	0.9	0.0	26.3
155.2	22.8	3.7	0.0	0.0	2.5	3.6	0.8	0.3	21.0
155.3	22.8	0.0	0.6	0.0	3.9	4.8	0.7	0.6	31.6
155.4	22.5	4.4	0.0	0.0	2.0	3.6	1.6	0.0	23.7
157.0	21.9	15.3	0.3	0.0	1.2	0.7	2.3	0.0	31.2
157.1	22.6	0.0	1.8	0.0	2.3	4.1	1.9	0.0	31.1
157.3	21.8	12.8	0.0	0.0	6.0	2.8	3.1	0.0	34.6
Upper Farfield									
166.6	21.2	4.0	0.0	0.0	11.8	6.2	1.6	0.0	33.7
176.0	20.8	2.8	0.7	0.0	7.8	5.3	1.5	0.0	26.5
187.1	20.4	0.4	0.7	0.0	10.4	4.9	0.3	0.0	30.6

* Gizzard and threadfin shad.
** Totals include taxa shown taxa plus not shown.
† Significantly different ($p < 0.0019$) from RM 69.9.
†† Significantly different ($p < 0.0019$) from 141.7.

Source: Paller et al., 1985.

TABLE V-4.77

Mean Ichthyoplankton Densities (no./1,000 m^3) and Temperatures (°C) in the Savannah River During July 1984

River Mile	Temp. (°C)	American Shad	Blue-back Herring	Striped Bass	Other Shad*	Unid. Cyprinids	Sunfish	Crappie	Total Ichthyo-plankton**
					Lower Farfield				
29.6	26.0	0.0	0.0	0.0	0.0	0.5	1.7	0.0	2.7
40.2	25.7	0.0	0.0	0.0	0.0	0.0	1.8	0.0	2.3
50.2	25.3	0.0	0.0	0.0	0.0	0.3	0.6	0.0	3.0
60.0	25.4	0.0	0.0	0.0	0.0	0.8	4.4	0.0	8.5
69.9	25.6	0.0	0.0	0.0	0.0	0.3	0.8	0.0	1.2
79.9	25.2	0.0	0.0	0.0	0.0	0.3	0.8	0.0	1.7
89.3	25.0	0.0	0.0	0.7	0.6	2.0	0.3	0.0	4.4
97.5	24.4	0.4	0.0	0.0	0.0	0.3	1.2	0.0	4.8
110.0	25.1	0.0	0.0	0.3	0.0	0.7	0.8	0.0	2.8
120.0	24.8	0.4	0.0	0.4	0.0	0.6	0.7	0.0	3.2
					Nearfield				
128.9	24.3	0.0	0.0	0.0	0.7	0.0	0.8	0.0	1.8
129.1	24.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.7
137.7	24.0	1.0	0.0	0.0	0.7	1.4	1.3	0.0	5.0
141.5	24.0	0.5	0.0	0.0	0.0	0.4	1.4	0.0	2.7
141.7	24.0	1.1	0.0	0.4	0.0	0.7	1.3	0.0	3.4
150.4	23.9	0.0	0.0	0.0	0.0	0.0	1.2	0.0	1.2
150.8	23.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4
152.0	23.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
152.2	23.6	0.4	0.0	0.7	0.3	0.0	0.0	0.0	2.3
155.2	23.8	1.1	0.0	0.0	0.0	0.0	0.0	0.0	1.9
155.3	23.7	0.0	0.5	0.0	0.6	0.0	1.2	0.0	5.1
155.4	23.5	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.6
157.0	22.9	0.3	0.0	0.4	0.7	0.0	0.3	0.0	1.8
157.1	23.4	0.7	0.0	0.0	0.0	0.0	0.6	0.0	1.3
157.3	22.8	0.3	0.0	0.7	0.3	0.3	0.7	0.0	3.9
					Upper Farfield				
166.6	22.6	0.6	0.0	0.0	3.2	0.0	0.0	0.0	4.5
176.0	22.4	0.7	0.0	0.0	1.6	0.0	1.2	0.0	6.2
187.1	21.6	0.0	0.0	0.4	2.2	0.6	1.1	0.0	7.5

* Gizzard and threadfin shad.
** Totals include taxa shown taxa plus not shown.

Source: Paller et al., 1985.

Mean density over the entire February through July 1984 sampling period ranged from 23.6 ichthyoplankters/1,000 m^3 at RM 187.1 to 67.6/1,000 m^3 at RM 141.7 (Figure V-4.56; Table V-4.78). The high density observed at RM 141.7 was due either to high levels of spawning activity somewhere between RM 150.4 and 141.7 (the section of river just upstream of Steel Creek) during May and June or to the fact that RM 141.7 was sampled earlier in the day than the other transects. Results of the diel study (see Section V.4.3.5.6) indicated that ichthyoplankton densities in the Savannah River were higher at night than during the day in 1984. During the routine study, RM 141.7 was generally sampled between 0700-0900 hr, and the higher densities may reflect a transition period from night to daytime conditions. Results of sampling at RM 141.7 on 11 dates during April through July 1985 during morning and afternoon revealed consistently higher means for the morning samples, with greatest (approximately 3-fold) differences in April. Reduced densities in the afternoon samples were exhibited by nearly all taxa. With the exception of the high densities at RM 141.7, there were no indications of unusual changes in ichthyoplankton density near the SRP (Paller et al., 1985). From mean ichthyoplankton densities measured from February through July 1984, the nearfield exhibited the greatest mean density.

Table V-4.79 shows the results of the chemical and physical parameters that were measured in the river concurrently with the ichthyoplankton study in 1985. The average temperature from February through July 1985 varied from 15.9 to 19.0°C at the 23 sample stations. Temperatures progressively increased from the upstream to the downstream end of the study area indicating the presence of a temperature gradient in the Savannah River. The gradient is probably due to the discharge of cool hypolimnetic water from Clarks Hill Reservoir at RM 221.7, which gradually warms due to solar insolation as the water moves downstream. Similar temperature gradients were observed during 1983 and 1984 (Paller et al., 1986b).

During 1985, American shad numerically dominated the river ichthyoplankton, comprising 50.8% of the assemblage (Table V-4.65). Density of American shad in the intake canals was 1/27th of that in the rivers. Much of this difference may be related to the low water velocities in the intake canals, which probably caused American shad eggs to settle to the bottom. The relative proportions of striped bass eggs and larvae were similar in the river and intake canals but densities were twice as high in the river (Table V-4.65). On the other hand, unidentified clupeids, gizzard and/or threadfin shad, carp and spotted suckers occurred in the intake canals in densities 2 to 3 times those in the river (Table V-3.65).

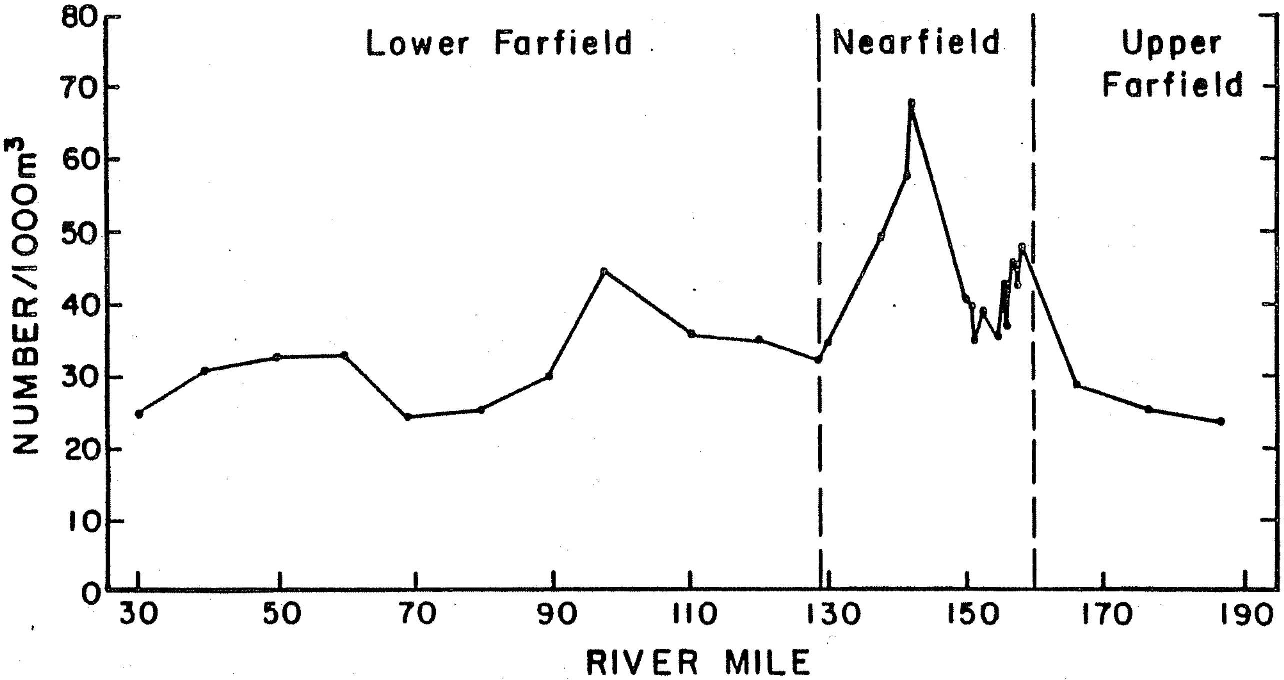


FIGURE V-4.56. Average Ichthyoplankton Density at Transects in the Savannah River (February-July 1984)
Source: Paller et al., 1985

TABLE V-4.78

Mean Ichthyoplankton Densities (no./1,000 m^3) and Temperatures (°C) in the Savannah River During February-July 1984

River Mile	Temp. (°C)	American Shad	Blue-back Herring	Striped Bass	Other Shad*	Unid. Cyprinids	Sunfish	Crappie	Total Ichthyo-plankton**
				Lower Farfield					
29.6	18.2	1.2	0.7	0.0	2.1	1.0	8.3	5.5	24.5
40.2	18.3	1.3	0.8	0.0	2.8	0.9	9.1	8.4	30.8
50.2	18.2	1.7	0.9	0.0	3.2	2.7	12.6	4.8	32.5
60.0	18.1	1.3	2.4	0.0	4.4	1.9	6.1	10.3	33.0
69.9	18.0	0.8	0.9	0.0	3.9	3.1	3.2	5.3	24.2
79.9	17.7	1.5	2.6	0.0	4.2	2.3	1.8	4.1	25.2
89.3	17.7	3.8	1.6	0.6	4.7	4.3	2.5	3.9	30.2
97.5	17.6	6.2	4.1	0.7	11.3	3.1	4.0	5.1	44.8
110.0	17.6	10.5	1.3	1.6	1.1	5.2	4.6	3.9	35.8
120.0	17.3	5.6	1.7	4.1	2.5	5.8	3.2	3.6	34.9
				Nearfield					
128.9	17.4	3.6	0.9	3.7	2.1	6.6	3.4	3.1	32.3
129.1	17.3	5.2	0.9	3.1	1.3	7.8	5.1	2.8	34.3
137.7	17.0	8.0	1.1	6.4	1.7	9.6	6.4	4.1	49.0
141.5	16.9	7.4	2.2	3.4	2.1	13.6	10.0	6.7	57.1
141.7	16.8	11.2	1.0	14.3	2.5	12.1	10.4	6.4	67.6
150.4	17.0	2.8	3.1	6.7	3.8	5.2	2.7	6.0	41.4
150.8	16.7	5.8	2.9	5.2	4.5	4.8	1.7	5.8	39.7
152.0	16.8	5.8	1.6	2.1	4.8	4.4	1.5	6.4	34.7
152.2	16.7	9.8	1.1	2.8	3.5	5.1	0.9	4.5	38.6
155.2	16.6	5.6	1.9	6.1	3.7	3.8	0.6	4.9	35.5
155.3	16.8	0.2	6.6	1.6	4.9	3.0	0.8	10.9	43.1
155.4	16.5	4.0	1.1	6.1	3.8	4.2	1.0	5.9	36.8
157.0	16.4	9.9	1.5	4.0	3.5	4.6	1.9	6.1	45.3
157.1	16.9	0.2	4.6	1.4	5.2	2.4	1.9	10.1	42.5
157.3	16.3	11.8	2.6	3.2	4.0	6.5	1.7	4.6	47.4
				Upper Farfield					
166.6	15.9	3.3	2.5	0.0	8.2	5.6	0.4	1.1	28.7
176.0	15.7	4.0	0.8	0.0	7.0	6.1	1.1	0.3	26.2
187.1	15.2	3.6	0.2	0.1	4.0	5.7	0.9	0.4	23.6

* Gizzard and threadfin shad.
** Totals include taxa shown taxa plus not shown.

Source: Paller et al., 1985.

TABLE V-4.79

Mean (and range) of Chemical and Physical Parameters at Each Savannah River Transect (February-July 1985)

River Mile	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (μS/cm)	pH	Alkalinity (mg/L)
89.3	19.0 (6.3-26.5)	6.9 (4.9-9.2)	88.1 (60.0-124.0)	6.6 (4.6-8.4)	18.8 (10.9-22.0)
97.5	19.0 (5.6-26.5)	6.8 (5.1-9.5)	87.3 (56.0-126.0)	6.5 (4.0-8.4)	18.9 (7.0-38.0)
110.0	18.9 (6.5-25.5)	6.6 (4.4-8.3)	82.2 (38.0-110.0)	6.5 (4.3-8.2)	18.2 (11.5-22.0)
120.0	18.5 (6.0-26.0)	6.6 (4.4-8.4)	83.1 (38.0-114.0)	6.5 (4.7-7.9)	19.4 (13.3-34.9)
128.9	18.4 (7.0-25.3)	6.8 (4.8-12.3)	85.4 (46.0-121.0)	6.3 (4.1-7.9)	18.1 (11.0-21.0)
129.1	18.3 (7.0-25.2)	6.8 (4.8-12.3)	85.4 (46.0-121.0)	6.3 (4.2-9.1)	18.1 (11.0-21.0)
137.7	18.0 (7.0-24.7)	6.7 (2.0-11.4)	84.6 (44.0-118.0)	6.2 (4.5-8.6)	18.2 (11.0-21.8)
141.5	17.8 (6.0-24.9)	6.8 (4.4-11.5)	83.4 (43.0-118.0)	6.3 (4.3-9.1)	18.2 (11.0-21.3)
141.7	18.8 (7.0-25.1)	6.8 (4.8-11.3)	84.4 (43.0-128.0)	6.4 (4.3-9.8)	18.0 (6.0-21.5)
145.7	18.0 (7.5-24.4)	6.9 (4.8-9.1)	84.3 (68.0-95.0)	6.7 (5.4-7.9)	18.3 (11.3-21.5)
150.4	18.5 (6.9-26.0)	6.9 (5.3-9.2)	86.8 (70.0-101.0)	6.6 (5.5-7.9)	18.0 (4.5-27.5)
150.8	18.2 (6.8-24.6)	7.0 (5.4-9.3)	87.3 (68.0-100.0)	6.6 (5.6-8.7)	18.1 (10.0-21.5)
152.0	18.1 (6.6-25.1)	7.0 (4.7-9.4)	87.8 (69.0-100.0)	6.5 (5.5-8.1)	18.3 (10.0-22.0)
152.2	17.8 (7.4-24.5)	7.1 (5.1-9.3)	87.2 (70.0-100.0)	6.5 (5.2-8.6)	18.6 (11.5-22.3)
155.2	17.4 (6.6-24.0)	7.4 (4.8-10.2)	84.4 (50.0-100.0)	6.6 (5.3-9.5)	18.6 (11.8-21.3)
155.3*	17.6 (7.0-26.1)	7.0 (4.7-10.2)	81.5 (36.0-98.0)	6.6 (5.3-7.8)	18.7 (11.3-27.5)
155.4	17.3 (7.0-23.8)	7.3 (4.8-10.1)	83.7 (49.0-100.0)	6.5 (4.7-8.4)	18.2 (4.0-25.0)
157.0	17.1 (7.0-23.5)	7.3 (4.6-10.2)	83.6 (42.0-109.0)	6.5 (5.4-7.7)	18.7 (9.0-27.0)
157.1*	17.6 (7.0-26.4)	7.0 (4.3-9.5)	69.8 (28.0-86.0)	6.6 (5.2-7.8)	15.4 (7.3-20.5)
157.3	17.0 (7.1-23.5)	7.3 (4.7-9.8)	84.8 (45.0-102.0)	6.6 (5.4-17.8)	19.2 (11.5-22.0)
166.6	16.6 (6.7-22.5)	7.5 (5.2-10.2)	83.3 (50.0-108.0)	6.5 (4.6-8.5)	18.7 (12.5-22.0)
176.0	16.6 (6.8-23.7)	8.2 (5.3-13.6)	81.3 (51.0-110.0)	6.5 (4.5-8.5)	19.3 (13.3-34.0)
187.1	15.9 (6.8-23.0)	8.8 (5.5-11.6)	58.2 (39.0-88.0)	6.5 (4.5-8.8)	15.8 (5.0-20.4)

Note: Twenty-six dates sampled.

* Intake canals.

Source: Paller et al., 1986b.

Ichthyoplankton densities from February through July 1985 ranged from a mean of 22.2/1,000 m^3 in the 1G intake canal (RM 157.1) to a mean of 149.3/1,000 m^3 at RM 166.6 (Table V-4.80). Densities were significantly higher in the upper farfield (mean of 94.6/1,000 m^3) than in the nearfield (mean of 54.1/1,000 m^3) or lower farfield (mean of 55.6/1,000 m^3). In contrast, in 1984, ichthyoplankton densities were highest in the nearfield section, while in 1983, ichthyoplankton densities were highest in the lower farfield section. The data from the three years illustrate the natural year-to-year variability of ichthyoplankton densities in the Savannah River (Paller et al., 1985). Table V-4.80 also lists mean ichthyoplankton densities at all Savannah River transects for the nine most abundant taxa collected in the 1985 February through July sampling period.

An examination of the average density at each transect over all dates indicated that densities were lower at RM 150.8 and RM 152.0 than at the rest of the transects (excluding the intake canals). This was due primarily to a relative scarcity of American shad ichthyoplankton at those transects (Figure V-4.57). These two transects were upstream from the mouth of Four Mile Creek (RM 150.6) and so were not exposed to heated waters from reactor discharge in Four Mile Creek. RMs 150.8 and 152.0 were, however, downstream from Beaver Dam Creek (RM 152.1) which receives heated effluents from the coal-fired power plant in D Area. The reasons for the low densities at these two transects are unknown (Paller et al., 1986b), but are not believed to be related to the heated effluent in Beaver Dam Creek, since temperatures in the mouth of creek are only slightly elevated.

V.4.3.5.3 Oxbow Ichthyoplankton

Six oxbows were sampled during 1984; two in the upper farfield, two in the nearfield, and two in the lower farfield. Since all the oxbows were connected to the river at both ends (at least during high water), they had some current, although the water velocity and subsequent extent of water exchange with the river varied from oxbow to oxbow.

The chemical and physical parameters in the oxbows were similar to those in the river (Table V-4.81). The water velocities and depths, however, were much lower in the oxbows than the river. Unlike the river, some of the more slowly moving oxbows tended to stratify in the summer.

A total of 7,207 larvae and 28 eggs were collected from the six oxbows sampled during 1984 (Table V-4.82). The species composition in the oxbows were dominated by gizzard and threadfin shad and unidentified Clupeidae (see Table V-4.64). Other dominant taxa

TABLE V-4.80

Mean Ichthyoplankton Densities (no./1,000 m^3) and Temperatures (°C) in the Savannah River Transects During February-July 1985

River Mile	Temp. (°C)	American Shad	Blue-back Herring	Striped Bass	Other Shad*	Unid. Cyprinids	Minnows (Cyprinidae)	Spotted Suckers	Sunfish	Crappie	Total Ichthyo-plankton**
					Lower Farfield						
89.3	19.0	47.4	0.9	2.0	2.2	1.2	2.5	3.7	1.4	0.1	67.8
97.5	19.0	26.6	1.7	1.2	4.7	1.3	1.6	2.1	0.2	0.1	44.1
110.0	18.9	39.6	0.6	1.5	1.2	0.7	3.2	2.7	0.2	0.1	55.6
120.0	18.5	35.3	0.8	1.3	1.7	2.3	2.2	3.6	0.7	0.4	51.7
					Nearfield						
128.9	18.4	41.7	1.4	5.3	2.2	0.3	4.1	4.2	1.0	0.2	64.2
129.1	18.3	31.3	0.8	6.3	1.9	0.7	2.9	3.5	1.4	0.2	54.7
137.7	18.0	34.1	1.8	0.4	2.9	1.7	1.9	5.4	1.4	0.1	55.2
141.5	17.8	30.0	1.4	0.1	3.4	1.5	1.5	6.4	1.1	0.1	50.9
141.7	17.7	54.6	0.9	0.5	3.7	1.5	1.8	10.6	1.8	0.3	83.2
145.7	18.0	63.2	0.7	0.6	3.0	1.2	1.6	10.0	1.5	0.5	84.3
150.4	18.5	22.0	1.0	2.4	2.1	1.0	0.8	4.1	0.2	0.3	44.7
150.8	18.2	12.6	1.9	0.3	3.0	0.6	1.0	6.2	0.1	0.0	31.8
152.0	18.1	10.6	1.4	3.7	3.2	1.3	1.6	4.6	0.1	0.1	28.7
152.2	17.8	14.2	2.2	3.3	3.6	1.3	2.0	5.9	0.1	0.1	43.1
155.2	17.2	18.2	2.6	16.0	3.1	1.5	1.0	5.8	0.0	0.2	67.1
155.3†	17.4	0.3	0.9	2.5	7.0	3.4	1.0	11.7	0.1	0.2	30.7
155.4	17.1	19.3	0.8	13.6	4.8	1.7	1.6	5.7	0.1	0.0	57.0
157.0	16.9	24.6	0.4	0.5	3.8	1.0	1.7	4.7	0.2	0.1	47.5
157.1†	17.3	0.8	1.1	0.1	3.0	2.1	0.7	10.4	0.2	0.1	22.2
157.3	16.7	36.0	0.5	2.1	3.8	0.7	1.6	7.0	0.2	0.2	81.6
					Upper Farfield						
166.6	16.6	59.4	3.2	10.7	22.3	10.4	2.5	4.0	0.2	0.1	149.3
176.0	16.6	15.7	2.4	0.1	27.2	5.3	4.5	2.0	0.4	0.2	70.9
187.1	15.9	3.3	2.8	0.1	22.7	3.8	5.4	0.6	0.6	0.4	58.6

* Gizzard and threadfin shad.
** Totals include taxa shown taxa plus not shown.
† Intake canals.

Source: Paller et al., 1985.

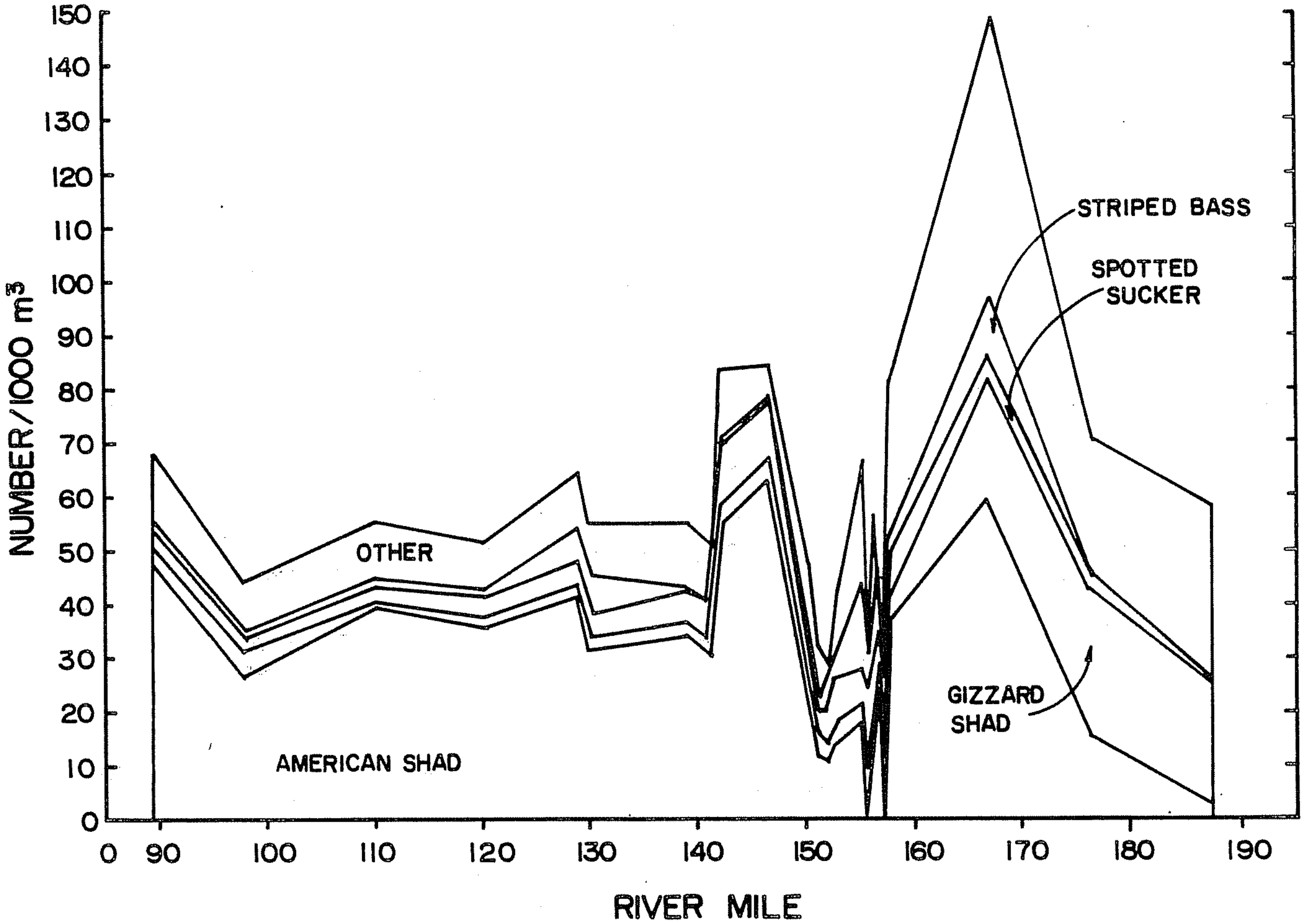


FIGURE V-4.57. Average Density of Ichthyoplankton Taxa at Savannah River Transects (February-July 1985)
Source: Paller et al., 1986b

TABLE V-4.81

Mean (and range) of Chemical and Physical Parameters in Six Oxbows on the Savannah River (February-July 1984)

Parameter	Oxbow Location RM 51.3	RM 100.2	RM 153.2	RM 156.7	RM 167.4	RM 183.0
Top*						
Temperature (°C)	18.6 (7.4-28.0)	18.0 (6.0-26.8)	17.2 (7.8-25.3)	16.6 (7.2-24.5)	16.5 (7.6-25.0)	17.3 (6.2-26.8)
Dissolved oxygen (mg/L)	7.3 (4.8-10.2)	6.1 (2.5-9.1)	7.4 (4.4-10.2)	7.5 (4.1-12.0)	7.4 (3.0-10.5)	7.8 (1.9-11.2)
pH	6.0 (5.1-7.3)	5.2 (3.9-7.5)	6.7 (6.0-7.4)	6.2 (5.2-7.6)	6.4 (5.7-7.9)	6.3 (5.6-8.1)
Conductivity (µmhos/cm)	67.6 (40.0-88.8)	69.4 (45.0-102.0)	73.3 (48.0-134.0)	64.5 (20.0-90.0)	69.7 (41.0-95.0)	58.0 (40.0-140.0)
Alkalinity (mg/L)	15.5 (10.0-18.8)	16.4 (0.3-30.5)	15.3 (12.0-19.5)	15.4 (11.8-21.0)	15.5 (10.5-19.8)	14.3 (11.0-19.3)
Current (cm/s)	5.3 (0.0-72.0)	2.5 (0.0-65.0)	14.2 (0.0-84.0)	18.2 (0.0-72.0)	6.0 (0.0-80.0)	8.3 (0.0-80.0)
Depth (m)	3.4 (1.5-5.2)	3.9 (2.1-6.1)	4.1 (2.4-6.1)	3.3 (1.5-5.5)	4.3 (2.2-7.6)	3.2 (1.2-6.1)

* Top samples taken approximately 1 m below the surface.

Source: Paller et al., 1985.

TABLE V-4.81, Contd

Parameter	Oxbow Location RM 51.3	RM 100.2	RM 153.2	RM 156.7	RM 167.4	RM 183.0
Bottom**						
Temperature (°C)	18.2 (7.3-26.0)	16.9 (5.2-26.8)	16.5 (7.3-24.0)	16.6 (7.2-24.5)	15.9 (7.3-23.0)	14.6 (6.7-22.1)
Dissolved oxygen (mg/L)	6.8 (3.6-10.0)	4.1 (0.1-7.8)	6.7 (0.9-10.0)	7.4 (3.5-12.3)	7.2 (3.4-10.5)	6.2 (0.0-10.3)
pH	6.1 (5.1-7.3)	5.1 (3.8-7.5)	6.4 (5.5-7.6)	6.0 (5.0-7.6)	6.3 (5.5-7.9)	6.2 (5.6-8.0)
Conductivity (μmhos/cm)	68.6 (40.0-88.8)	76.8 (45.0-102.0)	71.0 (48.0-134.0)	63.5 (20.0-90.0)	69.3 (41.0-95.0)	65.7 (40.0-140.0)
Alkalinity (mg/L)	11.3†	9.5	-††	15.0	-	-
Current (cm/s)	3.1 (0.0-82.0)	2.5 (0.0-65.0)	5.5 (0.0-83.0)	13.4 (0.0-71.0)	5.8 (0.0-80.0)	3.3 (0.0-85.0)
Depth (m)	3.4 (1.5-5.2)	3.9 (2.1-6.1)	4.1 (2.4-6.1)	3.3 (1.5-5.5)	4.3 (2.2-7.6)	3.2 (1.2-6.1)

** Bottom samples taken approximately 1 m above the bottom.
† Only one sample taken.
†† Samples not taken.

Source: Paller et al., 1985.

TABLE V-4.82

Numbers of Ichthyoplankton Collected and Average Ichthyoplankton Densities in Savannah River Oxbows (February-July 1984)

Location (RM)	Number Larvae	Number Eggs	Number Taxa	Mean Ichthyoplankton Density (no./1,000 m^3)	Density Range	Density Coefficient of Variation (%)
51.3	379	0	16	63.4	0.0 - 467.7	157.8
100.2	5,900	6	16	1,043.0	0.0 - 16,698.3	224.1
153.2	377	6	14	62.3	0.0 - 641.6	190.6
156.7	121	14	15	21.1	0.0 - 174.5	162.6
167.4	166	1	9	29.7	0.0 - 243.9	158.7
183.0	264	1	15	51.4	0.0 - 835.1	222.8
Total	7,207	28				

in the oxbows were the sunfishes. While these taxa apparently spawned in the oxbows, others, most notably the striped bass and American shad, did not utilize the oxbows.

Ichthyoplankton densities varied among oxbows and were particularly high in the oxbow at RM 100.2. The average density in the oxbow at RM 100.2 was 1,043.0 ichthyoplankters/1,000 m^3, compared to 21.1 to 63.4/1,000 m^3 in the other oxbows (Figure V-4.58). Other than the high density, the seasonal trends and taxonomic composition in the oxbow at RM 100.2 were similar to those in the other oxbows and the river, indicating that the high density in this oxbow was not due to an unusual level of spawning by a single species.

Isolation from the river may partially explain the unusually high densities in the oxbow at RM 100.2 (Paller et al., 1985). The mean current velocity was lower compared to the other oxbows, suggesting it was sheltered from river currents and more like a lake than the others. The lake-like conditions apparently favored the reproduction of gizzard and threadfin shad, sunfishes, and other taxa. In addition, the lower current velocities may have flushed fewer ichthyoplankton into the river than the higher current velocities at other oxbows (Paller et al., 1985). Table V-4.83) lists species by percent abundance at each oxbow.

In 1985, five oxbows were sampled; two in the upper farfield, two in the nearfield, and one in the lower farfield. These oxbows were the same as those sampled in 1984 with the exception of the oxbow at RM 51.3. It was not sampled in 1985 because the study did not include stations downstream from RM 89.3. All the oxbows were connected to the river at one end, and some were connected at both ends.

The chemical and physical parameters in the oxbows were similar to those in the river in 1985 also (Table V-4.84). The current velocities and depths, however, were much lower in the oxbows than the river. As in 1984, it was found that some of the more slow moving oxbows tended to stratify in the summer.

A total of 10,214 larvae and 108 eggs were collected from the five oxbows sampled during 1985 (Table V-4.85). The species compositions in the oxbows (see Table V-4.65) were dominated by gizzard and threadfin shad, and to a lesser extent by sunfishes, unidentified Clupeidae, and blueback herring. Although American shad and striped bass did not utilize the oxbows in 1984, American shad was the most abundant taxa collected in the oxbow at RM 156.7 in 1985 (Table V-4.86).

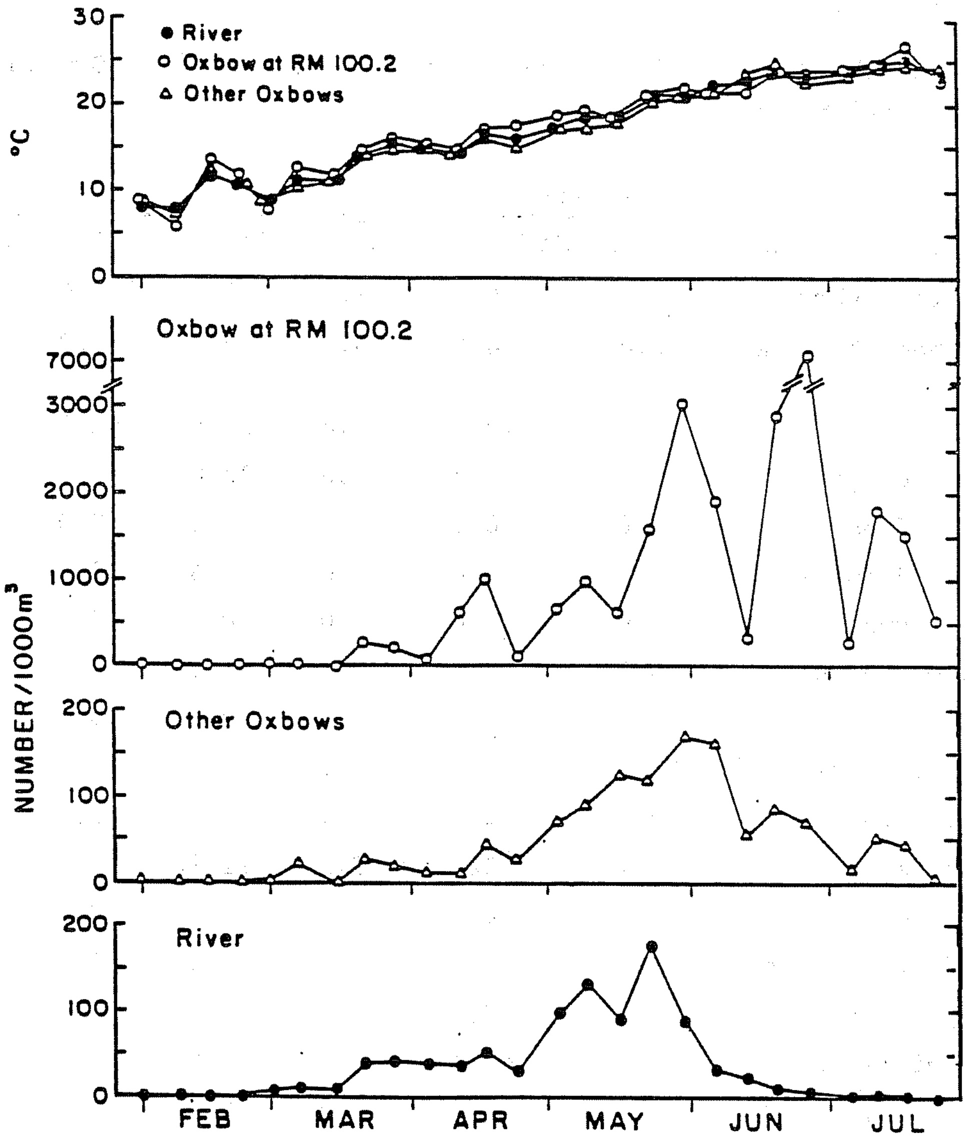


FIGURE V-4.58. Mean Ichthyoplankton Density and Water Temperature in the Savannah River and Savannah River Oxbows (February-July 1984)
Source: Paller et al., 1985

TABLE V-4.83

Percent Abundance of Ichthyoplankton in Savannah River Oxbows (February-July 1984)

Taxa	Oxbows (RM) 51.3	100.2	153.2	156.7	167.4	183.0
American shad	0.3	0.1	1.0	3.0	0.0	0.4
Blueback herring	2.4	4.2	9.7	5.2	7.2	7.9
Gizzard and/or threadfin shad	40.6	42.3	39.4	24.4	42.5	55.1
Unid. clupeid	15.0	20.5	36.0	23.0	34.1	20.8
Striped bass	0.0	0.0	0.0	10.4	0.0	0.0
Spotted sucker	0.3	0.0	1.0	7.4	3.0	0.4
Unid. sucker	0.0	0.0	0.0	0.7	0.0	0.0
Yellow perch	0.5	0.2	0.5	1.5	0.0	1.5
Darter	0.8	0.4	0.5	0.0	0.6	0.8
Sunfish (*Lepomis*)	22.4	21.4	0.3	3.0	0.6	5.7
Unid. sunfish	2.1	2.5	1.6	1.5	1.2	0.8
Crappie	7.4	2.8	7.3	11.1	10.2	4.9
Largemouth bass	0.3	0.0	0.0	0.0	0.0	0.0
Unid. cyprinids	3.4	1.0	1.3	4.4	0.0	0.8
Carp	0.8	0.3	0.3	0.7	0.0	0.0
Mosquitofish	0.0	<0.1	0.0	0.0	0.0	0.0
Brook silverside	0.3	0.1	0.0	0.0	0.0	0.0
Pickerel	3.4	4.1	1.1	3.7	0.6	0.4
Total percent	100.0	99.9	100.0	100.0	100.0	99.9
Total number	379	5,906	383	135	167	265

Source: Paller et al., 1985.

TABLE V-4.84

Mean (and range) of Chemical and Physical Parameters in Five Oxbows on the Savannah River (February-July 1985)

Oxbow River Mile (RM)		Temperature (°C)	Dissolved Oxygen (mg/L)	pH	Conductivity (µS/cm)	Alkalinity (mg/L	Depth (m)
100.2	Top*	21.3 (5.5-30.0)	7.9 (3.6-12.0)	7.0 (4.3-9.6)	25.5 (63.0-118.0)	25.5 (12.5-38.0)	2.8 (2.1-5.2)
	Bottom**	19.3 (5.5-28.0)	4.3 (0.1-8.7)	6.4 (4.2-7.5)	94.8 (64.0-144.0)	-† -	- -
153.2	Top	19.9 (6.6-30.4)	8.3 (5.9-11.3)	6.8 (5.8-8.5)	84.9 (62.0-108.0)	19.7 (13.8-22.5)	2.7 (1.8-4.6)
	Bottom	17.3 (6.6-25.8)	5.4 (0.1-9.0)	6.6 (5.8-7.8)	97.1 (56.0-187.0)	- -	- -
156.7	Top	17.8 (6.9-26.6)	6.4 (2.8-9.9)	6.3 (5.3-7.1)	81.8 (49.0-112.0)	19.0 (11.3-25.1)	2.1 (1.5-3.0)
	Bottom	12.1 (6.9-19.5)	6.4 (3.1-9.5)	6.1 (4.2-7.0)	79.2 (41.0-122.0)	- -	- -
167.4	Top	18.8 (6.7-31.2)	8.8 (4.9-12.2)	6.7 (4.9-8.3)	84.3 (53.0-120.0)	19.0 (11.8-21.8)	3.6 (2.1-6.4)
	Bottom	16.7 (6.7-28.3)	7.7 (4.0-15.7)	6.6 (5.0-8.8)	81.7 (51.0-106.0)	- -	- -
183.0	Top	21.8 (6.8-33.1)	8.9 (4.5-19.7)	6.6 (5.1-9.3)	49.7 (39.0-70.0)	14.6 (9.3-50.0)	2.0 (1.5-4.0)
	Bottom	18.8 (6.8-27.8)	5.3 (0.8-8.6)	6.2 (4.9-7.8)	51.6 (34.0-72.0)	- -	- -

Note: Twenty six dates sampled.

* Top samples taken approximately 1 m below the surface.
** Bottom samples taken approximately 1 m above the bottom.
† Samples not taken.

Source: Paller et al., 1986b.

TABLE V-4.85

Numbers of Ichthyoplankton Collected and Average Ichthyoplankton Densities in Savannah River Oxbows (February-July 1985)

Oxbow Location (RM)	Number Larvae	Number Eggs	Number Taxa*	Mean Ichthyoplankton Density (no./1,000 m^3)	Density Range	Density Coefficient of Variation (%)
100.2	7,711	0	8	1,556.2	0.0-17,190.5	189.7
153.2	185	10	10	38.6	0.0-352.4	168.7
156.7	148	1	6	57.2	0.0-469.3	205.4
167.4	1,760	40	9	289.7	0.0-3,837.4	276.1
183.0	410	57	11	108.1	0.0-791.1	141.4
Total	10,214	108				

* Unidentified clupeids are not included in taxa counts if identified clupeids are present. Unidentified sunfish are not included in taxa counts if identified sunfish are present. Unidentified ichthyoplankton is not included in taxa counts when identified ichthyoplankton is present.

Source: Paller et al., 1986b.

TABLE V-4.86

Percent Abundance of Ichthyoplankton in Savannah River Oxbows (February-July 1985)

Taxa	Oxbows (RM) 100.2	153.2	156.7	167.4	183.0
Unid. Clupeidae	10.3	26.2	22.1	35.6	3.4
Blueback herring	5.6	12.8	9.4	8.1	5.4
American shad	0.1	2.1	43.6	-	0.2
Gizzard and/or threadfin shad	48.4	35.4	10.7	53.9	21.6
Minnow (Cyprinidae)	0.0	0.0	0.7	0.1	0.2
Carp	0.0	0.5	0.0	0.1	0.2
Spotted sucker	0.0	1.5	0.0	0.1	0.0
Topminnow	0.0	0.0	0.0	0.1	0.0
Mosquitofish	0.0	0.0	0.0	0.0	0.9
Brook silverside	0.1	0.0	0.0	0.1	1.7
Striped bass	0.0	3.1	0.0	0.0	0.0
Unid. sunfish	1.6	1.0	5.4	0.0	10.9
Sunfish (*Lepomis* spp.)	23.2	0.5	4.7	0.1	31.3
Crappie	3.2	3.1	1.3	0.0	7.3
Darter	2.5	10.8	0.0	0.1	8.4
Yellow perch	4.5	1.5	0.0	0.0	5.1
Unid. larvae	0.6	1.0	1.3	0.3	3.4
Other eggs	0.0	0.5	0.7	1.6	0.0
Total percent	100.1	100.0	99.9	100.2	100.0
Total ichthyoplankton	7,711	195	149	1,800	467
Number of samples	26	26	26	26	26

Source: Paller et al., 1986b.

Ichthyoplankton densities varied between oxbows and were particularly high in the oxbow at RM 100.2, as in 1984. The average density in this oxbow was 1,556.2 ichthyoplankters/1,000 m^3 compared to 38.6 to 289.7/1,000 m^3 in the other oxbows. The reasons for the higher ichthyoplankton density in the oxbow at RM 100.2 are similar to those explained in the discussion on ichthyoplankton densities in the oxbows in 1984.

Table V-4.86 lists species by percent abundance at each oxbow. Although approximately half of all the larvae collected in the 1985 study were collected in the oxbows, only 15% of the samples were collected there, which suggests that oxbows may be important spawning areas. In addition to being important spawning areas, some oxbows may function as nurseries where larvae can remain until they become less vulnerable juveniles.

V.4.3.5.4 Spatial and Temporal Distribution of Selected Ichthyoplankton Taxa

V.4.3.5.4.1 American Shad

American shad support a sport and commercial fishery in the Savannah River during their spring spawning migrations. Adult fish spawn at varying distances upstream from the brackish water zone and have been captured as far upstream as the Augusta Diversion Dam at RM 187.1 (Osteen et al., 1984). The eggs are transported downstream with the current until they hatch or sink to the bottom. Larval shad grow into juveniles in the river and generally migrate to the sea in the fall of the year that they were spawned (Leggett, 1976).

A total of 2,520 American shad eggs and 196 American shad larvae were collected from the study area during 1984. American shad comprised 51.3% of all eggs and 0.7% of all larvae collected from the study area during 1984 (Table V-4.58).

In 1984, American shad ichthyoplankton were first collected in February at temperatures as low as 7 to 8°C (Figure V-4.59). Densities increased in later months, peaking in April at approximately 15°C and late May at approximately 21°C. These data suggest two different spawning runs (Paller et al., 1985).

The total number of American shad ichthyoplankton transported in the river over the entire study period ranged from an estimated 5.49 million at RM 141.7 to 0.65 million at RM 69.9 (Figure V-4.60). American shad were not abundant in the oxbows, and transport of American shad ichthyoplankton from the creeks was minimal compared to transport in the river, indicating that the river is the principal spawning habitat for this species.

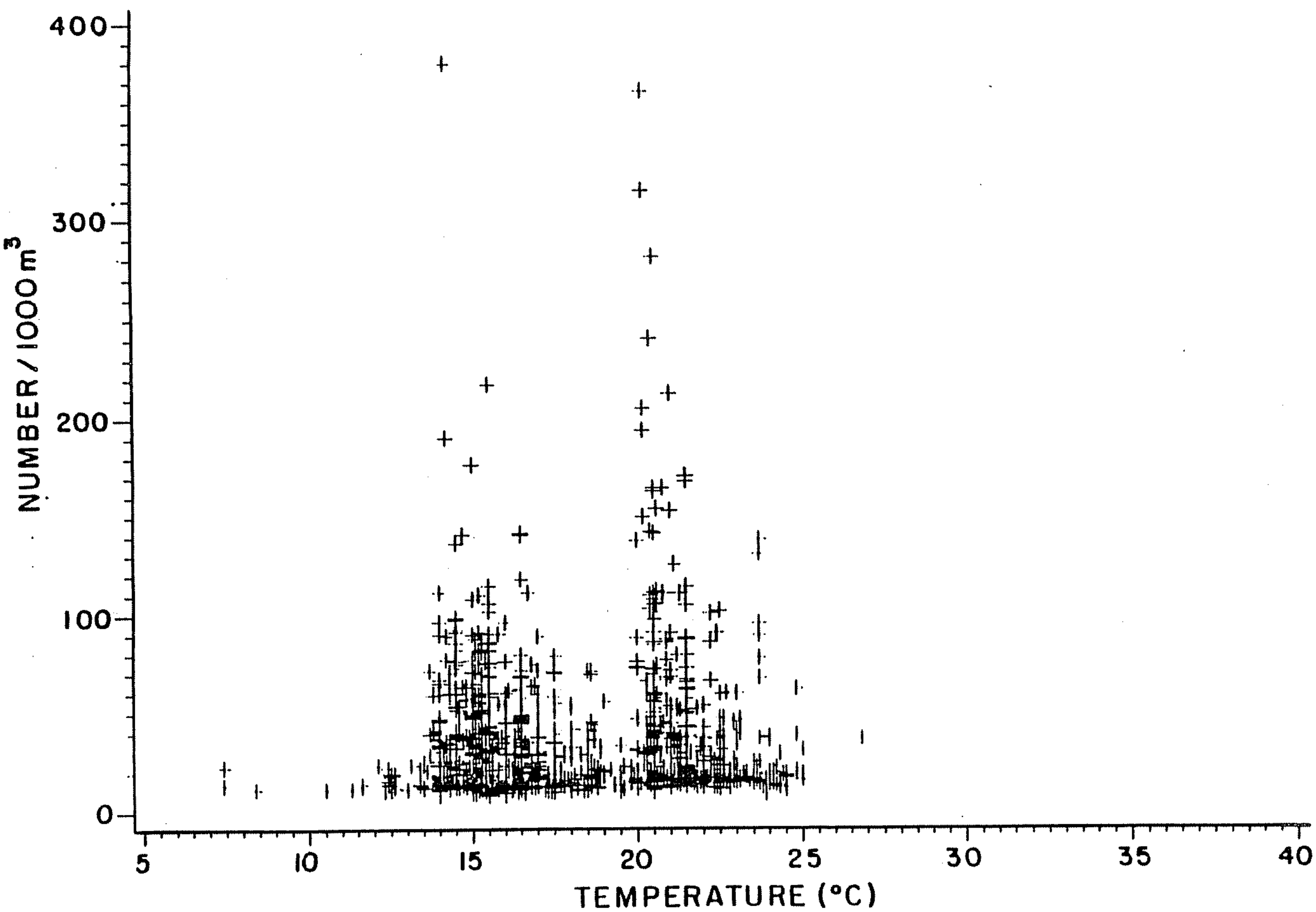


FIGURE V-4.59. Density of American Shad Ichthyoplankton and Water Temperature in the Savannah River (February-July 1984)
Source: Paller et al., 1985

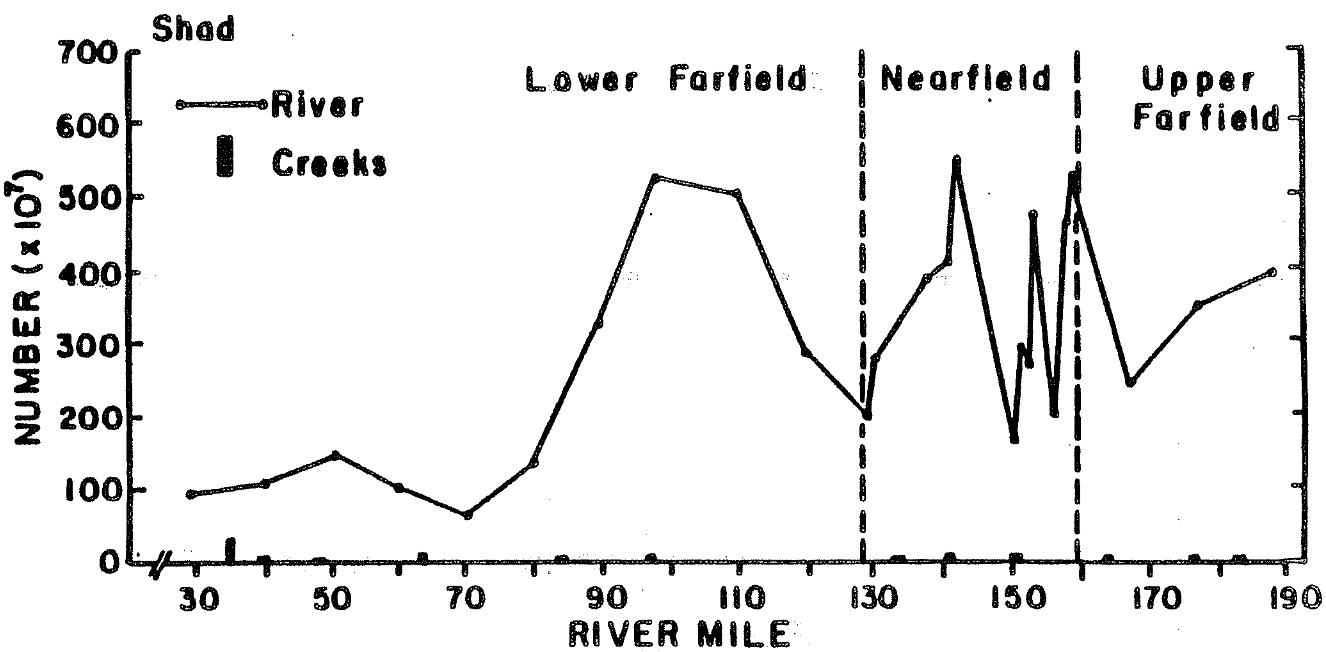


FIGURE V-4.60. Transport of American Shad Ichthyoplankton at Transects in the Savannah River Tributaries (February-July 1984)
Source: Paller et al., 1985

A total of 11,494 American shad eggs and 261 American shad larvae were collected from the study area during 1985 (Table V-4.59). American shad comprised 50.7% of all the ichthyoplankton collected in the Savannah River in 1985 (Table V-4.65). The abundance of American shad ichthyoplankton (primarily eggs) during 1985 may have been due to greater egg survival or to the migration of more spawning adults into the study area during 1985 than during previous years of the study. Greater concentration of eggs into a more limited area due to reduced river discharge during 1985 may also be a contributing factor, although unlikely to account for more than a relatively small percentage of the several fold increase in American shad ichthyoplankton abundance between 1985 and earlier years.

As in 1984, American shad ichthyoplankton were first collected in February 1985 at temperatures as low as 10°C. Their densities increased in later months, peaking in April and May at temperatures of 16 to 22°C (Figure V-4.61). American shad ichthyoplankton were largely absent from the study area by July; very few were collected at temperatures above 26°C.

The total number of American shad ichthyoplankton transported in the Savannah River over the entire 1985 study period ranged from an estimated 160 million at RM 145.7 and RM 166.6 to 8 million at RM 187.1 (Figure V-4.62). The peaks at RMs 145.7 and 166.6 probably reflect localized concentrations of spawning fish. Steel Creek transported approximately 1.6 million American shad eggs and larvae (primarily eggs). Contributions from the other creeks to American shad numbers in the river were minimal compared to Steel Creek (Table V-4.87).

V.4.3.5.4.2 Striped Bass

Adult striped bass are most abundant in coastal areas but often are found in freshwater, particularly during winter and spring. Upriver spawning migrations along the east coast generally occur between winter and mid-summer (Merriman, 1950). Eggs and larvae drift downstream to nursery areas, which are generally in estuaries and the lower portions of rivers. Water currents are important in striped bass spawning areas because egg survival is dependent upon having a sufficient current to keep the eggs suspended in the water column (Stevens, 1967; Bayless, 1968).

In 1984, striped bass ichthyoplankton were not collected in the Savannah River until May. Densities peaked in mid-May, then declined to very low levels during June and July. The highest striped bass densities were 100 to 500 ichthyoplankters/1,000 m^3. These numbers were associated with river temperatures of 17 to 22°C (Figure V-4.63).

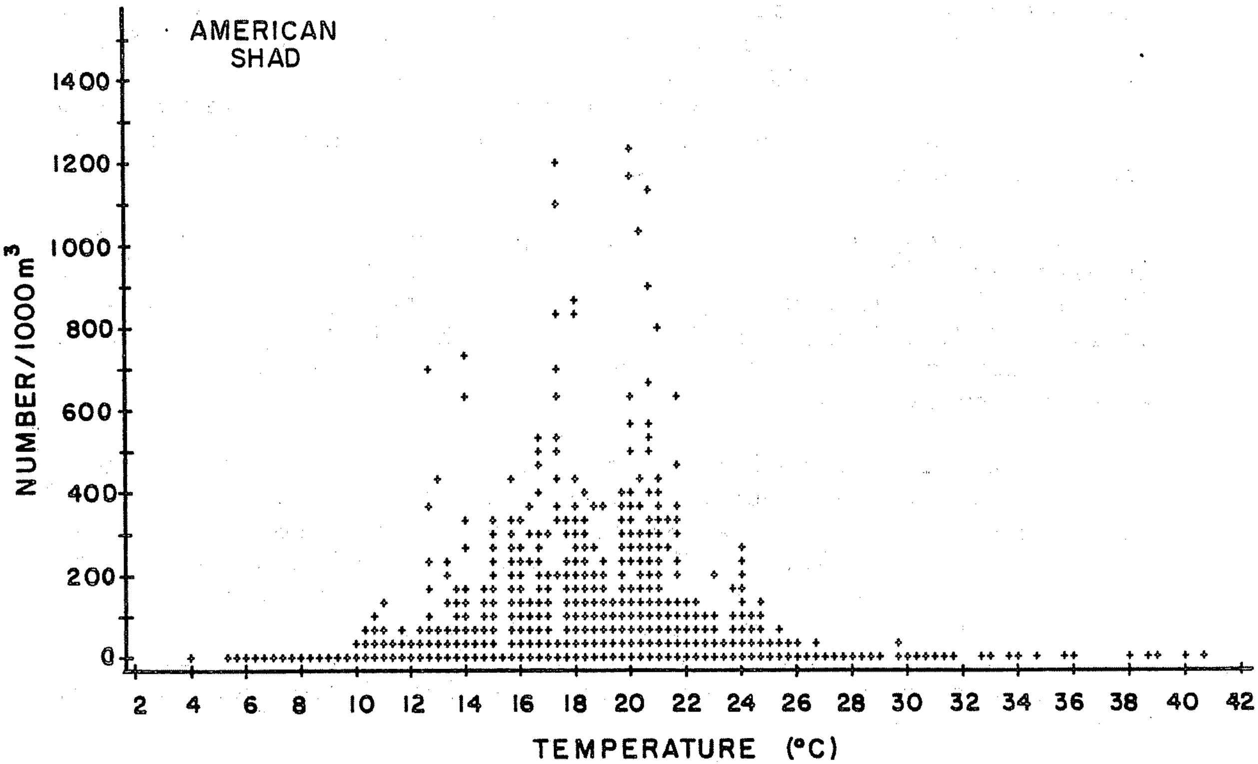


FIGURE V-4.61. Density of American Shad Ichthyoplankton (no./1,000 m^3) Collected at Different Temperatures (°C) in the Savannah River Study Area (February-July 1985)
Source: Paller et al., 1986b

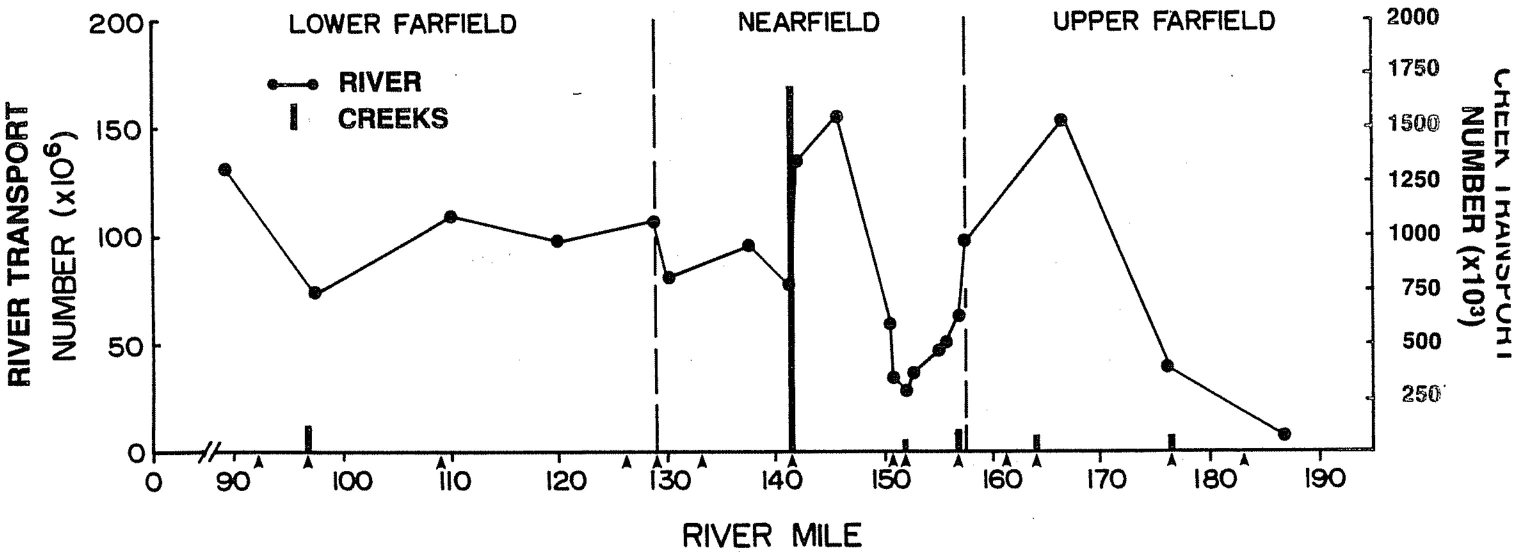


FIGURE V-4.62. Number of American Shad Ichthyoplankton Transported Through Savannah River Sampling Transects (February–July 1985)

Source: Paller et al., 1986b

TABLE V-4.87

Number of Ichthyoplankton (x 10^3) Transported from the Mouths of Selected Savannah River Tributaries (February-July 1985)

Creek (RM)	American Shad	Blueback Herring	Striped Bass
Buck (92.6)	0	0	0
Briar (97.6)	90	229	71
The Gaul (109.0)	0	0	0
Smith Lake (126.5)	0	0	0
Lower Three Runs (129.0)	0	39	0
Sweetwater (133.5)	0	0	0
Steel (141.6)	1623	1340	0
Four Mile (150.6)	0	15	0
Beaver Dam (152.1)	12	567	0
Upper Three Runs (157.2)	62	201	0
Upper Boggy Gut (162.2)	0	0	0
McBean (164.2)	59	137	0
Hollow (176.1)	61	272	0
Spirit (183.3)	0	60	0

Source: Paller et al., 1986b.

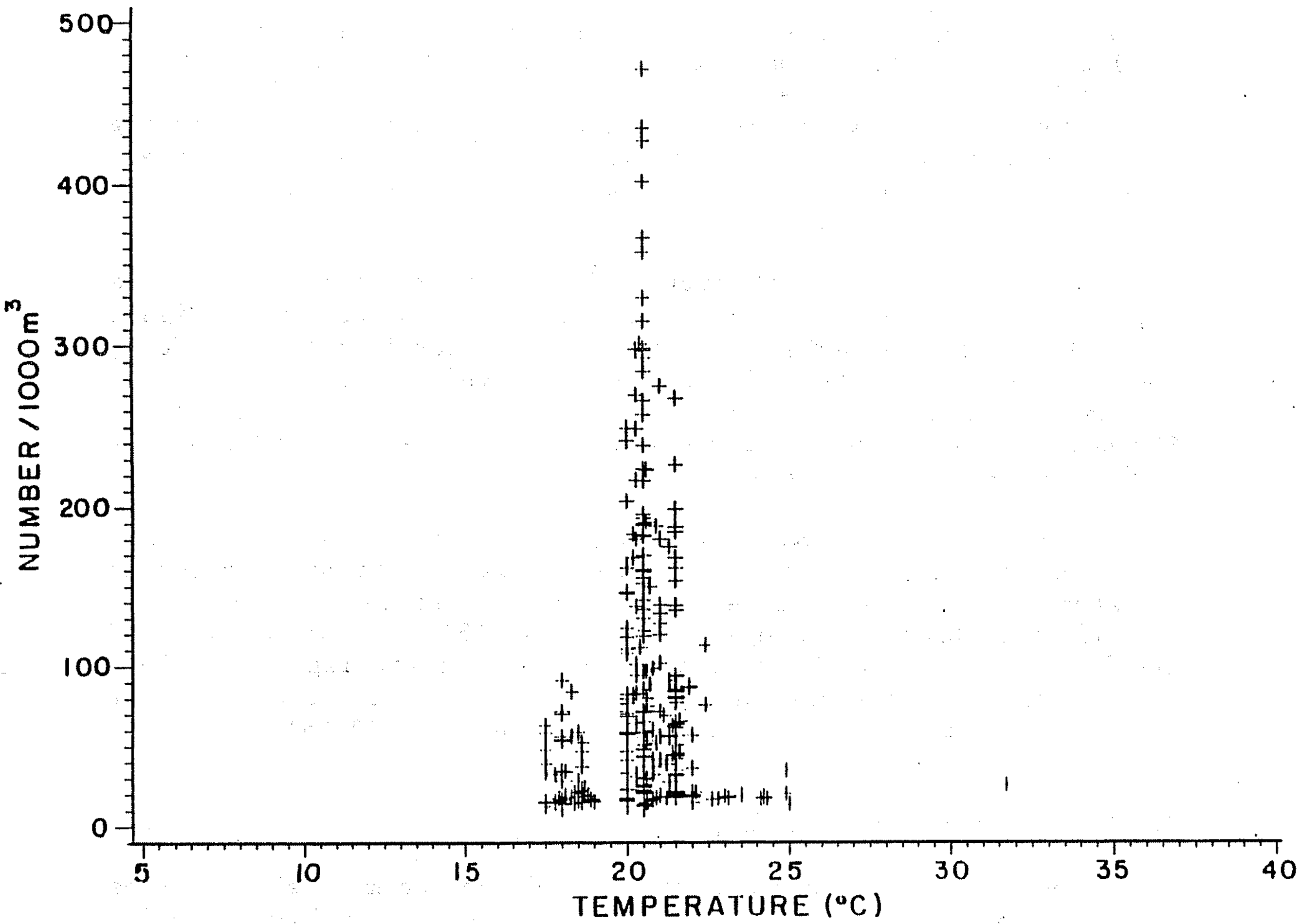


FIGURE V-4.63. Density of Striped Bass Ichthyoplankton and Water Temperature in the Savannah River (February-July 1984)
Source: Paller et al., 1985

The area of maximum striped bass ichthyoplankton abundance was restricted to the nearfield in 1984. Density and transport peaked at RM 141.7 and, on the average, exhibited a fairly regular decline downstream (Figure V-4.64). These data suggest the occurrence of at least one important spawning area, possibly in the region of RM 141.7 (Steel Creek is located at RM 141.6). Very few striped bass larvae or eggs were collected from the tributary creeks during 1984, indicating their relative insignificance as spawning areas. A total of 1,381 striped bass larvae and eggs were collected in the study area in 1984 (Table V-4.58).

In 1985, the greatest striped bass ichthyoplankton densities were associated with river temperatures of 17 to 25°C (Figure V-4.65). Densities peaked in April and May, declined through June, and were zero by July. Striped bass spawning began earlier and lasted somewhat longer during 1985 than during 1983 or 1984. Striped bass spawning was largely confined to May in 1983 and 1984 (Paller et al., 1984; 1985).

Striped bass transport in 1985 exhibited three peaks, suggesting localized aggregations of spawning fish. The peaks occurred at stations in the nearfield and upper farfield: at RM 166.6 (28 million larvae and eggs), RM 155.4 (39 million larvae and eggs), and RM 129.0 (15 million larvae and eggs; Figure V-4.66). The highest peak occurred at RM 155.4 which was the transect just upstream from the 3G intake canal (Paller et al., 1986b).

V.4.3.5.4.3 Blueback Herring

Blueback herring support bait, food, and commercial fisheries in east coast rivers during their spawning migrations (Curtis, 1981). Adults move from coastal waters into brackish and freshwater where they deposit mildly adhesive eggs in swamps, creeks, and floodlands (Adams & Street, 1969; Frankensteen, 1976). Juveniles generally migrate downstream when they are approximately 50 mm in length (Jones et al., 1978).

In 1984, blueback herring ichthyoplankton were first collected during March, peaked in abundance during May and declined to very low levels in June and July. Spawning occurred primarily between 13 and 23°C (Figure V-4.67).

Average densities of blueback herring ichthyoplankton were greatest in the nearfield in 1984 with 2.2 ichthyoplankters/1,000 m^3, compared to 1.7/1,000 m^3 in the lower farfield and 1.2/1,000 m^3 in the upper farfield (Figure V-4.68).

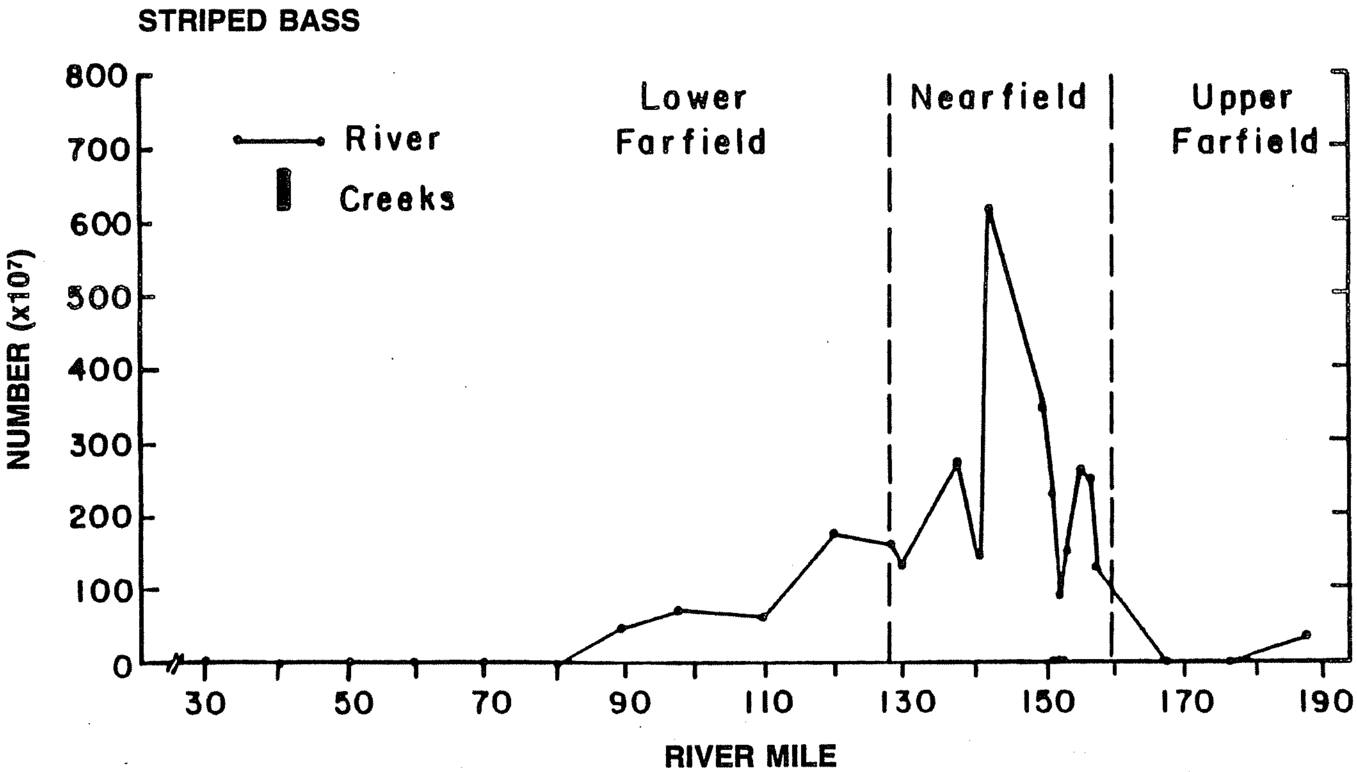


FIGURE V-4.64. **Transport of Striped Bass Ichthyoplankton at Transects in the Savannah River and from the Mouths of the Savannah River Tributaries (February-July 1984)**
Source: Paller et al., 1985

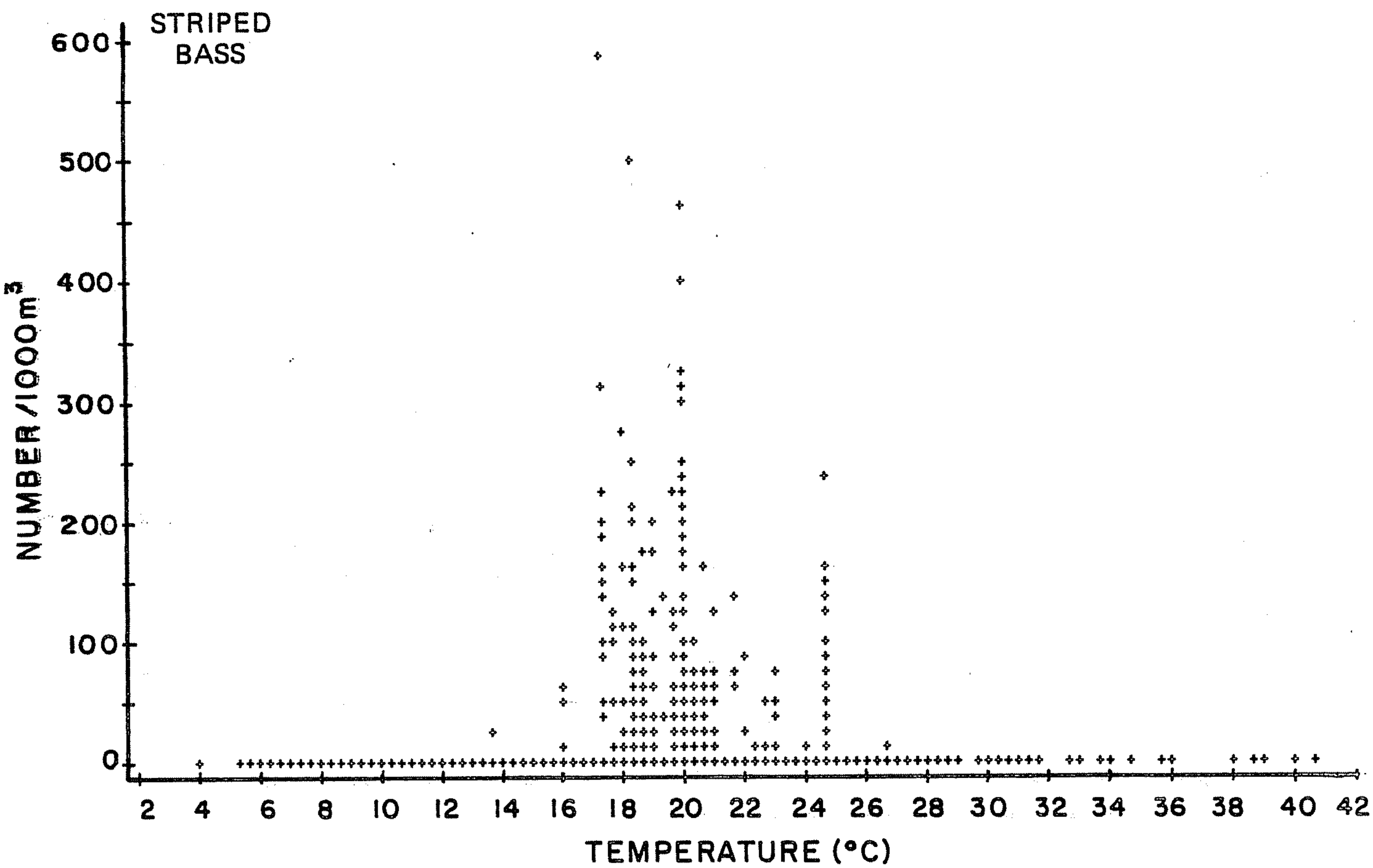


FIGURE V-4.65. Density of Striped Bass Ichthyoplankton (no./1,000 m^3) Collected at Different Temperatures (°C) in the Savannah River Study Area (February-July 1985)
Source: Paller et al., 1986b

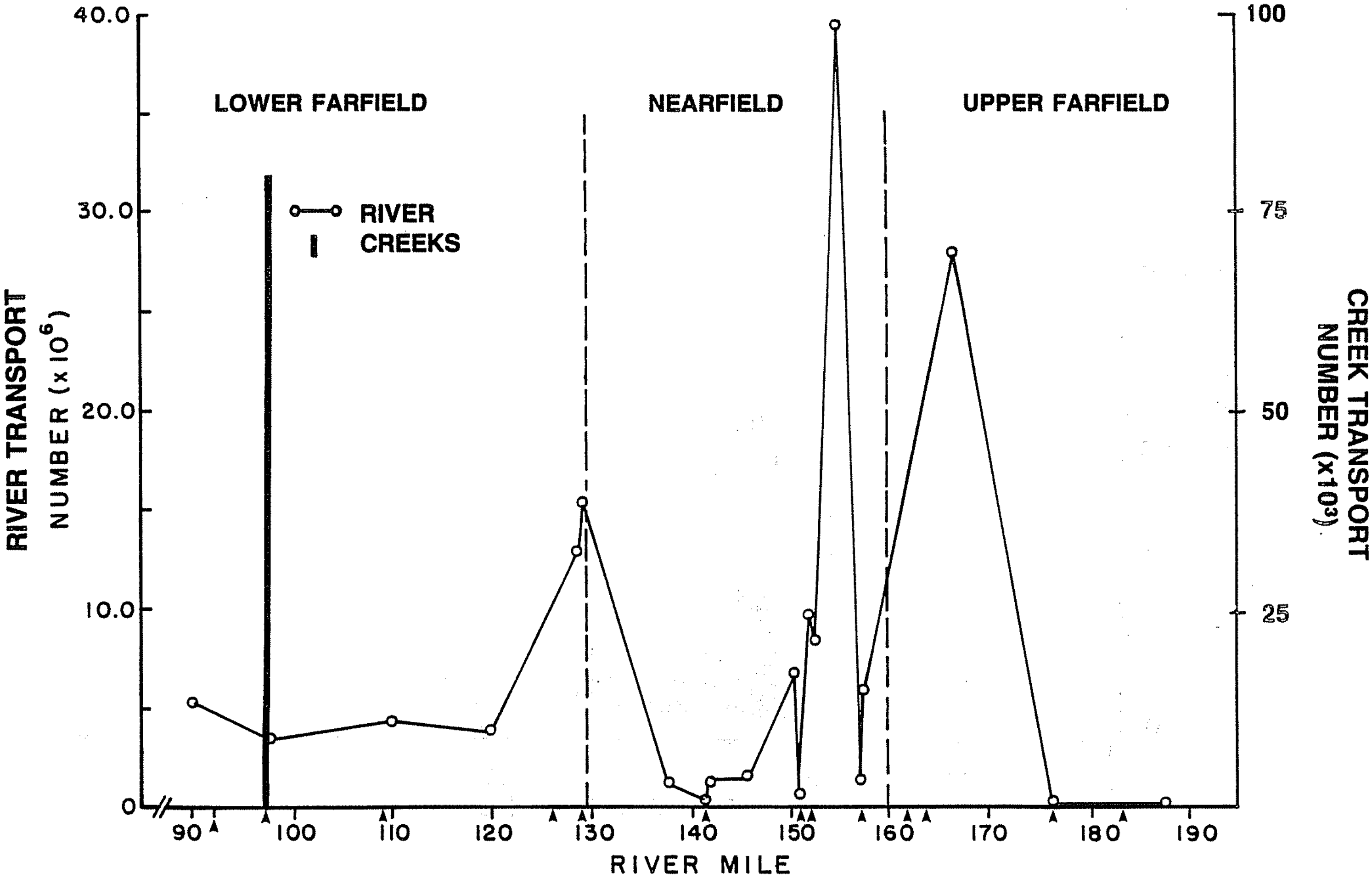


FIGURE V-4.66. Number of Striped Bass Ichthyoplankton Transported Through Savannah River Sampling Transects (February-July 1985)
Source: Paller et al., 1986b

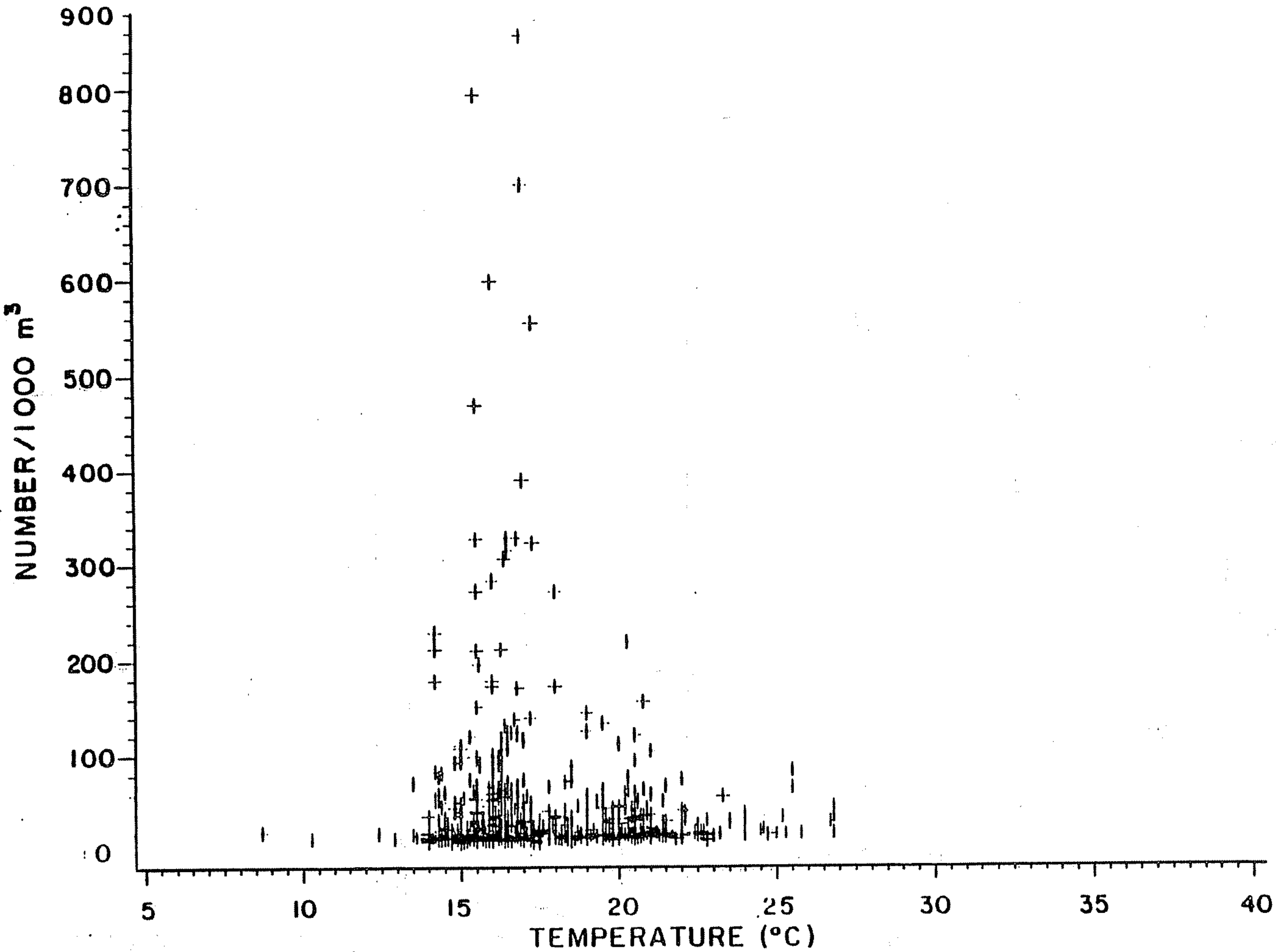


FIGURE V-4.67. Density of Blueback Herring Ichthyoplankton and Water Temperature in the Savannah River (February-July 1985)
Source: Paller et al., 1986b

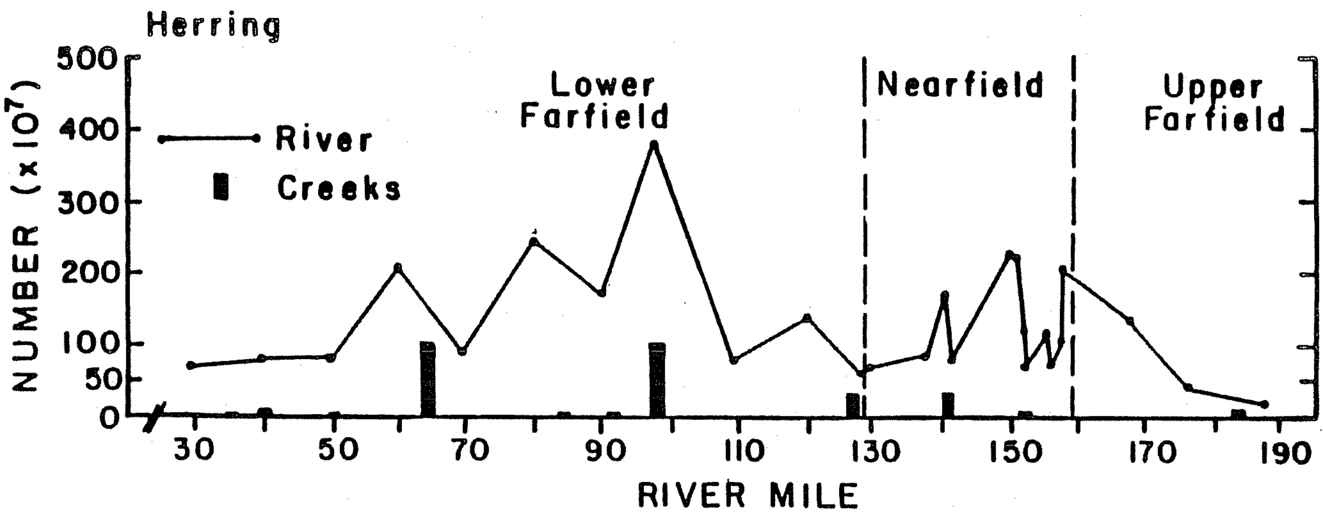


FIGURE V-4.68. Transport of Blueback Herring Ichthyoplankton at Transects in the Savannah River and from the Mouths of Savannah River Tributaries (February-July 1984)
Source: Paller et al., 1985

Unlike the other anadromous species, blueback herring were abundant in the creeks. Four creeks, Lake Parachuchia Outlet, Briar Creek, Smith Lake, and Steel Creek contributed large numbers of blueback herring ichthyoplankton to the Savannah River during 1984.

In 1985, blueback herring ichthyoplankton were first collected in the study area again during March. They peaked in abundance in April and May, declined in June, and declined further in July. Spawning occurred primarily between 13 and 27°C (Figure V-4.69).

Blueback herring transport during the 1985 study period averaged approximately 2.6 million in the lower farfield, 3.2 million in the nearfield, and 7.1 million in the upper farfield (Figure V-4.70). As in 1984, blueback herring were more abundant in the creeks in 1985 than in the river (mean density of 10.2/1,000 m^3 in the creeks compared to 1.4/1,000 m^3 in the river). Steel Creek contributed large numbers of blueback herring ichthyoplankton to the Savannah River during 1985 (1.34 million) as well as in 1983 and 1984 (Paller et al., 1986b).

V.4.3.5.4.4 Gizzard and/or Threadfin Shad

Gizzard and threadfin shad larvae were the most abundant taxonomic group in the study area in 1984, comprising 21.0% of all larvae and 4.6% of all eggs collected. In addition, the category "unidentified Clupeidae" (14.4% of all larvae) probably consisted mainly of gizzard and threadfin shad because blueback herring, the only other important taxon in this category, were not abundant in 1984. Gizzard and threadfin shad are important because they serve as a link between predatory fishes and the energy sources at the base of the food web, such as detritus and plankton (Pflieger, 1975).

In 1984, gizzard and threadfin shad were collected in low numbers in April (mean of 0.5 ichthyoplankters/1,000 m^3), peaked in May (17.6/1,000 m^3), and declined in June [(2.1/1,000 m^3) and July (0.4/1,000 m^3)]. Most spawning occurred between 15 and 25°C (Figure V-4.71).

The greatest abundance of gizzard and threadfin shad in 1984 occurred in the oxbows (mean of 85.9/1,000 m^3), followed by the creeks (11.8/1,000 m^3), intake canals (5.0/1,000 m^3), and the river (3.0/1,000 m^3). These data suggest the importance of the oxbows as habitat for these species.

In 1985, gizzard and threadfin shad larvae were again the most abundant taxonomic group in the study area, comprising 35.5% of all larvae and 2.2% of all eggs collected during 1985 (Table V-4.59).

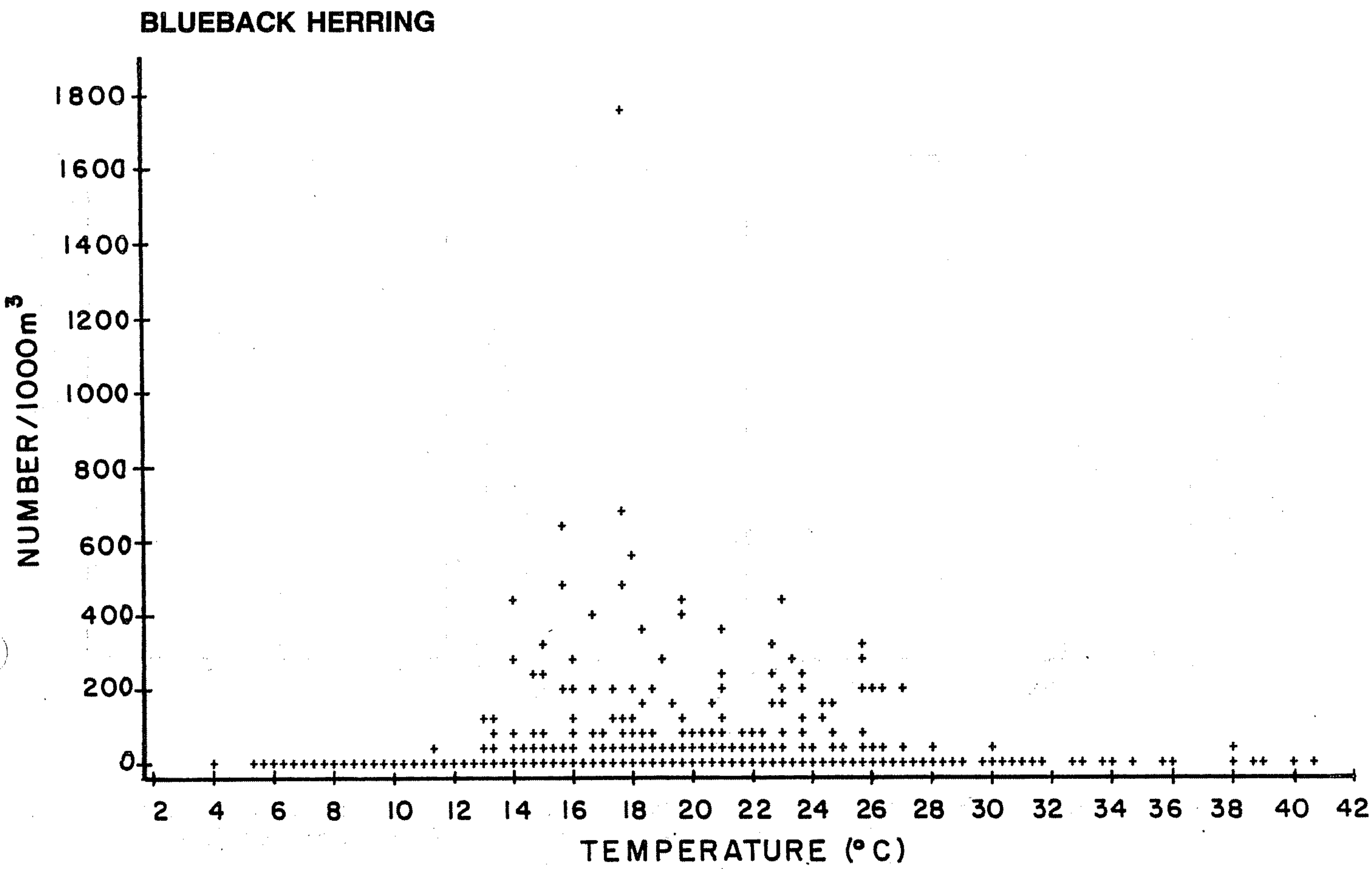


FIGURE V-4.69. Density of Blueback Herring Ichthyoplankton (no./1,000 m^3) Collected at Different Temperatures (°C) in the Savannah River Study Area (February-July 1985)
Source: Paller et al., 1986b

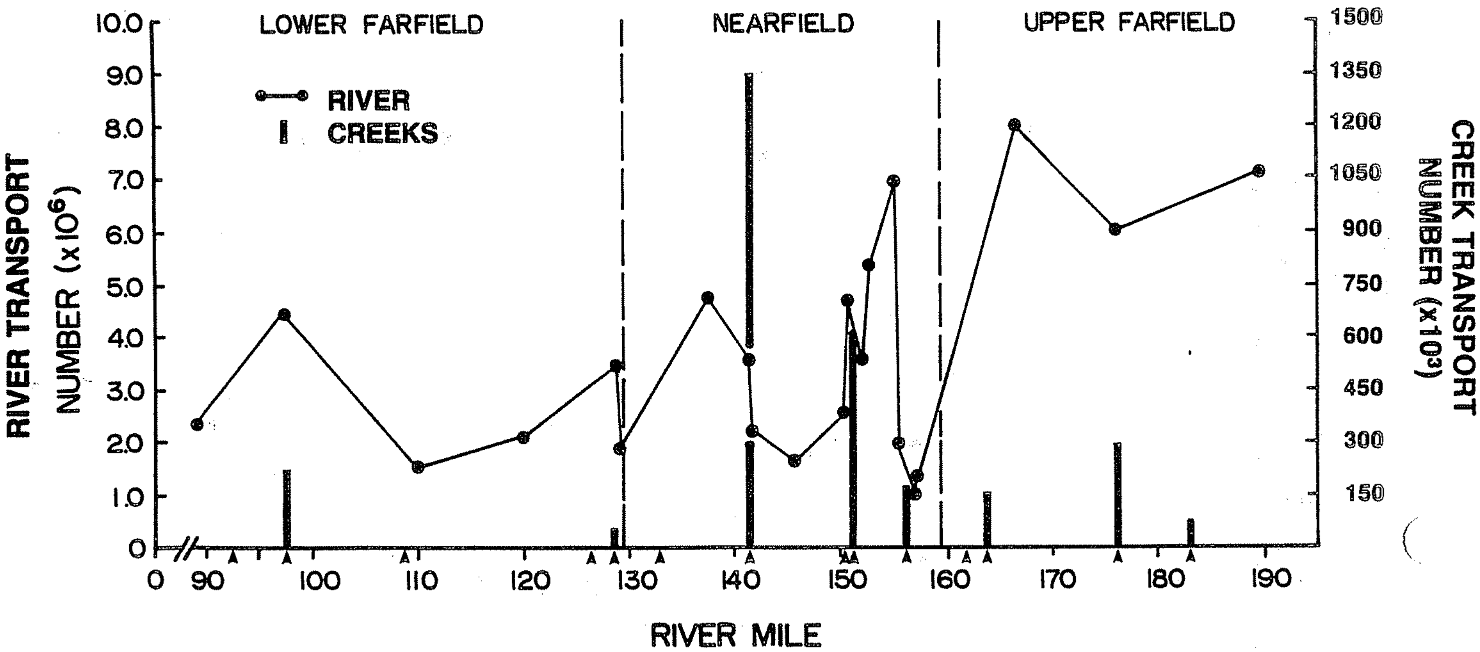


FIGURE V-4.70. Number of Blueback Herring Ichthyoplankton Transported Through Savannah River Transects (February-July 1985)
Source: Paller et al., 1986b

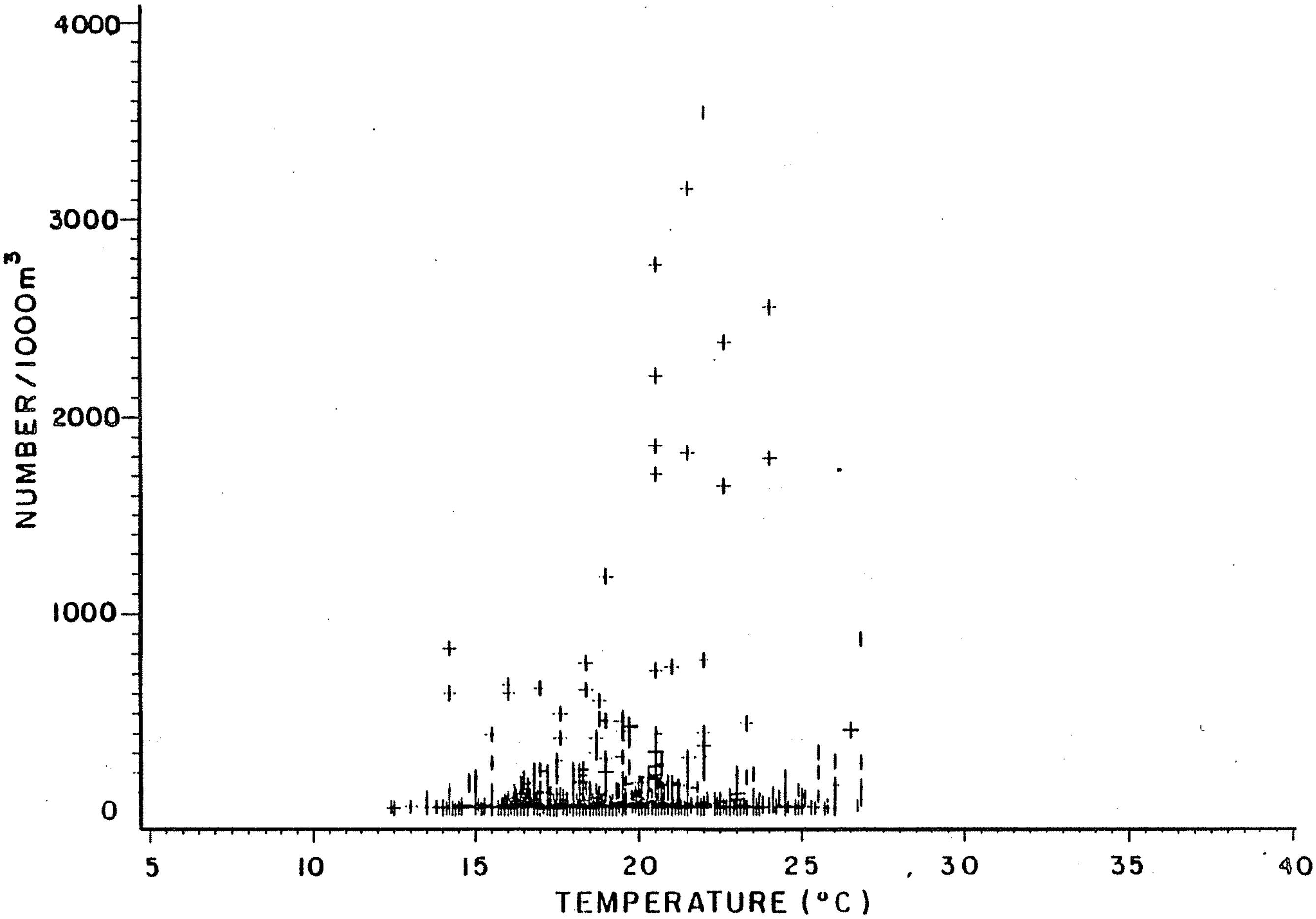


FIGURE V-4.71. Density of Gizzard and Threadfin Shad Ichthyoplankton and Water Temperature in the Savannah River (February-July 1984)
Source: Paller et al., 1985

Most spawning of gizzard and threadfin shad occurred between 16 and 25°C in 1985 (Figure V-4.72). The same trends for ichthyoplankton densities from February through July were observed in 1985 as in 1984.

Gizzard and threadfin shad densities averaged 221.6/1,000 m^3 in the oxbows, 7.1/1,000 m^3 in the river, 4.2/1,000 m^3 in the creeks, and 12.0/1,000 m^3 in the intake canals (Table V-4.65). These data indicate that gizzard shad spawned in all the major habitats in the study area but made particular use of the oxbows (especially the oxbow at RM 100.2).

V.4.3.5.4.5 Sunfish

In 1984, sunfish (Lepomis and unidentified sunfishes) larvae were one of the most abundant types of ichthyoplankton in the study area, comprising 18.7% of all larvae collected (no eggs were identified as sunfish). Sunfish spawning began in March, peaked in May, and was still occurring at low levels in July.

Sunfish spawning in 1984 occurred over a wide range of water temperatures, from 14 to 28°C, probably because the category "sunfishes" includes many species with varied optimal spawning temperatures (Figure V-4.73). A few sunfish larvae were collected at temperatures as high as 30°C in the thermal creeks. While some of these larvae may have drifted into thermal areas from other sources, the sunfishes may make greater use of mildly thermal areas than most other species.

While sunfish larvae were abundant in all major habitats except the intake canals, the greatest densities occurred in the oxbows. Mean sunfish density over all dates was 49.2 ichthyoplankters/1,000 m^3 in the oxbows, 17.2/1,000 m^3 in the creeks, 4.0/1,000 m^3 in the river, and 1.4/1,000 m^3 in the intake canals.

As in 1984, sunfish were one of the most abundant species in the study area in 1985, comprising 13.2% of all larvae collected (no sunfish eggs were identified; Table V-4.59). Sunfish spawning began in March, peaked in April, May, and June, and was still occurring at decreased levels in July. Sunfish larvae were collected when water temperatures ranged from 11 to 33°C (Figure V-4.74), comparable to the 14 to 28°C temperature range in which they were found in 1984.

Oxbows were important spawning areas for the sunfishes in 1985, especially the oxbow at RM 100.2 (Table V-4.86). Sunfish densities averaged 96.5/1,000 m^3 in the oxbows compared to 0.7/1,000 m^3 in the river, 6.5/1,000 m^3 in the creeks, and 0.4/1,000 m^3 in the intake canals (Table V-4.65).

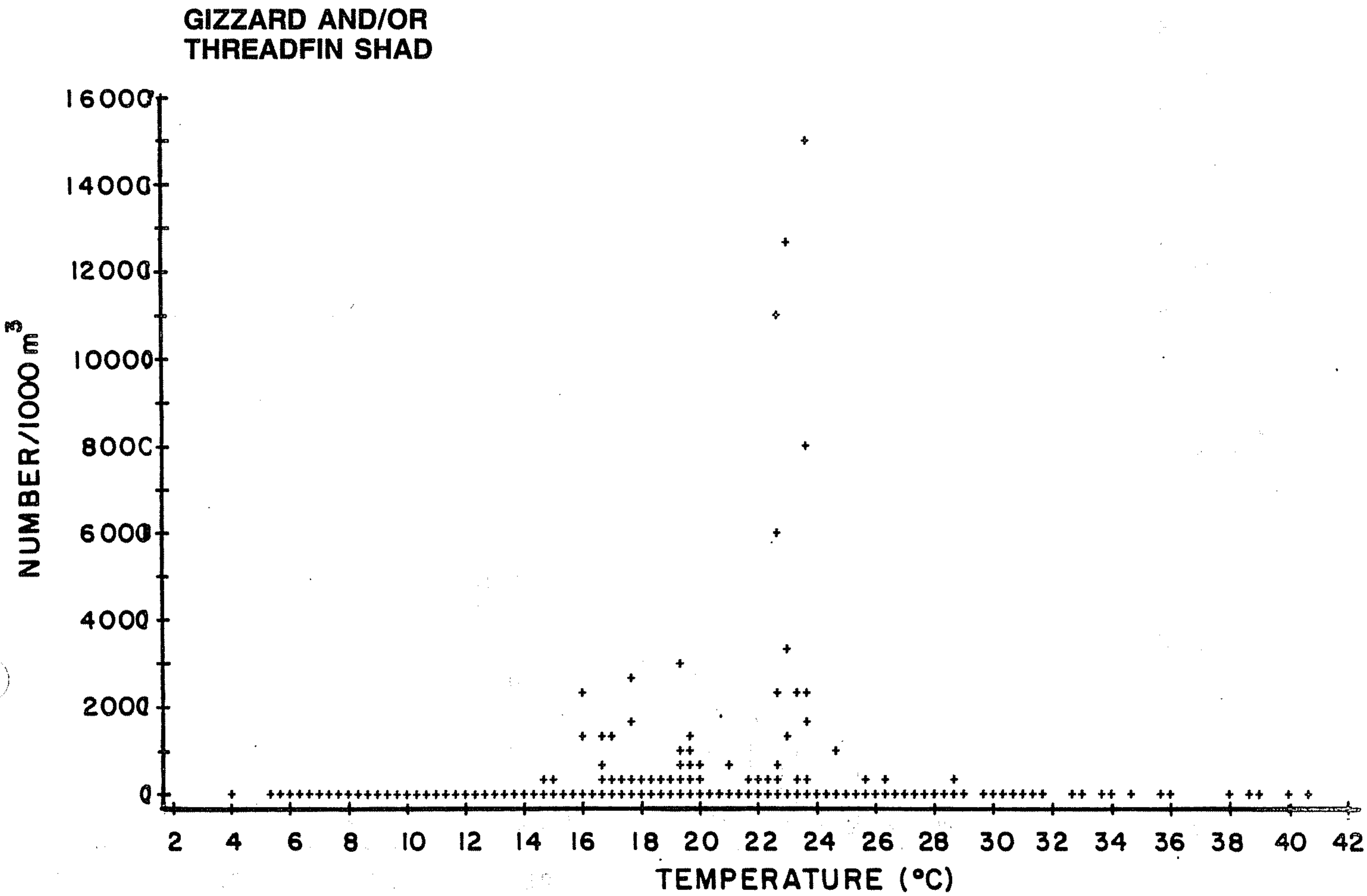


FIGURE V-4.72. Density of Gizzard and Threadfin Shad (no./1,000 m^3) Collected at Different Temperatures (°C) in the Savannah River Study Area (February-July 1985)
Source: Paller et al., 1986b

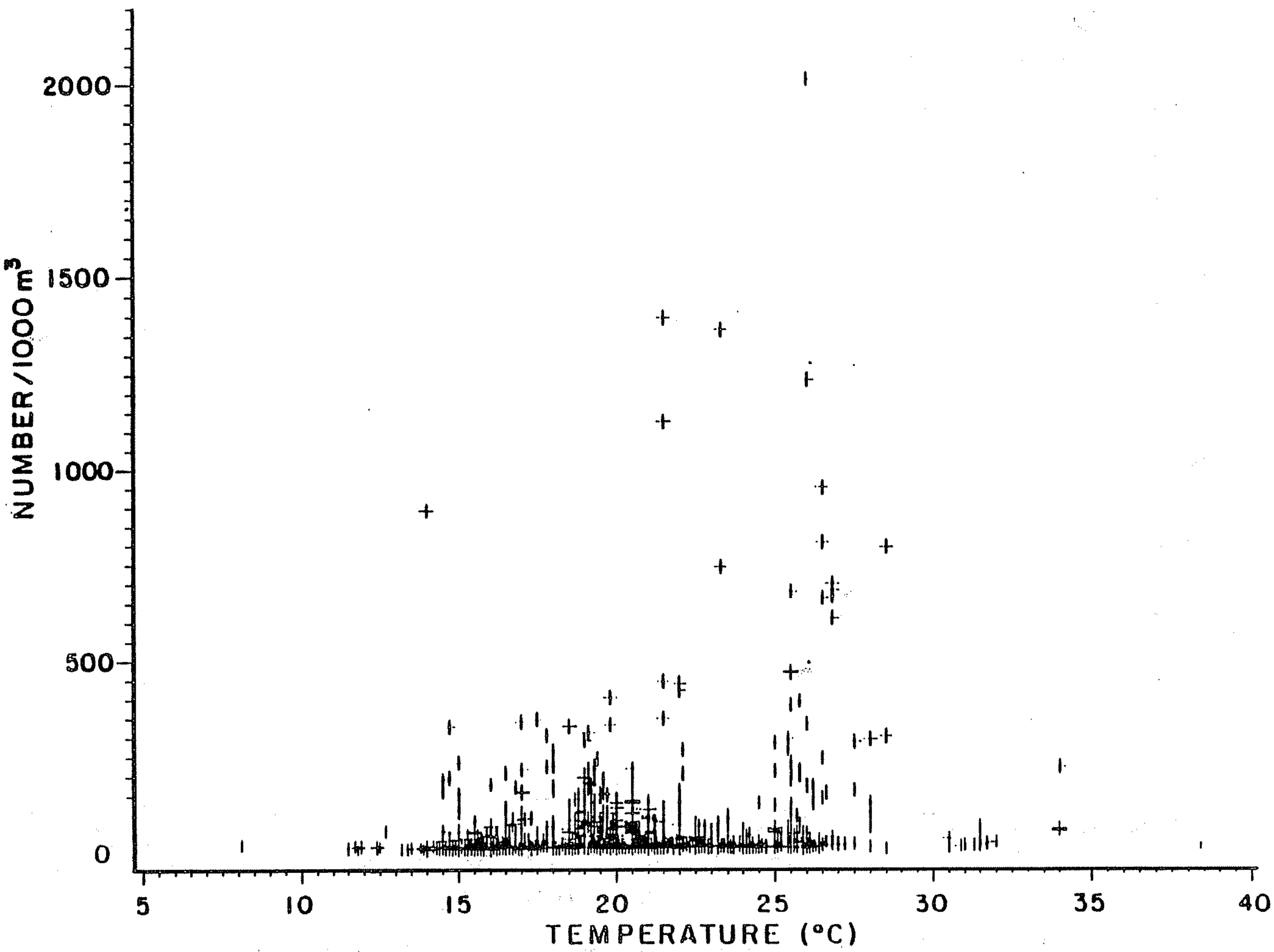


FIGURE V-4.73. Density of Sunfish Ichthyoplankton and Water Temperature in the Savannah River (February–July 1984)
Source: Paller et al., 1985

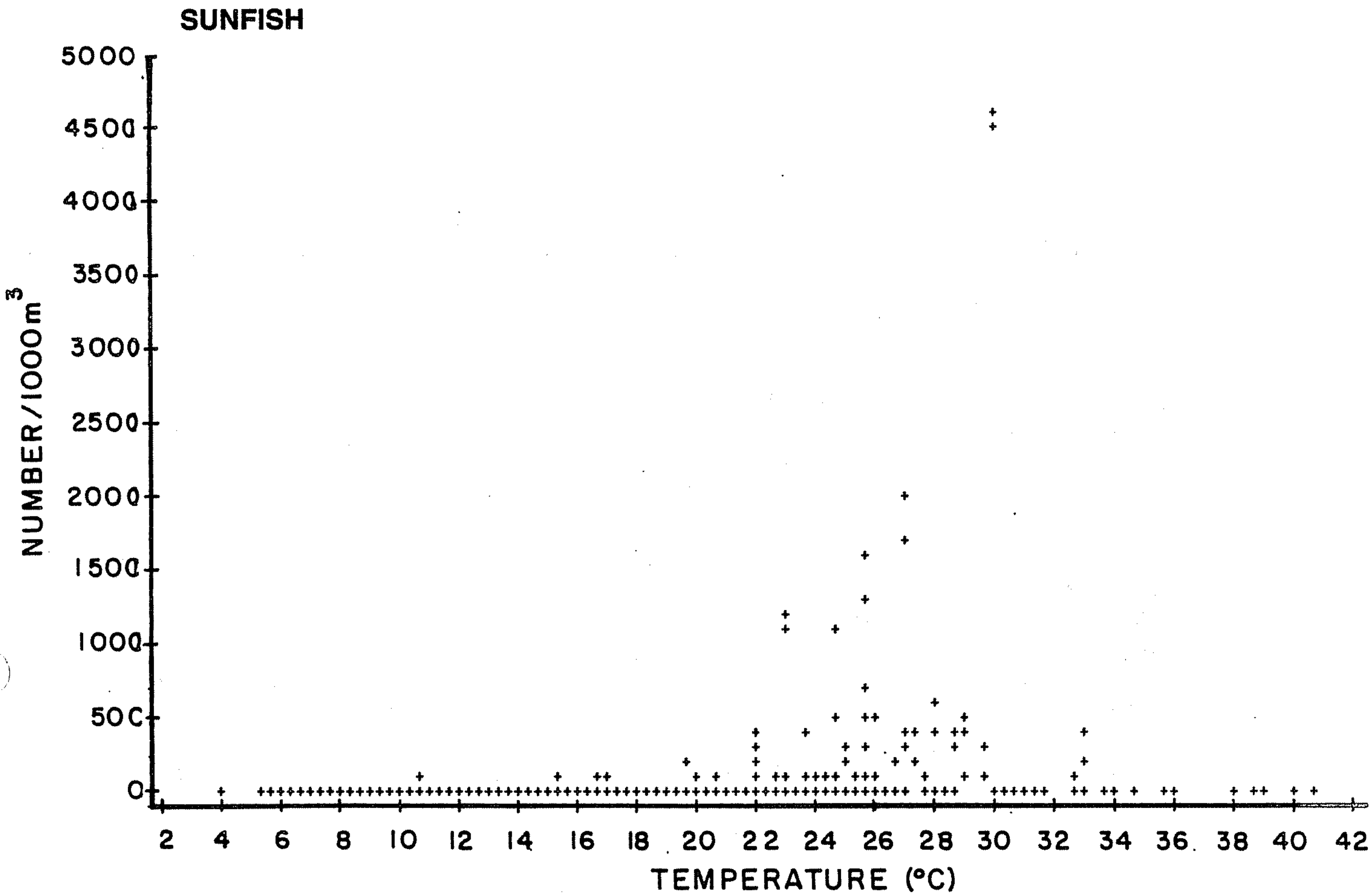


FIGURE V-4.74. Density of Sunfish Ichthyoplankton (no./1,000 m^3) Collected at Different Temperatures (°C) in the Savannah River Study Area (February–July 1985)
Source: Paller et al., 1986b

Sunfish densities were lower in 1985 than in previous years except for in the oxbows. This decrease may have been related to low water levels in 1985 which, in the creeks and river, would tend to reduce the amount of spawning habitat by eliminating sheltered areas. Low water levels in the oxbows would not necessarily have had a deleterious effect however, because currents were minimal in most of the oxbows at all but the highest water levels.

V.4.3.5.4.6 Crappie

In 1984, crappie were a dominant component of the ichthyoplankton in all parts of the study area except the upper farfield and in all habitats except the oxbows. The total number of crappie collected in 1984 was 4,236.

The greatest density of crappie ichthyoplankton throughout the study area occurred in March. Densities were low during the other sample months at all stations. Most of the crappie spawning occurred between temperatures of approximately 8 to 22°C, with peak spawning occurring between 15 and 18°C (Figure V-4.75).

Mean crappie densities in 1984 were 4.7 ichthyoplankters/1,000 m^3 in the creeks, 7.6/1,000 m^3 in the oxbows, and 10.5/1,000 m^3 in the intake canals (Table V-4.64). Of the four "habitats," the relative composition of crappie in the ichthyoplankton ranged from 3.7% in the oxbows to 24.1% in the intake canals. Crappie made a greater relative contribution to the ichthyoplankton of the creek mouths (20.5%) than to the ichthyoplankton of the Savannah River (13.5%) during 1984. The higher density in the intake canals than in the river suggests that crappie selectively spawned there (Paller et al., 1985).

Crappie were a much reduced component of the ichthyoplankton during 1985, constituting 1.9% of the total, and with a mean density of 0.2/1000 m^3 in the Savannah River. The reduced abundance of crappie during 1985 may be due to low water levels. During 1984, crappie ichthyoplankton abundance peaked during flood periods, when large floodplain areas served as favorable spawning and nursery areas. Flooding did not occur in 1985 except for a brief period during February, before spawning began in earnest.

V.4.3.5.4.7 Minnows

Minnows (family Cyprinidae), which are important forage for predatory fishes, were one of the most abundant ichthyoplankton groups, comprising 11.1% of all larvae and 0.6% of all eggs collected during 1984 (Table V-4.58). A total of 3,060 minnow ichthyoplankton was collected during 1984.

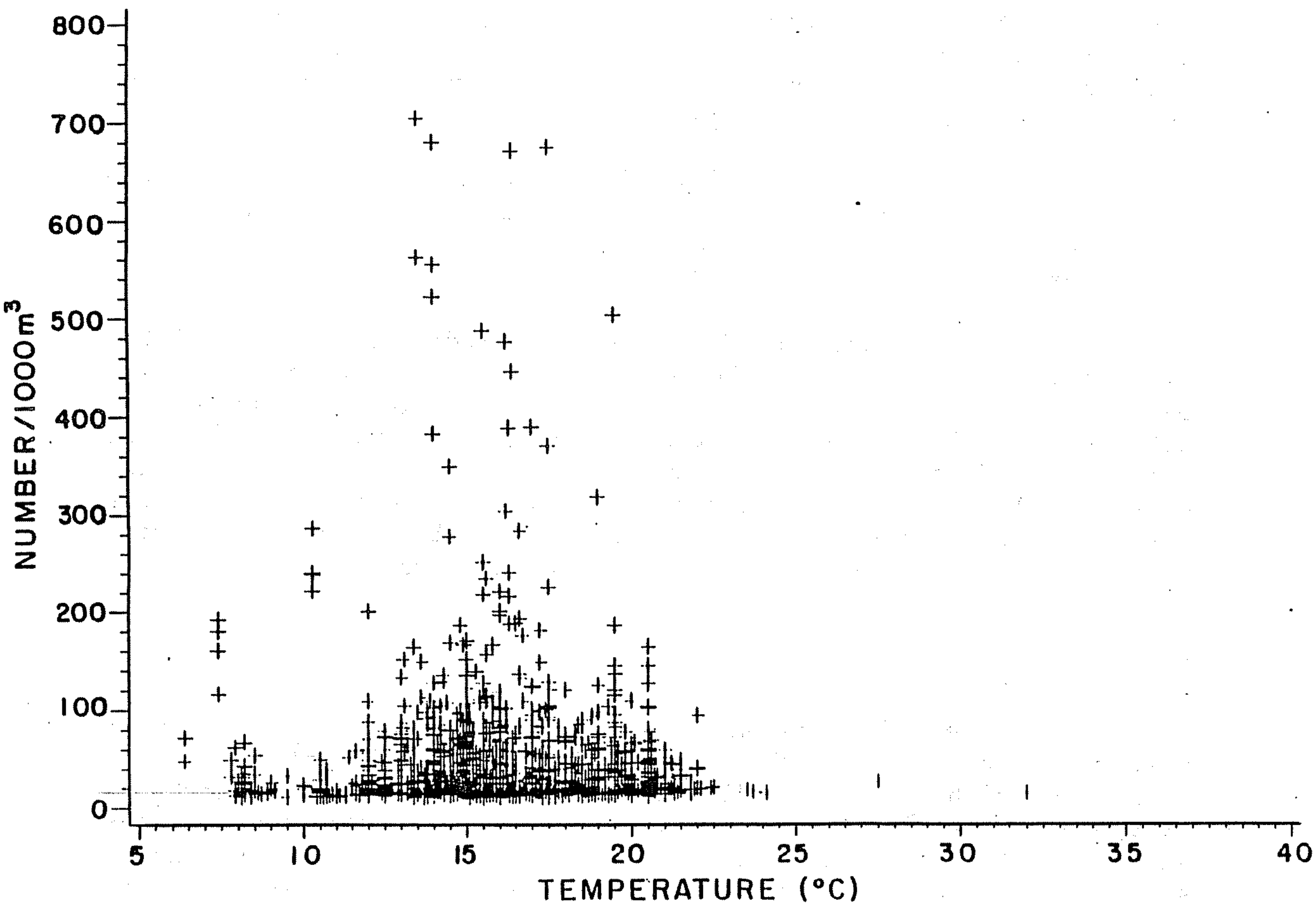


FIGURE V-4.75. Density of Crappie Ichthyoplankton and Water Temperature in the Savannah River (February-July 1984)
Source: Paller et al., 1985

Minnow ichthyoplankton first appeared in 1984 in low densities during March when spawning activity was largely confined to the lower farfield (Table V-4.58). Minnow densities peaked in May and declined in June and July. Temperatures of spawning ranged between approximately 15 and 25°C (Figure V-4.76).

In 1984, the mean density of minnow ichthyoplankton in the river was 5.2 ichthyoplankters/1,000 m^3 compared to 6.0/1,000 m^3 in the creeks, 2.7/1,000 m^3 in the intake canals, and 2.2/1,000 m^3 in the oxbows.

Minnows were not abundant in the study area during 1985. Minnows comprised 4.3% of all the ichthyoplankton collected during 1985 (Table V-4.59) and mean densities in the river were just 2.2/1,000 m^3 for minnows (Table V-4.65). As with crappie, the reduced abundance of minnows during 1985 may have been due to low water levels. Both taxa peaked in abundance during flood periods during 1984. Flooding did not occur during 1985 except for a brief period during early February, before spawning was initiated.

V.4.3.5.4.8 Sturgeon

Two species of sturgeon, the Atlantic sturgeon and the shortnose sturgeon, occur in the Savannah River. The Atlantic sturgeon is a large fish often exceeding 3 m in total length. The shortnose sturgeon is smaller, seldom exceeding 1.3 m total length. The shortnose sturgeon is extremely rare and is listed as an endangered species by the U.S. Fish and Wildlife Service and by South Carolina and Georgia. In the past several years, adult shortnose sturgeon have been collected in the Savannah River about 16 km south of the SRP boundary. In addition, small numbers of larvae of the Atlantic and shortnose sturgeon have been collected in the vicinity of the SRP (Paller et al., 1986b).

During 1982, 14 sturgeon larvae were collected, 13 were collected in 1983, and 9 sturgeon larvae were collected in 1984 (Table V-4.73); all were taken from the river or the intake canals. Darrel E. Snyder of the Larval Fish Laboratory at Colorado State University considered two of the larvae collected during 1982 and six of the larvae collected during 1983 as shortnose sturgeon. Using criteria established by Snyder (1984), ECS personnel identified two of the larvae collected during 1984 and two of the larvae collected during 1985 as shortnose sturgeon also. Definitive separation of shortnose sturgeon from Atlantic sturgeon larvae is difficult because of their similar appearance (Paller et al., 1985).

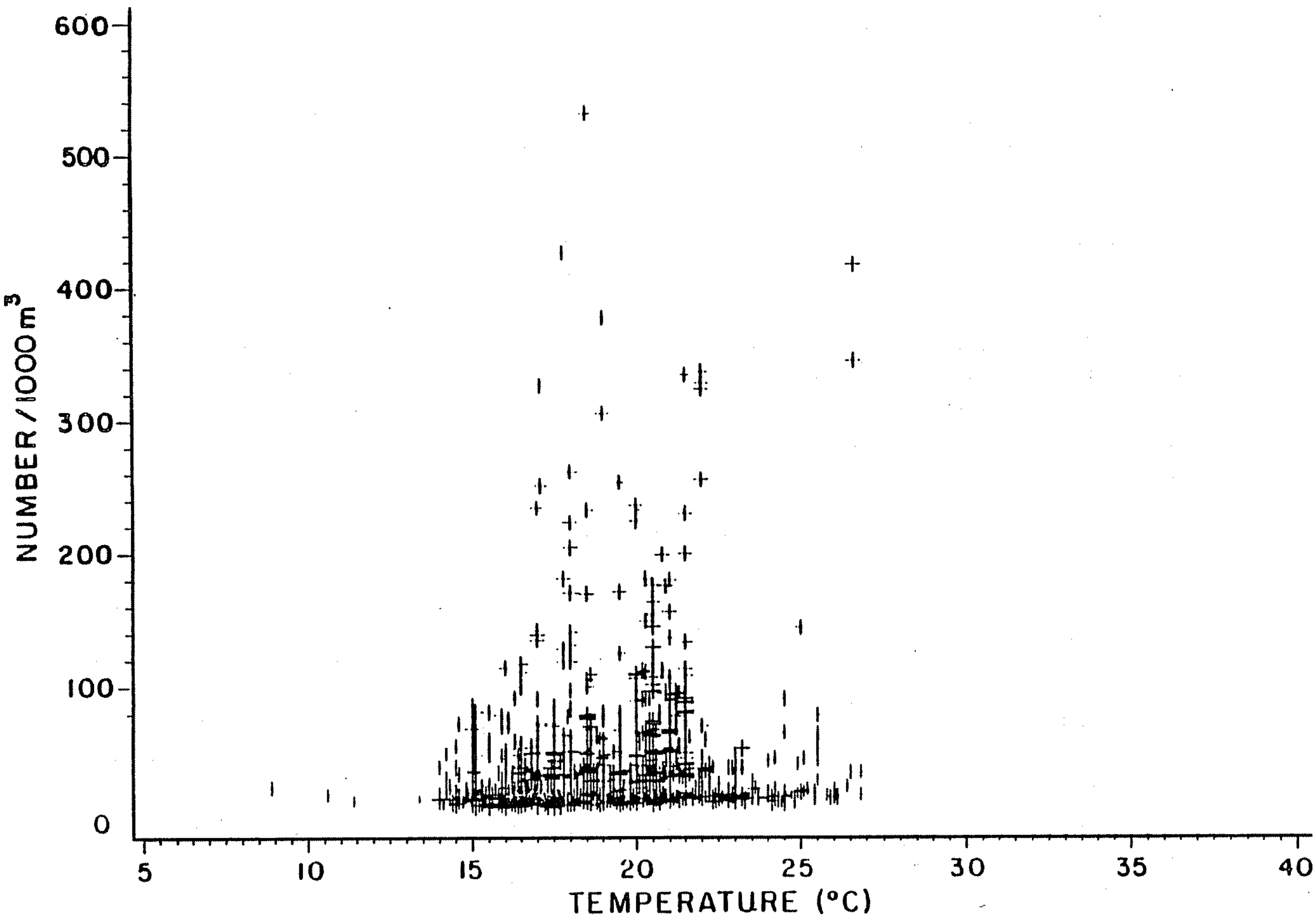


FIGURE V-4.76. Density of Minnow Ichthyoplankton and Water Temperature in the Savannah River (February–July 1984)
Source: Paller et al., 1985

V.4.3.5.5 Entrainment

The cooling water for C and K Reactors and makeup water for Par Pond is pumped from the Savannah River at the 1G and 3G pumphouses. The D-Area power plant receives cooling water from the 5G pumphouse. Ichthyoplankton from the river are entrained into the cooling water system along with the river water. The 1984 and 1985 entrainment studies attempted to estimate the loss of ichthyoplankton caused by river water withdrawal at the SRP intake structures. Entrainment of ichthyoplankton was divided into larval entrainment and egg entrainment in the following discussions.

The average density of larvae (measured in number/1,000 m^3) in the six surface and two bottom samples from each intake canal was used to calculate entrainment of larvae at the 1G and 3G pumphouses. The average density of larvae in six surface and six bottom samples collected at RM 155.4 (the upstream transect closest to the 5G intake) was used to calculate entrainment of larvae at the 5G pumphouse, which has no intake canal.

Samples were collected in the intake canals and river weekly from February through July in both 1984 and 1985. The number of larvae entrained was calculated by multiplying the volume of water pumped at each pumphouse by the mean density of larvae from the appropriate canal or river transect. The entrainment calculations for fish eggs were more complicated. Generally, freshwater fish have demersal (bottom dwelling) rather than planktonic eggs, and as a result, few eggs were actually collected in the canals. The only exceptions to this in the Savannah River drainage are American shad and striped bass eggs (Jones et al., 1978; Hardy, 1978). The reduced water velocities in the intake canals allow the suspended eggs to settle out of the water column (McFarlane, 1982). Silt settles over these eggs and they are assumed to die. Thus egg entrainment estimates were based on egg densities at the river transects just above the canals, or, in the case of the 1G canal (where Upper Three Runs Creek contributes a substantial portion of the canal water), on egg densities at nearby river and creek mouth stations. Entrainment per interval was calculated by multiplying the total volume of water pumped during the sampling interval by the appropriate mean egg density. The total entrainment of fish egg was estimated by summing the entrained eggs during each sampling interval. Egg entrainment losses were calculated assuming that fish eggs that settle out of the water column as well as those actually entrained by the pumps are lost. For a more detailed discussion on the calculations of egg entrainment, see Paller et al., 1986b.

At least 17 taxa of larval fish were entrained at the SRP pumphouses during the 1984 spawning season (Table V-4.88). The family most commonly found in the entrainment samples was Clupeidae which comprised 50% of the larval fish that were entrained. The

TABLE V-4.88

Number and Percent Composition of Larval Fish Entrained at 1G, 3G, and 5G Pumphouses (February-July 1984)

Taxa	Pumphouse 1G (no. x 1,000)	3G (no. x 1,000)	5G (no. x 1,000)	Total (no. x 1,000)	Percent Composition
Clupeidae					
American shad	36	26	-	62	0.4
Blueback herring	891	1,398	39	2,328	13.2
Other shad	1,010	1,085	139	2,234	12.7
Unid. clupeids	2,102	1,975	116	4,193	23.9
Esocidae					
Unid. pickerel	23	7	-	30	0.2
Cypriniidae					
Carp	175	203	46	424	2.4
Unid. cyprinids	449	679	167	1,295	7.4
Catostomidae					
Spotted suckers	495	506	118	1,119	6.4
Other suckers	-	23	12	35	0.2
Aphredoderidae					
Pirate perch	-	-	3	3	<0.1
Percichthyidae					
Striped bass	33	73	17	123	0.7
Centrarchidae					
Unid. crappie	1,908	2,181	233	4,322	24.5
Unid. sunfish	147	100	22	269	1.5
Other centrarchids	200	59	16	275	1.6
Percidae					
Yellow perch	77	218	5	300	1.7
Other percids	84	219	39	342	1.9
Lepisosteidae					
Gar	19	-	-	19	0.1
Others	99	87	19	205	1.2
Total				17,578	100.0

Source: Paller et al., 1985.

single most abundant taxon was crappie, with 4.3 million larvae entrained, or 24.5% of all ichthyoplankton entrained. Other abundant taxa in 1984 were unidentified clupeids, blueback herring, and other shad. Generally, there were no differences in the species composition among the three pumphouses.

The total number of larval fish entrained due to SRP activities from February through July 1984 was calculated to be 17.6 million. Of the 17.6 million, 7.7 million of total larvae (44%) were entrained at the 1G pumphouse, 8.8 million of total larvae (50.3%) were entrained at the 3G pumphouse, and 1.0 million of total larvae (5.6%) were entrained at the 5G pumphouse. Tables V-4.89 through V-4.91 list the numbers of larvae entrained at each pumphouse in 1984.

The total fish egg entrainment from February through July 1984 was calculated to be 5.8 million eggs, of which 2.7 million eggs (46.6%) were entrained at the 1G pumphouse, 2.6 million eggs (45.4%) at the 3G pumphouse, and 460,000 eggs (8.0%) at the 5G pumphouse. Tables V-4.92 through V-4.94 list the numbers of fish eggs entrained at each pumphouse. American shad eggs represented 50.4% of the total eggs entrained in 1984 (Table V-4.95).

The impact of entrainment on the Savannah River ichthyoplankton that passed by the SRP was estimated by calculating the total entrainment for all three pumphouses (23.4 million organisms) as a percent of the total ichthyoplankton upstream from all three intake structures (282 million organisms). In 1984, 8.3% of the total susceptible ichthyoplankton was entrained (Paller et al., 1985).

In 1985, there were at least six taxa of larvae entrained at the SRP pumphouses (Table V-4.96). The most common larval fish entrained were suckers, which comprised 43% of the larval fish entrained. The spotted sucker was the single most abundant taxon, comprising 42.7% of larvae entrained at the three pumphouses. Other abundant taxa were gizzard and threadfin shad (22.0%), unidentified Clupeidae (11.4%), and carp (10.3%; Table V-4.96). Generally, there were no major differences in the species composition between the three pumphouses. On March 19, 1985 at RM 155.4 (the river transect used to calculate entrainment at the 5G pumphouse) a single sturgeon larvae was collected (the species was not determined).

The total number of larval fish entrained due to SRP activities from February through July 1985 was calculated to be 10.9 million. The 1G, 3G, and 5G pumphouses entrained 3.8 million (35% of total), 6.4 million (59.0% of total), and 0.7 million (6.0% of total) larvae, respectively (Tables V-4.97 through V-4.99).

TABLE V-4.89

Estimated Entrainment of Larval Fish at the 1G Pumphouse (February-July 1984)

Interval	Total Volume Pumped (x 1,000 m^3)	Mean Density (no./1,000 m^3)	Total Larvae
1/31 - 2/07	7,661	0.0	0
2/07 - 2/14	5,712	2.2	12,566
2/14 - 2/21	4,909	2.2	10,800
2/21 - 2/28	5,144	0.0	0
2/28 - 3/06	5,314	2.5	13,285
3/06 - 3/13	4,610	10.0	46,100
3/13 - 3/20	5,542	48.4	268,233
3/20 - 3/28	7,787	60.0	467,220
3/28 - 4/03	7,310	35.5	259,505
4/03 - 4/10	8,819	21.1	186,081
4/10 - 4/17	8,445	9.7	81,917
4/17 - 4/24	9,015	29.5	265,943
4/24 - 5/01	6,983	66.9	467,163
5/01 - 5/08	7,698	120.4	926,839
5/08 - 5/15	8,059	197.6	1,592,458
5/15 - 5/22	7,862	182.9	1,437,960
5/22 - 5/29	5,970	100.3	598,791
5/29 - 6/05	6,143	49.2	302,236
6/05 - 6/12	6,492	48.7	316,160
6/12 - 6/19	7,245	47.7	345,587
6/19 - 6/26	7,338	13.6	99,797
6/26 - 7/04	8,487	3.9	33,099
7/04 - 7/10	6,564	2.7	17,723
7/10 - 7/17	7,044	1.2	8,453
7/17 - 7/24	6,878	0.0	0
Total number of fish			7,757,916

Source: Paller et al., 1985.

TABLE V-4.90

Estimated Entrainment of Larval Fish at the 3G Pumphouse (February-July 1984)

Interval	Total Volume Pumped (x 1,000 m^3)	Mean Density (no./1,000 m^3)	Total Larvae
1/31 - 2/07	6,917	0.0	0
2/07 - 2/14	4,766	1.1	5,243
2/14 - 2/21	1,923	1.1	2,115
2/21 - 2/28	4,987	0.0	0
2/28 - 3/06	5,291	3.0	15,873
3/06 - 3/13	5,378	7.4	39,797
3/13 - 3/20	6,454	42.8	276,231
3/20 - 3/28	7,057	101.3	714,874
3/28 - 4/03	7,038	73.4	516,589
4/03 - 4/10	8,590	14.8	127,132
4/10 - 4/17	8,997	11.9	107,064
4/17 - 4/24	8,683	31.9	276,988
4/24 - 5/01	7,569	108.5	821,237
5/01 - 5/08	9,602	120.9	1,160,882
5/08 - 5/15	9,256	108.1	1,000,574
5/15 - 5/22	9,729	127.6	1,241,420
5/22 - 5/29	7,910	120.6	953,946
5/29 - 6/05	6,677	78.1	521,474
6/05 - 6/12	7,346	61.9	454,717
6/12 - 6/19	9,284	49.6	460,486
6/19 - 6/26	8,689	1.3	11,296
6/26 - 7/04	8,627	1.2	10,352
7/04 - 7/10	6,702	4.6	30,829
7/10 - 7/17	7,166	6.8	48,729
7/17 - 7/24	7,270	5.7	41,439
Total number of fish			8,839,287

Source: Paller et al., 1985.

TABLE V-4.91

Estimated Entrainment of Larval Fish at the 5G Pumphouse (February-July 1984)

Interval	Total Volume Pumped (x 1,000 m^3)	Mean Density (no./1,000 m^3)	Total Larvae
1/31 - 2/07	1,520	0.0	0
2/07 - 2/14	1,520	0.0	0
2/14 - 2/21	1,520	0.0	0
2/21 - 2/28	1,520	0.0	0
2/28 - 3/06	1,520	1.8	2,736
3/06 - 3/13	1,520	2.5	3,800
3/13 - 3/20	1,520	6.8	10,336
3/20 - 3/28	1,615	37.5	60,562
3/28 - 4/03	1,520	46.5	70,680
4/03 - 4/10	1,425	17.1	24,368
4/10 - 4/17	1,520	3.5	5,320
4/17 - 4/24	1,520	10.4	15,808
4/24 - 5/01	1,520	41.8	63,536
5/01 - 5/08	1,520	101.1	153,672
5/08 - 5/15	1,520	87.2	132,544
5/15 - 5/22	1,520	66.1	100,472
5/22 - 5/29	1,520	101.2	153,824
5/29 - 6/05	1,520	71.6	108,832
6/05 - 6/12	1,520	24.0	36,480
6/12 - 6/19	1,520	17.3	26,296
6/19 - 6/26	1,520	12.5	19,000
6/26 - 7/04	1,615	1.7	2,746
7/04 - 7/10	1,520	0.0	0
7/10 - 7/17	1,425	0.7	998
7/17 - 7/24	1,520	0.7	1,064
Total number of			993,074

Source: Paller et al., 1985.

TABLE V-4.92

Estimated Entrainment of Fish Eggs at the 1G Pumphouse (February-July 1984)

Interval	Total Volume Pumped (x 1,000 m^3)	Mean Density (no./1,000 m^3)	Total Eggs
1/31 - 2/07	7,661	0.0	0
2/07 - 2/14	5,712	0.0	0
2/14 - 2/21	4,909	0.0	0
2/21 - 2/28	5,144	0.0	0
2/28 - 3/06	5,314	0.0	0
3/06 - 3/13	4,610	0.0	0
3/13 - 3/20	5,542	1.0	5,542
3/20 - 3/28	7,787	1.8	14,017
3/28 - 4/03	7,310	5.3	38,743
4/03 - 4/10	8,819	15.7	138,458
4/10 - 4/17	8,445	44.0	371,580
4/17 - 4/24	9,015	36.0	324,540
4/24 - 5/01	6,983	5.2	36,312
5/01 - 5/08	7,698	2.7	20,785
5/08 - 5/15	8,059	10.2	82,202
5/15 - 5/22	7,862	41.1	323,128
5/22 - 5/29	5,970	91.3	545,061
5/29 - 6/05	6,143	79.7	489,597
6/05 - 6/12	6,492	25.5	165,546
6/12 - 6/19	7,245	7.3	52,889
6/19 - 6/26	7,338	2.4	17,611
6/26 - 7/04	8,487	1.1	9,336
7/04 - 7/10	6,564	1.6	10,502
7/10 - 7/17	7,044	3.2	25,541
7/17 - 7/24	6,878	2.8	19,258
Total eggs			2,690,648

Source: Paller et al., 1985.

TABLE V-4.93

Estimated Entrainment of Fish Eggs at the 3G Pumphouse (February-July 1984)

Interval	Total Volume Pumped (x 1,000 m^3)	Mean Density (no./1,000 m^3)	Total Eggs
1/31 - 2/07	6,917	0.0	0
2/07 - 2/14	4,766	0.0	0
2/14 - 2/21	1,923	0.0	0
2/21 - 2/28	4,987	0.0	0
2/28 - 3/06	5,291	0.0	0
3/06 - 3/13	5,378	0.0	0
3/13 - 3/20	6,454	0.0	0
3/20 - 3/28	7,057	0.6	4,234
3/28 - 4/03	7,038	8.7	61,231
4/03 - 4/10	8,590	19.3	165,787
4/10 - 4/17	8,997	31.8	286,105
4/17 - 4/24	8,683	24.5	212,734
4/24 - 5/01	7,569	3.8	28,762
5/01 - 5/08	9,602	0.7	6,721
5/08 - 5/15	9,256	11.1	102,742
5/15 - 5/22	9,729	89.4	869,773
5/22 - 5/29	7,910	85.7	677,887
5/29 - 6/05	6,677	16.8	112,174
6/05 - 6/12	7,346	10.9	80,071
6/12 - 6/19	9,284	0.8	7,427
6/19 - 6/26	8,689	0.0	0
6/26 - 7/04	8,627	0.5	4,314
7/04 - 7/10	6,702	0.5	3,351
7/10 - 7/17	7,166	0.0	0
7/17 - 7/24	7,270	0.0	0
Total eggs			2,623,313

Source: Paller et al., 1985.

TABLE V-4.94

Estimated Entrainment of Fish Eggs at the 5G Pumphouse (February-July 1984)

Interval	Total Volume Pumped (x 1,000 m^3)	Mean Density (no./1,000 m^3)	Total Eggs
1/31 - 2/07	1,520	0.0	0
2/07 - 2/14	1,520	0.0	0
2/14 - 2/21	1,520	0.0	0
2/21 - 2/28	1,520	0.0	0
2/28 - 3/06	1,520	0.0	0
3/06 - 3/13	1,520	0.0	0
3/13 - 3/20	1,520	0.0	0
3/20 - 3/28	1,615	0.6	969
3/28 - 4/03	1,520	8.7	13,224
4/03 - 4/10	1,425	19.3	27,503
4/10 - 4/17	1,520	31.8	48,336
4/17 - 4/24	1,520	24.5	37,240
4/24 - 5/01	1,520	3.8	5,776
5/01 - 5/08	1,520	0.7	1,064
5/08 - 5/15	1,520	11.1	16,872
5/15 - 5/22	1,520	89.4	135,888
5/22 - 5/29	1,520	85.7	130,264
5/29 - 6/05	1,520	16.8	25,536
6/05 - 6/12	1,520	10.9	16,568
6/12 - 6/19	1,520	0.8	1,216
6/19 - 6/26	1,520	0.0	0
6/26 - 7/04	1,615	0.5	808
7/04 - 7/10	1,520	0.5	760
7/10 - 7/17	1,425	0.0	0
7/17 - 7/24	1,520	0.0	0
Total eggs			462,024

Source: Paller et al., 1985.

TABLE V-4.95

Number and Percent Composition of Fish Egg Entrainment at 1G, 3G, and 5G Pumphouses (February-July 1985)

Taxa	Pumphouse 1G (no. x 10^3)	3G (no. x 10^3)	5G (no. x 10^3)	Total	Percent Composition
American shad	1,898	851	157	2,906	50.4
Blueback herring	48	17	3	68	1.2
Dorosoma spp.	60	56	11	127	2.2
Striped bass	249	1,299	224	1,772	30.7
Unid. percids	19	0	0	19	0.3
Other	415	396	67	878	15.2
Total				5,770	100.0

Source: Paller et al., 1985.

TABLE V-4.96

Number and Percent Composition of Larval Fish Entrained at the 1G, 3G, and 5G Pumphouses (February-July 1985)

Taxa	1G		3G		5G		Total	
	No. x 10^3	Percent Comp.	No. x 10^3	Percent Comp.	No. x 10^3	Percent Comp.	No. x 10^3	Percent Comp.
Unid. Clupeidae	379	9.9	797	12.5	69	10.1	1,245	11.4
Blueback herring	195	5.1	198	3.1	21	3.1	414	3.8
American shad	46	1.2	9	0.1	5	0.7	60	0.6
Gizzard and/or threadfin shad	563	14.7	1,660	26.0	171	25.2	2,393	22.0
Unid. Cyprinidae	122	3.2	225	3.5	61	8.9	408	3.8
Carp	341	8.9	687	10.8	89	13.1	1,117	10.3
Spotted sucker	1,835	48.0	2,585	40.5	223	32.8	4,643	42.7
Unid. suckers	-	-	24	0.4	6	0.9	46	0.4
Other	341	8.9	195	3.0	39	5.3	556	5.1
Total	3,822	99.9	6,380	99.9	684	100.1	10,882	100.1

Source: Paller et al., 1986b.

TABLE V-4.97

Estimated Entrainment of Fish Larvae at the 1G Pumphouse (February-July 1985)

Interval	Unid. Clupeidae	Blueback Herring	American Shad	Threadfin and/or Gizzard Shad	Unid. Cyprinidae	Carp	Spotted Suckers	Unid. Crappie	Unid. Darters	Other	Total
2/05-2/12	0	0	0	0	0	0	0	0	0	5,370	5,370
2/12-2/19	0	0	0	0	0	0	0	0	0	5,701	5,701
2/19-2/26	0	0	0	0	0	0	0	0	0	0	0
2/26-3/05	0	0	0	0	0	0	0	0	0	0	0
3/05-3/12	0	0	0	0	0	0	0	0	0	0	0
3/12-3/19	0	0	0	0	0	0	0	5,796	20,194	5,796	31,786
3/19-3/26	0	0	0	0	0	0	0	6,756	23,538	6,756	37,050
3/26-4/02	0	76,359	0	0	0	0	87,748	0	19,320	0	183,526
4/02-4/09	0	64,833	0	0	0	0	221,067	0	16,404	0	302,304
4/09-4/16	0	0	0	0	0	0	230,483	0	21,566	0	252,049
4/16-4/23	0	0	0	0	0	0	213,365	0	35,919	0	219,284
4/23-4/30	0	0	6,330	24,791	13,001	0	222,682	0	7,250	0	274,054
4/30-5/07	0	0	11,693	39,189	12,648	0	252,478	0	5,535	5,535	327,078
5/07-5/14	0	0	6,265	23,143	18,256	6,085	157,763	0	6,265	10,722	228,499
5/14-5/21	25,577	0	10,004	68,445	24,995	40,588	123,981	0	0	4,302	297,892
5/21-5/28	112,239	0	11,403	180,314	8,404	150,269	165,740	0	8,404	8,404	645,177
5/28-6/04	145,187	27,458	0	169,115	9,317	127,243	93,314	0	8,359	25,826	595,819
6/04-6/11	59,804	26,526	0	58,042	16,373	16,378	55,783	0	0	16,703	249,339
6/11-6/18	0	0	0	0	7,317	0	20,694	0	0	9,398	37,409
6/18-6/25	0	0	0	0	0	0	0	0	0	6,546	6,546
6/25-7/02	16,881	0	0	0	0	0	0	0	0	4,888	21,769
7/02-7/09	19,431	0	0	0	5,887	0	0	0	0	5,634	30,952
7/09-7/16	0	0	0	0	5,680	0	0	0	11,247	0	16,927
7/16-7/23	0	0	0	0	0	0	0	0	9,227	0	9,227
7/23-7/30	0	0	0	0	0	0	0	0	9,424	4,312	13,736
Total	379,119	194,906	45,695	563,039	121,878	340,563	183,517	12,552	202,652	125,893	3,821,494

Source: Paller et al., 1986b

TABLE V-4.98

Estimated Entrainment of Fish Larvae at the 3G Pumphouse (February-July 1985)

Interval	Unid. Clupeidae	Blueback Herring	American Shad	Threadfin and/or Gizzard Shad	Unid. Cyprinidae	Carp	Spotted Suckers	Unid. Suckers	Unid. Crappie	Unid. Darters	Other	Total
								0				
2/05-2/12	0	0	0	0	0	0	0	0	0	0	0	0
2/12-2/19	0	0	0	0	0	0	0	0	0	0	0	0
2/19-2/26	0	0	0	0	0	0	0	0	0	0	0	0
2/26-3/05	0	0	0	0	0	0	0	0	0	0	8,694	8,694
3/05-3/12	0	0	0	0	0	0	0	0	7,829	0	8,184	16,013
3/12-3/19	0	0	0	0	0	0	0	0	7,708	9,100	0	16,808
3/19-3/26	0	0	0	0	0	0	0	0	0	10,709	0	10,709
3/26-4/02	0	0	0	0	0	0	215,350	0	0	0	0	215,350
4/02-4/09	0	0	0	0	9,729	0	443,375	0	0	0	9,729	462,833
4/09-4/16	0	0	0	14,769	6,443	0	170,560	0	0	0	6,443	198,215
4/16-4/23	0	0	0	37,468	10,080	0	180,878	0	0	0	0	228,426
4/23-4/30	0	8,477	0	64,676	12,200	0	388,028	0	0	0	0	473,381
4/30-5/07	24,811	20,613	0	86,533	0	10,333	344,157	0	0	11,827	0	486,447
5/07-5/14	38,231	0	0	72,297	10,282	64,980	271,924	0	0	11,188	0	469,541
5/14-5/21	84,430	0	0	118,640	47,476	104,559	139,374	0	12,501	0	0	518,168
5/21-5/28	179,532	0	0	315,443	49,098	256,810	133,339	0	13,337	0	0	947,559
5/28-6/04	243,939	66,674	0	563,544	33,051	213,803	175,341	0	0	0	44,320	1,340,672
6/04-6/11	176,022	84,991	0	364,319	34,729	19,112	98,868	12,797	0	0	32,983	823,821
6/11-6/18	46,265	17,021	0	22,724	11,491	17,045	20,551	11,413	0	0	0	146,510
6/18-6/25	3,516	0	3,638	0	0	0	3,516	0	0	0	0	10,670
6/25-7/02	0	0	5,028	0	0	0	0	0	0	0	0	5,028
7/02-7/09	0	0	0	0	0	0	0	0	0	0	0	0
7/09-7/16	0	0	0	0	0	0	0	0	0	0	0	0
7/16-7/23	0	0	0	0	0	0	0	0	0	0	0	0
7/23-7/30	0	0	0	0	0	0	0	0	0	0	0	0
Total	796,746	197,776	8,666	1,660,413	224,579	686,642	2,585,261	24,210	41,375	42,824	110,353	6,378,845

Source: Paller et al., 1986b

TABLE V-4.99

Estimated Entrainment of Fish Larvae at the 5G Pumphouse (February-July 1985)

Interval	Unid. Clupeidae	Blueback Herring	American Shad	Threadfin and/or Gizzard Shad	Unid. Cyprinidae	Carp	Spotted Suckers	Unid. Suckers	Unid. Crappie	Unid. Darters	Other	Total
2/05-2/12	0	0	0	0	0	0	0	0	0	0	0	0
2/12-2/19	0	0	0	0	0	0	0	0	0	0	0	0
2/19-2/26	0	0	0	0	0	0	0	0	0	0	0	0
2/26-3/05	0	0	0	0	0	0	0	0	0	0	0	0
3/05-3/12	0	0	0	0	0	0	0	0	0	0	0	0
3/12-3/19	0	0	0	0	0	0	0	0	0	0	1,360	1,360
3/19-3/26	0	0	0	0	0	0	886	0	0	0	1,360	2,246
3/26-4/02	0	0	0	0	0	0	15,958	0	0	1,135	0	17,093
4/02-4/09	0	0	0	0	0	0	44,118	0	0	1,135	0	45,253
4/09-4/16	0	1,374	0	0	5,453	0	31,721	0	0	2,472	0	41,020
4/16-4/23	0	4,856	0	1,989	9,260	0	11,862	0	0	4,097	0	32,064
4/23-4/30	0	3,482	0	9,397	5,657	0	19,263	1,987	0	1,624	1,151	42,561
4/30-5/07	1,293	1,020	0	17,181	3,847	0	16,112	1,987	977	0	1,151	43,568
5/07-5/14	3,512	2,276	1,094	21,246	15,459	10,890	18,331	0	977	0	2,664	76,449
5/14-5/21	15,487	1,257	2,403	32,619	14,878	23,406	25,586	0	0	0	5,188	120,824
5/21-5/28	24,956	0	1,309	46,904	1,416	29,567	20,271	1,034	0	870	5,281	131,608
5/28-6/04	16,690	1,042	0	32,807	1,088	17,951	12,175	1,034	0	870	0	83,657
6/04-6/11	6,087	2,036	0	8,134	2,296	3,220	6,042	0	0	0	1,097	28,912
6/11-6/18	1,086	994	0	1,086	1,208	2,320	999	0	0	0	2,710	10,403
6/18-6/25	0	0	0	0	0	0	0	0	0	0	1,613	1,613
6/25-7/02	0	1,249	0	0	0	0	0	0	0	0	0	1,249
7/02-7/09	0	1,249	0	0	0	0	0	0	0	0	0	1,249
7/09-7/16	0	0	0	0	0	1,040	0	0	0	0	0	1,040
7/16-7/23	0	0	0	0	0	1,040	0	0	0	0	0	1,040
7/23-7/30	0	0	0	0	0	0	0	0	0	0	989	989
Total	69,111	20,835	4,806	171,363	60,562	89,434	223,324	6,042	1,954	12,203	24,564	684,198

Source: Paller et al., 1986b

The total number of larval fish entrained by the SRP in 1985 was relatively low compared to estimates of entrainment for previous years (Paller et al., 1986b) and was attributed to fewer numbers of larvae in the intake canals. The low densities of larvae were probably related to low river levels in 1985 which reduced the spawning and nursery habitat for species that prefer to spawn in flooded or sheltered areas (Paller et al., 1986b).

The total fish egg entrainment from February through July 1985 was calculated to be 15.1 million, of which 7.8 million eggs (51.4% of total) were entrained at the 1G pumphouse, 6.2 million (41.4% of total) at the 3G pumphouse, and 1.1 million (7.3% of total) at the 5G pumphouse. American shad eggs were the most common taxa entrained at the 1G pumphouse and at the three pumphouses combined. The relative abundance of entrained eggs differed between pumphouses. Whereas, American shad eggs were the dominant species entrained at the 1G pumphouse, eggs of the striped bass were dominant at the 3G and 5G pumphouses. Tables V-4.100 through V-4.102 list the numbers of eggs entrained at each pumphouse by taxa.

The impact of entrainment on the Savannah River ichthyoplankton that passed by the SRP was estimated in the same way it was estimated in 1984, by calculating the total entrainment for all three pumphouses (25.9 million organisms) as a percent of the total ichthyoplankton upstream from all three intake structures (211.6 million organisms). In 1985, 12.1% of the total susceptible ichthyoplankton was entrained (Paller et al., 1986b).

V.4.3.5.6 Diel Study

Spawning for many species is temporally regulated. Some species, including American shad and striped bass, spawn near dusk or dawn (Breder and Rosen, 1966; Williams and Bruger, 1972), while other species, such as gizzard or threadfin shad, spawn primarily during daylight hours (Graser, 1979). These differences in spawning times can strongly influence the density of ichthyoplankton in the water column at any given time.

In order to evaluate diel fluctuations of ichthyoplankton density in the 1984 and 1985 Savannah River ichthyoplankton studies, collections were made during four 6 hr time intervals in a 24 hr period in the months of March, April, May, and June. Ichthyoplankton samples were collected by methods described in Section 4.4.2 of this report at four river transects (RMs 155.2, 155.4, 157.0, and 157.3) and in the 1G (RM 157.1) and 3G (RM 155.3) intake canals.

TABLE V-4.100

Estimated Entrainment of Fish Eggs at the 1G Pumphouse (February-July 1985)

Interval	Blueback Herring	American Shad	Threadfin and/or Gizzard Shad	Striped Bass	Other	Total
2/05-2/12	0	0	0	0	0	0
2/12-2/19	0	0	0	0	0	0
2/19-2/26	0	0	0	0	0	0
2/26-3/05	0	7,488	0	0	0	7,488
3/05-3/12	0	16,596	0	0	0	16,596
3/12-3/19	0	31,498	0	0	0	31,498
3/19-3/26	0	127,940	0	0	13,875	141,815
3/26-4/02	26,537	153,149	0	0	50,375	230,061
4/02-4/09	31,584	135,415	0	0	38,155	205,154
4/09-4/16	18,508	381,482	6,763	0	15,478	422,231
4/16-4/23	30,480	1,078,700	8,386	156,364	1,610,899	2,884,829
4/23-4/30	14,895	812,829	0	123,546	1,272,517	2,223,787
4/30-5/07	0	324,277	0	0	13,848	338,125
5/07-5/14	0	251,649	0	0	9,150	260,799
5/14-5/21	0	220,150	0	0	0	220,150
5/21-5/28	0	155,840	10,644	0	0	166,484
5/28-6/04	0	135,966	34,513	0	13,090	183,569
6/04-6/11	0	112,616	26,833	0	42,917	182,366
6/11-6/18	0	114,629	3,880	0	29,801	148,310
6/18-6/25	0	57,990	0	0	7,163	65,153
6/25-7/02	0	4,122	0	0	5,850	9,972
7/02-7/09	0	0	0	0	7,514	7,514
7/09-7/16	0	0	0	0	7,250	7,250
7/16-7/23	0	0	0	0	0	0
7/23-7/30	0	0	0	0	0	0
Total	122,004	4,122,336	91,019	279,910	3,137,882	7,753,151

Source: Paller et al., 1986b

TABLE V-4.101

Estimated Entrainment of Fish Eggs at the 3G Pumphouse (February-July 1985)

Interval	Blueback Herring	American Shad	Threadfin and/or Gizzard Shad	Striped Bass	Other	Total
2/05-2/12	0	0	0	0	0	0
2/12-2/19	0	0	0	0	0	0
2/19-2/26	0	0	0	0	0	0
2/26-3/05	0	0	0	0	0	0
3/05-3/12	0	0	0	0	0	0
3/12-3/19	0	0	0	0	0	0
3/19-3/26	0	0	0	0	0	0
3/26-4/02	0	20,251	0	0	0	20,251
4/02-4/09	0	85,365	0	0	0	85,365
4/09-4/16	0	170,789	8,511	0	17,031	196,331
4/16-4/23	0	248,844	9,672	25,044	44,284	327,844
4/23-4/30	0	330,664	0	30,320	30,176	391,160
4/30-5/07	5,378	384,873	0	0	0	390,251
5/07-5/14	6,018	463,832	0	818,556	21,717	1,310,113
5/14-5/21	0	329,634	0	774,297	20,542	1,124,473
5/21-5/28	0	135,015	8,447	772,095	27,137	892,688
5/28-6/04	0	131,874	26,595	775,143	84,493	1,018,105
6/04-6/11	0	132,037	31,971	0	146,944	310,952
6/11-6/18	0	39,252	13,059	0	82,244	134,555
6/18-6/25	0	6,791	0	0	0	6,791
6/25-7/02	0	5,861	0	0	6,613	12,474
7/02-7/09	0	0	0	0	8,570	8,570
7/09-7/16	0	0	0	0	4,633	4,633
7/16-7/23	0	0	0	0	8,892	8,892
7/23-7/30	0	0	0	0	4,278	4,278
Total	11,396	2,485,082	98,255	3,145,455	507,554	6,247,742

Source: Paller et al., 1986b

TABLE V-4.102

Estimated Entrainment of Fish Eggs at the 5G Pumphouse (February-July 1985)

Interval	Blueback Herring	American Shad	Threadfin and/or Gizzard Shad	Striped Bass	Other	Total
2/05-2/12	0	0	0	0	0	0
2/12-2/19	0	0	0	0	0	0
2/19-2/26	0	0	0	0	0	0
2/26-3/05	0	0	0	0	0	0
3/05-3/12	0	0	0	0	0	0
3/12-3/19	0	0	0	0	0	0
3/19-3/26	0	0	0	0	0	0
3/26-4/02	0	3,411	0	0	0	3,411
4/02-4/09	0	13,670	0	0	0	13,670
4/09-4/16	0	41,331	0	0	4,121	47,512
4/16-4/23	0	52,990	2,060	5,334	9,430	69,814
4/23-4/30	0	58,172	2,060	5,334	5,309	68,815
4/30-5/07	1,020	72,969	0	0	0	73,989
5/07-5/14	1,020	78,598	0	138,707	3,680	222,005
5/14-5/21	0	59,051	0	138,707	3,680	201,438
5/21-5/28	0	22,672	1,418	121,253	4,557	149,900
5/28-6/04	0	20,629	4,160	121,253	13,217	159,259
6/04-6/11	0	20,895	5,059	0	23,254	49,208
6/11-6/18	0	6,944	2,318	0	14,594	23,856
6/18-6/25	0	3,183	0	0	0	3,183
6/25-7/02	0	1,986	0	0	2,243	4,229
7/02-7/09	0	0	0	0	2,243	2,243
7/09-7/16	0	0	0	0	1,187	1,187
7/16-7/23	0	0	0	0	2,101	2,101
7/23-7/30	0	0	0	0	914	914
Total	2,040	456,501	17,075	530,588	90,530	1,096,734

Source: Paller et al., 1986b

Species composition of the ichthyoplankton community differed between months in the 1984 diel study. In March, the ichthyoplankton community was dominated by crappie larvae during all sampling hours periods. Results of statistical analysis indicated that there were no significant differences in day and night collections (Table V-4.103). Means for the four 6-hr collection periods (Figure V-4.77) indicate two periods of high egg and larval densities, morning (0600-1200 hr) and evening (1800-2400 hr), and two periods of low density, mid-day (1200-1800 hr) and the middle of the night (2400-0600).

In April, total ichthyoplankton density in day and night collections were not significantly different, although there was a difference between the 1200 to 1800 hr period and all other periods, indicating a mid-day low in spawning activity and larval abundance (Figure V-4.77). The period 0600 to 1200 hr was strongly influenced by high numbers of American shad eggs which represented about 40% of the total ichthyoplankton collections. During the periods 2400-0600 hr and 1200-2400 hr, shad eggs represented no more than 10% of the ichthyoplankton collection. These results indicate an early morning peak in spawning activity of this species (Paller et al., 1985). Crappie larvae were the dominant ichthyoplankton collected during the remainder of the diel collections in April.

In May 1984, ichthyoplankton densities were substantially higher than in April (Figure V-4.77). Crappie was the dominant larval taxon, although Cyprinidae and gizzard and threadfin shad larvae were also abundant. American shad and striped bass eggs were common in the ichthyoplankton during the 0600 to 1200 hr period, but were virtually absent during all other periods. The period 1200 to 1800 hr again had the lowest density of organisms, repeating the mid-day low in ichthyoplankton activity observed in April. Density was significantly higher during the night due to higher means during both the 1800-2400 hr and 2400-0600 hr periods.

In June, the ichthyoplankton densities were considerably lower than in May, indicating the end of the spawning season for most taxa (Figure V-4.77). Crappie, which had been so prevalent in the river during previous months, were completely absent from June collections. Instead, sunfish larvae and American shad eggs were abundant during periods 1800 to 2400 hr and 2400 to 0600 hr. Night collection densities were again significantly higher than densities in the day collections, due, as in May, to higher means during both the 1800-2400 hr and 2400-0600 hr periods. During both months, the mean for the period 2400-0600 hr was significantly higher than that for any other period.

TABLE V-4.103

Duncan's Multiple Range Tests for Average Density of Ichthyoplankton During Four Diel Time Periods*

Month	Sampling Hours 0600 - 1200	1200 - 1800	1800 - 2400	2400 - 0600	Time Periods Day	Night
March	26.8	58.3	25.3	60.2	33.2	42.8
April	40.7	27.2	53.1	35.9	38.0	44.5
May	137.6	96.5	186.8	264.3	130.7	225.6
June	28.6	9.0	29.6	42.5	24.6	36.1

* Tests were conducted using transformed data but mean densities are presented as arithmetic averages (no./1,000 m^3). Time periods underscored by the same line are not significantly different at the $p < 0.05$.

Source: Paller et al., 1985

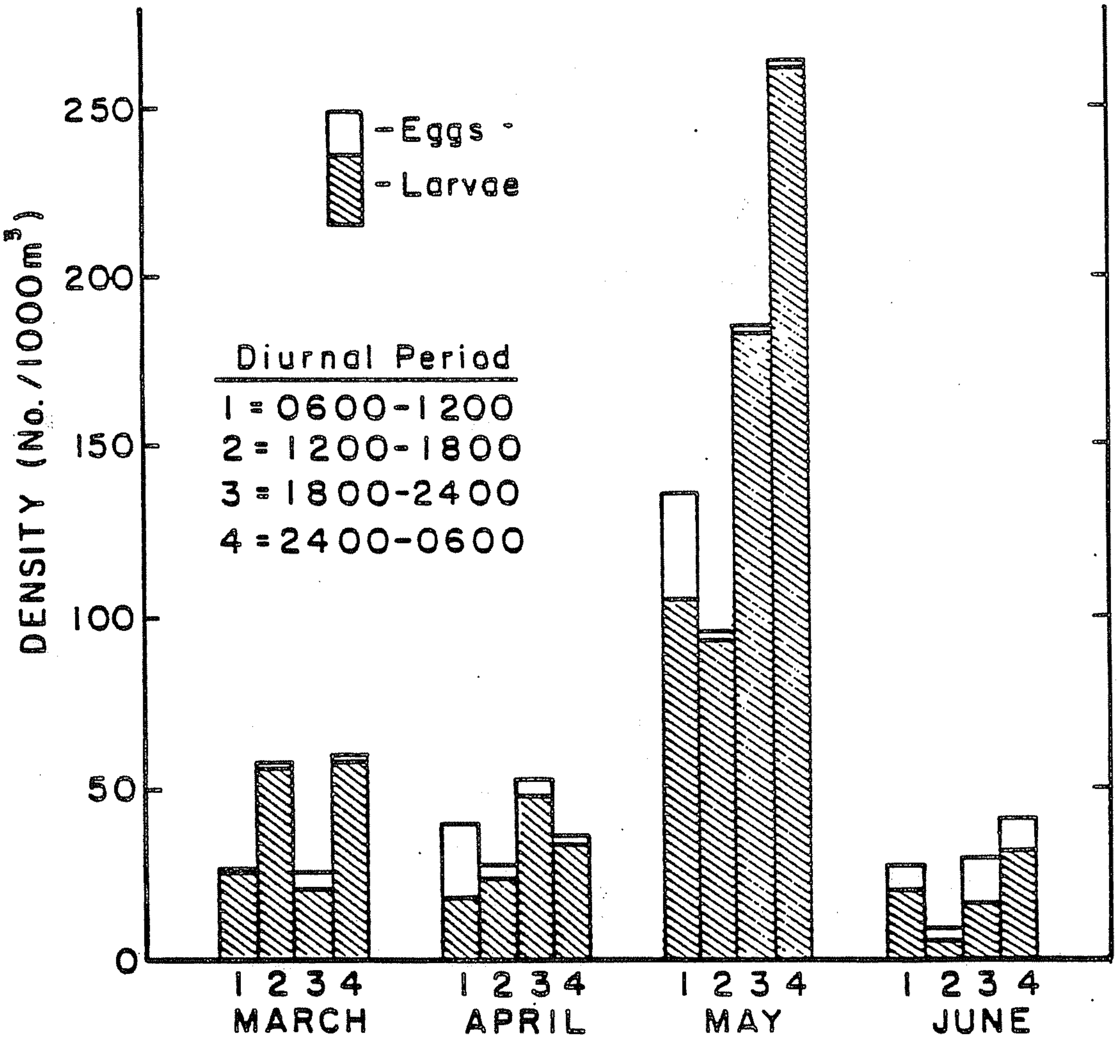


FIGURE V-4.77. Differences in Diel Ichthyoplankton Densities (March-July 1984)
Source: Paller et al., 1985

As in 1984, species composition of the ichthyoplankton community differed between months in the 1985 diel study. In March, the ichthyoplankton community was dominated by American shad eggs during the day and pirate perch and sunfish larvae during the night (Table V-4.104). Statistical analysis indicated that night densities of total ichthyoplankton were significantly higher than day densities.

In April, ichthyoplankton densities were significantly greater during the night than during the day; however, the species composition of ichthyoplankton was similar in daytime and nighttime samples. American shad comprised the majority of the eggs and spotted suckers comprised most of the larvae for all time periods (Table V-4.105). The April ichthyoplankton densities were more than 20 times higher than those in March, indicating much greater spawning activity.

In May, fish larvae constituted over 50% of the total ichthyoplankton density in each collection (Table V-4.106). Dominant larval species included spotted suckers, gizzard and threadfin shad, unidentified Clupeidae, and carp. As in the previous months, ichthyoplankton densities were significantly higher during the night than during the day. Figure V-4.78 shows the decline in eggs collected in May, which may have been attributed to a decline in American shad spawning because most of the eggs collected in March and April were those of American shad (Paller et al., 1986b).

In June, a relatively large number of American shad eggs were collected at night, making nighttime ichthyoplankton densities six times (and significantly) higher than daytime densities (Table V-4.107). The general reduction in total density during June (Figure V-4.78) indicated that the spawning season was nearly over for most species.

Overall, diel collections of ichthyoplankton from March to June 1985 resulted in significantly higher densities at night than during the day during every month. This pattern of temporal distribution is similar to results found by other investigators (Gald & Mohr, 1978; Hergenrader et al., 1982) and is consistent with the findings from comparable collections in this area of the Savannah River (Paller et al., 1984; 1985). During 1984, mean densities were consistently higher during the night, but were significantly higher only in May and June.

Ichthyoplankton densities in large turbulent rivers reflect both riverine spawning and the transport of eggs and larvae out of feeder streams, oxbows, and floodplain swamps along the length of the river. Difference in density of ichthyoplankton over 24 hr may be a result of behavioral characteristics of the fish species present in the ichthyoplankton (Gale & Mohr, 1978). Some species,

TABLE V-4.104

Relative Abundance of Ichthyoplankton Collected During the Diel Sampling Program in March (February-July 1985)

Taxa (common name)	March 0600-1200 hr Eggs Number	Percent	Larvae Number	Percent	1200-1800 hr Eggs Number	Percent	Larvae Number	Percent	1800-2400 hr Eggs Number	Percent	Larvae Number	Percent	2400-0600 hr Eggs Number	Percent	Larvae Number	Percent
Unid. Clupeidae											2	2.4			1	5.6
Unid. herring/shad			1	9.1												
American shad	37	100.0			16	100.0			8	100.0			14	77.8		
Gizzard and/or Threadfin shad																
Minnow (Cyprinidae)																
Carp																
Spotted sucker																
Unid. sucker																
Unid. catfish																
Swampfish																
Pirate perch											15	36.6			10	55.6
Brook silverside																
Striped bass																
Unid. sunfish											24	58.6			1	5.6
Unid. crappie			2	18.2												
Yellow perch																
Unid. darter			6	54.5			1	100.0			1	2.4			6	33.2
Sturgeon			1	9.1												
Unknown			1	9.1									4	22.2		
Total	37	100.0	11	100.0	16	100.0	1	100.0	8	100.0	41	100.0	18	100.0	18	100.0
Mean temperature (°C)		10.5				10.9				11.1				10.8		

Source: Paller et al., 1986b.

TABLE V-4.105

Relative Abundance of Ichthyoplankton Collected During the Diel Sampling Program in April (February-July 1985)

Taxa (common name)	April 0600-1200 hr Eggs Number	Eggs Percent	Larvae Number	Larvae Percent	1200-1800 hr Eggs Number	Eggs Percent	Larvae Number	Larvae Percent	1800-2400 hr Eggs Number	Eggs Percent	Larvae Number	Larvae Percent	2400-0600 hr Eggs Number	Eggs Percent	Larvae Number	Larvae Percent
Unid. Clupeidae			1	1.0							1	0.3			5	1.4
Unid. herring/shad	9	2.3	18	18.6	2	0.3	3	3.8	9	1.0	4	1.4	6	0.4	7	1.9
American shad	294	73.7	2	2.1	560	83.2	2	2.6	391	42.7	8	2.7	1133	79.8	2	0.6
Gizzard and/or Threadfin shad	1	0.2	4	4.1	2	0.3	8	10.3	1	0.1	5	1.7	6	0.4	12	3.3
Unid. minnow			6	6.2							2	0.7			10	2.8
Carp																
Spotted sucker			61	62.9			54	69.2			247	84.0			203	83.9
Unid. sucker			1	1.0			3	3.8			8	2.7			9	2.5
Unid. catfish																
Swampfish															1	0.3
Pirate perch											3	1.0				
Brook silverside																
Striped bass	60	15.0			46	6.8			76	8.3			107	7.5		
Unid. sunfish											2	0.7				
Unid. crappie											1	0.3				
Yellow perch							1	1.3			2	0.7			1	0.3
Unid. darter			3	3.1			5	6.4			2	0.7			7	1.9
Sturgeon																
Unknown	35	8.8	1	1.0	63	9.4	2	2.6	439	47.9	9	3.1	168	11.8	4	1.1
Total	399	100.0	97	100.0	673	100.0	78	100.0	916	100.0	294	100.0	1420	99.9	360	100.0
Mean temperature (°C)		18.5				18.5				18.2				18.0		

Source: Paller et al., 1986b.

TABLE V-4.106

Relative Abundance of Ichthyoplankton Collected During the Diel Sampling Program in May (February-July 1985)

Taxa (common name)	May 0600-1200 hr Eggs Number	Percent	Larvae Number	Percent	1200-1800 hr Eggs Number	Percent	Larvae Number	Percent	1800-2400 hr Eggs Number	Percent	Larvae Number	Percent	2400-0600 hr Eggs Number	Percent	Larvae Number	Percent
Unid. Clupeidae			20	8.7			13	7.3			135	18.9			72	8.3
Unid. herring/shad									1	2.4	5	0.7				
American shad	90	96.8	6	2.6	35	97.2	1	0.6	40	95.2	4	0.6	693	99.3	4	0.5
Gizzard and/or Threadfin shad			71	30.7	1	2.8	50	27.9	1	2.4	362	50.8	3	0.4	302	34.7
Unid. minnow			11	4.8			12	6.7			23	3.2			31	3.6
Carp			59	25.5			50	27.9			119	16.7			112	12.9
Spotted sucker			57	24.7			48	26.8			60	8.4			340	39.0
Unid. sucker			1	0.4			2	1.1			1	0.1			2	0.2
Unid. catfish																
Swampfish																
Pirate perch																
Brook silverside															1	0.1
Striped bass																
Unid. sunfish											1	0.1			1	0.1
Unid. crappie			2	0.9											3	0.4
Yellow perch																
Unid. darter							2	1.1			1	0.1				
Sturgeon																
Unknown	3	3.2	4	1.7			1	0.6			2	0.3	2	0.3	2	0.2
Total	93	100.0	231	100.0	36	100.0	179	100.0	42	100.0	713	99.9	698	100.0	870	100.0
Mean temperature (°C)		19.0				19.7				19.7				20.1		

Source: Paller et al., 1986b

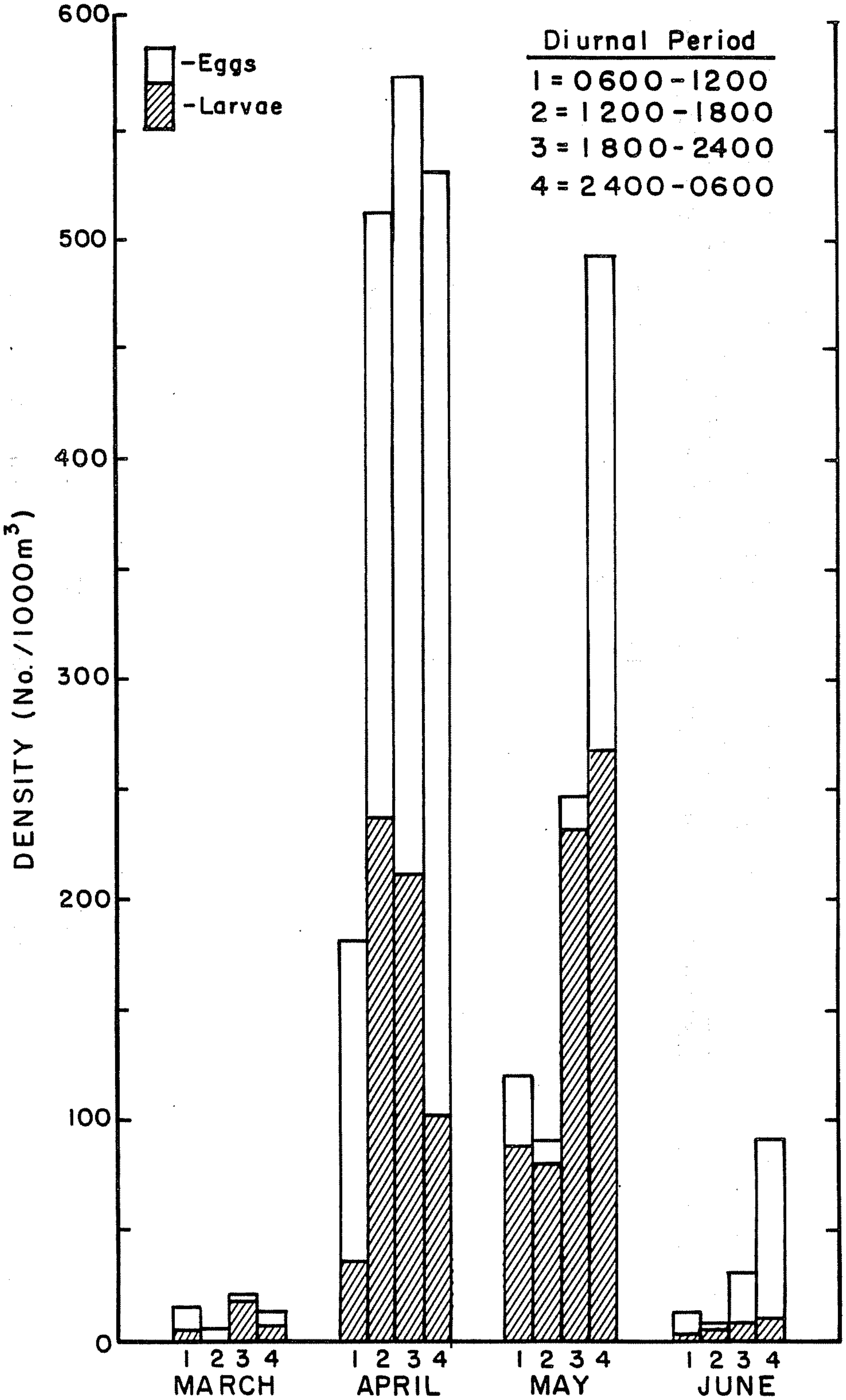


FIGURE V-4.78. Density of Larvae and Eggs Collected During the Diel Sampling Program in March, April, May, and June (February-July 1985)
Source: Paller et al., 1986b

TABLE V-4.107

Relative Abundance of Ichthyoplankton Collected During the Diel Sampling Program in June (February-July 1985)

Taxa (common name)	May 0600-1200 hr Eggs Number	Percent	Larvae Number	Percent	1200-1800 hr Eggs Number	Percent	Larvae Number	Percent	1800-2400 hr Eggs Number	Percent	Larvae Number	Percent	2400-0600 hr Eggs Number	Percent	Larvae Number	Percent
Unid. Clupeidae			1	16.7			2	18.2			4	17.4				
Unid. herring/shad									3	5.1	1	4.4				
American shad	25	96.2			8	80.0			31	52.5	4	17.4	266	100.0	3	8.1
Gizzard and/or Threadfin shad							1	9.1			6	26.0				
Unid. minnow							1	9.1			1	4.4			3	8.1
Carp			1	16.7			4	36.4			1	4.4			2	5.4
Spotted sucker							3	27.3			1	4.4				
Unid. sucker			1	16.7												
Unid. catfish											3	13.0			22	59.5
Swampfish																
Pirate perch																
Brook silverside																
Striped bass																
Unid. sunfish			3	50.0							2	8.7			7	18.9
Unid. crappie																
Yellow perch																
Unid. darter																
Sturgeon																
Unknown	1	3.8			2	20.0			25	42.4						
Total	26	100.0	6	100.0	10	100.0	11	100.1	59	100.0	23	100.1	266	100.0	37	100.0
Mean temperature (°C)	21.5				22.3				22.1				22.1			

Source: Paller et al., 1986b

including American shad and striped bass, spawn near dusk or dawn (Breder and Rosen, 1966; Williams and Bruger, 1972), while other species, such as gizzard shad, spawn primarily during daylight hours (Grasser, 1979). These differences in spawning times can strongly influence the density of ichthyoplankton, particularly eggs, in the water column at any given time. While most larvae have limited motility in rapidly flowing water, many can swim sufficiently well to leave protected areas and be caught in the current. The movement of larvae from protected areas generally occurs at night (Gale and Mohr, 1978; Hergenrader et al., 1982) and is reflected in higher nighttime densities in ichthyoplankton collections.

Because there is natural diurnal variation in the density of river ichthyoplankton, daily production and transport rates, as well as entrainment calculations (including those presented in this study) based on ichthyoplankton densities taken during daylight hours and extrapolated to a 24-hr period, are commonly underestimates. While it is recognized that the limited diurnal sampling conducted during this study is insufficient to justify recalculation of entrainment rates and total density of ichthyoplankton in the river, it does provide an indication of the magnitude of the bias of the estimates.

V.4.3.6 Summary: Savannah River and Associated Tributaries Studies

During the 1984 river ichthyoplankton sampling program, collections were made weekly at 26 river transects, two intake canals, six oxbows, and in 28 creek mouths. In 1985, the study area was reduced to weekly collections at 21 river transects, two intake canals, five oxbows, and in 14 creek mouths (in 1984 the study area extended from RM 187.1 to RM 29.6; whereas in 1985, it extended from 187.1 to RM 89.3). The primary objective of the 1984-1985 study was to assess spawning activity and ichthyoplankton distribution upstream and downstream from the SRP. The sampling program focused on evaluating the possible impacts of existing and proposed thermal discharges and the removal of river water for once-through cooling of the SRP nuclear reactors. The evaluation of ichthyoplankton production in Steel Creek was emphasized in this study because of the potential impacts following the restart of L Reactor.

A total of 24,298 fish larvae and 4,756 fish eggs were collected from February through July 1984. The dominant taxa collected were the Clupeidae (42% of all ichthyoplankton) which included the American shad, threadfin and gizzard shad, and blueback herring. Other abundant taxa were the sunfishes, crappie, and minnows (Cyprinidae).

In 1985, a total of 19,926 fish larvae and 15,749 fish eggs were collected from February through July. As in 1984, the dominant taxa collected were the Clupeidae (65% of all ichthyoplankton). The large number of American shad and blueback herring collected from Steel Creek during both years of study indicated that the lower reaches of Steel Creek were a spawning area for these anadromous species.

Steel Creek transported more fish larvae and fish eggs in 1984 than any other creek draining the SRP and more than any of the upper farfield creeks. Steel Creek had the fourth highest transport value for all creeks sampled, with Lake Parachuchia Outlet, Briar Creek, and Coleman Lake, all lower farfield creeks, exceeding transport values of Steel Creek. Total ichthyoplankton transport from Steel Creek over the entire 1984 sampling period increased river ichthyoplankton numbers an estimated 12.8%, a contribution comparable to the 1983 transport values from Steel Creek, indicating that Steel Creek is an important producer of ichthyoplankton for the Savannah River system.

In 1985, more ichthyoplankton was transported from Steel Creek than from any other creek sampled in the study area. Ichthyoplankton transport from all creeks was much lower during 1985 than during 1984, possibly due to decreased creek discharges (79% lower in 1985 than in 1984) or decreased spawning resulting from comparatively low water levels.

In 1984, temperatures in the mouth of Four Mile Creek were as much as 15°C higher than in the other creeks, due to thermal discharge from C Reactor. C Reactor was not operating during the first two months of the study (i.e., February and March), but operated continuously for the remainder of the study. Ichthyoplankton were absent from Four Mile Creek during June and July when temperatures reached 38 to 40°C. Due to flooding of the Savannah River and inundation of creek mouths with river water, ichthyoplankton samples were not collected during the periods of February through late March and mid-April through late May. The predominant ichthyoplankton in Four Mile Creek were sunfish larvae (60.0%) and brook silverside (8.0%).

In 1985, temperatures in the mouth of Four Mile Creek were as much as 20°C higher than in the other creeks, due to the thermal discharge from C Reactor. During the period February through mid-June, C Reactor operated most of the time, with brief (less than a week) interruptions in early February, March, and May. C Reactor was not operating from the third week of June through July. Ichthyoplankton were collected from Four Mile Creek during periods when the reactor was not operating and occasionally when the reactor was operating. However, ichthyoplankton were largely absent from the mouth of Four Mile Creek when the reactor was operating and water temperatures were high. Fish rapidly moved into Four Mile Creek and began spawning when the reactor shut down. This general pattern of low or zero densities punctuated by a few brief peaks was also observed in Four Mile Creek during 1984 (Paller et al., 1985).

Most (93.3%) of the ichthyoplankton collected from the mouth of Four Mile Creek were unidentified eggs, the majority of which were collected in the density peak of May 7. Other taxa found in Four Mile Creek were blueback herring, brook silverside, unidentified sunfish, and crappie.

Beaver Dam Creek, the other thermally influenced SRP creek sampled during the 1984-1984 study, was approximately 3 to 8°C warmer than most of the creeks in the study area in 1984. There were few indications of thermal impacts on spawning activity, except possibly in June and July when temperatures were as high as 30 to 32°C.

In 1985, Beaver Dam Creek was warmer than the average of the other creeks studied by approximately 7°C. During much of the study period, trends in Beaver Dam Creek were different from those in other Savannah River tributaries sampled. Ichthyoplankton densities in Beaver Dam Creek were lower during March, early April, and mid-May, and higher in mid-April and late May. In June and July, when temperatures often exceeded 30°C, ichthyoplankton densities in Beaver Dam Creek were usually low compared to the overall average for other creek mouths studied.

Ichthyoplankton densities in the river exhibited pronounced temporal changes during 1984 and 1985. In 1984, mean ichthyoplankton densities for the entire section of river under study (RM 187.1 to RM 29.6) were 2 organisms/1,000 m^3 in February, 26/1,000 m^3 in March, 39/1,000 m^3 in April, 118/1,000 m^3 in May, 19/1,000 m^3 in June, and 3/1,000 m^3 in July. In February and March, abundant spawning was occurring in the warmer lower farfield and little or no spawning was occurring in the cooler nearfield and upper farfield. By April, spawning was occurring throughout the study area, while in May and June, spawning appeared to be subsiding in the lower farfield and increasing at the cooler transects in the upper farfield. In July, most spawning had ceased throughout the river. Similar results were observed in 1983.

In 1985, mean ichthyoplankton densities for the entire section of river under study (RM 187.1 to RM 89.3) were 0.3 organisms/1,000 m^3 in February, 18.2/1,000 m^3 in March, 156.6/1,000 m^3 in April, 139.4/1,000 m^3 in May, 42.9/1,000 m^3 in June, and 3.5/1,000 m^3 in July. Ichthyoplankton were collected in small numbers at all of the lower farfield transects and some of the nearfield and upper farfield transects in February. Spatial trends in ichthyoplankton density in March were similar to those in February, with lowest densities in the upper farfield and highest densities in the lower farfield. As in 1984, these trends were consistently and positively related to temperature gradients in the river. In April, similar spatial trends were apparent, but the differences were not as great as those in March, indicating that spawning was occurring throughout the river section under study. A major contributor to the relatively low densities at the upper farfield transects during March and April was the low numbers of American shad eggs. In May, the spatial trends were reversed, with highest densities in the upper farfield and lowest densities in the lower farfield. In June, the trend for decreasing ichthyoplankton densities downriver was even stronger than in May, indicating that spawning in the lower farfield region was subsiding. Similar spatial trends were evident in July, although spawning was low in all river segments. These spatial trends for 1985 were remarkably consistent with those found in 1984 and in previous years of sampling in the Savannah River.

There are three important anadromous species that spawn in the Savannah River: American shad, blueback herring, and striped bass. American shad were collected in large numbers throughout the river and were far more abundant in 1985 than in 1984. Blueback herring abundances were greater in the upper farfield area of the study in 1985, while they were found in greater abundances in the lower farfield in 1984. Striped bass were nearly as abundant in 1985 as in 1984. Striped bass ichthyoplankton densities showed different spatial trends over the two years of the study. In 1984, densities peaked at RM 141.7, while in 1985, densities showed three peaks (RM 166.6, RM 155.4, and RM 129.0), suggesting localized aggregations of spawning fish (Paller et al., 1986b). In 1983, sampling in the Savannah River indicated peak striped bass densities at RM 120.0 and RM 152.2. The collection of striped bass ichthyoplankton at and above RM 141.7 contrasts with the finding of earlier researchers (Dudley et al., 1977; McFarlane et al., 1978). Very few striped bass larvae or eggs were collected from tributary creeks during 1985, indicating the relative unimportance of the lower reaches of these creeks as striped bass spawning areas. Seasonally, striped bass ichthyoplankton were first observed in low numbers in March. Densities peaked in April and May, declined in June and were zero in July. The greatest striped bass ichthyoplankton densities were associated with river temperatures of 17-25°C.

The chemical and physical parameters in the oxbows were similar to those in the river. Ichthyoplankton densities varied between oxbows and were particularly high at RM 100.2. Species composition of the oxbows was dominated by gizzard and threadfin shad and, to a lesser extent, sunfishes, unidentified Clupeidae, and blueback herring.

On the basis of ichthyoplankton samples taken during daylight hours at the three intake structures for the SRP, an estimated 23.4 million ichthyoplankters were entrained during 1984. Of these, 17.6 million were larvae and 5.8 million were eggs.

In 1985, an estimated 25.9 million ichthyoplankters were entrained at the three intake structures for the SRP. Of these, 10.8 million were larvae and 15.1 million were eggs. This represented approximately 12.1% of the total number of ichthyoplankters that drifted past the SRP pumphouses.

Diel collections from the Savannah River and intake canals during May and June 1984 indicated significantly higher ichthyoplankton densities during the night than during the day. Based on these results, the entrainment calculations conducted for this study (based on densities in samples collected during daylight hours and extrapolated to a 24 hr period) underestimate entrainment. The limited diel sampling provides an indication of the magnitude of the bias of these estimates of entrainment.

SRP operations can impact ichthyoplankton assemblages in SRP creek mouths and the adjacent Savannah River by plume entrainment, intake entrainment and impacts to the Steel Creek ecosystem. Investigations of ichthyoplankton distribution and abundance in the CCWS and during previous years provide no evidence of plume entrainment impacts on Savannah River ichthyoplankton assemblages. During years (such as 1984) when springtime flooding of the Savannah River coincides with major spawning periods, potential impacts in the creek mouths are minimized since water temperatures in thermal creek mouths are reduced. During 1985, when the Savannah River did not flood, there were apparent impacts to spotted suckers from plume entrainment, but the impacts were localized (in the mouth of Four Mile Creek).

Steel Creek consistently transported high numbers of ichthyoplankton to the Savannah River compared to the other tributaries sampled during the study. This was attributable primarily to its large size, high discharge volume and extensive areas of aquatic macrophyte growth. From 1983-1985, Steel Creek increased the ichthyoplankton densities of the Savannah River just below Steel Creek by 2 to 13% (depending on volume discharge). These results indicate that Steel Creek is an important spawning area for both anadromous and nonanadromous species. However, none of the ichthyoplankton taxa collected from Steel Creek were rare or endangered and all were found in large numbers at many locations in the river and other tributaries.

In 1983 and 1985, intake entrainment was calculated to be 8.3 and 12.3%, respectively, of the total ichthyoplankton that drifted past the intake canals in the Savannah River. While those numbers may be large, impact may be mitigated by the fact that all of the species entrained have numerous spawning sites in the Savannah River (including areas downstream of the SRP) and the fact that most ichthyoplankton have high natural mortalities. There has been no evidence to indicate decreasing numbers of ichthyoplankton in the Savannah River during the CCWS or during previous years studied.

V.4.4 Cold Shock Studies

V.4.4.1 Introduction

The nuclear reactors at the SRP operate intermittently. This results in substantial fluctuations of water temperatures in associated receiving waters. Secondary cooling water is discharged from the heat exchangers of these reactors at temperatures ranging from 75°C to ambient (which can be <10°C in winter). Within the confines of the SRP site, the discharged cooling waters combine with ambient temperature waters from man-made ponds and/or natural streams and a large swamp to the extent that water temperatures in the Savannah River adjacent to the SRP are not significantly effected by reactor operations. However, mitigation plans are presently being developed to reduce the thermal impact on receiving waters on the plantsite. Studies on the acute mortality of fish subjected to sudden, major reductions in water temperature ("cold shock") were conducted as part of this mitigation effort.

It is generally accepted that thermal requirements for survival, growth, and reproduction differ between life stages and among species of fishes (National Academy of Sciences, 1973; Brungs and Jones, 1977; McCormick, 1978). However, only a few previous studies (Hart, 1952; Brett, 1952; Carlander, 1969; Ash et al., 1974; Coutant, 1977; have compared cold shock effects, on more than one species, and/or a life stage other than adults.

Juvenile specimens of largemouth bass, bluegill sunfish, and channel catfish were selected for testing in the present study because juveniles may be more sensitive to cold shock effects than adults and because these three species are: (1) indigenous to SRP streams, (2) popular game species, (3) representative of three different ecological niches, and (4) readily available in large numbers.

The overall objective of the study was to document acute mortality percentages for the three species resulting from exposure to various cold shock temperature regimes. These regimes bracketed expected average and worst case temperature exposures with the thermal mitigation options (cooling towers) being considered for some of the SRP reactor cooling water systems. Abrupt (2 hr) and gradual (24 hr) temperature drops were compared to simulate and evaluate the protective value and possible need for a holding pond between the cooling tower discharge point (i.e., cooling tower outfall) and the receiving stream. The validity and margin of error for protecting the three species using the temperature criteria for cold shock proposed by the US EPA (Brungs & Jones, 1977) was also investigated.

V.4.4.2 Methods and Materials

V.4.4.2.1 Test System

All experiments were conducted at the Par Pond Laboratory at the SRP. Water was supplied to the test system on a once-through basis and was filtered by an in-line sand filter. A portion of the incoming water was chilled to about 8°C by two 5 hp Filtrine water chillers. Hours of light and darkness were maintained at 12 hr each by a timer.

The test system (Figure V-4.79) consisted of six trough and headbox combinations (Figure V-4.80). A combination of chilled and unchilled Par Pond water was pumped to the six stainless steel headboxes. The headboxes were supported by unistrut frames near ceiling level and contained immersion heaters and a float valve. Water drained from each headbox into a series of nine 20-l aquaria immersed in 2.4 m x 0.6 m x 0.3 m fiberglass troughs that contained 0.2 m standpipes and served as water baths. Coarse temperature control was achieved by adjusting valves controlling the relative amounts of chilled and unchilled (ambient temperature) Par Pond water routed to the headboxes. Precise automatic temperature control was achieved by the use of electronic relay boxes connected to mercury thermoregulators and immersion heaters in each headbox.

Water temperatures were measured by thermocouples immersed in one aquarium of each trough. Thermocouples were linked to a microcomputer system which monitored temperatures every few seconds and recorded hourly temperature means and ranges for each trough. To assure precision of the data acquisition system, the temperature in each aquarium was manually measured daily with a mercury thermometer.

Self starting siphons in each aquarium (Figure V-4.80), above the water level of the trough, provided a once-through flow and slowly fluctuating water levels within the aquariums. An electric air pump attached to tubing and airstones delivered air to each aquarium to help maintain adequate levels of dissolved oxygen.

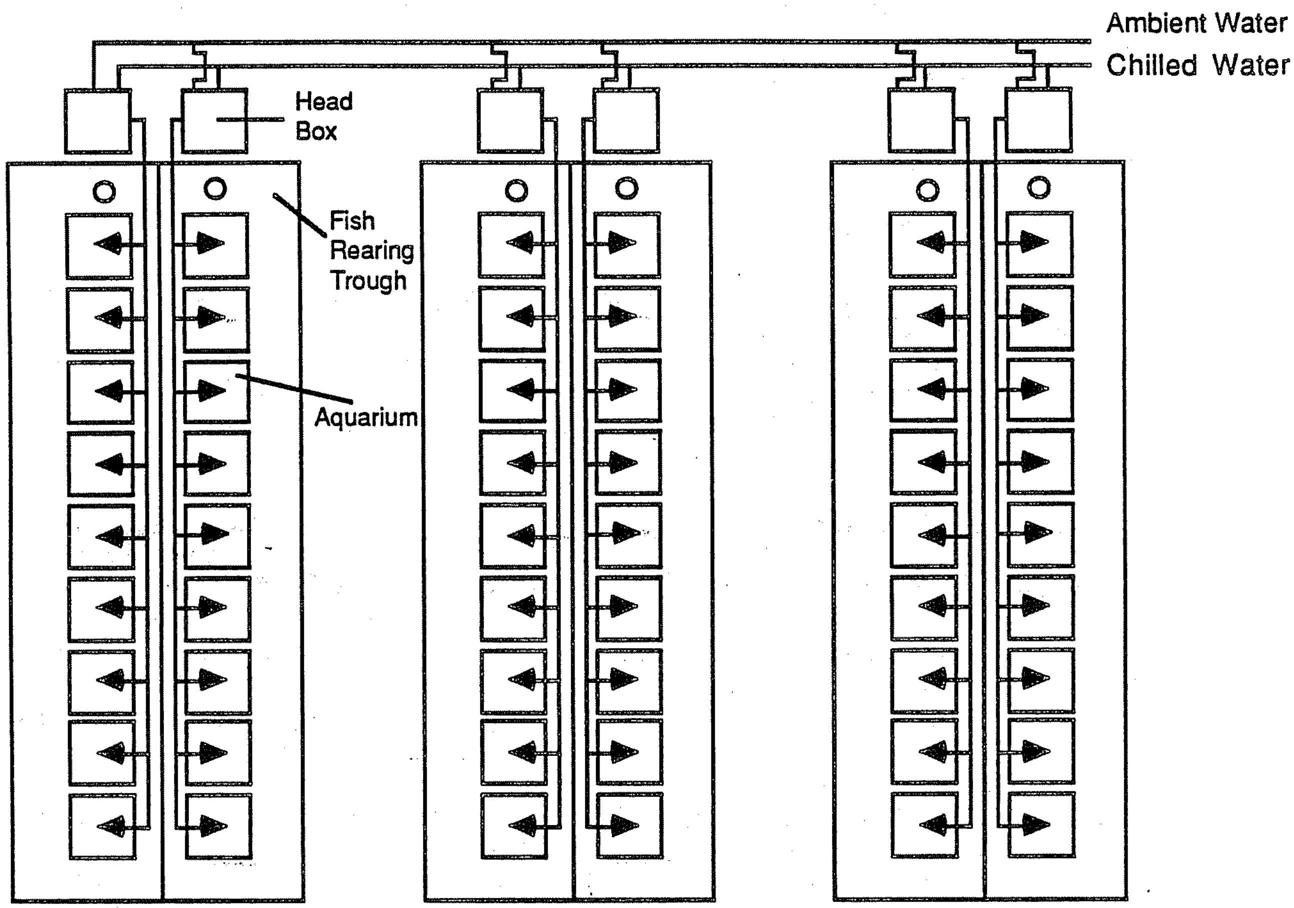


FIGURE V-4.79. Laboratory Floor Plan for Cold Shock Study

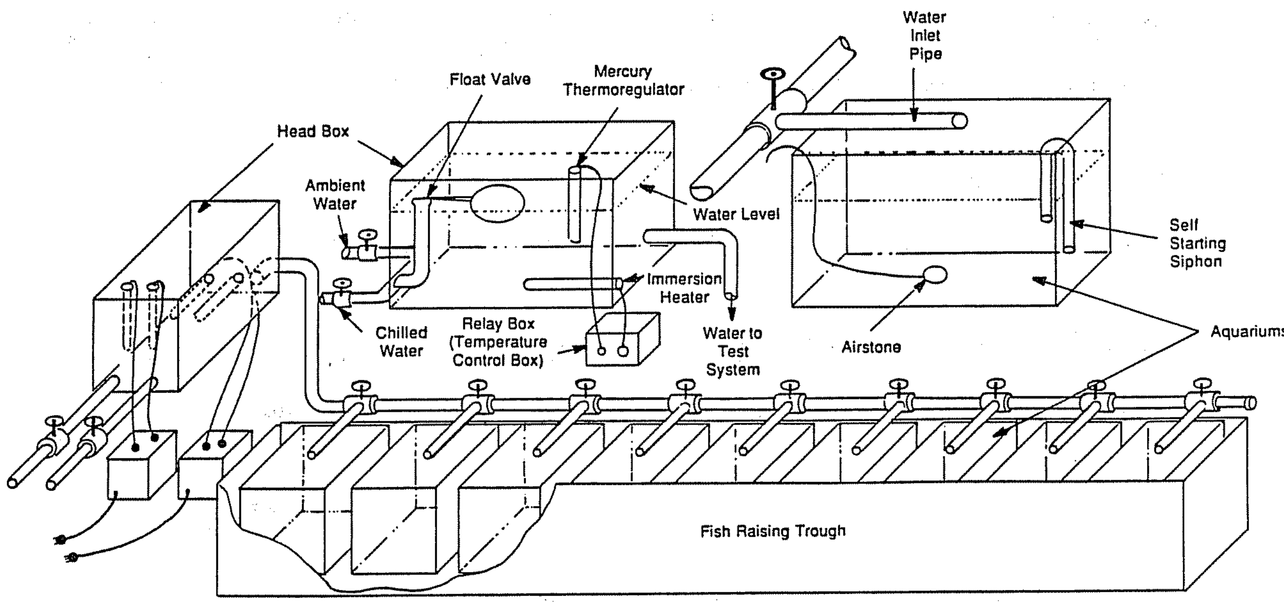


FIGURE V-4.80. Test System Schematic for Cold Shock Study

V.4.4.2.2 Test Organisms

Fingerling (5.1-7.6 cm long) specimens of largemouth bass (Micropterus salmoides), bluegill sunfish (Lepomis macrochirus), and channel catfish (Ictalurus punctatus) were simultaneously tested in August and October, 1985. In December, 1985, channel catfish and bluegill from two different sources (a Virginia hatchery and Par Pond SC) were comparatively tested, Sources of the test specimens for all experiments are shown in Table V-4.108.

TABLE V-4.108

Sources of Juvenile Fishes for Cold Shock Experiments

Experiment Date	Largemouth Bass	Bluegill	Channel Catfish
August 1985	Hatchery Inwood, WV	Par Pond SRP, SC	Hatchery Orangeburg, SC
October 1985	Hatchery Inwood, WV	Hatchery Inwood, WV	Hatchery Inwood, WV
December 1985	Not tested	Par Pond SRP, SC & Hatchery Inwood, WV	Hatchery Inwood, WV

V.4.4.2.3 Experimental Procedures

The three types of fish, separated by species and source were tested simultaneouly, but in separate aquaria. Generally, each of the six troughs contained nine aquaria (triplicate aquaria for each species with about 20 specimens per aquarium).

During each of the three experimental periods (August, October, and December, 1985), fish were gradually acclimated (by elevating temperature at a rate of 1°C/hr or less) to and held for a week at a near-constant predetermined temperature representing a maximum weekly average temperature (MWAT). To determine the impact of cold shock, temperatures in the aquaria were then abruptly (in a 2-hr period) or gradually (in a 24-hr period) lowered to a predetermined exposure temperature and held at the exposure temperature for 24 hr to assess the amount of mortality. Temperature drops were primarily accomplished by changing the relative amounts of chilled and ambient temperature water flowing to the headboxes of the troughs. Fine tuning of the temperature decreases were accomplished by the use of the thermoregulator system described earlier. MWAT and exposure temperatures are shown in Table V-4.109.

TABLE V-4.109

Temperature Conditions for Cold Shock Experiments

Date of Experiment	MWAT Temp. (°C)	Exposure Temp. (°C)	Time of Temp. Drop (hr)
August 1985	23.3	9.1	2
October 1985	32.0	9.0	2
October 1985	32.0	9.0	24
October 1985	27.0	9.0	2
October 1985	27.0	9.0	24
October 1985	23.0	9.0	2
December 1985	30.9	11.4	2
December 1985	31.8	11.6	24
December 1985	31.1	8.8	2
December 1985	32.3	8.9	24

The fish were fed brine shrimp or a commercial fish food daily during acclimation, but were not fed during the 2- or 24-hr period of temperature decrease or the subsequent 24-hr exposure period.

Throughout the period of temperature reduction and subsequent exposure periods, each aquarium was inspected hourly and all dead fish were removed and noted. The two principal criteria for determining death were (1) a lack of visible opercular movement and (2) no reaction after gentle prodding (Peltier and Weber, 1985).

V.4.4.2.4 Statistical Procedures

Statistical comparisons of mortality between species and test conditions were performed using the SAS PROC GLM procedure (SAS Institute Inc., 1982).

V.4.4.3 Results

The percentages of fish killed with each cold shock treatment during each experiment date are listed in Table V-4.110. Figure V.4-81 shows the amount of mortality in relation to species and the time (2 hr or 24 hr) for the temperature to drop from the MWAT temperature to the exposure temperature. The amount of mortality resulting from a given temperature drop spread over a 24-hr period was significantly ($P = <0.05$) lower for each species and for all test specimens combined than the amount of mortality resulting from a 2-hr temperature drop of the same magnitude.

Figure V-4.82 shows the percentage of mortality resulting from a sudden (within 2 hr) drop to a temperature of 9°C from MWAT temperatures of 23, 27, 31, and 32°C. The data indicate that largemouth bass were the most vulnerable to cold shock mortality and that channel catfish were the least vulnerable. However, the differences were not statistically significant ($P = >0.05$).

Figure V-4.83 shows the amounts of mortality for each test condition in the present study in relation to a nomograph developed by the EPA (Brungs & Jones, 1977) for ensuring "no more than negligible mortality for any fish species."

V.4.4.4 Discussion

The significant decrease in mortality resulting from a 24 hr period for a temperature reduction compared to a reduction of the same quantity over a 2-hr period suggests that a holding pond between the discharge and the receiving stream would enhance mitigation. However, the need for such a pond in the present situation at SRP seems unwarranted since adherence to the EPA guidance nomograph (Brungs & Jones, 1977) should provide adequate protection. The three species of fish tested in the present experiments were protected by the EPA guidelines with a considerable "cushion". For example, a 31-11°C temperature drop caused no significant mortality with any of the three species while being 2°C more severe than the safe acceptable limits proposed by the nomograph (Figure V-4.83).

Table V-4.111 shows predicted discharge temperatures from proposed cooling towers for the C and K Reactors at the SRP along with the associated cold shock temperature limits recommended by the U.S. EPA (Brungs & Jones, 1977) and historical Savannah River water temperatures. It appears that operation within the EPA guidelines should be readily achievable. Furthermore, the experimental results described herein suggest that an accidental slight variance (i.e., 1-2°C) from the temperature drop limits defined by the EPA nomograph is unlikely to kill any fish in the receiving streams.

TABLE V-4.110

Results of Cold Shock Exposures

Temp. Decrease	Time For Decrease	Exposure Date	Percent Mortality Largemouth Bass	Virginia Bluegill	Par Pond Bluegill	Channel Catfish
23-9	2	8/85	12.2(57)*	-**	0(61)	0(28)
23-9	2	10/85	1.7(60)	0(56)	-	0(59)
27-9	2	10/85	56.4(55)	55.2(58)	-	0(60)
27-9	24	10/85	10.2(59)	9.4(64)	0	0(60)
31-9	2	12/85		100(62)	91.4(58)	20(25)
31-11	2	12/85		0(69)	2.3(43)	0(22)
32-9	2	10/85	100(55)	100(58)		100(60)
32-9	24	10/85	73.4(64)	13.6(59)		0(57)
32-9	24	12/85		49.2(61)	16.7(54)	0(10)
32-12	24	12/85		2.9(34)	0.0(89)	0(32)

* Number in parenthesis is the total tested.
** - indicates none tested.

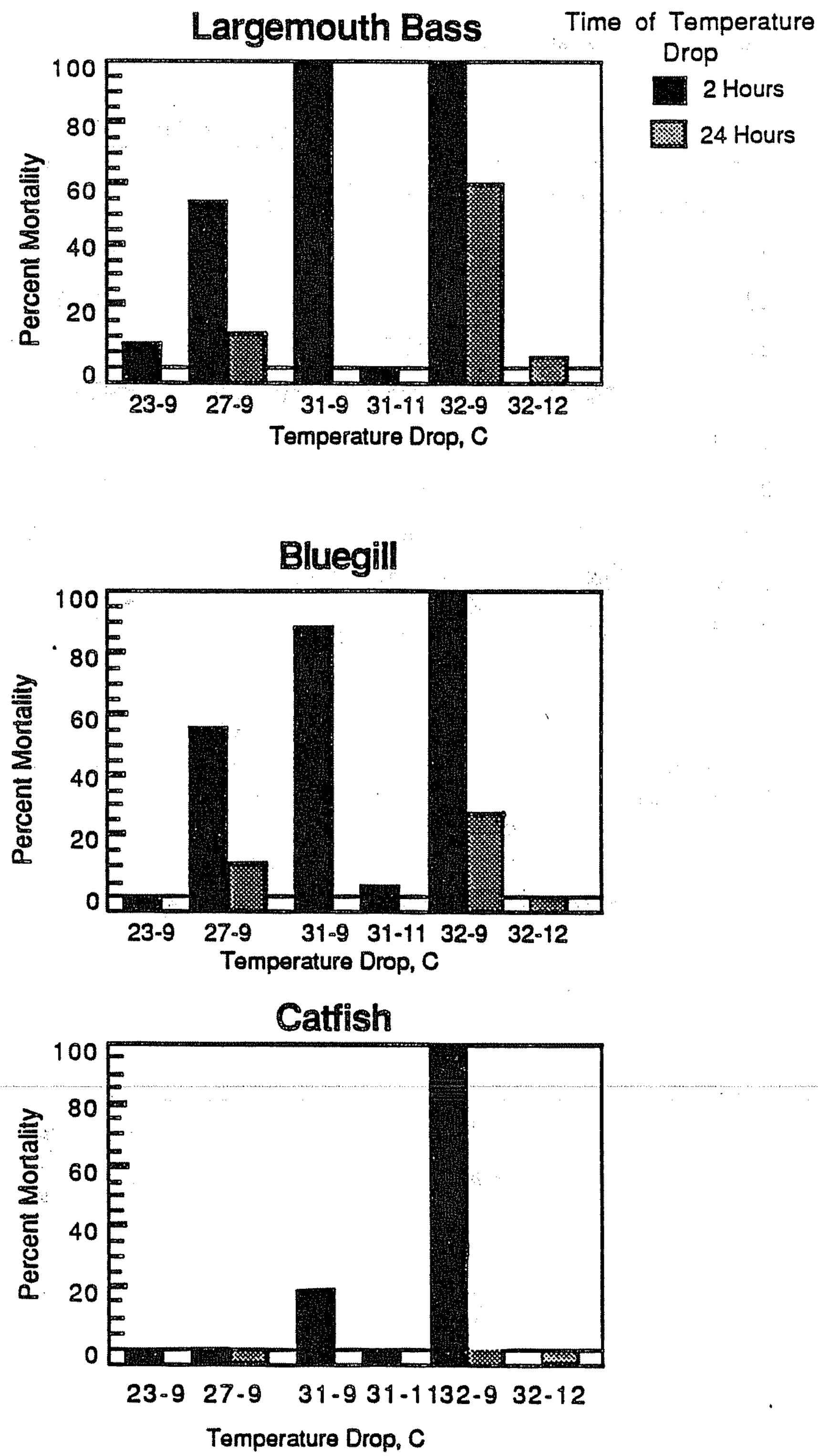


FIGURE V-4.81. **Percent Mortality for Three Species of Fish Following 24 Hours of Exposure to 9-12°C Water After a Sudden Drop From an Acclimation Temperature of 23-32°C**

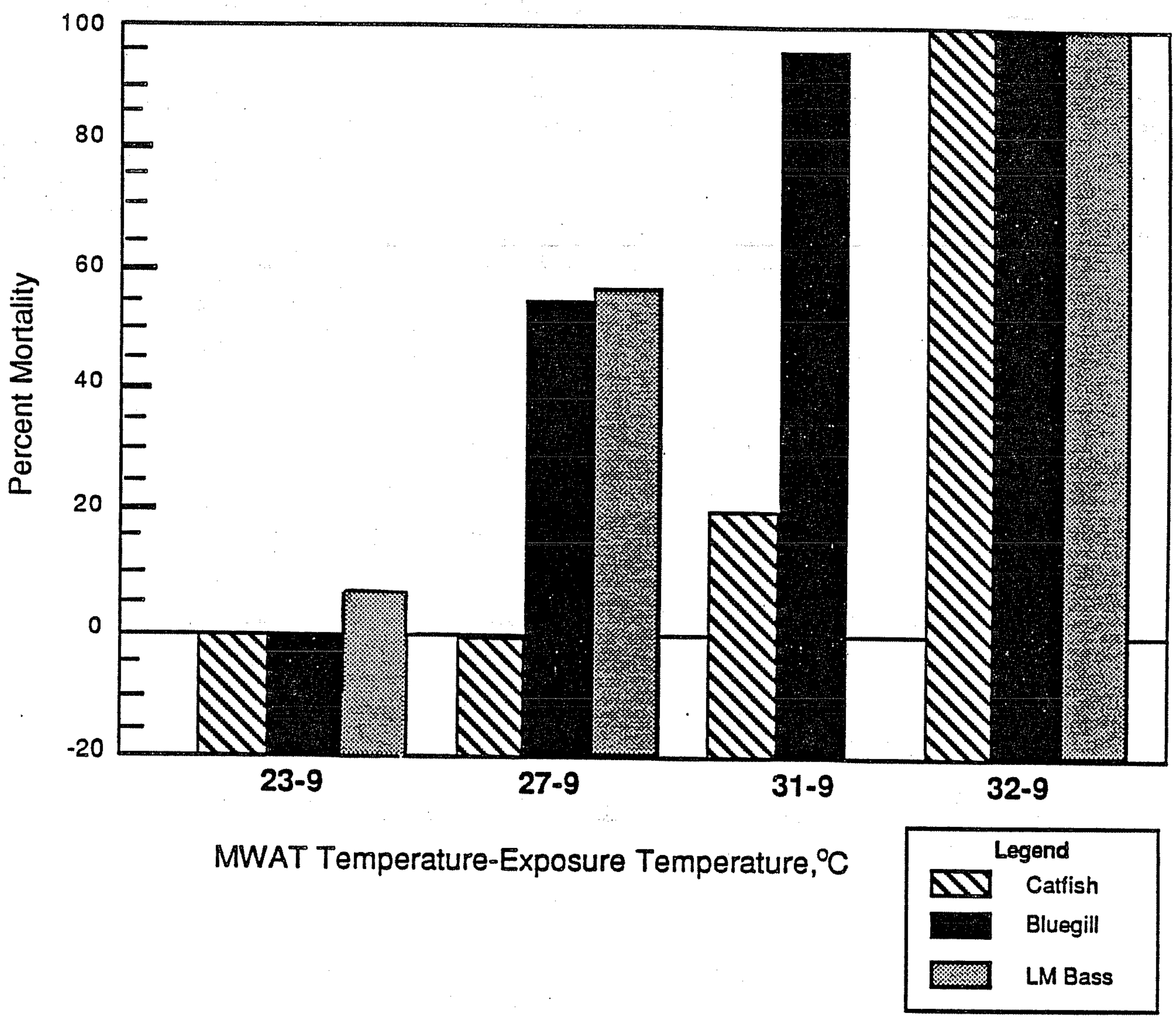


FIGURE V-4.82. Cold Shock Mortality With Four Cold Shock Regimes

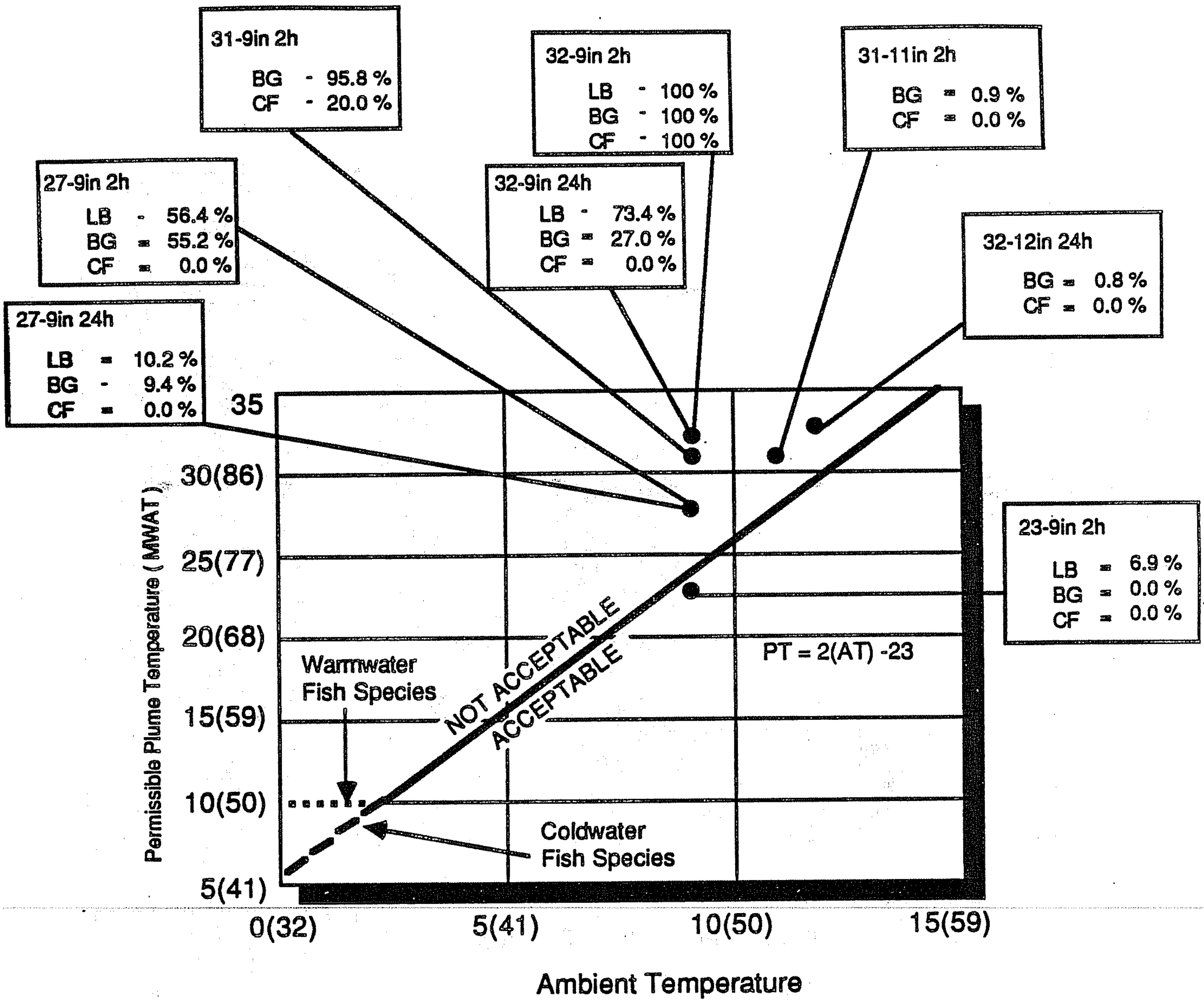


FIGURE V-4.83. **Cold Shock Mortality Percentages Observed in Relation to a Nomograph to Determine the Maximum Weekly Average Temperature of Plumes for Various Ambient Temperatures, °C (°F).**
(Taken from Brungs and Jones, 1977).

TABLE V-4.111

Predicted Monthly Mean Discharge Temperatures (°C) for SRP C- and K-Reactor Cooling Towers Compared to Associated Cold Shock Temperature Limits Recommended by the U.S. EPA and Mean Ambient Savannah River Temperatures

	Once-Through System			Recirculating System		
Month	RX C.T.* Disch.	EPA** Limit	S.R.† Amb.	RX C.T.* Disch.	EPA** Limit	S.R.† Amb.
Jan	19.2	7.1	8.9	14.4	4.7	8.9
Feb	19.7	7.4	9.1	15.0	5.0	9.1
Mar	22.8	8.9	11.8	18.6	6.5	11.8
Apr	24.2	9.6	15.2	20.0	7.5	15.2
May	26.1	10.6	18.4	23.0	9.0	18.4
Jun	28.3	11.7	20.9	25.6	10.3	20.9
Jul	29.2	12.2	23.0	26.9	11.0	23.0
Aug	28.9	11.9	23.5	26.4	10.7	23.5
Sep	28.1	11.5	22.9	25.0	10.0	22.9
Oct	24.4	9.7	20.1	20.0	7.5	20.1
Nov	22.5	8.8	16.3	17.8	6.4	16.3
Dec	20.6	7.8	11.8	15.3	5.2	11.8

* Based on calculations by Du Pont Engineering Dept. using average air temperature and humidity recorded at SRP from 1972 through 1983. Normal production rates are assumed. Once-through systems designed for cool tower performance of 27.8°C (82°F) wet bulb temperature with a 4.4°C (8°F) approach temperature. Recirculating system is designed for a 26°C (80°F) wet bulb temperature with a 2.8°C (5°F) approach temperature.

** Based on the nomograph described in Brungs and Jones, 1977.

† Based on USGS continuous monitoring of water temperature in the Savannah River near Jackson, SC (adjacent to the SRP) for the period through 1985.

Additional factors facilitating the conclusion that the proposed cooling tower scenarios for the SRP will not result in cold shock mortality include the following:

1. Cooling occurs rapidly in the vicinity of the discharge where temperatures differ the most when the reactor goes down.

2. Fish are prevented from migrating into the discharge canals below the outfalls by physical barriers such as rubble dams. Thus, fish are not expected to inhabit the areas experiencing the greatest amount of temperature change.

3. Temperatures in the reactor discharge areas average about 2°C higher than ambient river temperatures when the reactors are not operating due to heat from other sources within the system.

V.4.4.5 Summary: Cold Shock Studies

Juvenile specimens of largemouth bass, bluegill sunfish (from two sources), and channel catfish were tested to determine their ability to withstand abrupt temperature decreases (cold shock) simulating the environmental impact from a sudden shutdown of a nuclear reactor at the Savannah River Plant (SRP) near Aiken, SC during the winter. Temperature reductions were administered over 2 hr and 24 hr periods to assess the mitigative value of having a holding pond between a proposed cooling tower discharge point and the receiving stream. Results were compared to temperature criteria guidelines published by the U.S. EPA (Brungs & Jones, 1977) and proposed for usage at SRP following mitigation with cooling towers. Temperature decreases administered over a 2 hr period resulted in significantly more mortality than decreases of the same magnitude administered over a 24 hr period. Thus, the value of a pond for mitigation from cold shock was substantiated. However, the need for such a pond in the present situation at SRP seems unwarranted because the three species of fish tested in this study were protected by the EPA guidelines with a considerable "cushion". For example, a 31-11°C temperature drop caused no significant mortality with any of the three species while being 2°C more severe than the safe limits proposed by the EPA guidelines.

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APPENDIX V-3.1

A Checklist of the Aquatic and Semi-Aquatic Vascular Macrophytes and Riparian Flora of the Lower Food Chain Study Sites (1983-1984)

Source: Gladden et al., 1985

Family	Genus—Species	Common Name	1	2	3	4	5	6	7	8	9	10	11	12
Osmundaceae	Osmunda regalis	Royal fern										x		x
	O. cinnamomea	Cinnamon fern												x
Azollaceae	Azolla caroliniana	Mosquito fern					x				x	x		
Blechnaceae	Woodwardia areolata	Netted chain fern	x	x						x		x		x
Pinaceae	Pinus taeda	Loblolly pine	x		x				x					
Taxodiaceae	Taxodium distichum	Bald cypress						x			x	x		x
Typhaceae	Typha latifolia	Common cattail								x				
Potamogetonaceae	Potamogeton pusillus										x	x	x	
Allsmataceae	Echinodorus cordifolius	Creeping burhead					x	x		x				
	Sagittaria graminae						x							
	S. latifolia	Duck potato					x	x		x			x	
Poaceae	Arundinaria gigantea	Cane				x			x				x	x
	Panicum agrostoides	Redtop panicgrass												x
	Panicum sp.			x		x								
	Leersia sp.	Cutgrass	x	x	x					x				
	Elymus sp.	Wild ryegrass	x		x									
Cyperaceae	Cyperus sp.	Sedge		x	x									
	Carex sp.				x									
Arecaceae	Sabal minor	Palmetto			x		x							
Araceae	Orontium aquaticum	Golden club												x
	Arisaema triphyllum	Jack-in-the-pulpit											x	x
Lemnoceae	Lemna valdiviana	Duckweed					x	x			x	x		
	Spirodela oligorrhiza	Great duckweed					x				x			
Bromelliaceae	Tillandsia usneoides	Spanish moss					x	x			x	x		x
Juncaceae	Juncus effusus	Common rush		x					x	x			x	

APPENDIX V-3.1, Contd

Family	Genus—Species	Common Name	1	2	3	4	5	6	7	8	9	10	11	12
Liliaceae	Smilax rotundifolia	Greenbriar			x				x			x	x	
	S. bona-nox	Catbriar			x	x				x				
Saururaceae	Saururus cernuus	Lizard's tail										x		x
Salicaceae	Salix nigra	Black willow		x		x			x	x	x			
Myricaceae	Myrica cerifera	Wax myrtle	x	x		x				x				x
Juglandaceae	Carya aquatica	Water hickory			x						x			
Betulaceae	Alnus serrulata	Tag alder		x					x	x			x	x
Fagaceae	Quercus nigra	Water oak			x									
	Q. phellos	Willow oak	x						x					x
Ulmaceae	Planera aquatica	Water elm									x	x		
	Ulmus americana	American elm			x					x			x	
Urticaceae	Boehmeria aquatica	False nettle	x		x				x	x				
Polygonaceae	Polygonum lapathifolium	Knotweed								x	x	x		
Phytolaccaceae	Phytolacca americana	Pokeweed												x
Ceratophyllaceae	Ceratophyllum demersum	Hornwort									x	x		
Magnoliaceae	Liriodendron tulipifera	Tulip tree							x					
Lauraceae	Sassafrass albidum	Sassafras		x					x					
Nymphaceae	Nuphar luteum	Spatter dock									x	x		
Saxifragaceae	Itea virginica	Tassel white	x							x	x	x	x	
Hamamelidaceae	Liquidambar styraciflua	Sweet gum	x	x	x					x				x
Platanaceae	Platanus occidentalis	Sycamore							x				x	
Rosaceae	Rubus argutus	Blackberry	x	x		x			x	x	x	x	x	x
	Prunus sp.	Wild cherry							x					
Fabaceae	Wisteria frutescens	Wisteria		x		x					x	x		x
	Gleditsis aquatica	Water locust		x										

APPENDIX V-3.1, Contd

Family	Genus—Species	Common Name	1	2	3	4	5	6	7	8	9	10	11	12
Callitrichaceae	Callitriche heterophylla	Water starwort									x	x		x
Anacardiaceae	Toxicodendron radicans	Poison ivy	x	x		x		x	x	x	x	x	x	x
Aquifoliaceae	Ilex opaca	American holly			x								x	
	I. decidua	Possum haw												
Aceraceae	Acer rubrum	Red maple	x	x		x							x	x
Hippocastanaceae	Aesculus pavia	Red buckeye			x		x			x				x
Balsaminaceae	Impatiens capensis	Jewel weed							x	x		x		x
Vitaceae	Vitis aestivalis	Summer grape	x		x				x	x		x	x	
	Ampelopsis arborea	Pepper vine	x	x	x	x			x	x	x	x	x	
	Partenocissus quinquefolia	Virginia creeper		x		x			x	x			x	x
Malvaceae	Hibiscus militaris	Marsh mallow										x		
Violaceae	Viola sp.	Violet												x
Onagraceae	Ludwigia palustris	Water purslane	x		x		x			x			x	x
	L. decurrens	Primrose willow					x							
	L. leptocarpa						x	x						
	Ludwigia sp. 1								x	x				
	Ludwigia sp. 2		x								x			
Haloragaceae	Myriophyllum brasiliense	Parrot feather								x	x	x		
Apiaceae	Hydrocotyl ranunculoides	Water pennywort									x	x		
	Hydrocotyl sp.	March pennywort	x				x						x	x
	Cicuta maculata	Water hemlock								x		x		x
Nyssaceae	Nyssa aquatica	Water tupelo										x		
Cornaceae	Corrus florida	Dogwood								x			x	x
Ericaceae	Oxdendrum aboreum	Sourwood							x				x	
Loganiaceae	Gelsemium sempervirens	Yellow jessamine			x	x			x				x	
Asclepiadaceae	Asclepias sp.	Milkweed							x	x				
Convolvulaceae	Cuscuta sp.	Dodder								x				
Lamiaceae	Scutellaria lateriflora	Skullcap		x										
Scronphlariaceae	Bacopa egensis	Water hyssop											x	
	Bacopa sp.		x		x				x					

APPENDIX V-4.1

Common and Scientific Names of Adult Fishes Collected in the Savannah River (November 1983-August 1985)

Source: Paller and Saul, 1986

Common Name	Scientific Name
Spotted gar	Lepososteus oculatus
Longnose gar	L. osseus
Florida gar	L. platyrhincus
Bowfin	Amia calva
American eel	Anguilla rostrata
Unid. clupeid	Clupeidae
Unid. 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
Unid. pickerel	Esox spp.
Redfin pickerel	Esox americanus americanus
Chain pickerel	E. niger
Unid. 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
Sailfish shiner	N. hypselopterus
Bannerfin shiner	N. leedsi
Yellowfin shiner	N. lutipinnis
Taillight shiner	N. maculatus
Whitefin shiner	N. nivens
Coastal shiner	N. petersoni
Unid. carpsucker	Carpiodes spp.
Quillback carpsucker	Carpiodes cyprinus
Unid. chubsucker	Erimyson spp.
Creek chubsucker	E. sucetta
Spotted sucker	Minytrmea melanops
Unid. redhorse	Moxostoma spp.

APPENDIX V-4.1, Contd

Common Name	Scientific Name
Silver redhorse	Moxostoma anisurum
Unid. catfish	Ictalurus spp.
Snail bullhead	Icthalurus brunnens
White catfish	I. catus
Yellow bullhead	I. natalis
Brown bullhead	I. nebulosus
Flat bullhead	I. platycephalus
Channel catfish	I. punctatus
Unid. 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
Unid. sunfish	Centrarchidae
Mud sunfish	Acantharchus pomotis
Flier	Centrarchus macropterus
Banded pygmy sunfish	Elassoma zonatum
Bluespotted sunfish	Enneacanthus gloriosus
Unid. 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
Unid. crappie	Pomoxis annularis
Black crappie	P. nigromaculatus
Unid. darter	Etheostoma spp.
Sawcheek darter	Etheostoma serriferum
Savannah darter	E. fricksum
Swamp darter	E. fusiforme
Tessellated darter	E. olmstedi
Yellow perch	Perca flavescens
Blackbanded darter	Percina nigrofasciata
Striped mullet	Mugil cephaus
Hogchoker	Trinectes maculatus
River goby	Awaous tajasica