Macrophytes

Introduction

Aquatic macrophytes provide stream structure, substrate for periphyton development, cover and substrate for smaller animals, and a source of carbon for the stream system. Although aquatic macrophytes are an important component of the function of many aquatic systems, they tend to be less important in flowing waters. Macrophytes could not colonize channels during the large thermal and flow impacts from reactor operations. Because K-Reactor operation ceased in 1988, recolonization of the slower reaches and backwaters of the stream would be expected.

Comprehensive Cooling Water Study

Introduction

The only data dealing with aquatic macrophytes in Pen Branch comes from the CCWS (Specht 1987) and was collected from 1983 to 1985. The CCWS data do not represent the current status of aquatic macrophytes in the system because they were collected at only four stations, all of which were impacted by reactor operations. Only one of the sampled stations was in the stream itself; two were in the thermal delta; and one was in the river swamp.

Number of Taxa Collected

The total number of taxa at the thermal stream station and the thermal swamp stations were similar; the stream, however, had no taxa growing in the channel. The delta stations had approximately one-third of their taxa in the water channels and a similar number (<50%) growing on the floodplain. The channel and floodplain accounted for slightly more than three-quarters of the total taxa found in the two delta stations. Little additional information is available from the CCWS except the observation of greater biomass in the thermal delta during the winter of 1983-1984 and the presence of little or no vegetation in the thermal stream and delta channels or the nonthermal swamp during the 1984-1985 sampling period (Specht 1987).

Expectations Since the Cessation of K-Reactor Operations

Normal successional patterns and development of macrophyte beds would be likely to occur in suitable sections of Pen Branch with the cessation of K-Reactor operation. However, baseline data have not been collected on this component of the ecosystem. Analyses of remote sensing data (Chapter 6—Wetlands and Carolina Bays of the SRS) suggest that macrophyte recolonization of the stream and delta have been substantial.

Zooplankton

Chimney and Cody (1986) documented the temporal and spatial characteristics of zooplankton species based on quarterly sampling from December 1984 to August 1985 in Pen Branch. This study evaluated populations with regard to regulatory compliance issues covered by the Clean Water Act, Section 316(a) Demonstration. Surface-water grab samples were collected adjacent to macrophyte beds at two stations: the first approximately one-third of the distance downstream from the headwaters and a second approximately another third downstream. Because of thermal discharges, mean temperature was greater than 32°C (89°F). Species richness consisted of 7 Protozoa, 15 Rotifera, 14 Cladocera, 4 Copepoda, and 1 Ostracoda.

Figure 5-45 indicates that the greatest densities occurred during April 1985. Eighty percent of the monthly total densities comprised Protozoa and Rotifera. As with other SRS streams, this result is representative of zooplankton populations, which are warm-water, summer species (Hutchinson 1967).

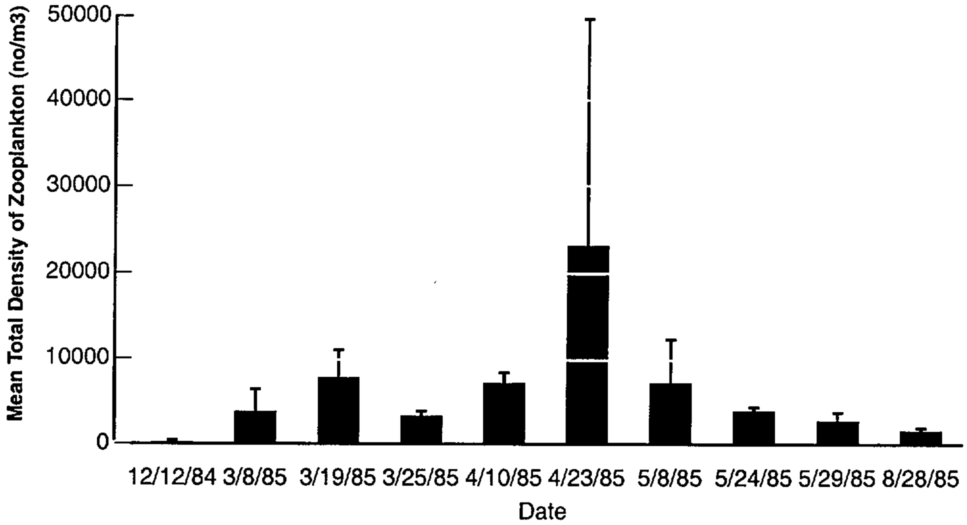

Figure 5-45. Total Zooplankton Mean Density in Pen Branch

Macroinvertebrates

Sampling Locations and Methods

Comprehensive Cooling Water Study

Macroinvertebrates were sampled monthly at three locations in Pen Branch from November 1983 through September 1984 using Hester-Dendy multiplate samplers, leaf bags, artificial snags, sediment coring and at five locations in Pen Branch from October 1984 through September 1985 (Figure 5-46) using Hester-Dendy multiplate samplers, leaf bags, and drift sampling. Data from 1983 through 1985 were collected as part of the CCWS when K Reactor was discharging thermal effluent to Pen Branch; these data are representative of the conditions that would exist if K Reactor were to be operated at full power. Details of sampling methodology can be found in Kondratieff and Kondratieff (1984, 1985) and Firth et al. (1986).

Pen Branch Recovery Studies

Subsequent to K-Reactor shutdown in April 1988, the macroinvertebrate community of Pen Branch was sampled with Hester-Dendy multiplate samplers at seven locations in December 1988 and February and May 1989 (Enwright Laboratories1989a, b, and c) to document the recovery of the macroinvertebrate community.

Macroinvertebrates were sampled during the summer of 1993 at five locations in Pen Branch and at one site on Indian Grave Branch. Hester-Dendy multiplate macroinvertebrate samplers were deployed for 1 month (Specht 1994b).

	1983-1984[a]	1988-1989	1993-1994
01	20	Road B	Road B
02	21	Road A-13.2	Road A-13.2
03	22	Boardwalk	Boardwalk
04	23	Swamp	
05	24	Stave Island	
06		Road C	Road C
07		Indian Grave at Road B	Indian Grave at Road B
08		Road A	Road A

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[a]Station designations are as in Firth et al. 1986.

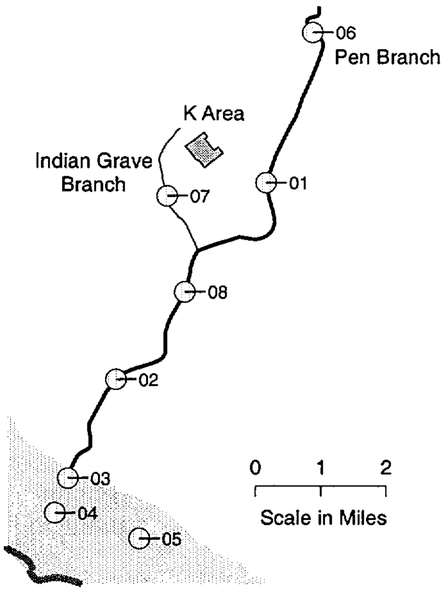

Figure 5-46. Macroinvertebrate Sampling Stations for Pen Branch

Macroinvertebrates also were sampled in September 1994 using Hester-Dendy multiplate samplers in order to develop a biotic index for southeastern streams. While not specifically designed to characterize SRS streams, these data contribute to a better understanding of the streams. Pen Branch was sampled at Roads A, B, and C. Indian Grave Branch was sampled at Road B (Specht and Paller 1995).

Results

Introduction

Pen Branch and its tributary, Indian Grave Branch, receive effluents from seven NPDES outfalls in K Area and Central Shops. Until 1989, Indian Grave Branch also received thermal effluents directly from K Reactor. Indian Grave Branch and Pen Branch, downstream from its confluence with Indian Grave Branch, were subject to extremely high water temperatures and flows.

The data presented in this summary are primarily Hester-Dendy multiplate data because this was the only sampling method used consistently in the 1984-1985, 1988-1989, 1993, and 1994 sampling periods. Macroinvertebrate data from the other sampling methods can be found in Kondratieff and Kondratieff (1984, 1985) and in Firth et al. (1986).

Macroinvertebrate Community of Pen Branch During the Operation of K Reactor

Introduction

From the onset of macroinvertebrate sampling in 1983 until K Reactor shut down in 1988, Pen Branch was subject to severe thermal stress, with temperatures greater than 60°C (140°F) recorded at Station 21. However, during reactor outages, which sometimes lasted several weeks or longer, stream temperatures were near ambient. Because the multiplate samplers were collected monthly, some collections followed periods of reactor outages when stream temperatures were ambient. Therefore, the macroinvertebrate data must be interpreted cautiously to prevent erroneous conclusions.

Nonthermal Station

Station 20, which is at Road B, upstream from all thermal discharges, was similar to other nonthermal SRS streams during 1984-1985 with respect to density of organisms, biomass, and average number of taxa. Total taxa richness (70 taxa, Table 5-103) was higher than at all but one of the stations that were sampled during the CCWS. Dominant taxa included orthoclad, tanytarsine, and chironomini chironomids; the mayfly *Stenonema modestum*; the beetle *Macronychus glabratus*; and several species of caddisflies (Table 5-104). Macroinvertebrate biomass (ash-free dry weight) was higher at Station 20 (0.187 g/m^2) than at the thermally impacted delta stations (0.003 to 0.078 g/m^2), but lower than at Station 24, which was the mildly impacted swamp station (Table 5-103). At Station 20, large numbers of mayflies (primarily *Stenonema modestum*) and fewer numbers of large predatory stoneflies (*Perlesta*) and dobsonflies (*Corydalus*) made up the majority of the biomass.

Table 5-103. Mean Number of Taxa, Density, and Biomass of Macroinvertebrates Collected on Hester-Dendy Multiplate Samplers in Pen Branch, October 1984-September 1985

	Station[a]					
Parameter	**20 (01)**	**21 (02)**	**22 (03)**	**23 (04)**	**24 (05)**	
Mean number of taxa/sampler	15.2	3.2	6.0	7.1	14.4	
Mean density (no./m^2)	695.2	55.6	841.6	2144.9	1620.1	
Mean biomass (g AFDW/m^2)[b]	0.187	0.003	0.078	0.070	0.320	
Total number taxa collected	70	28	33	38	55	
Total number unique taxa collected, all stations combined						92

Source: Firth et al. (1986).

[a] Station numbers from CCWS.

[b] AF DW= Ash-free dry weight.

Table 5-104. Mean Invertebrate Density (number/m^2) at Each Station on Pen Branch for Each Taxon Collected on Hester-Dendy Multiplate Samplers, October 1984-September 1985

			Station		
Taxa	**20 (01)**	**21 (02)**	**22 (03)**	**23 (04)**	**24 (05)**
Turbellaria	0.2				13.8
Nematoda	2.9	3.1	208.4	1533.4	305.4
Oligochaeta	19.2	4.3	50.4	34.9	77.3
Hirudinea	0.2			0.2	1.1
Gastropoda	1.7		0.5	0.3	9.0
Family Ancylidae	3.1			0.2	1.7
Ferrissia rivularis	1.1		0.3	0.2	11.3
Laevapex fuscus					0.3
Family Hydrobiidae					
Amnicola					0.9
Somatogyrus sp.		0.2	0.2		1.6
Family Physidae					
Physella heterostropha	0.2	1.1	10.2	117.9	25.5
Family Planorbidae					0.8
Gyraulus parvus					12.1
Helisoma					0.9
Helisoma trivolvis	0.2				18.3
Family Viviparidae					
Campeloma decisum					0.5
Pelecypoda					
Family Corbiculidae					
Corbicula fluminea	0.8				4.5
Family Sphaeriidae	0.2				
Crustacea					
Isopoda					
Asellus			0.2		1.4

Table 5-104. (cont)

	Station				
Taxa	**20 (01)**	**21 (02)**	**22 (03)**	**23 (04)**	**24 (05)**
Amphipoda		0.2			
Family Talitridae					
Hyalella azteca	0.2	0.2			0.5
Decapoda					
Family Astacidae					
Procambarus	0.3				
Arachnida					
Hydracarina	1.2	0.2	0.2	0.3	30.7
Insecta					
Ephemeroptera					
Family Baetidae					
Baetis	6.1		0.3	0.2	8.7
Pseudocloeon parvulum				0.2	
Family Caenidae					
Caenis	0.5	0.3	1.7	75.3	37.7
Family Ephemerellidae					
Dannella simplex	1.7				
Ephemerella invaria	2.8			11.5	
Eurylophella temporalis	1.6			0.2	0.8
Family Heptageniidae					1.4
Stenacron interpunctatum	0.3	0.2		0.3	36.2
Family Heptageniidae, cont.					
Stenonema modestum	74.5	0.6	0.6	0.3	279.5
Family Neoephemeridae					
Neoephemera youngi	0.2				
Family Oligoneuriidae					
Isonychia	0.9				
Family Tricorythidae					
Tricorythodes	9.5				0.2
Odonata					
Anisoptera	0.2	0.2	0.2		
Family Aeshnidae					
Boyeria vinosa	0.5				
Nasiaeschna pentacantha	0.5				
Family Libellulidae					
Erythemis simplicicollis				0.3	
Pachydiplax longipennis				0.2	
Zygoptera					
Family Calopterygidae					
Hetaerina	0.2				
Family Coenagrionidae					
Argia	1.2	0.2	0.2		0.5
Enallagma	0.2			0.9	0.5
Ischnura	0.2		0.3		
Plecoptera	0.3		0.2		
Family Perlidae	0.2				
Acroneuria abnormis	0.2				0.2
Paragnetina fumosa	0.5				
Perlesta placida	17.7				0.2

Table 5-104. (cont)

	Station				
Taxa	**20 (01)**	**21 (02)**	**22 (03)**	**23 (04)**	**24 (05)**
Family Perlodidae					
Helopicus bogaloosa	0.5				
Isoperla	0.8				
Family Pteronarcyidae					
Pteronarcys dorsata	0.3				
Family Taeniopterygidae					
Taeniopteryx longicera	0.6				
Taeniopteryx robinae	0.2				
Hemiptera					
Family Belostomatidae					
Belostoma				0.2	
Coleoptera					
Family Dryopidae					
Helichus	0.3				
Family Elmidae	2.0				
Ancyronyx variegatus	20.3		0.2		0.5
Macronychus glabratus	68.4	0.5	0.2	0.2	10.9
Microcylloepus pusillus	0.3	0.2			
Stenelmis	0.6				0.6
Family Eubriidae					
Ectopria nervosa	0.6				0.2
Family Gyrinidae					
Dineutes	0.3				1.4
Gyrinus					0.2
Family Hydrophilidae					
Berosus				0.2	0.2
Enochrus spp.		0.2			
Hydrobius			0.2		
Tropisternus				0.3	
Megaloptera					
Family Corydalidae					0.3
Corydalus cornutus	2.3				
Nigronia	0.2				
Family Sialidae					
Sialis	1.2				
Trichoptera					
Family Brachycentridae					
Brachycentrus	0.9				0.2
Family Hydropsychidae	0.6			0.2	
Cheumatopsyche spp.	29.2	0.3	1.1	1.1	2.8
Hydropsyche	0.5		0.5	0.2	0.5
Macrostemum carolina	0.2				
Family Hydroptilidae					
Orthotrichia			0.2		
Oxyethira	0.2		0.2	0.3	5.1
Family Leptoceridae					
Ceraclea	0.3				
Nectopsyche candida	0.2				
Oecetis	2.3				

Table 5-104. (cont)

Taxa	Station 20 (01)	21 (02)	22 (03)	23 (04)	24 (05)
Family Limnephilidae					
Pycnopsyche					0.2
Family Philopotamidae					
Chimarra	0.8	0.3			
Family Polycentropodidae					
Cernotina					1.6
Neureclipsis				0.2	
Phylocentropus					1.1
Polycentropus	0.3		0.2		0.9
Family Psychomyiidae					
Lype diversa	40.2	0.2	0.2	0.3	0.3
Diptera					
Family Ceratopogonidae	4.2	0.2	46.6	5.6	38.5
Ceratopogonidae pupae			0.9		
Subfamily Forcipomyiinae	0.2		0.3	0.3	0.2
Family Chaoboridae					
Chaoborus punctipennis		0.2			2.0
Family Chironomidae					
Chironomidae pupae	22.0	1.2	18.2	35.5	44.5
Subfamily Chironominae					
Tribe Chironomini	81.2	24.2	173.7	153.9	99.5
Tribe Tanytarsini	96.7	9.9	263.5	74.2	377.6
Subfamily Diamesinae					
Potthastia	0.2		0.3	0.2	0.2
Subfamily Orthocladiinae	124.5	6.7	31.7	16.3	81.2
Subfamily Tanypodinae	17.2	0.5	28.4	78.4	58.2
Family Empididae	20.5	0.3			
Family Ephydridae			0.5		
Family Simulidae	0.8				
Simulium	2.0	0.3	0.2	0.6	0.5
Family Stratiomyliidae			0.3	0.3	
Odontomyia sp.				0.2	
Family Tipulidae	0.2				
Hexatoma			0.5		
Tipula	0.2				

Source: Firth et al. 1986.

Thermally Impacted Delta and Swamp Stations

Number of Taxa Collected

During reactor operation, 51 taxa were collected from the thermally impacted stations in Pen Branch. Taxonomic richness below the reactor outfall was lowest at the station closest to the reactor outfall (Station 21; 28 taxa) and gradually increased farther downstream to 33 taxa at Station 22 and 38 taxa at Station 23. At Station 24, where temperatures were near ambient, 55 taxa were collected (Table 5-103).

Dominant Species

Table 5-105 presents the relative abundance of major taxonomic groups of macroinvertebrates at each sampling station, while Table 5-104 contains a complete taxonomic listing for each station. At all of the thermally impacted stations, except Station 23, Diptera was by far the most common insect order collected, ranging from 43.3 to 77.7% of the organisms collected (Table 5-105), Chironominae and Tanytarsini predominated at the thermally impacted stations (Table 5-105). Nematode worms were the dominant taxon at Station 23 (71.5%) and were also abundant at the other thermally impacted stations. Nematodes are often an important component of the fauna at thermally stressed sites because of their tolerance for heated water. Oligochaete worms also were collected commonly at all of the stations, with abundances ranging from 1.6 to 7.7% (Table 5-105).

Mayflies (Ephemerotera) were abundant in the swamp, at Station 24, accounting for 22.5% of the macroinvertebrates collected. *Stenonema modestum, Caenis*, and *Stenocron interpunctatum* were the most common species of mayflies collected at Station 24. Gastropods (primarily *Physella heterostropha, Helisoma trivolvis*, and *Gyralus parvus*) were abundant at Stations 23 and 24, accounting for 5.5 and 5.1% of the organisms collected (Table 5-105). Beetles (Coleoptera) and caddisflies (Trichoptera) were abundant at Station 20, above the outfall, but less abundant farther downstream. The remaining taxa listed in Table 5-105 (Turbellaria, Arachnida, Odonata, and Plecoptera) each generally accounted for less than 3% of the organisms collected at any station.

Densities

Mean densities of macroinvertebrates on the multiplate samplers ranged from 55.6/m^2 at the most thermally impacted station (Station 21) to 2144.9/m^2 in the delta (Station 23; Table 5-103). The high density at Station 23 was due primarily to large numbers of nematodes (Table 5-105).

Biomass

Macroinvertebrate biomass (ash-free dry weight) was low at the thermally impacted stations (0.003-0.078 g/m^2) and much higher (0.320 g/m^2) at Station 24, which was mildly thermal (Table 5-103). At Station 24, mayflies and gastropods accounted for most of the biomass. Although Station 23 had by far the greatest mean density of organisms (2144.g/m^2; Table 5-103), biomass was relatively low at this station (0.070 g/m^2) due to a preponderance of small nematodes.

Table 5-105. Percent Abundance of Major Groups of Macroinvertebrate Taxa Collected on Hester-Dendy Multiplate Samplers in Pen Branch During Reactor Operation, October 1984-September 1985

	Station[a]				
Taxa	**20 (01)**	**21 (02)**	**22 (03)**	**23 (04)**	**24 (05)**
Turbellaria	0.03	0.00	0.00	0.00	0.85
Nematoda	0.42	5.54	24.75	71.47	18.84
Oligochaeta	2.76	7.68	5.99	1.63	4.77
Gastropoda	0.90	2.32	1.33	5.53	5.12
Arachnida	0.17	0.36	0.02	0.01	1.89
Ephemeroptera	14.09	1.96	0.31	4.10	22.49
Odonata	0.46	0.71	0.08	0.07	0.07
Plecoptera	3.06	0.00	0.02	0.00	0.02
Coleoptera	13.35	1.61	0.07	0.03	0.88
Trichoptera	10.87	1.43	0.29	0.11	1.25
Diptera[b]	53.12	77.68	67.11	17.04	43.34
Chironomini	(11.66)	(43.21)	(20.63)	(7.17)	(6.14)
Tanytarsini	(13.89)	(17.68)	(31.29)	(3.46)	(23.30)
Orthocladiinae	(17.88)	(11.96)	(3.76)	(0.76)	(5.01)
Tanypodinae	(2.47)	(0.89)	(3.37)	(3.65)	(3.59)
Other	0.77	0.71	0.03	0.01	0.48
Total	100.00	100.00	100.00	100.00	100.00

Source: Modified from Firth et al. 1986.

[a] Includes original station designation and location designation on the map in Figure 5-46 (in parentheses).

[b] Includes subtaxa densities in parentheses.

Recovery of Macroinvertebrate Community Subsequent to K-Reactor Shutdown

Introduction

The macroinvertebrate data collected subsequent to K-Reactor shutdown differ from the data collected during reactor operation in that data were collected for 3 months in the 1988-1989 program rather than 12 months and the level of taxonomic resolution was better in the 1988-1989 study, particularly for chironomids. Macroinvertebrates were sampled only from July to August 1993 and in September 1994. Any comparisons of species richness or taxonomic composition should take these important differences into consideration.

Number of Taxa Collected

During the sampling conducted during three months in 1988 and 1989, 132 taxa of macroinvertebrates were collected in Pen Branch and Indian Grave Branch (Table 5-104). Of these taxa, 86 were collected from the portions of the creeks that had been thermally impacted. It is likely that more taxa would have been collected if sampling had been conducted over an entire year because some species occur seasonally, and some rare species are collected infrequently. The total number of taxa collected was highest at Road C (58 taxa; Table 5-106). Fewer taxa were collected at the other five stations in Pen Branch, ranging from 48 at the boardwalk to 53 at Road B and Stave Island (Table 5-106). In Indian Grave Branch, substantially fewer taxa were collected (35) (Table 5-106).

Table 5-106. Mean Number of Taxa, Density, and Biomass of Macroinvertebrates Collected on Hester-Dendy Multiplate Samplers in Pen Branch and Indian Grave Branch during Ambient Thermal Conditions, December 1988-May 1989

	Station						
Parameter	**Road C**	**Road B**	**Road A**	**Road A-13.2**	**Board-walk**	**Stave Island**	**Indian Grave Branch at Road B**
Mean number of taxa/sampler	14.0	19.6	12.9	13.9	16.1	14.3	8.9
Mean density (no./m^2)	635.7	534.7	692.7	864.0	988.3	610.7	681.7
Mean biomass (g AFDW/m^2)[a]	0.040	0.039	0.044	0.089	0.082	0.030	0.029
Total number of taxa collected	58	53	50	50	48	53	35

Source: Enwright Laboratories 1989 a, b, and c.

[a] AFDW = ash-free dry weight.

The station in Indian Grave Branch and three of the five stations in Pen Branch in 1993 all had relatively high numbers of taxa present (40-62; Table 5-107). Macroinvertebrate communities at the two remaining stations in Pen Branch, at Road C and in the river swamp, differed from the others, with fewer total taxa (12 and 4, respectively). Results from the 1994 sampling indicate that the macroinvertebrate community improved downstream. The total number of taxa collected at the Pen Branch stations ranged from 37-51, and total taxa at the Indian Grave Branch Station was 38 (Table 5-107).

Taxa Richness

Taxa richness (mean number of taxa collected per multiplate sampler) ranged from 8.9 in Indian Grave Branch to 19.6 at Road B (Table 5-106) in 1988-1989. In general, fewer taxa were collected from the portions of the creek that had been thermally perturbed (Indian Grave Branch, Road A, Road A-13.2, and the boardwalk, in order of increasing distance from the reactor outfall) than from unperturbed areas of the creek (Road C, Road B, and Stave Island; Table 5-106). However, in the Pen Branch delta (the boardwalk) species richness was relatively high (16.1), probably due to the increasing habitat diversity that resulted from recolonization by aquatic macrophytes. These data indicate that although the macroinvertebrate community of Pen Branch had undergone some recovery subsequent to reactor shutdown in April 1988, taxonomic richness was still somewhat depressed and it is likely that the macroinvertebrate community had not completely recovered and was still undergoing succession.

In 1993, the stations in Indian Grave Branch and three of the five Pen Branch stations had taxa richness values from 22.0 to 34.2. However, taxa richness at the swamp station and at Road C was low (1.0 and 5.2, respectively). Data from 1994 remained essentially unchanged from the higher 1993 taxa richness numbers, with taxa richness from 20.2 to 35.0 at the three Pen Branch stations (Table 5-107). In Indian Grave Branch, there was a mean of 18 taxa per sampler.

Table 5-107. Mean Number of Taxa, Density, and Biomass For Macroinvertebrates Collected on Hester-Dendy Multiplate Samplers in Pen Branch, July-August 1993 and September 1994

	1993						**1994**			
	Indian Grave Branch Road B	**Pen Branch Road C**	**Pen Branch Road B**	**Pen Branch Road A**	**Pen Branch Road A-13.2**	**Pen Branch Board-walk**	**Indian Grave Branch Road B**	**Pen Branch Road C**	**Pen Branch Road B**	**Pen Branch Road A**
Mean number of taxa /sampler	22.0	5.2	26.8	31.6	34.2	1.0	18.0	20.2	26.0	35.0
Density (No./m^2)	1106.1	158.7	1331.8	1453.6	2765.4	5.59	2520.7	1360.9	1194.1	2235.8
Mean Biomass (g/m^2)	0.1826	0.0118	0.1339	0.1962	0.4648	0.0008	0.3462	0.0336	0.2828	0.5365
Total number of taxa collected	40	12	53	62	47	4	38	37	40	51

Source: Specht 1994b; Specht and Paller 1995.

Dominant Species

For all stations combined, chironomid dipterans were by far the most common group of macroinvertebrates on the 1988-1989 multiplate samplers, making up 68.4-91.8% of the organisms collected (Table 5-108). Orthoclad midges were the most abundant chironomids (36.5-71.2%) at all but the boardwalk, where tanytarsine midges were more common (46.9%; Table 5-108). Nonchironomid dipterans (mostly blackflies or danceflies) were abundant at some stations, comprising 0.4-26.6% of the collections. Trichoptera (caddisflies) and Ephemeroptera (mayflies) were also abundant at most stations, accounting for 0.4-11.2% and 0-8.4%, respectively, of the organisms collected on the multiplate samplers. Plecoptera (stoneflies) and Coleoptera (beetles) were abundant locally at Road B (7.8 and 9.3%, respectively), but accounted for less than 1% of the macroinvertebrates collected at each of the other stations.

Dominant taxa included several species of orthoclad midges (*Corynoneura* nr. *tarsis*, *Cricotopus* spp., *Orthocladius* spp., and *Tvetenia discoloripes* gr.), chironomini midges (*Microtendipes pedellus*, and *Polypedilum* spp.), tanytarsine midges (*Rheotanytarsus distinctissimus* and *Tanytarsus* spp.), and blackflies (*Simulium tuberosum* and *S. vittatum*) (Table 5-109). Other species that were abundant locally at at least one station included the mayflies, *Caenis* sp. and *Stenonema modestum/smithae*; the stonefly, *Perlesta placida*; the caddisflies, *Cheumatopsyche* spp. and *Hydropsyche* spp.; the beetle, *Macronychus glabratus*; and danceflies (*Empidae*) (Table 5-109).

Station 7, in Indian Grave Branch just downstream from the reactor outfall, differed from the other stations in that the community was composed almost exclusively of dipterans (99.57%; Table 5-108). Dominant dipterans at this station included the chironomids, *Cricotopus* and *Orthocladius,* blackflies, and empidid danceflies (Table 5-104). This difference is probably due, at least in part, to differences in substrate composition. Station 7 contains rock rip-rap, which provides stable substrate for attachment by blackflies and other species that prefer rock substrate. However, the conspicuous absence of clinging mayflies, such as *Stenonema*, and the overall low taxonomic richness suggest that Station 7 still was perturbed at the time of sampling.

Table 5-108. Percent Abundance of Major Groups of Macroinvertebrates Collected from Hester-Dendy Multiplate Samplers in Pen Branch and Indian Grave Branch during Ambient Thermal Conditions, December 1988-May1989

	Station							
Taxon	**Road C**	**Road B**	**Road A**	**Road A-13.2**	**Board-walk**	**Stave Island**	**Indian Grave Branch at Road B**	**Mean**
Annelida	0.00	0.00	0.16	0.04	0.19	0.42	0.00	0.12
Crustacea	0.06	0.00	0.00	0.00	0.00	0.67	0.00	0.09
Mollusca	0.76	0.00	0.05	0.00	0.15	1.09	0.00	0.27
Ephemeroptera	7.36	8.45	1.98	0.62	6.07	1.33	0.00	3.58
Odonata	0.12	0.07	0.00	0.00	0.46	0.12	0.00	0.13
Plecoptera	0.76	7.76	0.05	0.04	0.00	0.00	0.00	0.95
Trichoptera	0.70	1.80	5.03	11.20	10.16	1.09	0.44	5.06
Lepidoptera	0.00	0.00	0.05	0.00	0.04	0.00	0.00	0.01
Megaloptera	0.18	0.00	0.00	0.00	0.04	0.00	0.00	0.03
Coleoptera	0.53	9.28	0.21	0.09	0.08	0.73	0.00	1.22
Diptera - Misc.	0.35	4.22	12.14	13.54	8.14	2.79	26.65	10.07
Diptera - Chironomidae[a]	89.20	68.42	80.32	74.47	74.68	91.75	72.92	78.47
Tanypodinae	(2.57)	(1.73)	(0.80)	(0.26)	(2.56)	(9.22)	(0.05)	(2.31)
Orthocladiinae	(36.54)	(48.75)	(71.23)	(62.08)	(18.83)	(55.25)	(68.17)	(50.20)
Diamesinae	(0.00)	(1.52)	(0.00)	(0.00)	(0.08)	(0.49)	(0.05)	(0.25)
Chironomini	(33.98)	(12.47)	(0.80)	(6.22)	(6.26)	(4.31)	(0.98)	(8.74)
Tanytarsini	(16.11)	(3.95)	(7.49)	(5.91)	(46.94)	(22.50)	(3.65)	(16.97)
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: Enwright Laboratories 1989a, b, and c.

[a] Total of subfamilies in parentheses.

Table 5-109. Mean Density (number/m^2) of Macroinvertebrates on Hester-Dendy Multiplate Samplers in Pen Branch and Indian Grave Branch during Ambient Thermal Conditions, December 1988-May 1989

	Station							
Taxon	**Road C**	**Road B**	**Road A**	**Road A-13.2**	**Boardwalk**	**Stave Island**	**Indian Grave Branch**	**Total**
Annelida (worms and leeches)								
Batrachobdella phalera	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.37
Glossiphoniidae	0.00	0.00	0.00	0.00	1.48	0.00	0.00	1.48
Nais communis	0.00	0.00	1.11	0.40	0.00	0.37	0.00	1.88
Placobdella parasitica	0.00	0.00	0.00	0.00	0.00	0.74	0.00	0.74
Stylaria lacustris	0.00	0.00	0.00	0.00	0.00	1.48	0.00	1.48
Mollusca (snails and clams)								
Ferrissia henderson	3.33	0.00	0.00	0.00	0.37	0.00	0.00	3.70
Micromenetus dilatatus	0.37	0.00	0.00	0.00	0.00	2.59	0.00	2.96
Physella heterostropha	1.11	0.00	0.37	0.00	0.37	4.07	0.00	5.92
Pseudosuccinea columella	0.00	0.00	0.00	0.00	0.74	0.00	0.00	0.74
Crustacea								
Crangonyx obliquus	0.37	0.00	0.00	0.00	0.00	3.70	0.00	4.07
Hyallela azteca	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.37
Ephemeroptera (mayflies)								
Acerpenna pygmaeus	1.85	0.00	0.00	0.00	0.00	0.00	0.00	1.85
Baetis intercalaris	0.00	1.85	0.74	0.40	6.67	0.00	0.00	9.66
Baetis propinquus	0.00	1.11	0.00	0.00	0.00	0.00	0.00	1.11
Caenis sp.	0.00	0.00	2.96	0.40	47.78	2.22	0.00	53.36
Dannella simplex	0.00	1.48	0.00	0.00	0.00	0.00	0.00	1.48
Ephemerella dorothea	0.37	5.19	1.85	0.00	0.00	0.00	0.00	7.41
Ephemerella inconstans	0.00	5.93	0.00	0.00	0.00	0.00	0.00	5.93
Ephemerella rotunda/invaria	0.00	2.22	0.00	0.00	0.00	0.00	0.00	2.22
Ephemerellidae	0.00	0.37	0.00	0.40	0.00	0.00	0.00	0.77
Eurylophella doris	0.00	0.00	0.00	0.00	0.00	1.11	0.00	1.11
Eurylophella nr. *temporalis*	1.11	0.00	0.00	0.00	0.00	0.00	0.00	1.11
Eurylophella prudentalis	0.00	0.00	0.00	0.00	0.00	1.11	0.00	1.11
Heptagenia flavescens	0.37	0.00	0.00	0.40	0.00	0.00	0.00	0.77
Heptageniidae[a]	0.37	0.00	0.00	0.40	0.00	0.37	0.00	1.14
Leptophlebia sp.	2.59	0.00	0.00	0.00	0.00	0.00	0.00	2.59
Paraleptophlebia sp.	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.37
Stenacron interpunctatum	25.93	0.00	0.00	0.00	1.48	0.00	0.00	27.41
Stenonema integrum	0.00	0.00	0.74	0.00	0.00	0.00	0.00	0.74
Stenonema modestum/smithae	13.70	23.70	7.41	3.57	2.96	3.33	0.00	54.67
Tricorythodes sp.	0.00	3.33	0.00	0.00	0.00	0.00	0.00	3.33
Odonata								
Argia tibialis	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.37
Boyeria vinosa	0.00	0.37	0.00	0.00	0.00	0.74	0.00	1.11
Argia translata	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.37
Enallagma sp.	0.00	0.00	0.00	0.00	4.44	0.00	0.00	4.44
Plecoptera (stoneflies)								

Table 5-109. (cont)

	Station							
Taxon	**Road C**	**Road B**	**Road A**	**Road A-13.2**	**Board-walk**	**Stave Island**	**Indian Grave Branch**	**Total**
Amphinemura delosa	0.00	1.48	0.00	0.00	0.00	0.00	0.00	1.48
Isoperla bilineata	0.00	2.22	0.00	0.00	0.00	0.00	0.00	2.22
Isoperla clio	0.37	1.48	0.00	0.00	0.00	0.00	0.00	1.85
Isoperla nr. *nana*	1.11	0.00	0.00	0.00	0.00	0.00	0.00	1.11
Perlesta placida	3.33	28.89	0.00	0.40	0.00	0.00	0.00	32.62
Perlidae[a]	0.00	7.41	0.00	0.00	0.00	0.00	0.00	7.41
Perlodidae	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.37
Trichoptera (caddisflies)								
Cernotina spicata	0.00	0.00	0.37	0.00	0.00	0.37	0.00	0.74
Cheumatopsyche spp.	0.37	3.70	5.19	30.56	96.67	3.70	0.79	140.98
Chimarra sp.	0.00	0.00	0.00	14.68	0.37	0.00	0.00	15.05
Hydropsyche elissoma/rossi	0.00	0.00	8.89	28.17	0.00	1.11	1.19	39.36
Hydropsyche nr. *incommoda*	0.00	0.00	0.74	3.17	0.37	0.00	0.00	4.28
Hydropsyche rossi	0.00	0.00	5.19	18.65	0.74	0.00	0.40	24.98
Hydroptila sp.	0.00	0.00	1.11	0.40	0.00	0.00	0.00	1.51
Lype diversa	4.07	5.93	0.00	0.00	0.00	0.00	0.00	10.00
Macrostemum carolina	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.40
Neureclipsis sp.	0.00	0.00	11.85	2.38	0.00	0.00	0.79	15.02
Oecetis sp.	0.00	0.00	1.11	1.98	0.00	0.37	0.00	3.46
Oxyethira sp.	0.00	0.00	0.00	0.00	0.00	1.11	0.00	1.11
Triaenodes nr. *marginata*	0.00	0.00	0.37	0.40	0.37	0.00	0.00	1.14
Lepidoptera (moths)								
Parapoynx obscuralis	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.37
Pyralidae	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.37
Megaloptera (hellgrammites)								
Chauliodes pectinicornis	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.37
Nigronia serricornis	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.37
Sialis sp.	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.74
Coleoptera (beetles)								
Ancyronyx variegatus	0.37	1.48	0.37	0.00	0.37	0.00	0.00	2.59
Dineutus sp.	0.00	0.37	0.00	0.40	0.00	0.00	0.00	0.77
Gyrinus sp.	0.00	0.00	0.00	0.00	0.00	2.22	0.00	2.22
Hydroporus sp.	2.22	0.00	0.00	0.00	0.00	0.00	0.00	2.22
Macronychus glabratus	0.37	47.41	1.11	0.00	0.00	2.22	0.00	51.11
Sperchopsis tessellatus	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.37
Stenelmis sp.	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.37
Tropisternus sp.	0.00	0.00	0.00	0.40	0.37	0.00	0.00	0.77
Diptera-Chironomidae (midges)								
Tanypodinae								
Ablabesmyia janta	0.00	0.00	0.00	0.00	0.74	1.48	0.00	2.22
Ablabesmyia mallochi	4.44	1.11	0.37	0.00	10.00	27.78	0.00	43.70
Ablabesmyia sp.[a]	2.22	0.37	0.00	0.00	0.74	0.00	0.00	3.33

Table 5-109. (cont)

	Station							
Taxon	**Road C**	**Road B**	**Road A**	**Road A-13.2**	**Board-walk**	**Stave Island**	**Indian Grave Branch**	**Total**
Conchapelopia sp.	2.96	7.78	5.19	1.59	12.22	6.67	0.00	36.41
Labrundinia becki	0.37	0.00	0.00	0.00	1.11	0.00	0.00	1.48
Labrundinia nr. *neopilosella*	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.17
Labrundinia pilosella	0.37	0.00	0.00	0.00	0.00	18.52	0.00	18.89
Nilotanypus fimbriatus	1.48	0.00	0.00	0.00	0.00	0.00	0.40	1.88
Paramerina sp.	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.37
Procladius sp.	0.00	0.00	0.00	0.00	0.00	1.48	0.00	1.48
Zavrelimyia sp.	4.07	0.00	0.00	0.79	0.00	0.00	0.00	4.86
Diptera - Orthocladiinae								
Brillia flavifrons	0.00	9.63	1.48	1.98	0.00	0.00	2.38	15.47
Cardiocladius sp.	0.00	0.00	4.07	0.40	0.00	0.00	13.89	18.36
Corynoneura nr. taris	176.30	17.78	1.48	14.68	57.78	117.04	2.78	387.84
Corynoneura sp.	0.00	3.33	2.22	0.00	0.00	0.17	0.00	5.92
Corynoneura sp. 4	5.19	5.56	0.00	0.00	3.70	0.37	0.00	14.82
Cricotopus bicinctus	0.00	0.37	0.74	0.40	11.85	111.48	0.00	124.84
Cricotopus sp.	0.74	2.59	5.93	2.38	1.11	0.37	200.79	213.91
Cricotopus tremulus gp.	0.00	0.00	0.74	1.19	0.00	0.00	0.00	1.93
Eukiefferiella claripennis gp.	0.00	0.74	18.89	24.60	0.00	0.00	5.16	49.39
Eukiefferiella devonica gp.	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.40
Nanocladius distinctus	0.37	0.00	0.00	0.00	0.00	6.67	0.00	7.04
Nanocladius sp.	0.74	0.00	0.74	0.00	2.22	4.81	0.00	8.51
Orthocladius (Eudactylocladius)	0.00	0.00	4.44	1.59	0.00	0.00	5.95	11.98
Orthocladius curtiseta	0.00	0.00	2.22	0.00	1.85	0.37	38.89	43.33
Orthocladius nigritus	11.11	11.85	76.30	14.29	0.00	0.00	5.16	118.71
Orthocladius nr. oliveri	0.00	2.22	0.00	0.00	0.00	0.00	0.00	2.22
Orthocladius obumbratus	0.00	7.04	0.00	0.40	0.00	0.00	0.00	7.44
Orthocladius sp.	0.37	11.11	110.37	191.27	1.11	0.74	97.22	412.19
Orthocladius sp. a	0.00	0.00	0.00	0.00	1.48	0.00	0.00	1.48
Parakiefferiella sp.	2.22	2.22	8.15	4.37	6.67	31.11	3.97	58.71
Parakiefferiella sp. B	2.96	2.59	5.93	3.97	11.11	9.26	1.19	37.01
Parametriocnemus lundbecki	3.33	44.44	0.74	0.40	0.00	1.85	0.00	50.76
Parametriocnemus sp. C	1.11	2.22	0.00	0.00	0.00	0.00	0.00	3.33
Psectrocladius (Meso.) sp.	0.00	0.00	0.74	0.00	0.00	0.00	0.00	0.74
Rheocritcotopus robacki	0.37	23.70	11.85	5.16	9.63	12.96	3.57	67.24
Rheocritcotopus tuberculatus	0.37	1.85	0.00	0.00	0.00	0.00	0.00	2.22
Symposiocladius lignicola	2.22	1.48	3.33	0.79	0.37	0.00	4.37	12.56
Synorthocladius semivirens	0.00	0.00	0.00	0.00	0.00	0.00	4.76	4.76
Thienemanniella fusca gp.	4.44	42.59	0.00	0.40	5.93	7.41	7.54	68.31
Thienemanniella xena gp.	1.85	22.22	8.15	29.76	40.74	31.48	25.79	159.99
Tvetenia discoloripes gp.	0.00	10.74	224.44	260.32	25.19	0.74	72.22	593.65
Tvete nia paucunca/vitracies	0.00	34.44	0.37	0.00	1.85	0.37	0.79	37.82
Unniella multivirga	18.15	0.00	0.00	0.00	0.00	0.00	0.00	18.15
Diamesinae								
Potthastia longimana	0.00	8.15	0.00	0.00	0.74	2.96	0.40	12.25
Chironomini								
Chironomus sp.	1.11	0.37	0.00	0.00	1.11	0.37	0.00	2.96

Table 5-109. (cont)

	Station							
Taxon	Road C	Road B	Road A	Road A-13.2	Board-walk	Stave Island	Indian Grave Branch	Total
Cryptochironomus parafulvus	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.37
Dicrotendipes modestus	0.00	0.00	0.00	0.00	12.22	0.37	0.40	12.99
Microtendipes pedellus	198.52	2.22	0.00	0.00	0.00	0.37	0.00	201.11
Phaenopsectra flavipes	1.85	0.00	1.11	0.00	0.00	0.74	0.00	3.70
Phaenopsectra/Tribelos sp.	6.67	4.44	0.00	0.00	0.00	10.37	0.00	21.48
Polypedilum convictum	0.37	42.22	3.33	32.94	38.15	6.30	1.59	124.90
Polypedilum fallax	2.59	17.04	0.00	2.78	0.00	0.37	1.19	23.97
Polypedilum halterale	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40
Polypedilum illinoiense	0.00	0.37	0.00	0.40	9.26	6.30	2.38	18.71
Polypedilum sp.	0.74	0.00	0.37	0.00	0.00	0.00	0.00	1.11
Polypedilum sp.[a]	3.70	0.00	0.37	19.44	0.00	1.11	0.00	24.62
Stenochironomus sp.	0.00	0.00	0.00	0.40	0.00	0.00	1.19	1.59
Tanytarsini								
Microsectra sp.	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.37
Paratanytarsus sp.	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.37
Rheotanytarsus distinctissimus	1.11	11.11	42.22	48.02	32.96	110.37	26.19	271.00
Tanytarsus glabrescens gp.	0.00	2.59	2.59	0.40	0.37	0.00	0.00	5.95
Tanytarsus sp.	56.67	7.04	6.67	4.76	85.93	19.26	0.40	180.73
Tanytarsus sp. XVI Rutter	34.81	0.00	0.00	0.00	0.00	0.00	0.00	34.81
Tanytarsus sp. XVII Rutter	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.74
Tantarsus sp·[a]	8.52	0.00	0.37	0.00	335.93	7.78	0.00	352.60
Diptera - Misc. (true flies)								
Atrichopogon sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40
Bezzia sp	0.00	0.00	0.00	0.00	0.37	0.74	0.00	1.11
Bezzia sp. 2	0.00	0.00	0.00	0.40	8.89	13.70	0.00	22.99
Empididae	2.22	7.41	10.74	3.57	0.00	0.00	36.90	60.84
Palpomyia sp. 4	0.00	0.00	0.00	0.00	0.00	1.11	0.00	1.11
Sciomyzidae	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40
Simulium dixiense/jonesi	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.37
Simulium tones	0.00	0.00	0.74	0.00	0.00	0.00	0.00	0.74
Simulium tuberosum	0.00	14.44	42.96	109.92	37.04	0.37	3.97	208.70
Simulium venustum/verecundum	0.00	0.00	0.00	0.00	16.67	1.11	0.00	17.78
Simulium venustum/vittatum	0.00	0.00	1.48	0.00	14.07	0.00	0.00	15.55
Simulium vittatum	0.00	0.37	28.15	7.54	1.85	0.00	152.38	190.29
Tipula sp. 1	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.40

Source: Enwright Laboratories 1989a, b, and c.

[a] Immature or damaged organisms; probably the same as another taxon.

In 1993, the macroinvertebrate community in Indian Grave Branch and Road B, Road A, and Road A-13.2 in Pen Branch was dominated by Ephemeroptera (23.57-38.74%) or Trichoptera (2.77-39.70%; Table 5-110) and by collector-gatherers or collector-filterers (Table 5-110). The macroinvertebrate community at Road C was composed mostly of Chironomini chironomids. Both the Road C and the swamp stations were perturbed at the time of sampling with very low concentrations of dissolved oxygen, which was probably responsible for the observed poor community structure (Specht 1994b). Orthoclad chironomids and Coleoptera also were abundant in Pen Branch but not Indian Grave Branch. Gastropods accounted for 24.65% of the organisms collected in Indian Grave Branch.

Common Pen Branch taxa in 1994 included Tanytarsini and Ephemeroptera at Roads B and C; Chironomini, and Orthocladiinae at Road B and oligochaetes, Trichoptera, Ephemeroptera, and Orthocladiinae at Road A. Oligochaetes dominated the Indian Grave station (72%). The dominant functional group at all stations in 1994 was collector-gatherer (56.62-88.7%). Road A also had a good number of collector-filterers (27.39%).

Densities

Macroinvertebrate densities on the multiplate samplers in 1988-1989 ranged from 534.7/m^2 at Road B to 988.3/m^2 at the Boardwalk (Table 5-106). Densities were variable from month to month (Enwright 1989a, b, and c), and no relationship between density and thermal history was apparent.

Densities ranged from 1106.1 to 2765.4 organisms/m^2 in Indian Grave and at Roads A, B, and C in 1993. Densities at the Pen Branch Road C and swamp station were low, 157.8 and 5.59 organisms/m^2, respectively. In 1994, the mean numbers of organisms at the three Pen Branch sample locations ranged from 1194.1 to 2235.8 organisms/m^2, similar to the higher 1993 values. Density at the Indian Grave Branch location in 1994 was 2520.7 organisms/m^2 (Table 5-107).

Biomass

Macroinvertebrate biomass was exceptionally low at all stations in 1988-1989, ranging from 0.029 g/m^2 at Station 7 to 0.089 g/m^2 at Station 4 (Table 5-106). The low biomass was due primarily to the predominance of small chironomids on the multiplate samplers.

Biomass was also high in 1993, ranging from 0.1339 to 0.4648 g AFDW/m^2 in Indian Grave Branch and the three stations in Pen Branch. The two remaining stations in Pen Branch had low biomass values (0.0118 g AFDW/m^2 at Road C and 0.0008 g AFDW/m^2 in the swamp). At the 1994 sample locations, biomass ranged from 0.0336 to 0.5365 g AFDW/m^2 in Pen Branch and was 0.3462 g AFDW/m^2 in Indian Grave Branch (Table 5-107).

Table 5-110. Percent Composition of Macroinvertebrate Taxa Collected on Hester-Dendy Multiplate Samples in Pen Branch, July - August 1993 and September 1994

	1993						**1994**			
	Indian Grave Branch at Rd B	**Pen Branch at Rd C**	**Pen Branch at Rd B**	**Pen Branch at Rd A**	**Pen Branch at Rd A-13.2**	**Pen Branch Board-walk**	**Indian Grave at Rd B**	**Pen Branch at Rd C**	**Pen Branch at Rd B**	**Pen Branch at Rd A**
Ephemeroptera	24.65	0.00	23.57	38.74	16.77	0.00	1.06	19.38	16.49	14.29
Plecoptera	0.00	0.00	0.08	0.08	0.08	0.00	0.00	0.00	1.05	0.00
Trichoptera	39.70	0.00	2.27	18.06	28.00	20.00	0.80	0.66	1.17	24.09
Coleoptera	0.51	0.00	11.24	10.38	7.11	40.00	0.04	0.66	6.43	4.60
Odonata	0.61	0.00	1.43	1.46	0.04	0.00	0.09	1.07	0.47	0.40
Megaloptera	0.10	0.00	0.76	0.61	4.61	0.00	0.04	0.00	0.82	1.10
Lepidoptera	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15
Other Diptera	1.92	1.41	1.01	0.38	0.93	0.00	1.68	0.08	0.23	0.30
Tanypodinae	5.15	1.41	7.55	3.69	4.65	20.00	4.65	4.27	3.27	3.30
Tanytarsini	0.71	1.41	10.74	5.61	8.93	0.00	5.54	64.29	30.88	8.75
Orthocladiinae	1.31	0.70	36.58	15.14	23.03	0.00	1.24	0.90	11.93	12.94
Chironomini	0.40	95.07	3.44	3.54	5.17	0.00	10.06	4.11	12.51	1.10
Pseudochiromomini	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.12	0.00
Diamesinae	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.12	0.00
Oligochaeta	0.00	0.00	0.00	0.00	0.00	0.00	71.81	3.87	11.23	25.04
Hirudinea	0.00	0.00	0.000	0.00	0.00	0.00	0.04	0.00	0.00	0.00
Gastropoda	24.65	0.00	0.76	1.69	0.20	0.00	0.53	0.16	1.40	0.55
Pelecypoda	0.00	0.00	0.25	0.46	0.00	0.00	0.00	0.00	0.00	0.00
Isopoda	0.00	0.00	0.00	0.00	0.00	20.00	0.00	0.00	0.00	0.00
Hydracarina	0.00	0.00	0.34	0.08	0.44	0.00	0.13	0.00	0.58	0.40
Nemertea	0.00	0.00	0.00	0.00	0.00	0.00	2.26	0.90	0.70	2.45
Turbellaria	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.12	0.00
Bivalvia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00
Nematoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35
Turbellaria	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20
Total	100.01	100.00	100.02	100.00	100.00	100.00	99.97	100.01	99.99	100.01

Source: Specht 1994b; Specht and Paller 1995.

Fish

Introduction

Fisheries studies have been conducted at Pen Branch. Apart from an early survey by Bennett and McFarlane (1983) and later studies by Meffe and Sheldon (1989a and b), these studies generally have been motivated by concern about possible impacts to Pen Branch and its tributary, Indian Grave Branch, as a result of SRS operations. The objective of studies conducted prior to 1988 (Aho et al. 1986; Paller and Saul 1987) generally was to assess the impacts of water temperature elevations caused by the discharge of cooling water from K Reactor in Indian Grave Branch and hence to Pen Branch.

In 1988, K Reactor was shut down for maintenance and safety upgrades. The objectives of studies conducted during and after 1988 (Mealing and Paller 1989; Mealing and Heuer 1989a, b, c, and d; Paller et al. 1992) were to monitor the recovery of the fish community in Indian Grave Branch and Pen Branch and assess possible impacts caused by flow perturbations from tests of the K-Reactor pumping system. Fisheries data collected from the Pen Branch system are summarized in Paller et al. (1989).

K-Reactor Operations

Adult Fish

Aho et al. (1986) used multiple-pass electrofishing to sample the fish assemblages in 100-m (328-ft) sample sites in the headwaters of Pen Branch, a relatively unperturbed reach above the confluence of Pen Branch and Indian Grave Branch. Samples also were taken from Steel Creek and Meyers Branch. They found that species richness and community structure were generally comparable among streams with the exception of one relatively depauperate sample site in Pen Branch that had low habitat diversity (PB1 in Table 5-111).

Paller and Saul (1987) sampled the midreach of Pen Branch (i.e., the reach between the Indian Grave Branch/Pen Branch confluence and the delta) during 1984 and 1985. Their sampling was restricted to side channels and pools connected to the main channel because the main channel was too hot to safely electrofish during periods of reactor operation. They found mosquitofish in these relatively cool refugia when the reactor was operating. During outages dollar sunfish (*Lepomis marginatus*) and unidentified juvenile sunfish (*Lepomis* spp.) also were collected from these areas, suggesting recolonization by immigrating fish. During periods of reactor operation, fish were presumably absent from the main channel of the midreach because of extremely high temperatures (>40°C [104°F]).

Aho et al. (1986) studied the fish assemblages in Pen Branch just above the delta and in a similar section of Fourmile Branch in relation to the operating cycles of K and C Reactors, respectively. Their work involved collections made with fyke nets placed in the stream channels during outage periods to monitor the upstream and downstream movements of fish. Few fish were collected from the midreach when heated effluents were being released. However, when water temperatures returned to ambient levels during outages, fish moved upstream into the creek from the Savannah River swamp. Both juveniles and adults rapidly

Table 5-111. Distribution and Percent Composition of the Fish Assemblages Collected from Streams on the Savannah River Site

		Stream Sites[a]								
Scientific Name	**Common Name**	**PB1**	**PB2**	**PB3**	**SC1**	**SC2**	**SC3**	**MB1**	**MB2**	**MB3**
Notropis lutipinnis	yellowfin shiner	-	51.7	50.9	53.8	41.1	9.6	59.4	54.7	43.9
Nocomis leptocephalus	bluehead chub	-	9.7	3.0	13.6	13.2	0.2	8.9	8.0	2.0
Hypentilium nigricans	northern hogsucker	-	-	-	11.3	1.7	0.4	0.6	1.0	1.6
Ictalurus nebulosus	brown bullhead	11.7	1.6	0.3	< 0.1	0.1	0.2	0.1	0.1	0.5
Erimyzon spp. (*oblongus* and *sucetta*)	lake and creek chubsucker	13.0	1.6	1.1	0.9	1.5	0.5	1.6	3.2	1.9
Ictalurus natalis	yellow bullhead	3.2	0.7	0.3	0.1	0.6	0.5	-	0.1	0.8
Ictalurus platycephalus	flat bullhead	-	1.5	0.8	2.0	1.2	0.3	0.1	0.5	0.3
Noturus insignis	margined madtom	-	1.1	4.2	0.6	0.4	0.2	1.0	2.2	0.1
Noturus leptacanthus	speckled madtom	-	-	4.8	2.6	3.2	2.3	1.7	1.8	3.1
Noturus gyrinus	tadpole madtom	-	0.7	0.7	0.2	1.4	0.4	0.9	0.1	0.3
Lepomis marginatus	dollar sunfish	19.4	0.7	0.1	0.2	1.5	0.5	1.4	0.5	0.1
Lepomis auritus	redbreast sunfish	0.9	1.5	5.4	7.2	2.7	3.8	2.2	4.0	1.9
Lepomis punctatus	spotted sunfish	1.9	4.4	4.4	0.4	5.9	14.6	1.5	2.4	4.9
Micropterus salmoides	largemouth bass	-	0.1	0.5	0.4	0.8	2.5	-	0.2	0.1
Anguilla rostrata	American eel	0.7	1.3	0.4	1.2	1.2	3.8	0.4	0.9	10.9
Aphredoderus sayanus	pirate perch	7.8	11.5	8.8	0.2	6.4	11.2	10.6	8.9	9.3
Gambusia affinis	mosquitofish	-	-	-	0.8	5.0	1.9	-	0.1	0.2
Esox niger	chain pickerel	-	0.3	0.5	-	-	0.4	-	0.2	0.1
Esox americanus	redfin pickerel	12.3	5.9	0.6	0.2	1.7	0.9	1.4	0.6	1.4
Acantharchus pomotis	mud sunfish	27.2	1.5	-	-	-	< 0.1	-	0.2	0.1
Notropis chalybaeus	ironcolor shiner	-	0.1	-	< 0.1	-	0.7	-	< 0.1	0.1
Etheostoma fricksium	Savannah darter	-	3.4	3.5	0.3	0.4	0.3	2.7	1.8	1.1
Percina nigrofasciata	blackbanded darter	-	-	4.4	2.3	2.3	1.9	0.3	0.7	1.3
Fundulus lineolatus	lined topminnow	-	-	0.1	-	-	< 0.1	-	0.1	-
Etheostoma olmstedi	tessellated darter	-	-	4.6	0.2	4.3	8.6	1.4	4.8	8.8
Notropis cummingsae	dusky shiner	1.9	0.5	0.4	0.1	1.2	23.8	3.5	1.9	4.4
Amia calva	bowfin	-	-	0.1	-	-	-	-	-	-
Semotilus atromaculatus	creek chub	-	-	-	0.1	0.3	-	0.2	-	-
Notropis petersoni	coastal shiner	-	-	-	-	1.9	7.2	-	-	-
Lepomis gulosus	warmouth	-	-	0.1	< 0.1	-	0.2	0.1	0.1	-
Enneacanthus gloriosus	bluespotted sunfish	-	-	-	0.1	-	0.1	-	0.1	-
Elassoma zonatum	banded pygmy sunfish	-	-	0.1	-	-	< 0.1	-	-	-
Etheostoma serriferum	sawcreek darter	-	-	-	-	-	0.2	-	-	-
Notropis emiliae	pugnose minnow	-	-	-	-	-	0.2	-	-	-
Perca flavescens	yellow perch	-	-	-	0.2	-	< 0.1	-	0.1	0.1
Notemigonus crysoleucas	golden shiner	-	-	-	0.2	-	-	-	-	-
Centrarchus macropterus	flier	-	-	-	-	-	< 0.1	-	< 0.1	0.1
Chologaster cornuta	swampfish	-	-	-	-	-	0.9	-	-	0.1
Ictalurus brunneus	snail bullhead	-	0.1	-	-	-	-	-	< 0.1	-
Umbra pygmaea	eastern mudminnow	-	-	0.1	-	0.1	0.1	-	< 0.1	0.1
Minytrema melanops	spotted sucker	-	-	-	0.8	-	0.8	-	-	-
Etheostoma fusiforme	swamp darter	-	-	0.1	-	-	0.3	-	-	0.1
Hybopsis rubrifrons	rosyface chub	-	-	-	-	-	< 0.1	-	-	-
Notropis leedsi	bannerfin shiner	-	-	-	-	-	< 0.1	-	-	-
Labidesthes sicculus	brook silverside	-	-	-	-	-	0.2	-	-	-
Enneacanthus chaetodon	blackbanded sunfish	-	-	-	-	-	< 0.1	-	< 0.1	-

Table 5-111. (cont)

		Stream Sites[a]								
Scientific Name	**Common Name**	**PB1**	**PB2**	**PB3**	**SC1**	**SC2**	**SC3**	**MB1**	**MB2**	**MB3**
Lepomis macrochirus	bluegill	-	0.1	-	-	-	< 0.1	-	-	-
Fundulus chrysotus	gold topminnow	-	-	-	-	-	-	-	-	0.2
Number of collections		5	8	8	7	7	7	4	8	4
Total number of individuals		309	1519	1809	2531	1174	3415	1579	2823	1501
Mean relative abundance (no. /100 m^2)		41.2	87.5	51.7	80.3	47.9	62.3	104.5	70.6	44.2

Source: Aho et al. 1986.

[a] PB = Pen Branch; SC = Steel Creek; MB = Meyers Branch.

reinvaded the stream channels; individuals were captured within 12 hours of the cessation of reactor operations. In total, 29 species were collected from the midreach of Pen Branch during reactor outages; the most abundant species were spotted sunfish (*L. punctatus*) and lake chubsucker (*Erimyzon oblongus*). Additional information on this study is in Section 5.3—Fourmile Branch.

The delta/swamp of Pen Branch included both disturbed, open-canopy areas where water temperatures elevated to high levels (>40°C [104°F] in some places), and comparatively undisturbed, closed canopy areas deeper in the swamp where water temperatures remained near ambient even during reactor operation.

Paller and Saul (1987) used backpack electrofishing to sample fish during periods of K-Reactor operation in the highly disturbed open-canopy delta of Pen Branch. Mosquitofish (*Gambusia affinis*) dominated the community at this location and were observed in high densities in cooler areas of the delta. Small numbers of spotted sunfish and dollar sunfish also were collected.

Aho et al. (1986) collected fish by electrofishing at 12 sites in the SRS Savannah River floodplain swamp, including three in the comparatively undisturbed area near Stave Island, which lies in the flowpath of Pen Branch. They collected 51 species from the Stave Island area, all of which were year-round residents with the exception of two migratory species: hickory shad (*Alosa mediocris*) and striped mullet (*Mugil cephalus*). Sunfishes and minnows were the dominant taxa in the swamp. Based on habitat analysis and multivariate analyses of fish community structure, Aho et al. (1986) hypothesized that two major habitat gradients influenced fish community structure in the Savannah River swamp. The first corresponded to the degree of habitat disturbance caused by elevated water temperatures, and the second corresponded to the amount of shading by the cypress/tupelo overstory. (This study is discussed more extensively in Section 5.3—Fourmile Branch).

Larval Fish

While not sampled as extensively as the adult fish, larval fish assemblages in Pen Branch have been studied by Paller et al. (1986) and Aho et al. (1986). Larval fish were collected by Paller et al. (1987) from three sampling stations on Pen Branch during 1984 and 1985 (Paller et al. 1985). One station was near Road B in the undisturbed headwaters. The second was located at Road A-13.2 (approximately 7.0 km (4.3 mi) downstream from K Reactor) where water temperatures were well above ambient. The third sample station was among the braided channels, dead cypress and tupelo, and emergent vegetation in the Pen Branch delta; this station was also highly thermal. Fifty-three fish larvae and eggs were collected from Pen Branch between March and July 1984. Most were collected upstream from K Reactor (primarily minnow and darters). However, juvenile mosquitofish and sunfish larvae were collected from the delta and a small number of unidentified eggs were collected from the sampling station near Road A-13.2. The latter probably drifted into the sampling area from relatively cool pools and side channels rather than being produced in the main channel where temperatures often exceeded 40°C (104°F). Similar patterns were observed during 1985 (Paller et al. 1986).

Ichthyoplankton

Aho et al. (1986) collected ichthyoplankton from two sample stations in the Stave Island area of Pen Branch as part of a study of the effects of varying temperature elevations on fish reproduction. At least 10 taxa were collected from the Stave Island sample stations; dominant taxa were darters, sunfishes, and minnows. Aho et al. (1986) found that spawning occurred earlier than usual at thermal sample sites, and that spawning was advanced even near Stave Island where temperatures were only one to two degrees warmer than ambient.

Shutdown of K Reactor

Recolonization of Pen Branch and Indian Grave Branch

Fish recolonized Pen Branch and Indian Grave Branch following the shutdown of K Reactor in April 1988 (Mealing and Paller 1989; Mealing and Heuer 1989a, b, c, and d). Sixteen species were collected from the midreaches of Pen Branch (sample station 3) and eleven species were collected from Indian Grave Branch (sample station 7) between November 1988 and January 1989 (Table 5-112). However, the average number of species (4.8) and the average catch per 100-m stream segment (9.3) were low. Samples collected by Paller et al. (1992) (February-May 1991) yielded significantly greater numbers of species (average of 9.9) and numbers of individuals per 100-m stream segment (average of 78.0), demonstrating further recovery of the fish assemblages in the midreach of Pen Branch.

The Pen Branch delta also was recolonized after K-Reactor shutdown. Mealing and Paller (1989) and Mealing and Heuer (1989a, b, c, and d) collected 14 species from the delta between November 1988 and January 1989; dominant species included spotted sunfish, coastal shiner (*Notropis petersoni*), lake chubsucker, mosquitofish, and dollar sunfish (Table 5-112). The relatively shallow water in the delta was probably responsible for the predominance of small species in this habitat. Mealing and Paller (1989) and Mealing and Heuer (1989a, b, c, and d) also electrofished three transects farther downstream near Stave Island in the closed canopy swamp (sample Station 6). They collected 17 species; large fish such as longnose gar (*Lepisosteus osseus*) and largemouth bass (*Micropterus salmoides*) were well represented in deeper channels (Table 5-112). Other relatively abundant species included brook silversides (*Labidesthes sicculus*) and coastal shiners.

Effects of Artificial Flow Perturbations

During the years following K-Reactor shutdown, high volumes of unheated water were twice pumped into Indian Grave Branch and Pen Branch during tests of the cooling-water

Table 5-112. Percent Composition of Electrofishing Collections from Pen Branch during the Extended Outage of K Reactor, Monthly from November 1988-March 1989

	Sample Station Numbers and Locations						
	Upper Reach		**Midreach**		**Delta/Swamp**		**Indian Grave Branch**
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**
longnose gar				3.3		8.9	
bowfin				1.6	0.1		
American eel	0.7	0.2	2.6	0.8		2.3	3.7
eastern mudminnow	4.2	0.1					
redfin pickerel	10.9	0.3			0.1	0.3	
chain pickerel			12.8	2.4		2.6	
bluehead chub	11.9	5.6					
golden shiner			1.3			0.7	3.7
spottail shiner			1.3			2.3	
yellowfin shiner	17.9	73.6					
taillight shiner						0.7	
coastal shiner				11.4	15.8	18.4	18.5
creek chub		1.1					
creek chubsucker	4.2	0.5	2.6	0.8	0.1	1.6	
lake chubsucker	1.8	0.4	14.1	11.4	19.1	7.2	14.8
spotted sucker			6.4			0.3	22.2
silver redhorse			1.3				
yellow bullhead	4.2			0.8	4.3		3.7
flat bullhead		0.3	1.3				
channel catfish				0.8			
tadpole madtom	2.8	1.2					
margined madtom		0.3					
speckled madtom		1.2					
pirate perch	24.2	5			0.3	0.7	3.7
mosquitofish		0.1			10.9		
lined topminnow	2.1	0.1					
brook silversides			3.8	1.6	0.3	41.8	
Everglades pygmy sunfish						0.3	
bluespotted sunfish					0.1		
mud sunfish	1.1						
redbreast sunfish	2.5	0.5	11.5	6.5	1	1.3	14.8
warmouth			1.3	0.8			
bluegill				0.8		1	
dollar sunfish	1.4			2.4	14.5	0.3	
redear sunfish			3.8	16.3		1.3	
spotted sunfish	9.8	0.5	1.3	3.3	33.1	1.3	3.7
largemouth bass	0.4	0.2	33.3	35		6.6	
Savannah darter		1.8					3.7
Christmas darter		0.7					
tessalated darter		4.3	1.3		0.1		
sawcheek darter		0.1					
blackbanded darter		1.7					7.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Mealing and Heuer 1989d.

pumps. High stream flows can result in the downstream displacement of fishes and marked reductions in the abundance of species that lack the physical and behavioral adaptations necessary to orient in fast waters (Minckley and Meffe 1987; Bain et al. 1988). Electrofishing samples collected before and after a one-week, nine-fold increase in discharge during January 1989 demonstrated a significant reduction in species number and abundance (Paller et al. 1992). A second period of increased discharge, from February to May 1991, had more limited effects consisting of reductions in shiners, spotted sucker, and largemouth bass. Species number, total fish abundance, and condition did not decline or declined only moderately. Differences between 1989 and 1991 may have been related to the extent of fish-assemblage recovery from previous thermal impacts. In 1989, recovery was in its early stages; many species were represented by only a few transient individuals, and flow-sensitive species comprised a relatively high percentage of the community (Paller et al. 1992).

In summary, fish-assemblage structure varied throughout the Pen Branch system, both as a result of the former influence of K-Reactor discharge and from natural changes in habitat and gradient that accompany the spatial transition along Pen Branch from a small headwater stream to a part of the Savannah River swamp. When K Reactor operated, water temperature exerted a controlling influence on community structure. Fish essentially were eliminated from Indian Grave Branch and the mid-reaches of Pen Branch, with the exception of a few species in relatively cool refugia off the main channel. Fish began to recolonize formerly thermal areas after K Reactor was shut down, and considerable recovery had occurred, although habitat degradation resulting from former cooling-water discharges undoubtedly influenced community structure in some areas. In the absence of elevated temperatures, habitat is the primary determinant of community structure with small stream species such as yellowfin shiner (*Notropis lutipinnis*) and bluehead chub (*Nocomis leptocephalus*) inhabiting the upper reaches; sunfishes, chubsuckers, and largemouth bass predominating in the midreaches; and a typical southeastern swamp community including longnose gar, brook silverside, largemouth bass, coastal shiner, and chain pickerel (*Esox niger*) inhabiting the deep swamp reaches.

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5.5 Steel Creek

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Drainage Description and Surface Hydrology

General Description

The headwaters of Steel Creek originate near P Reactor, southwest of Par Pond (Figure 5-47). The creek flows southwesterly about 3 km (1.8 mi) before it enters the headwaters of L Lake. The lake is 6.5 km (4.0 mi) long and relatively narrow, with an area of about 418 ha (1034 acres). Flow from the outfall of L-Lake dam travels about 5 km (3 mi) before entering the SRS Savannah River swamp and then another 3 km (1.8 mi) before entering the Savannah River. Meyers Branch, the main tributary of Steel Creek, flows approximately 10 km (6.2 mi) before entering Steel Creek. Meyers Branch is a small blackwater stream that has remained relatively unperturbed by SRS operations. The confluence of Steel Creek and Meyers Branch is downstream from the L-Lake dam and upstream from SRS Road A. The total area drained by the Steel Creek-Meyers Branch system is about 91 km^2 (35 mi^2) (Specht 1987).

From 1954 to 1968, 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 (1 mi) before entering the Savannah River. Just before it enters the river, the flow from Steel Creek is joined by the flow from Pen Branch and part of the flow from the Fourmile Branch-Beaver Dam Creek system (Specht 1987).

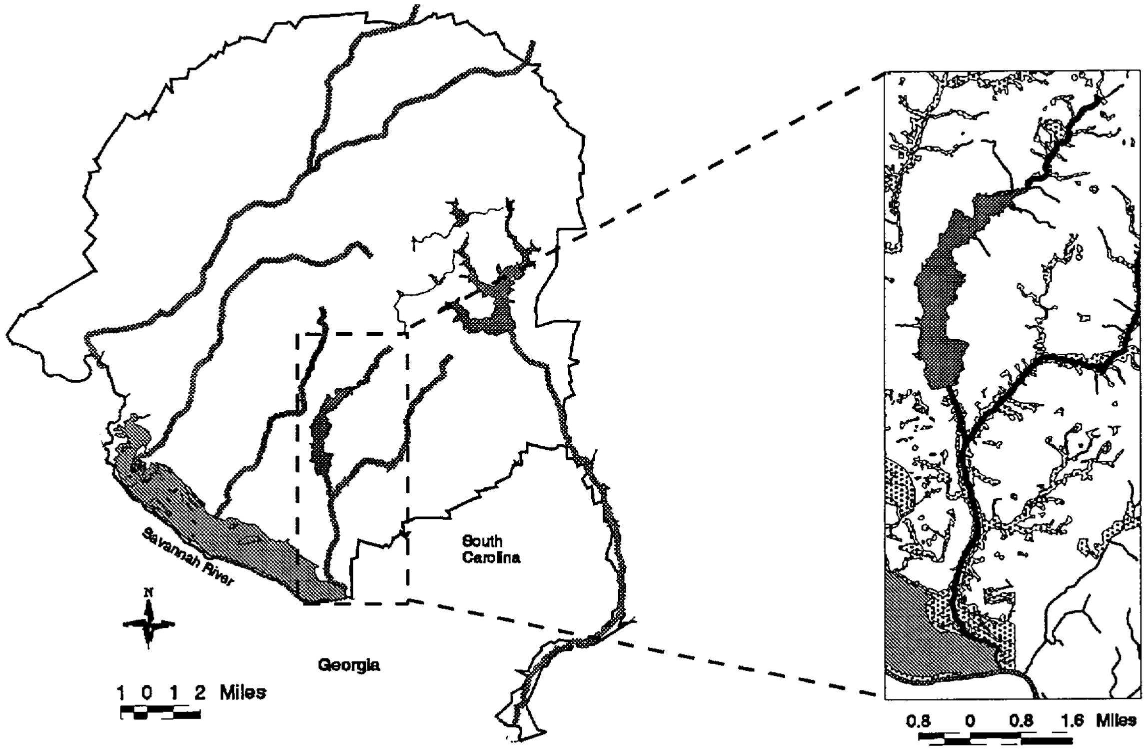

Figure 5-47. Location of Steel Creek on SRS

Effluents Contribution

In 1954, Steel Creek began receiving thermal effluents from P and L Reactors. By 1961, both reactors released a total of 24 m^3/sec (850 ft^3/sec) of thermal effluent into Steel Creek. From 1961 to 1964 P Reactor partially used the Par Pond recirculating system. In 1964, all P-Reactor effluent was diverted to Par Pond, and in 1968 L Reactor was put on standby. From 1968 until early 1985, Steel Creek recovered from the impacts of early SRS operations. In 1981, the U.S. Department of Energy (DOE) initiated activities to restart L Reactor. Based on an environmental assessment of various thermal mitigation alternatives, L Lake was constructed in 1985 along the upper reaches of Steel Creek to receive and cool the heated effluents from L Reactor (restarted in 1985) prior to their release into Steel Creek (Firth et al. 1986). L Reactor was shut down in 1988. Steel Creek also has received nonthermal effluents, including ash basin drainage, nonprocess cooling water, powerhouse waste water, reactor process effluents, sanitary treatment plant effluents, and vehicle wash waters.

Flow Measurements

The U.S. Geological Survey (USGS) measures flow at several locations on Steel Creek. Table 5-113 summarizes flow statistics for Steel Creek at SRS Road A (Figure 5-48). Records for the station at SRS Road A date back to March 1985. Prior to March 1985, this USGS station was farther downstream at the Old Hattiesville Bridge. Flow records at Old Hattiesville Bridge date back to March 1974. In water year 1995, the mean flow of Steel Creek at Road A was 2.4 m^3/s (86.2 ft^3/s). Over the period of record (water years 1985–1995) at Road A, the mean flow was 4.5 m^3/s (160 ft^3/s), the 7-day low flow was 0.33 m^3/s (12.0 ft^3/s), and the 7Q10 was 0.37 m^3/s (12.9 ft^3/s). Figure 5-49 shows the maximum, minimum, and mean daily flows for the period of record at Road A. These data do not represent natural flow conditions. Flows in Steel Creek below L Lake were influenced by the flow requirements mandated by the L-Reactor Operation Final Environmental Impact Statement (EIS) (DOE 1984). The EIS mandated that reactor outages during the spring spawning season had to maintain flow in Steel Creek at Road A at a rate of about 3.0 m^3/sec (106 ft^3/sec). During the remainder of the year, flow would be maintained at a rate of about 1.5 m^3/sec (53 ft^3/sec) at times of reactor outage.

Table 5-113. Flow Summary for Steel Creek

			Range									
			Mean		**Low**		**High**		**7Q10**		**7-Day Low Flow**	
Station Name	**Station Number**	**Period of Record**	**cms**	**cfs**	**cms**	**cfs**	**cms**	**cfs**	**cms**	**cfs**	**cms**	**cfs**
Steel Creek at Road A	021973565	1985-1995	4.5	160	0.22	7.7	14.2	500	0.37	12.9	0.34	12.0

cms = cubic meters per second.
cfs = cubic feet per second.

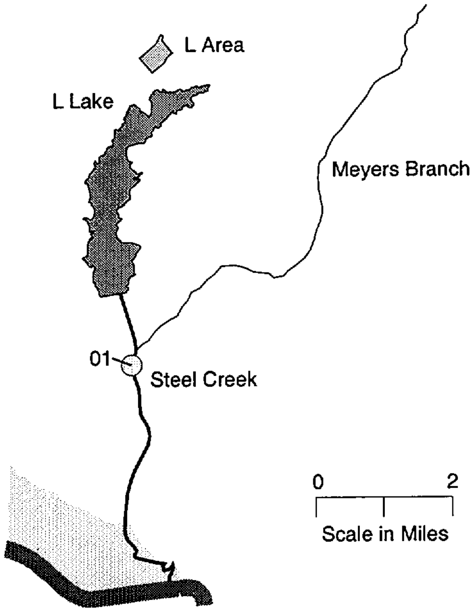

Figure 5-48. Flow Measurement Sampling Station for Steel Creek at Road A.

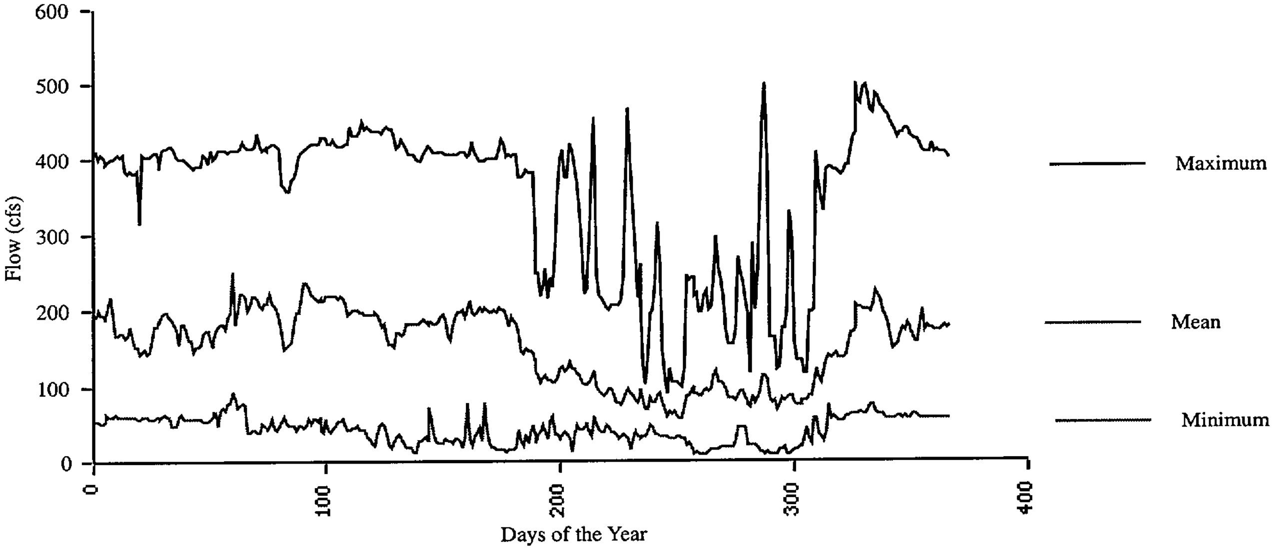

Figure 5-49. Maximum, Mean, and Minimum Flow for Steel Creek at Road A, March 1985-September 1995.

Water Chemistry and Quality

Studies and Monitoring

Water Quality Monitoring

The Westinghouse Savannah River Company Environmental Monitoring Section (EMS) has conducted routine water-quality monitoring of Steel Creek since 1973. One location (Steel Creek at Road A) has been monitored monthly for physical and biological properties and for metals (Figure 5-50). Temperature and dissolved oxygen measurements have also been taken hourly at Road A as part of Consent Order 84-4-W. The Environmental Monitoring Section also collects an additional sample annually and analyzes it for pesticides, herbicides, and PCBs.

Comprehensive Cooling Water Study

Ten locations on Steel Creek (01, 02, 03, 07, and 08), Meyers Branch (04, 05, and 06), and the Steel Creek swamp (09 and 10) were studied from 1983 to 1985 as part of the Comprehensive Cooling Water Study (CCWS). This study was designed to assess present and proposed SRS activities on water quality. Because the CCWS was conducted prior to construction of L Lake, data collected from this study are not representative of conditions in Steel Creek after L Lake. However, these data are presented in the following subsections for comparison purposes. Lower (1987) should be referenced for a synopsis of CCWS data for Steel Creek.

	Station
01	Road B
02	Road A-14
03	Upstream of confluence with Meyers Branch
04	Meyers Branch at Road B-6.2
05	Meyers Branch at Road 9
06	Meyers Branch upstream of confluence with Steel Creek
07	Road A
08	Old Hattiesville Bridge
09	Steel Creek Delta
10	Confluence with Savannah River

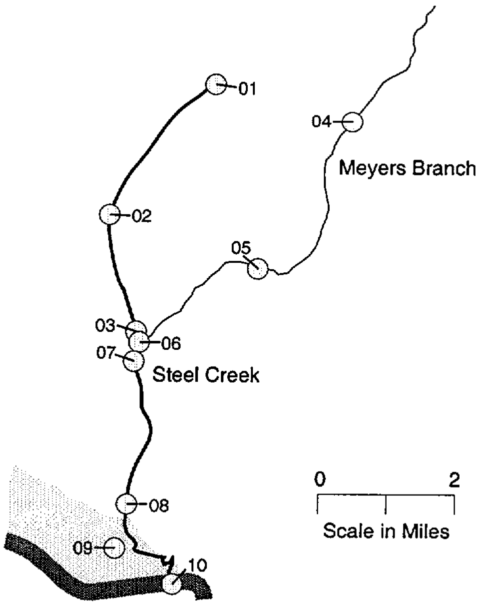

Figure 5-50. Water Quality Monitoring Stations for Steel Creek prior to construction of L Lake, 1983-1985

Priority Pollutants Survey

In 1984, a special instream survey of priority pollutants was conducted to determine the levels of volatile, acid, and base/neutral compounds in Steel Creek. Two locations - Steel Creek at Road B (01) and at Road A (07) - were sampled for this study. The results of this study are discussed later in this chapter and documented in Lower (1987).

Chemical Assessment Studies

In 1985, the L Lake/Steel Creek Biological Monitoring Program was initiated to assess various components of the system and identify any changes due to the operation of L Reactor or discharge from L Lake. The study was designed to meet environmental regulatory requirements associated with the restart of L Reactor and was driven primarily by Section 316(a) of the Clean Water Act. Kretchmer and Chimney (1992) reports the results of Steel Creek water quality over the six years of the study. A summary of their report is provided later in this chapter.

Field Data

Water Temperature

Water temperatures measured in Steel Creek since construction of L Lake have been similar to preconstruction conditions, with a range of 7.1-30°C (44.7-86°F), and an average of 19°C (66.2°F) (Table 5-114).

pH Measurements

The pH of Steel Creek at Road A ranged from 5.1-8.3 between 1987 and 1995. Similar pHs were measured prior to the construction of L Lake with pH ranges from 6 to 8.4 (Table 5-114).

Physical Characteristics and General Chemistry

Dissolved Oxygen

Concentrations of dissolved oxygen in Steel Creek at Road A reflect the lack of thermal input to the creek (range 5.0-14.8 mg/l; mean 8.1 mg/l). These concentrations, measured from 1987 to 1991, are similar to concentrations measured during the CCWS (Table 5-115).

Suspended Solids and Turbidity

Mean total suspended solids and turbidity levels in Steel Creek were 5.3 mg/l and 3.7 NTU, respectively, from 1987 to 1991 and 3.75 mg/l and 2.56 NTU, respectively from 1992 to 1995. These levels are within the ranges measured prior to the construction of L Lake (Table 5-115).

Conductivity

From 1987 to 1995, specific conductivity in Steel Creek at Road A ranged from 10 to 92 µS/cm (Table 5-115). These measurements are similar to those measured during the CCWS.

Table 5-114. Steel Creek Field Data

	Water Temperature (°C)	**pH**	**Stream Maximum Depth (cm)**	**Stream Velocity (cm/sec)**
Steel Creek at Road B (CCWS)[a]				
Mean	18.1	7.07	27	53
Range	4.6 - 27.5	6.20 - 8.30	15 - 57	10 - 115
Samples	46	46	22	41
Steel Creek at Road A-14 (CCWS)[a]				
Mean	18.7	7.03	43	55
Range	5.5 - 29.7	6.50 - 8.10	24 - 64	11 - 98
Samples	46	46	19	41
Steel Creek upstream of Meyers Branch (CCWS)[a]				
Mean	17.8	7.00	34	50
Range	6.4 - 31.7	6.10 - 8.10	0 - 53	0 - 75
Samples	44	46	35	39
Meyers Branch at Road B-6.2 (CCWS)[a]				
Mean	15.5	6.73	49	26
Range	0.6 - 25.2	5.80 - 8.30	35 - 111	5 - 82
Samples	46	46	40	41
Meyers Branch at Road 9 (CCWS)[a]				
Mean	15.0	6.90	47	26
Range	0.5 - 22.5	5.90 - 8.30	35 - 99	9 - 55
Samples	46	46	28	41
Meyers Branch upstream of Steel Creek confluence (CCWS)[a]				
Mean	16.7	6.93	52	33
Range	0.1 - 25.5	6.00 - 8.30	23 - 90	15 - 70
Samples	44	44	39	40
Steel Creek at Old Hattiesville Bridge (CCWS)[a]				
Mean	16.3	7.01	65	40
Range	2.6 - 27.5	6.00 - 8.40	30 - 100	19 - 56
Samples	46	46	40	41
Steel Creek swamp upstream of Pen Branch confluence (CCWS)[a]				
Mean	17.6	6.90	121	25
Range	1.0 - 28.0	6.10 - 8.10	32 - 278	3 - 48
Samples	43	44	30	38
Steel Creek upstream of confluence with Savannah River (CCWS)[a]				
Mean	17.3	6.93	219	44
Range	0.8 - 27.5	6.40 - 8.10	138 - 504	3 - 112
Samples	46	46	36	38
Steel Creek at Road A (1987-1991)[b]				
Mean	19			
Range	7.1 - 30	5.6 - 8.3	NA	NA
Samples	60	60		
Steel Creek at Road A (1992-1995)[b]				
Mean	19.2	6.8	NA	NA
Range	8.7 - 29.6	5.1 - 7.4		
Samples	48	48		

NA = Not analyzed.

Blank Spaces = mean not calculated due to insufficient data in report.

[a] CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).

[b] 1987-1995 = Data from Arnett 1993, 1994, 1995, 1996; Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; and Mikol et al. 1988.

Table 5-115. Steel Creek Physical Characteristics and General Chemistry

	Dissolved Oxygen (mg/l)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Total Suspended Solids (mg/l)
Steel Creek at Road B (CCWS)[a]				
Mean	8.33	58.9	76.4	26.0
Range	5.90 - 11.4	22.9 - 78.6	4.6 - 193	0.25 - 345
Samples	46	38	43	45
Steel Creek at Road A-14 (CCWS)[a]				
Mean	7.92	67.0	37.5	21.4
Range	4.60 - 11.4	27.2 - 167	2.80 - 200	0.25 - 134
Samples	46	38	43	45
Steel Creek upstream of Meyers Branch (CCWS)[a]				
Mean	7.94	68.5	40.9	17.0
Range	4.70 - 11.9	36.4 - 128	8.30 - 283	0.40 - 97.2
Samples	43	36	41	43
Meyers Branch at Road B-6.2 (CCWS)[a]				
Mean	7.09	52.7	5.50	6.13
Range	4.20 - 11.6	26.8 - 70.9	1.50 - 35.0	0.25 - 93.2
Samples	44	38	43	45
Meyers Branch at Road 9 (CCWS)[a]				
Mean	8.20	43.1	7.00	4.78
Range	5.20 - 12.2	25.0 - 61.0	1.60 - 47.0	0.25 - 31.2
Samples	45	38	43	45
Meyers Branch upstream of Steel Creek confluence (CCWS)[a]				
Mean	7.94	48.3	5.60	4.67
Range	5.10 - 12.4	30.4 - 72.4	1.60 - 18.8	0.25 - 17.2
Samples	44	37	42	44
Steel Creek at Old Hattiesville Bridge (CCWS)[a]				
Mean	7.42	62.5	26.3	10.8
Range	3.50 - 10.9	34.2 - 117	6.70 - 240	1.20 - 69.2
Samples	45	38	43	45
Steel Creek swamp upstream of Pen Branch confluence (CCWS)[a]				
Mean	6.69	68.5	6.10	2.49
Range	3.50 - 13.6	38.4 - 93.4	1.70 - 24.8	0.25 - 7.60
Samples	44	36	43	43
Steel Creek upstream of confluence with Savannah River (CCWS)[a]				
Mean	6.73	71.5	7.00	5.18
Range	3.40 - 13.1	46.2 - 91.6	2.50 - 25.3	0.25 - 16.3
Samples	46	38	43	45
Steel Creek at Road A (1987-1991)[b]				
Mean	8.1	59	3.7	5.3
Range	5.0 - 12	10 - 92	0.93 - 22	1.0 - 14
Samples	60	60	59	60
Steel Creek at Road A, (1992-1995)[b]				
Mean	8.5	66	2.6	3.8
Range	5.9 - 14.8	52- 80	0.86 - 4.9	1 - 19
Samples	48	48	48	48

NA = Not analyzed.

Blank Spaces = mean not calculated due to insufficient data in report.

[a] CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).

[b] 1987-1995 = Data from Arnett 1993, 1994, 1995, 1996; Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988.

Major Anions and Cations

Alkalinity, Chloride, and Sulfate

Alkalinity concentrations in Steel Creek at Road A ranged from 1.0 to 21 mg $CaCO_3$/l from 1987 to 1995, which was slightly lower than the range of measurements taken during the CCWS (Table 5-116). Chloride and sulfate concentrations measured during the same period were higher than data collected during the CCWS. Mean chloride and sulfate concentrations at Road A from 1987 to 1991 were 6.7 mg/l and 6.9 mg/l, respectively, and from 1992 to 1995 were 6.64 mg/l and 6.12 mg/l, respectively.

Calcium, Magnesium, Sodium, and Potassium

From 1987 to 1991, calcium concentrations ranged from 1.8 to 3.8 mg/l, and sodium concentrations ranged from 5.4 to 11.7 mg/l. These concentrations are slightly lower than the concentrations measured during the CCWS (Table 5-117). Magnesium concentrations ranged from 0.76 mg/l to 1.4 mg/l, which is in the range measured during the CCWS. Potassium is not measured during routine water quality monitoring.

Aluminum, Manganese, and Iron

Concentrations of aluminum, iron, and manganese have been much lower since the construction of L Lake (Table 5-117). From 1987 to 1991, aluminum ranged from <0.01 to 0.16 mg/l; iron ranged from <0.02 to 0.26 mg/l; and manganese ranged from <0.01 to 0.17 mg/l. Between 1992 and 1995, aluminum ranged from <0.01 to 0.28 mg/l, iron ranged from 0.05 to 0.59 mg/l, and manganese ranged from <0.01 to 0.10 mg/l.

Nutrients

Phosphorus

Total phosphorus is the only form of phosphorus measured during routine water quality monitoring. From 1987 to 1991, the mean total phosphorus concentration in Steel Creek at Road A was 0.032 mg/l, which is similar to the mean measured during the CCWS (Table 5-118). From 1992 to 1995, the mean total phosphorus concentration in Steel Creek at Road A was 0.02 mg/l (Table 5-118).

Nitrogen

Organic nitrogen, ammonia, and nitrate are the only forms of nitrogen measured during the Steel Creek routine water quality monitoring program. All forms of nitrogen have been higher in Steel Creek at Road A since the construction of L Lake. The means for these forms of nitrogen were as follows between 1987 and 1991: 0.37 mg/l organic nitrogen; 0.076
mg/l ammonia; and 1.00 mg/l nitrate. From 1992 to 1995, means were: 0.33 mg/l Kjeldahl nitrogen; 0.08 mg/l ammonia; and 0.18 mg/l nitrate (Table 5-118).

Table 5-116. Steel Creek Major Anions

	Alkalinity (mg $CaCO^3$/l)	**Chloride (mg/l)**	**Sulfate (mg/l)**
Steel Creek at Road B (CCWS)[a]			
Mean	14.8	5.16	3.84
Range	0.75 - 20.0	1.90 - 7.40	0.25 - 15.8
Samples	45	46	28
Steel Creek at Road A-14 (CCWS)[a]			
Mean	17.1	5.63	4.24
Range	4.75 - 32.7	1.60 - 27.4	0.25 - 11.0
Samples	45	46	28
Steel Creek upstream of Meyers Branch (CCWS)[a]			
Mean	17.1	5.33	4.93
Range	6.15 - 26.4	2.30 - 27.4	1.06 - 13.4
Samples	42	44	26
Meyers Branch at Road B-6.2 (CCWS)[a]			
Mean	15.0	3.95	1.85
Range	3.25 - 27.8	2.10 - 6.90	0.03 - 8.45
Samples	45	46	27
Meyers Branch at Road 9 (CCWS)[a]			
Mean	13.7	2.80	0.91
Range	3.54 - 25.3	1.30 - 4.20	0.13 - 5.61
Samples	45	45	26
Meyers Branch upstream of Steel Creek confluence (CCWS)[a]			
Mean	16.9	2.66	0.81
Range	3.75 - 26.9	1.60 - 4.20	0.06 - 5.48
Samples	44	45	25
Steel Creek at Old Hattiesville Bridge (CCWS)[a]			
Mean	17.8	4.52	3.65
Range	4.83 - 31.3	2.10 - 14.4	0.25 - 14.7
Samples	44	46	28
Steel Creek upstream of Pen Branch confluence (CCWS)[a]			
Mean	18.0	5.21	4.60
Range	10.5 - 24.6	2.20 - 8.10	1.09 - 8.45
Samples	43	44	26
Steel Creek upstream of confluence with Savannah River (CCWS)[a]			
Mean	18.4	5.59	5.23
Range	11.8 - 26.2	2.20 - 7.90	1.90 - 8.98
Samples	45	46	28
Steel Creek at Road A (1987-1991)[b]			
Mean	15	6.7	6.9
Range	1.0 - 21	1.9 - 9.6	2.0 - 56
Samples	60	60	60
Steel Creek at Road A, (1992-1995)[b]			
Mean	13.75	6.64	6.12
Range	11 - 18	3.54 - 14.48	4 - 8
Samples	48	48	48

NA = Not analyzed.

Blank Spaces = mean not calculated due to insufficient data in report.

[a] CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).

[b] 1987-1995 = Data from Arnett 1993, 1994, 1995, 1996; Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988.

Table 5-117. Steel Creek Major Cations (Total)

	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Aluminum (mg/l)	Iron (mg/l)	Manganese (mg/l)
Steel Creek at Road B (CCWS)[a]							
Mean	4.13	0.910	4.33	0.700	3.51	1.88	0.141
Range	1.14 - 6.16	0.388 - 1.33	1.82 - 6.33	<0.368 - 1.66	0.201 - 75.1	0.289 - 35.9	<0.0004 - 1.43
Samples	39	39	39	39	39	39	16
Steel Creek at Road A-14 (CCWS)[a]							
Mean	4.42	1.01	5.46	0.831	1.80	1.52	0.070
Range	1.64 - 9.07	0.175 - 1.30	1.57 - 23.0	<0.368 - 2.64	0.390 - 9.88	0.712 - 5.04	<0.0004 - 0.141
Samples	39	39	39	39	39	39	16
Steel Creek upstream of Meyers Branch (CCWS)[a]							
Mean	4.51	1.03	5.40	0.817	1.85	1.60	0.076
Range	2.62 - 6.72	0.526 - 1.40	1.61 - 15.7	<0.368 - 2.18	0.312 - 14.4	0.448 - 6.24	<0.0004 - 0.210
Samples	37	37	37	37	37	37	16
Meyers Branch at Road B-6.2 (CCWS)[a]							
Mean	5.00	0.791	2.94	0.518	0.480	0.979	0.089
Range	1.47 - 8.40	0.336 - 1.41	1.37 - 8.37	<0.368 - 1.38	<0.038 - 3.80	0.198 - 5.89	<0.0004 - 0.294
Samples	39	39	39	39	39	39	15
Meyers Branch at Road 9 (CCWS)[a]							
Mean	4.98	0.557	2.05	<0.368	0.460	0.845	0.092
Range	2.58 - 7.26	0.426 - 0.956	1.41 - 4.92	<0.368 - 1.03	0.087 - 1.94	0.248 - 1.73	<0.0004 - 0.430
Samples	38	38	38	38	38	38	16
Meyers Branch upstream of Steel Creek confluence (CCWS)[a]							
Mean	6.15	0.572	2.45	<0.368	0.619	0.794	0.082
Range	2.09 - 9.10	0.203 - 1.34	0.558 - 13.7	<0.368 - 1.39	0.070 - 2.40	0.258 - 1.26	<0.0004 - 0.286
Samples	36	36	36	36	36	36	16
Steel Creek at Old Hattiesville Bridge (CCWS)[a]							
Mean	5.43	0.878	4.28	0.635	1.45	1.70	0.125
Range	2.69 - 9.55	0.156 - 1.17	1.61 - 11.9	<0.368 - 2.06	0.248 - 19.2	0.577 - 7.83	<0.0004 - 0.293
Samples	39	39	39	39	39	39	16
Steel Creek swamp upstream of Pen Branch confluence (CCWS)[a]							
Mean	3.86	1.16	6.15	0.769	0.462	1.54	0.095
Range	2.65 - 5.29	0.786 - 1.61	2.00 - 11.9	<0.368 - 1.69	<0.038 - 2.87	0.316 - 18.2	<0.0004 - 0.182
Samples	37	37	37	37	37	37	17
Steel Creek upstream of confluence with Savannah River (CCWS)[a]							
Mean	3.57	1.22	6.47	0.827	0.461	0.976	0.080
Range	2.68 - 4.64	1.02 - 1.49	2.43 - 10.8	<0.368 - 1.69	0.147 - 1.48	0.329 - 1.56	<0.0004 - 0.281
Samples	39	39	39	39	39	39	17
Steel Creek at Road A (1987-1991)[b]							
Mean							
Range	1.9 - 3.8	0.89 - 1.4	5.4 - 11.0	NA	<0.01 - 0.16	<0.02 - 0.26	<0.01 - 0.17
Samples	18	18	20		19	20	18
Steel Creek at Road A (1992-1995)[b]							
Mean	2.32	1.07	7.57	NA	0.12	0.25	0.038
Range	1.74 - 3.06	0.764 - 1.41	5.44 - 11.70		<0.01 - 0.28	0.053 - 0.59	0.008 - 0.101
Samples	16	16	16		13	13	13

NA = Not analyzed.

Blank Spaces = mean not calculated due to insufficient data in report.

[a] CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).

[b] 1987-1995 = Data from Arnett 1993, 1994, 1995, 1996; Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988.

Table 5-118. Steel Creek Nutrients

	Total Phosphorus (mg/l)	Total Ortho-phos-phate (mg /l)	Organic Nitrogen (mg /l)	Total Kjeldahl Nitrogen (mg /l)	Ammonia (mg /l)	Nitrite (mg/l)	Nitrate (mg/l)
Steel Creek at Road B (CCWS)[a]							
Mean	0.036	0.009	0.211	0.227	0.028	0.003	0.201
Range	<0.010 - 0.391	0.002 - 0.033	0.170 - 0.885	0.012 - 0.900	<0.005 - 0.340	<0.001 - 0.020	0.019 - 0.450
Samples	46	39	45	46	46	44	42
Steel Creek at Road A-14 (CCWS)[a]							
Mean	0.067	0.034	0.229	0.252	0.037	0.004	0.207
Range	<0.010 - 0.362	0.005 - 0.123	0.022 - 0.895	0.020 - 0.920	<0.005 - 0.450	<0.001 - 0.013	0.005 - 0.400
Samples	46	40	45	46	46	44	43
Steel Creek upstream of Meyers Branch (CCWS)[a]							
Mean	0.062	0.031	0.203	0.218	0.037	0.004	0.207
Range	<0.010 - 0.181	0.003 - 0.201	0.020 - 0.840	0.048 - 0.910	<0.005 - 0.430	<0.001 - 0.012	0.072 - 0.410
Samples	45	39	42	45	43	42	41
Meyers Branch at Road B-6.2 (CCWS)[a]							
Mean	0.023	0.007	0.227	0.246	0.028	0.002	0.099
Range	<0.010 - 0.123	<0.001 - 0.024	0.021 - 0.764	0.048 - 0.800	<0.005 - 0.230	<0.001 - 0.005	0.013 - 0.220
Samples	46	41	45	46	46	44	43
Meyers Branch at Road 9 (CCWS)[a]							
Mean	0.028	0.006	0.257	0.276	0.026	0.002	0.109
Range	<0.010 - 0.406	<0.001 - 0.013	0.038 - 0.959	0.057 - 1.00	<0.005 - 0.390	<0.001 - 0.010	0.019 - 0.206
Samples	46	41	45	46	46	43	42
Meyers Branch upstream of Steel Creek confluence (CCWS)[a]							
Mean	0.022	0.007	0.250	0.251	0.030	0.002	0.092
Range	<0.010 - 0.072	<0.001 - 0.028	0.041 - 0.858	0.010 - 0.870	<0.005 - 0.060	<0.001 - 0.008	0.010 - 0.188
Samples	46	40	43	45	45	43	42
Steel Creek at Old Hattiesville Bridge (CCWS)[a]							
Mean	0.056	0.022	0.202	0.224	0.036	0.003	0.146
Range	<0.010 - 0.261	0.003 - 0.062	0.033 - 0.887	0.038 - 0.900	<0.005 - 0.280	<0.001 - 0.010	0.005 - 0.305
Samples	46	41	44	46	46	44	43
Steel Creek swamp upstream of Pen Branch confluence (CCWS)[a]							
Mean	0.054	0.036	0.205	0.219	0.027	0.002	0.075
Range	<0.010 - 0.161	0.005 - 0.096	0.039 - 0.543	0.028 - 0.560	0.005 - 0.390	<0.001 - 0.005	0.005 - 0.240
Samples	44	39	43	46	44	42	41
Steel Creek upstream of confluence with Savannah River (CCWS)[a]							
Mean	0.057	0.035	0.235	0.250	0.024	0.003	0.075
Range	<0.010 - 0.161	0.005 - 0.077	0.031 - 0.945	0.028 - 0.950	0.005 - 0.210	<0.001 - 0.012	0.003 - 0.228
Samples	44	40	45	46	46	43	42
Steel Creek at Road A (1987-1991)[b]							
Mean	0.032		0.37		0.076		1.00
Range	<0.01 - 0.36	NA	<0.1 - 1.9	NA	<0.01 - 0.30	NA	0.02 - 0.39
Samples	60		60		60		60
Steel Creek at Road A (1992-1995)[b]							
Mean[c]	0.02	NA	0.095[d]	0.33[e]	0.08	NA	0.18[f]
Range	ND - 0.03		0.02 - 0.17	ND - 0.92	ND - 0.19		0.12 - 0.31
Samples	12		23	27	27		24

NA = Not analyzed.

ND = None detected.

Blank Spaces = Mean not calculated due to insufficient data in report.

[a] CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).

[b] 1987-1995 = Data from Arnett 1993, 1994, 1995, 1996; Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988.

[c] All nondetectable quantities were excluded from the calculation of means.

[d] 1992-1993; nitrate + nitrite.

[e] 1993-1995.

[f] 1994-1995.

Table 5-119. Steel Creek Trace Elements (Total)

	Arsenic (µg/l)	Cadmium (µg/l)	Chromium (µg/l)	Copper (µg/l)	Lead (µg/l)	Nickel (µg/l)	Zinc (µg/l)
Steel Creek at Road B (CCWS)[a]							
Mean	2.8	0.32	4.9	3.8	2.0	4.6	4.8
Range	<0.4 - 12.0	<0.04 - 1.20	<0.4 - 41.0	<0.4 - 24.0	<0.4 - 9.0	<0.4 - 26.3	<0.4 - 26.1
Samples	16	16	16	16	16	16	16
Steel Creek at Road A-14 (CCWS)[a]							
Mean	3.9	0.50	6.2	2.9	1.8	3.7	6.2
Range	<0.4 - 22.1	<0.04 - 5.00	<0.4 - 46.0	<0.4 - 5.2	<0.4 - 9.3	<0.4 - 12.0	<0.4 - 28.8
Samples	16	16	16	16	16	16	16
Steel Creek upstream of Meyers Branch (CCWS)[a]							
Mean	2.4	0.50	6.1	2.3	2.2	4.0	12.4
Range	<0.4 - 8.1	<0.04 - 4.50	<0.4 - 46.0	<0.4 - 5.0	<0.4 - 7.3	<0.4 - 14.1	<0.4 - 119
Samples	16	16	16	16	16	16	16
Meyers Branch at Road B-6.2 (CCWS)[a]							
Mean	1.7	0.76	8.3	1.9	2.6	2.0	6.0
Range	<0.4 - 6.8	<0.04 - 6.20	<0.4 - 59.0	<0.4 - 4.2	<0.4 - 19.8	<0.4 - 7.0	<0.4 - 30.0
Samples	15	15	15	15	15	15	15
Meyers Branch at Road 9 (CCWS)[a]							
Mean	1.3	0.54	6.1	2.7	1.5	2.1	5.1
Range	<0.4 - 16.0	<0.04 - 3.10	<0.4 - 50.0	<0.4 - 12.8	<0.4 - 3.7	<0.4 - 8.4	<0.4 - 23.5
Samples	16	16	16	16	16	16	16
Meyers Branch upstream of Pen Branch confluence (CCWS)[a]							
Mean	1.7	0.49	6.9	2.2	1.3	4.7	5.3
Range	<0.4 - 7.8	<0.04 - 2.50	<0.4 - 47.0	<0.4 - 12.8	<0.4 - 5.3	<0.4 - 44.5	<0.4 - 21.6
Samples	16	16	16	16	16	16	16
Steel Creek at Old Hattiesville Bridge (CCWS)[a]							
Mean	2.4	0.26	7.8	2.6	1.7	3.9	6.3
Range	<0.4 - 8.2	<0.04 - 1.40	<0.4 - 55.0	<0.4 - 9.5	<0.4 - 7.0	<0.4 - 13.0	<0.4 - 25.8
Samples	16	16	16	16	16	16	16
Steel Creek swamp upstream of Pen Branch confluence (CCWS)[a]							
Mean	1.5	0.61	4.0	1.7	1.4	2.0	5.2
Range	<0.4 - 8.9	<0.04 - 5.00	<0.4 - 31.0	<0.4 - 4.2	<0.4 - 3.3	<0.4 - 7.0	<0.4 - 22.0
Samples	17	17	17	17	17	17	17
Steel Creek upstream of confluence with Savannah River (CCWS)[a]							
Mean	1.5	0.71	8.8	2.1	2.0	2.3	4.0
Range	<0.4 - 6.4	<0.04 - 7.00	<0.4 - 58.0	<0.4 - 8.1	<0.4 - 7.3	<0.4 - 6.7	<0.4 - 12.4
Samples	17	17	17	17	17	17	17
Steel Creek at Road A (1987-1991)[b]							
Mean							
Range	NA	<10	<10 - <50	<10 - 30	<3 - 20	<10 - 70	<10 - 50
Samples		20	20	20	20	20	20
Steel Creek at Road A (1992-1995)[b]							
Mean[c]	NA	<10	<15	<13	<5	<30	22
Range		ND - <10	ND - <20	ND - 40	ND - <10	ND - <50	ND - 45
Samples		4	4	9	6	4	7

NA = Not analyzed.

ND = None detected.

Blank Spaces = mean not calculated due to insufficient data in report.

[a] CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).

[b] 1987-1995 = Data from Arnett 1993, 1994, 1995, 1996; Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; Mikol et al. 1988.

[c] All non-detectable quantities were excluded from the means calculations.

Trace Elements

Maximum concentrations of trace elements detected in Steel Creek at Road A ranged from 5 µg/l of cadmium to 46 µg/l of chromium (Table 5-119). Nickel had a maximum concentration of 70 µg/l. Lead and zinc were detected at 30 µg/l and 50 µg/l, respectively.

Organic Carbon

Organic carbon is not measured during routine water quality monitoring.

Priority Pollutants

Lower (1987) reported the results of a special study to determine the levels of volatile, acid, base, and neutral organics in Steel Creek. Concentrations of all 88 tested organics were below detection limits at both the Steel Creek Road B and Road A sampling locations.

Pesticides, Herbicides, PCBs, and Volatile Organic Compounds

Water samples are collected annually from Steel Creek at Road A during routine water quality monitoring and analyzed for pesticides, herbicides, PCBs and volatile organic compounds. From 1987 to 1994, no analytes were detected in Steel Creek. In 1995, pesticides were detected (Arnett and Mamatey 1996).

Lower (1987) reported the results of analyses for pesticides, herbicides, and PCBs from 1982 to 1985; results from 1967 to 1981 can be found in Gladden et al. (1985). During these periods, concentrations were also near or below detection limits at all locations.

L-Lake/Steel Creek Biological Monitoring Program

The L-Lake/Steel Creek Biological Monitoring Program was an extensive water quality monitoring study initiated after the construction of L Lake. This study was designed to assess various components of the Steel Creek system and identify changes due to the operation of L Reactor or discharge from L Lake. Thirteen sampling stations were located throughout the Steel Creek corridor, marsh, swamp, and channel (Figure 5-51). Table 5-120 contains the range of values for 34 water quality parameters for Steel Creek from November 1985 to December 1991.

Steel Creek water quality during the Steel Creek Biological Monitoring Program was found to be similar to the range of values reported for other regional lotic systems and judged to be typical of southeastern waters in general (Kretchmer and Chimney 1992).

During parts of the study downstream gradients were observed between corridor Stations 275 (just below the L-Lake dam) and 290 (Old Hattiesville Bridge) for temperature, dissolved oxygen, pH total organic and inorganic carbon, ortho- and total phosphorus, nitrite-nitrogen, nitrate-nitrogen, and ammonia-nitrogen, total inorganic nitrogen, silica, total aluminum, total and dissolved iron, total and dissolved sodium, chloride, total and dissolved magnesium, total and dissolved potassium, and total and dissolved calcium. These differ-

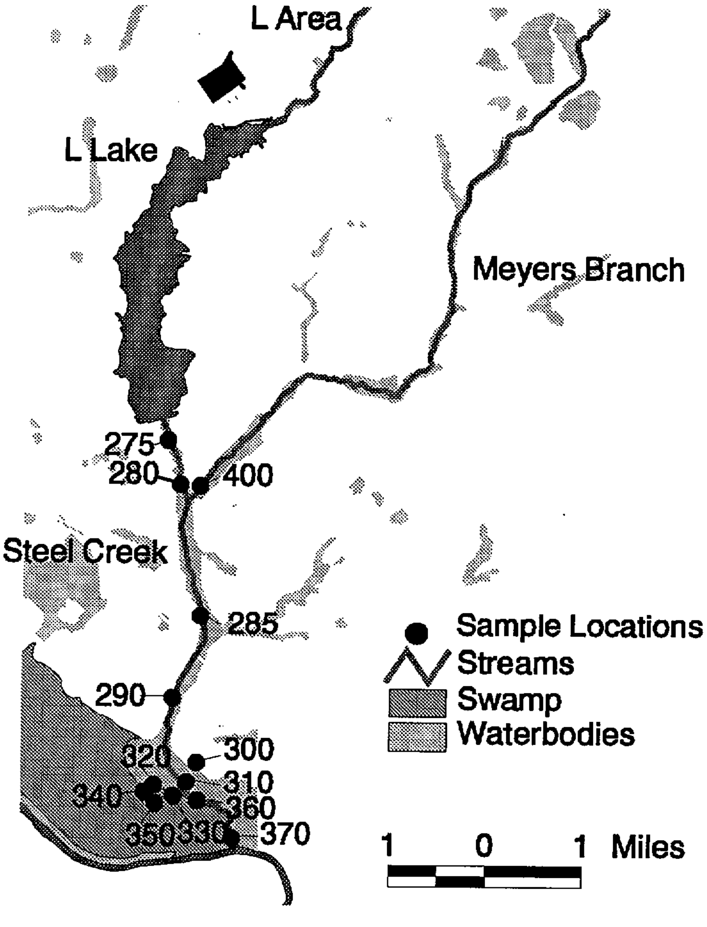

Figure 5-51. Sampling Stations used during the Steel Creek Biological Monitoring Program, 1985-1992

Table 5-120. Water Quality Data (range of values) for Steel Creek, November 1985-December 1991

	Temperature (°C)	Dissolved Oxygen (mg/l)	pH	Specific Conductivity (μS/cm)	Total Diss. Solids (mg/l)	Total Sus. Solids (mg/l)	Total Org. Carbon (mg/l)
Steel Creek (1985-1986)							
Corridor	10.9 - 29.9	4.9 - 11.1	5.4 - 6.2	41 - 97	29 - 74	<1 - 204	4 - 12
Swamp/ delta	7.6 - 27.7	0.6 - 11.4	4.8 - 7.3	22 - 135	7 - 84	4 - 40	3 - 13
Steel Creek (1987-1991)							
Corridor	6.6 - 29.3	4.7 - 13.0	5.3 - 8.5	18 - 126	27 - 83	1 - 59	1 - 8
Swamp/ delta	1.3 - 28.9	1.9 - 12.5	5.0 - 7.7	23 - 114	23 - 91	<1 - 148	1 - 19

	Diss. Org. Carbon (mg/l)	Total Inorg. Carbon (mg/l)	Alkalinity (mg/l)	Ortho-phosphate (mg/l)	Tot. Phosphorus (mg/l)	Nitrite (mg/l)	Nitrate (mg/l)
Steel Creek (1985-1986)							
Corridor	4 - 9	2 - 8	6.4 - 23.7	<5 - 87	18 - 343	1 - 20	<10 - 402
Swamp/ delta	3 - 12	1 - 13	1.8 - 50.0	<5 - 51	8 - 154	<1 - 5	<10 - 582
Steel Creek (1987-1991)							
Corridor	2 - 10	2 - 6	9 - 23	<5 - 136	19 - 180	<1 - 82	<10 - 611
Swamp/ delta	1 - 17	2 - 10	7 - 37	5 - 67	19 - 494	1 - 13	<10 - 366

	Ammonia (mg/l)	Total Inorg. Nitrogen (mg/l)	Silica (mg/l)	Total Aluminum (mg/l)	Diss. Aluminum (mg/l)	Total Calcium (mg/l)	Diss. Calcium (mg/l)
Steel Creek (1985-1986)							
Corridor	11 - 764	27 - 808	3.2 - 10.7	<100 - 991	<100 - 905	2.6 - 4.4	2.8 - 5.8
Swamp/ delta	<10 - 190	21 - 664	1.2 - 13.3	<100 - 1210	<100 - 1270	2.7 - 11.5	2.4 - 11.1
Steel Creek (1987-1991)							
Corridor	<10 - 1080	17 - 1119	0.8 - 9.7	<100 - 1216	<100 - 202	311 - 4.8	1.1 - 4.8
Swamp/ delta	<10 - 157	<10 - 407	0.6 - 19.1	<100 - 449	<100 - 240	2.6 - 7.8	1.9 - 7.8

	Tot. Iron (mg/l)	Diss. Iron (mg/l)	Total Magne-sium (mg/l)	Diss. Magnesium (mg/l)	Total Manganese (mg/l)	Diss. Manganese (mg/l)	Total Potassium (mg/l)
Steel Creek (1985-1986)							
Corridor	0.1 - 3.8	<0.1 - 3.2	0.74 - 1.94	0.70 - 2.01	<20 - 563	<20 - 466	1.06 - 1.98
Swamp/ delta	0.3 - 7.4	0.1 - 0.7	0.64 - 2.66	0.62 - 2.59	<20 - 3590	<20 - 3590	0.45 - 4.12
Steel Creek (1987-1991)							
Corridor	0.1 - 1.2	<0.1 - 1.1	0.77 - 1.40	0.87 - 1.46	<20 - 310	<20 - 311	0.87 - 1.92
Swamp/ delta	0.2 - 4.3	<0.1 - 2.7	0.78 - 1.87	0.84 - 1.83	<20 - 4173	<20 - 4067	0.79 - 4.28

Table 5-120. (cont)

	Diss. Potassium (mg/l)	Total Sodium (mg/l)	Diss. Sodium (mg/l)	Chloride (mg/l)	Hydrogen Sulfide (mg/l)	Sulfate (mg/l)
Steel Creek (1985-1986)						
Corridor	1.00 - 1.94	4.0 - 13.1	3.7 - 12.1	7 - 8	<0.1	3 - 11
Swamp/ delta	0.38 - 3.35	6.0 - 14.6	6.0 - 14.8	6 - 10	<0.1	1 - 12
Steel Creek (1987-1991)						
Corridor	0.24 - 1.96	4.1 - 13.5	6.9 - 13.6	4.0 - 11	<0.1	1 - 9
Swamp/ delta	0.54 - 4.45	5.1 - 13.1	5.4 - 13.3	3 - 12	<0.1	1 - 12

Source: Kretchmer and Chimney 1992b.

ences were attributed to natural conditions such as cooling, metabolic activity of stream organisms, or chemical reactions (Kretchmer and Chimney 1992).

Differences between swamp (closed canopy) and marsh (open canopy) stations were noted during at least a portion of the study for temperature, ortho- and total phosphorus, nitrate-nitrogen, total inorganic nitrogen, total and dissolved sodium, and sulfate. However, no consistent differences were evident. Such variation would not be unexpected between stations in different habitat types (Kretchmer and Chimney 1992).

Inspection of pre- and post-impoundment data for the years 1985-1989 indicated that increases in temperature, conductivity, total phosphorus, nitrate-nitrogen, ammonia-nitrogen, total and dissolved sodium, and chloride, and decreases in pH have occurred relative to preimpoundment conditions documented during the CCWS. These changes reflected differences between water being released from L Lake (dominated by Savannah River water) and the natural drainage of the Steel Creek basin (Kretchmer and Chimney 1992).

Higher levels were measured at Station 300 (Steel Creek marsh) for conductivity, total dissolved solids, total inorganic carbon, alkalinity, ammonia-nitrogen, total and dissolved calcium, total iron, total and dissolved magnesium, total and dissolved manganese, and total and dissolved potassium; and lower concentrations were found at Station 300 for orthophosphate and sulfate during the summers of 1986-1988. Reduced flow velocities due to the abundance of macrophytes were thought to have impeded water exchange with the rest of the swamp and marsh. Water quality differences were much reduced compared to previous years (Kretchmer and Chimney 1992).

Chemical, Including Radionuclide, and Toxicity Assessment Studies

No chemical, radionuclide or toxicity studies have been done on the waters of Steel Creek.

Algae

Phytoplankton

Primary producers in Steel Creek consist of macrophytes and periphyton. Phytoplankton are believed to contribute insignificantly to the food base, as is typically the case in shallow stream systems (Wetzel 1983) and, therefore, were not included in biological monitoring programs.

Periphyton

The abundance and community structure of periphyton assemblages in the Steel Creek system were studied from 1986-1991 as part of an extensive biological monitoring program initiated to assess the ecological impacts of L-Reactor operations. Sampling locations are shown in Figure 5-52. Detailed methods and results can be found in reports by Hooker (1990) and Toole and van Duyn (1992). Data from 1986-1987 have been previously summarized in compliance documents by Gladden et. al. (1988) and Wike et. al. (1989).

Biomass Quantities

Periphyton biomass values, measured as organisms per millimeter of glass slide surface, did not reveal consistent seasonal patterns (Figure 5-53 through Figure 5-56). The highest quantities were obtained from the corridor stations with successively lower quantities in the marsh, channel, and swamp locations, respectively. The largest quantities reported from the study were from the upper corridor during reactor operations (1986-1988). Periphyton bio-

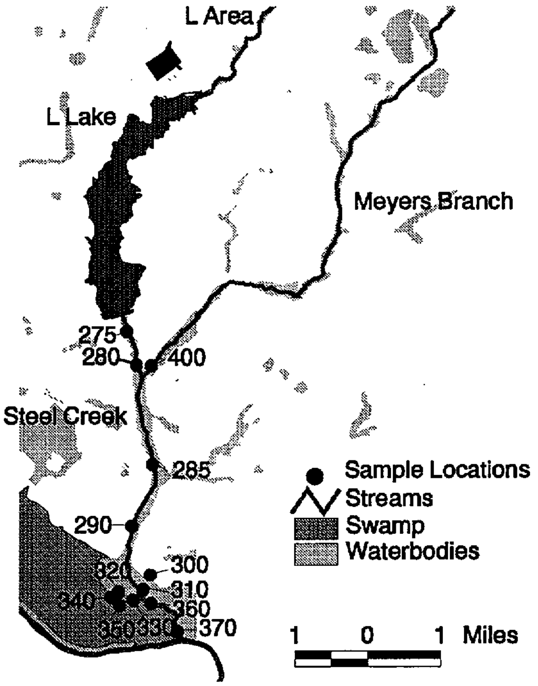

Figure 5-52. Periphyton Sampling Stations for Steel Creek

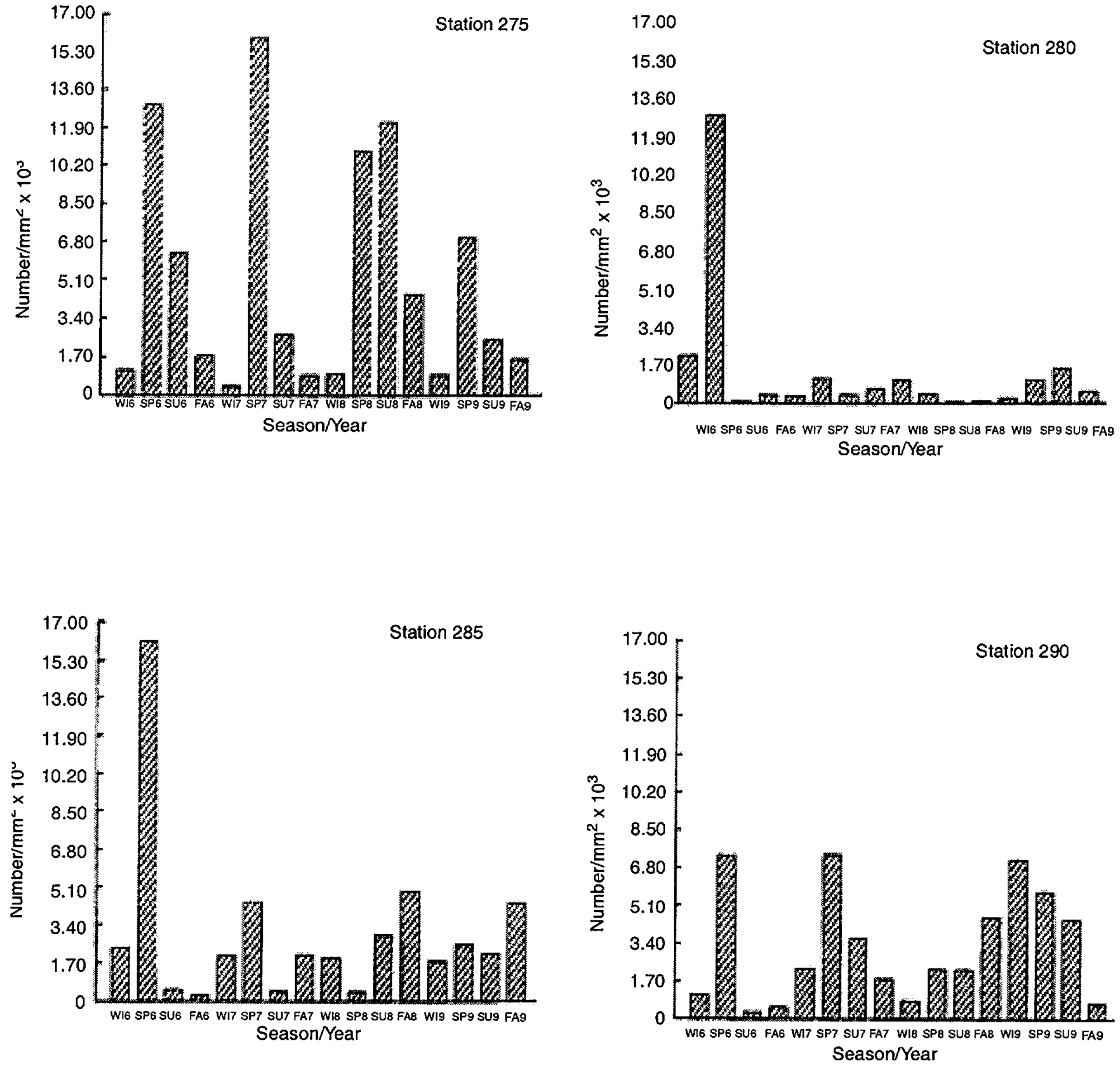

Figure 5-53. Seasonal Total Algal Counts (no./mm^2) on Glass Slides Incubated at Steel Creek Corridor Stations, January 1986-December 1989

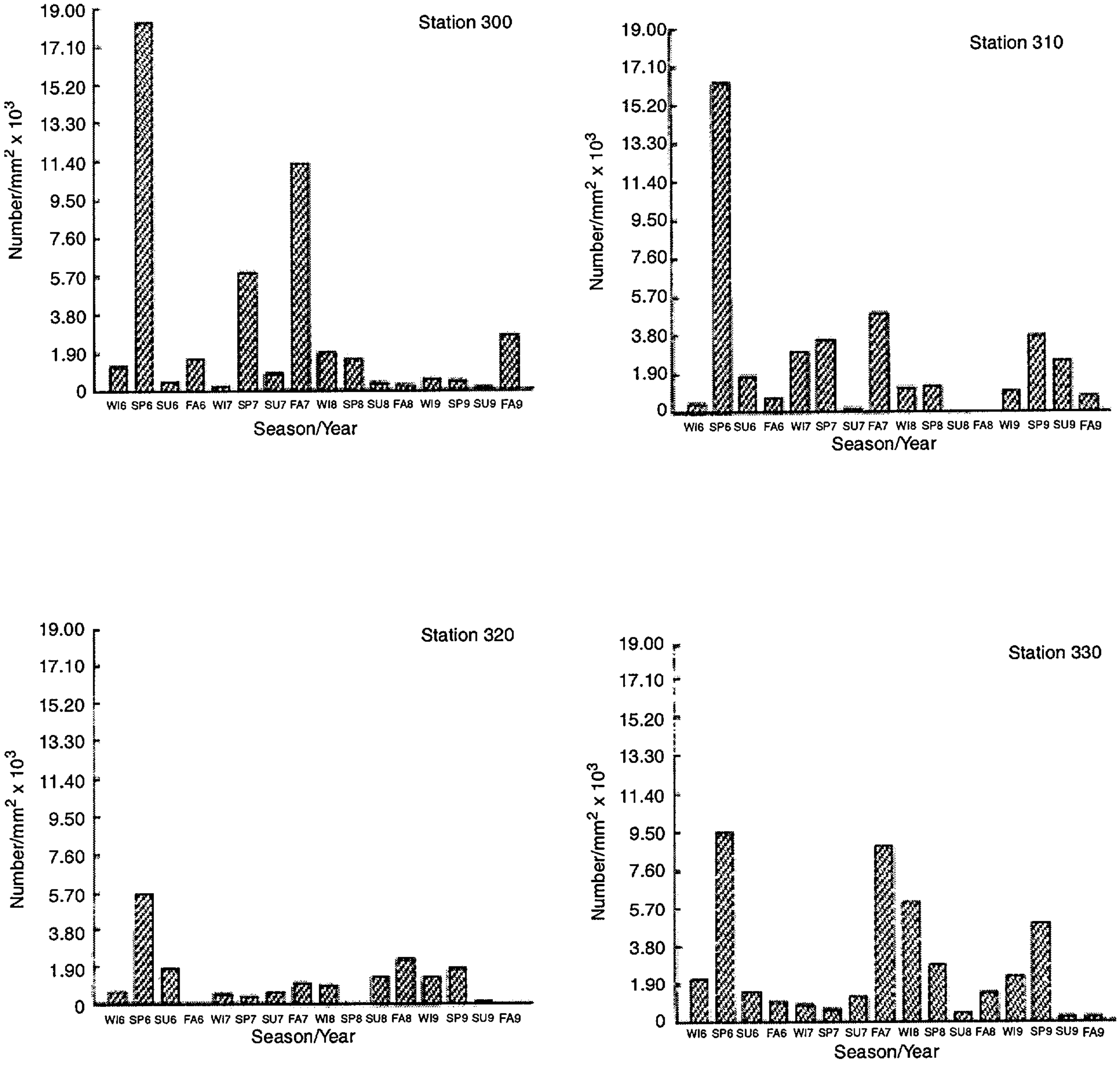

Figure 5-54. Seasonal Total Algal Counts (no./mm^2) on Glass Slides Incubated at Steel Creek Marsh Stations, January 1986-December 1989

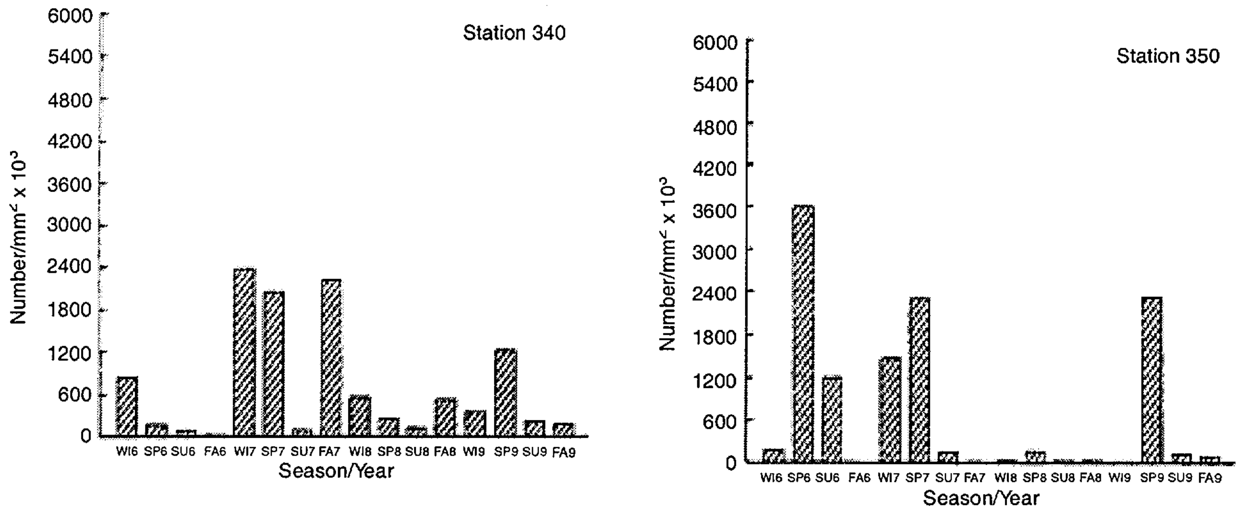

Figure 5-55. Seasonal Total Algal Counts (no./mm²) on Glass Slides Incubated at Steel Creek Swamp Stations, January 1986-December 1989

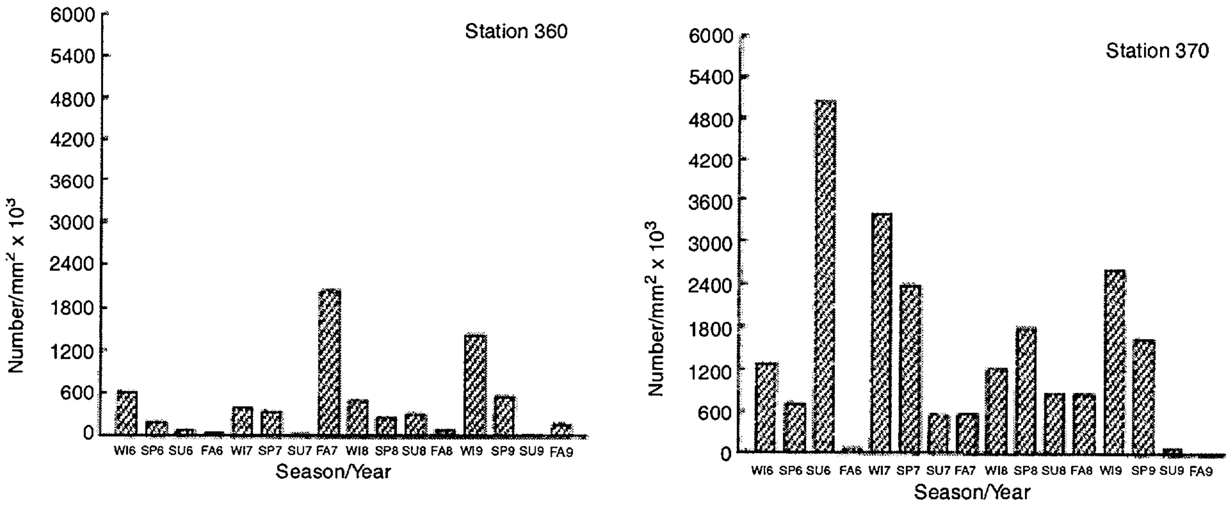

Figure 5-56. Seasonal Total Algal Counts (no./mm²) on Glass Slides Incubated at Steel Creek Channel Stations, January 1986-December 1989

mass values measured as chlorophyll *a* and ash free dry weight were also generally higher in the corridor than at the other sampling locations throughout the study (Table 5-121 and Table 5-122).

Taxa Identified

Diatoms (Bacillariophyta) were the dominant algal group in most samples from all stations and dates (Table 5-123). One exception was at Station 275 in the upper corridor of the creek where blue-green algae (Cyanophyta) made up 80.1% of the total periphyton during 1987 (Table 5-123). Major species of periphyton from the Steel Creek system are listed in Table 5-124.

Table 5-121. Annual Means for Periphyton Chlorophyll *a* (mg/m^2) Accumulated on Glass Slides Incubated in Steel Creek and Meyers Branch, January 1986-December 1991

		1986[a]		1987[a]		1988[a]		1989[a]		1990		1991	
Location	Station	Mean	SE[b]	Mean	SE[b]	Mean	SE[b]	Mean	SE[b]	Mean	SE[b]	Mean	SE[b]
Corridor	275	7.76	(.74)	13.59	(2.60)	12.62	(1.08)	10.91	(1.12)	-	-	-	-
	280	7.60	(1.07)	3.75	(0.60)	4.61	(0.87)	10.60	(1.34)	-	-	-	-
	285	10.73	(1.02)	15.92	(1.46)	17.40	(2.38)	14.04	(0.99)	-	-	-	-
	290	8.41	(0.70)	12.37	(1.76)	15.62	(1.82)	9.72	(0.83)	17.61	(0.68)	11.92	(2.11)
Marsh	300	5.99	(0.65)	5.95	(1.01)	7.95	(1.32)	4.41	(0.67)	-	-	-	-
	310	6.43	(0.97)	10.15	(1.65)	7.16	(1.70)	6.19	(0.61)	-	-	-	-
	320	6.23	(1.02)	6.38	(1.23)	10.29	(2.01)	5.41	(0.78)	-	-	-	-
	330	7.53	(0.85)	10.47	(1.78)	5.67	(0.81)	3.65	(0.74)	8.04	(1.52)	4.70	(1.09)
Swamp	340	2.44	(0.65)	2.73	(0.68)	1.12	(0.12)	3.18	(0.56)	-	-	-	-
	350	2.57	(0.90)	2.86	(0.93)	0.85	(0.31)	1.26	(0.38)	4.08	(1.18)	0.95	(0.30)
Channel	360	2.44	(0.68)	3.06	(0.54)	3.56	(0.63)	2.43	(0.65)	-	-	-	-
	370	8.00	(0.93)	5.38	(1.51)	8.49	(1.02)	4.18	(0.88)	5.30	(1.61)	0.96	(0.32)
Meyer's Branch	400	2.50	(0.54)	1.01	(0.35)	1.06	(0.35)	1.14	(0.34)	-	-	-	-

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[a] Summary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.
[b] Standard error.

Table 5-122. Annual Means for Periphyton Ash-free Dry Weight (g/m^2) Accumulated on Glass Slides Incubated in Steel Creek and Meyer's Branch, January 1986-December 1991.

		1986[a]		1987[a]		1988[a]		1989[a]		1990		1991	
Location	**Station**	**Mean**	**SE[b]**	**Mean**	**SE[b]**	**Mean**	**SE[b]**	**Mean**	**SE[b]**	**Mean**	**SE[b]**	**Mean**	**SE[b]**
Corridor	275	6.79	(1.51)	5.84	(0.94)	35.52	(7.33)	6.57	(1.04)	-	-	-	-
	280	3.13	(0.38)	1.70	(0.32)	1.49	(0.14)	1.38	(0.17)	-	-	-	-
	285	4.09	(0.52)	3.42	(0.50)	2.18	(0.22)	2.22	(0.22)	-	-	-	-
	290	1.95	(0.28)	1.73	(0.17)	2.07	(0.16)	2.03	(0.12)	2.29	(0.23)	2.53	(0.19)
Marsh	300	1.62	(0.27)	0.96	(0.18)	1.27	(0.12)	1.05	(0.13)	-	-	-	-
	310	1.06	(0.22)	1.20	(0.12)	0.85	(0.13)	1.02	(0.08)	-	-	-	-
	320	0.73	(0.12)	1.00	(0.12)	1.13	(0.18)	0.87	(0.13)	-	-	-	-
	330	1.44	(0.23)	0.79	(0.09)	0.94	(0.09)	0.68	(0.10)	1.47	(0.14)	1.63	(0.28)
Swamp	340	0.63	(0.05)	0.53	(0.07)	0.27	(0.02)	0.51	(0.06)	-	-	-	-
	350	0.58	(0.09)	0.49	(0.08)	0.26	(0.03)	0.34	(0.05)	0.60	(0.06)	1.11	(0.45)
Channel	360	0.50	(0.05)	0.30	(0.04)	0.44	(0.05)	0.28	(0.04)	-	-	-	-
	370	0.96	(0.33)	0.38	(0.07)	0.72	(0.09)	0.66	(0.10)	0.90	(0.12)	0.58	(0.24)
Meyer's Branch	400	1.16	(0.18)	1.03	(0.18)	0.70	(0.09)	0.62	(0.06)	-	-	-	-

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[a] Summary statistics for 1986-1989 were recalculated for comparison with 1990 and 1991 results by using data only from the four months that corresponded to the 1990 and 1991 quarterly sampling months.

[b] Standard error.

Table 5-123. Periphyton Community Composition on Glass Slides Incubated in Steel Creek and Meyers Branch, January 1986-December 1991

		Relative Abundance (%)					
Station	**Division[a]**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
275	Bacillariophyta	69.3	16.1	42.6	48.1	-	-
	Chlorophyta	17.9	3.7	40.4	40.4	-	-
	Cyanophyta	12.8	80.1	16.8	11.5	-	-
280	Bacillariophyta	71.8	54.2	79.9	37.4	-	-
	Chlorophyta	18.4	6.7	9.9	28.6	-	-
	Cyanophyta	9.8	39.1	10.2	33.7	-	-
285	Bacillariophyta	81.8	85.4	94.8	80.8	-	-
	Chlorophyta	5.8	1.8	1.2	1.8	-	-
	Cyanophyta	12.4	12.8	3.9	17.3	-	-
290	Bacillariophyta	28.6	82.2	87.1	84.7	80.1	70.8
	Chlorophyta	62.9	13.9	11.8	12.0	18.7	26.7
	Cyanophyta	8.4	3.8	1.1	3.3	1.2	2.5

Table 5-123. (cont)

		Relative Abundance (%)					
Station	**Division[a]**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
300	Bacillariophyta	43.4	60.8	32.2	52.4	-	-
	Chlorophyta	49.9	29.0	65.4	42.1	-	-
	Cyanophyta	6.4	10.1	2.3	5.3	-	-
310	Bacillariophyta	23.0	61.6	36.5	30.3	-	-
	Chlorophyta	72.0	30.8	59.9	54.4	-	-
	Cyanophyta	5.0	7.3	3.5	15.2	-	-
320	Bacillariophyta	33.4	50.7	55.4	24.1	-	-
	Chlorophyta	56.1	33.4	36.8	69.6	-	-
	Cyanophyta	10.4	15.7	7.8	6.3	-	-
330	Bacillariophyta	58.4	80.7	36.3	24.3	34.9	59.2
	Chlorophyta	27.8	16.0	57.1	41.4	53.6	
	Cyanophyta	13.7	3.2	6.5	34.2	10.4	2.5
340	Bacillariophyta	23.9	28.3	63.3	47.1	-	-
	Chlorophyta	69.3	42.1	30.9	43.5	-	-
	Cyanophyta	6.5	29.3	3.0	9.2	-	-
350	Bacillariophyta	76.9	52.4	61.1	34.5	60.2	65.5
	Chlorophyta	14.2	30.6	24.7	16.3	37.8	28.4
	Cyanophyta	8.7	16.7	12.8	49.2	2.0	5.8
360	Bacillariophyta	81.1	87.1	71.3	76.0	-	-
	Chlorophyta	14.9	8.9	4.0	10.6	-	-
	Cyanophyta	4.0	3.9	24.3	13.3	-	-
370	Bacillariophyta	40.8	72.1	74.1	64.9	42.6	82.5
	Chlorophyta	58.0	15.2	18.5	14.2	53.4	15.3
	Cyanophyta	1.1	12.4	7.4	20.8	3.9	1.6
400	Bacillariophyta	78.3	89.3	89.5	91.1	-	-
	Chlorophyta	3.2	7.2	1.6	2.3	-	-
	Cyanophyta	18.5	3.2	8.9	6.4	-	-

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[a] Bacillariophyta - diatoms.
Chlorophyta - green algae.
Cyanophyta - blue-green algae.

Table 5-124. Seasonally Common Taxa (> 5% abundance; listed in order of importance) of Periphytic Algae Growing on Glass Slides in Steel Creek, January 1986-December 1989.

		Common Taxa			
Station	**Season**	**1986**	**1987**	**1988**	**1989**
275	W	*Gomphonema parvulum* *Gomphonema gracile*	*Gomphonema parvulum* *Synedra rumpens*	*Skeletonema potamos* *Synedra rumpens* coccoid Cyanophyta spp. < 5 µm *Ankistrodesmus spiralis*	*Gomphonema parvulum* *Achnanthes minutissima* *Synedra rumpens* *Chlamydomonas* spp. 5 - 9.9 µm
	Sp	*Gomphonema parvulum* coccoid Cyanophyta spp. < 5 µm	coccoid Cyanophyta spp. < 5 µm *Microcystis aeruginosa*	*Microcystis aeruginosa* *Nitzschia fonticola* coccoid Chlorophyta spp. 5 - 9.9 µm *Nitzschia paleacea* *Cocconeis placentula*	*Achnanthes minutissima* *Leptosira medicinana* *Gomphonema parvulum*
	Su	*Achnanthes minutissima* coccoid Chlorophyta spp. 5 - 9.9 µm *Characium* spp.	*Achnanthes minutissima* *Phormidium* spp.	*Navicula mensuilus upsaliensis* *Coelochaetae* spp. *Navicula confervacea* coccoid Chlorophyta spp. 5 - 9.9 µm *Monoraphidium circinale* *Scenedesmus denticulatus*	coccoid Chlorophyta spp. < 5 µm coccoid Cyanophyta spp. < 5 µm coccoid Chlorophyta spp. 5 - 9.9 µm *Chaetophora elegans* *Lyngbya subtilis*
	F	*Ankistrodesmus spiralis* *Melosira granulata* *Synedra rumpens* coccoid Cyanophyta spp. < 5 µm *Navicula cryptocephala* *Scenedesmus dimorphus*	*Gomphonema parvulum* *Synedra rumpens* *Lyngbya subtilis* *Nitzschia paleacea* *Ankistrodesmus spiralis* *Gomphonema gracile*	coccoid Chlorophyta spp. 5 - 9.9 µm *Monoraphidium circinale* *Scenedesmus denticulatus* *Navicula menisculus* *Scenedesmus quadicauda*	*Microcystis incerta* *Nitzschia paleacea* *Navicula cryptocephala* coccoid Chlorophyta spp. < 5 µm *Navicula decussis* coccoid Chlorophyta 5 - 9.9 µm
280	W	*Gomphonema parvulum* *Gomphonema gracile*	*Gomphonema parvulum* *Synedra rumpens*	*Gomphonema parvulum* *Synedra rumpens* *Navicula minima*	*Gomphonema parvulum* *Synedra rumpens* *Cocconeis placentula* *Melosira varians*
	Sp	*Gomphonema parvulum* *Chaetophora elegans* *Gomphonema subclavatum* *Navicula minima*	coccoid Cyanophyta spp. < 5 µm *Cocconeis placentula*	*Microcystis incerta* *Nitzschia fonticola* *Nitzschia paleacea* *Cyclotella meneghiniana*	*Microcystis incerta* *Cyclotella pseudostelligera* coccoid Cyanophyta spp. < 5 µm *Nitzschia fonticola*

Table 5-124. (cont)

		Common Taxa			
Station	**Season**	**1986**	**1987**	**1988**	**1989**
		coccoid Cyanophyta spp. < 5 µm			*Scenedesmus quadricauda*
					Scenedesmus denticulatus
280	Su	*Cocconeis placentula*	*Navicula cryptocephala*	*Microcystis incerta*	coccoid Cyanophyta spp. < 5 µm
		Synedra rumpens	*Navicula minima*	*Navicula minima*	coccoid Chlorophyta spp. < 5 µm
		Navicula minima	*Achnanthes exigua*	*Achnanthes minutissima*	*Cocconeis fluviatilis*
		coccoid Cyanophyta spp. < 5 µm	*Eunotia pectinalis*	coccoid Chlorophyta spp. 5 - 9.9 µm	*Eunotia pectinalis*
			Merismopedia minima	*Lyngbya subtilis*	*Achnanthes lanceolata*
			Scenedesmus dimorphus	*Eunotia pectinalis*	*Gomphonema parvulum*
			Scenedesmus dentriculatus		
	F	*Melosira granulata*	*Gomphonema parvulum*	*Navicula menisculus*	*Pseudoulvella americana*
		Navicula cryptocephala	*Nitzschia palea*	*Microcystis incerta*	*Cocconeis fluviatilis*
		Ankistrodesmus spiralis	*Achnanthes minutissima*	coccoid Chlorophyta spp. 5 - 9.9 µm	*Eunotia pectinalis*
		Chaetophora elegans		*Scenedesmus quadricauda*	coccoid Chlorophyta spp. < 5 µm
		coccoid Cyanophyta spp. < 5 µm		*Navicula decussis*	
285	W	*Gomphonema parvulum*	*Gomphonema parvulum*	*Gomphonema parvulum*	*Gomphonema parvulum*
		Gomphonema gracile	*Synedra rumpens*	*Navicula minima*	*Navicula minima*
		Nitzschia agnita		*Synedra rumpens*	
		Navicula minima		*Melosira varians*	
		Cyclotella pseudostelligera		*Achnanthes lanceolata*	
		Nitzschia kutzingiana			
	Sp	*Gomphonema parvulum*	*Gomphonema parvulum*	*Achnanthes lanceolata*	coccoid Cyanophyta spp. 5 - 9.9 µm
		Gomphonema subclavatum	*Cymbella minuta*	*Cocconeis fluviatilis*	*Achnanthes lanceolata*
		Phormidium spp.	*Microcystis incerta*		*Cocconeis placentula*
		coccoid Chlorophyta spp. 5 - 9.9 µm	*Ulothrix subtilisma*		
		Gomphonema rhombicum	coccoid Cyanophyta spp. < 5 µm		
			Lyngbya subtilis		
	Su	coccoid Cyanophyta spp. < 5 µm	*Eunotia pectinalis*	*Eunotia pectinalis*	*Eunotia pectinalis*
		Eunotia pectinalis	*Cocconeis fluviatilis*	*Cocconeis fluviatilis*	coccoid Cyanophyta spp. < 5 µm
		Navicula menisculus		*Cocconeis placentula*	*Cocconeis fluviatilis*

Table 5-124. (cont)

Station	Season	Common Taxa 1986	 1987	 1988	 1989
285	F	*Navicula cryptocephala* *Melosira granulata* *Microcystis aeruginosa* coccoid Cyanophyta spp. < 5 µm *Ankistrodesmus spiralis* *Lyngbya subtilis*	*Gomphonema parvulum* *Achnanthes lanceolata*	*Oscillatoria limosa* *Gomphonema parvulum* *Navicula minima* *Achnanthes lanceolata*	*Gomphonema parvulum*
290	W	*Gomphonema parvulum* *Chaetophora elegans*	*Gomphonema parvulum* *Synedra rumpens* *Melosira varians* *Melosira granulata* *Navicula cryptocephala*	*Achnanthes lanceolata* *Cocconeis placentula* *Navicula minima*	*Gomphonema parvulum* *Melosira varians* *Navicula cryptocephala*
	Sp	*Chaetophora elegans* coccoid Chlorophyta spp. 5 - 9.9 µm coccoid Cyanophyta spp. <5 µm *Cocconeis diminuta* *Gomphonema parvulum*	*Gomphonema parvulum* *Achnanthes minutissima* *Cocconeis placentula* coccoid Chlorophyta spp. 5 - 9.9 µm *Characium* spp.	coccoid Chlorophyta spp. 5 - 9.9 µm *Gomphonema parvulum* *Characium* spp. *Achnanthes lanceolata* *Pseudoulvella americana* *Cocconeis fluviatilis* *Cocconeis placentula*	*Achnanthes lanceolata* *Gomphonema parvulum* coccoid Chlorophyta spp. <5 µm *Cocconeis placentula*
	Su	*Eunotia pectinalis* *Navicula minima* coccoid Cyanophyta spp. < 5 µm *Cocconeis diminuta*	*Navicula minima* *Eunotia pectinalis* *Achnanthes exigua*	*Achnanthes lanceolata* *Navicula minima* *Cocconeis fluviatilis* *Eunotia pectinalis*	*Gomphonema parvulum* coccoid Chlorophyta spp. < 5 µm *Pseudoulvella americana* coccoid Cyanophyta spp. < 5 µm *Achnanthes lanceolata*
	F	*Pseudoulvella americana* *Melosira granulata* *Eunotia pectinalis*	*Gomphonema parvulum* *Navicula crvptocephala* *Synedra tenera*	*Achnanthes lanceolata* *Navicula decussis* *Gomphonema parvulum* *Navicula minima* *Nitzschia paleacea*	*Achnanthes lanceolata* *Gomphonema parvulum* *Navicula decussis* *Navicula cryptocephala*
300	W	*Chaetophora elegans* coccoid Chlorophyta spp. 5 - 9.9 µm *Gomphonema parvulum* *Skeletonema potamus*	*Pseudoulvella americana*	*Pseudoulvella americana* coccoid Chlorophyta spp. 5 - 9.9 µm *Chaetophora elegans* *Achnanthes lanceolata*	*Gomphonema subclavatum* *Synedra rumpens* coccoid Chlorophyta spp. < 5 µm

Table 5-124. (cont)

		Common Taxa			
Station	**Season**	**1986**	**1987**	**1988**	**1989**
		Characium spp.		*Characium* spp.	
		Palmella spp.		*Gomphonema parvulum*	
	Sp	*Gomphonema parvulum*	*Chaetophora elegans*	*Chaetophora elegans*	coccoid Chlorophyta spp. <5 µm
		Chaetophora elegans	*Achnanthes minutissima*	coccoid Chlorophyta spp. 5 - 9.9 µm	*Characium* spp.
		Achnanthes minutissima	*Gomphonema parvulum*	*Gomphonema parvulum*	*Microcystis incerta*
		Characium spp.	*Cocconeis placentula*		coccoid Chlorophyta spp. 5 - 9.9 µm
		coccoid Chlorophyta spp. 5 - 9.9 µm	coccoid Cyanophyta spp. <5 µm		*Gomphonema parvulum*
		Phormidium spp.	coccoid Chlorophyta spp. 5 - 9.9 µm		*Oedogonium* spp. small
	Su	*Oedogonium* spp. large	coccoid Chlorophyta spp. 5 - 9.9 µm	*Characium* spp.	coccoid Chlorophyta spp. <5 µm
		coccoid Chlorophyta spp. 5 - 9.9 µm	*Navicula* spp.	*Chaetophora elegans*	*Navicula minimma*
		Oscillatoria princeps	*Navicula cryptocephala*	*Gomphonema parvulum*	*Microcystis incerta*
		coccoid Cyanophyta spp. <5 µm	*Navicula minima*	coccoid Chlorophyta spp. 5 - 9.9 µm	coccoid Cyanophyta spp. <5 µm
			Gomphonema parvulum		*Gomphonema parvulum*
			Ulothrix subtilisma		
			Oedogonium spp. small		
			Chaetophora elegans		
	F	*Ulothrix subtilisma*	*Synedra rumpens*	*Eunotia pectinalis*	*Achnanthes lanceolata*
		Oedogonium spp. small	*Nitzschia palea*	coccoid Chlorophyta spp. 5 - 9.9 µm	*Gomphonema parvulum*
		coccoid Chlorophyta spp. 5 - 9.9 µm	*Synedra tenera*	*Characium* spp.	*Oedogonium* spp. small
			Ulothrix subtilisma	*Navicula minima*	coccoid Chlorophyta spp. <5 µm
			Gomphonema parvulum	*Gomphonema parvulum*	coccoid Chlorophyta spp. 5 - 9.9 µm
			Oscillatoria geminata	*Nitzschia paleacea*	
			coccoid Chlorophyta spp. 5 - 9.9 µm	*Navicula menisculus*	
			Microcystis incerta		
310	W	*Gomphonema parvulum*	*Chaetophora elegans*	coccoid Chlorophyta spp. 5 - 9.9 µm	*Gomphonema parvulum*
		Eunotia pectinalis	*Gomphonema parvulum*	*Chaetophora elegans*	coccoid Chlorophyta spp. <5 µm
		Gomphonema gracile	coccoid Chlorophyta spp. 5 - 9.9 µm	*Achnanthes lanceolata*	*Achnanthes lanceolata*
		Fragilaria vaucheriae	*Ulothrix subtilisma*	*Cocconeis placentula*	coccoid Chlorophyta spp. 5 - 9.9 µm
				Pseudoulvella americana	*Navicula minima*

Table 5-124. (cont)

		Common Taxa			
Station	**Season**	**1986**	**1987**	**1988**	**1989**
	Sp	*Chaetophora elegans*	*Chaetophora elegans*	coccoid Chlorophyta spp. 5 - 9.9 µm	*Characium* spp.
		Characium spp.	*Cocconeis placentula*	*Navicula minima*	coccoid Chlorophyta spp. <5 µm
		Achnanthes minutissima	coccoid Cyanophyta spp. <5 µm	*Gomphonema parvulum*	*Pseudoulvella americana*
		coccoid Chlorophyta spp. 5 - 9.9 µm	*Gomphonema parvulum*	*Characium* spp.	coccoid Cyanophyta spp. <5 µm
			Achnanthes minutissima		*Eunotia pectinalis*
	Su	*Characium* spp.	*Characium* spp.	*Lyngboya* spp.	coccoid Cyanophyta spp. <5 µm
		Gomphonema parvulum	*Navicula minima*	*Schizothrix* spp.	*Leptosira medicinana*
		coccoid Cyanophyta spp. <5 µm	*Achnanthes lanceolata*	coccoid Chlorophyta spp. 5 - 9.9 µm	*Gomphonema parvulum*
		Lyngbya subtilis	*Chaetophora elegans*		coccoid Chlorophyta spp. <5 µm
		Eunotia pectinalis	*Eunotia pectinalis*		*Navicula minima*
			coccoid Chlorophyta spp. 5 - 9.9 µm		coccoid Chlorophyta spp. 5 - 9.9 µm
			Gomphonema parvulum		*Characium* spp.
	F	coccoid Chlorophyta spp. 5 - 9.9 µm	*Gomphonema parvulum*	Not sampled	coccoid Chlorophyta spp. 5 - 9.9 µm
		Navicula cryptocephala	*Navicula minima*		*Gomphonema parvulum*
		Gomphonema parvulum	coccoid Chlorophyta spp. 5 - 9.9 µm		coccoid Chlorophyta spp. <5 µm
					Navicula minima
					Navicula cryptocephala
		Achnanthes lanceolata	*Nitzschia palea*		*Eunotia pectinalis*
		Chaetophora elegans	*Achnanthes lanceolata*		*Cymbella minuta*
		Nitzschia kutzingiana	*Synedra tenera*		
			Characium spp.		
320	W	*Chaetophora elegans*	*Chaetophora elegans*	*Achnanthes lanceolata*	*Synedra rumpens*
		Eunotia pectinalis		*Gomphonema parvulum*	*Ulothrix subtilisma*
		Pseudoulvella americana		*Pseudoulvella americana*	*Oedogonium* spp. large
					coccoid Chlorophyta spp. <5 µm
					coccoid Chlorophyta spp. 5 - 9.9 µm
	Sp	*Chaetophora elegans*	coccoid Cyanophyta spp. <5 µm	Not sampled	coccoid Chlorophyta spp. <5 µm
		Cocconeis placentula	*Achnanthes lanceolata*		coccoid Cyanophyta spp. <5 µm
		Gomphonema parvulum	*Melosira varians*		coccoid Chlorophyta spp. 5 - 9.9 µm
		Characium spp.	*Navicula minima*		*Leptosira mediciana*
					Gomphonema parvulum

Table 5-124. (cont)

		Common Taxa			
Station	**Season**	**1986**	**1987**	**1988**	**1989**
	Su	*Anabaena subcylindrica*	coccoid Chlorophyta spp. 5 - 9.9 µm	*Characium* spp.	coccoid Chlorophyta spp. <5 µm
		Characium spp.	*Microcystis incerta*	*Chaetophora elegans*	*Achnanthes lanceolata*
		Navicula menisculus	*Characium* spp.	coccoid Chlorophyta spp. 5 - 9.9 µm	*Ankistrodesmus spiralis*
		Lyngbya subtilis	*Navicula minima*	*Microcystis incerta*	*Navicula minima*
		coccoid Cyanophyta spp. <5 µm	*Gomphonema parvulum*	*Navicula minima*	*Pseudoulvella americana*
		coccoid Chlorophyta spp. 5 - 9.9 µm		*Achnanthes lanceolata*	*Microcystis incerta*
					Characium spp.
	F	*Gomphonema parvulum*	*Melosira varians*	*Gomphonema parvulum*	Not sampled
		Navicula cryptocephala	*Achnanthes lanceolata*	coccoid Chlorophyta spp. 5 - 9.9 µm	
		coccoid Chlorophyta spp. 5 - 9.9 µm	*Gomphonema parvulum*	*Navicula minima*	
		Lyngbya subtilis	*Synedra tenera*	*Chaetophora elegans*	
		Oscillatoria geminata		*Nitzschia paleacea*	
		Characium spp.		*Lyngbya subtilis*	
		Cyanophyta colony 1			
330	W	*Gomphonema parvulum*	*Gomphonema parvulum*	*Chlamydomonas* spp. 5 - 9.9 µm	*Gomphonema parvulum*
		Cocconeis placentula	coccoid Chlorophyta spp. 5 - 9.9 µm	*Gomphonema parvulum*	coccoid Chlorophyta spp. <5 µm
		Achnanthes lanceolata	*Chaetophora elegans*	*Achnanthes lanceolata*	*Achnanthes lanceolata*
			Synedra rumpens		coccoid Chlorophyta spp. <5 µm
			Pseudoulvella americana		*Chlamydomonas* spp. 5 - 9.9 µm
	Sp	*Achnanthes minutissima*	*Chaetophora elegans*	*Chaetophora elegans*	coccoid Cyanophyta spp. <5 µm
		Chaetophora elegans	*Cocconeis placentula*	coccoid Chlorophyta spp. 5 - 9.9 µm	*Leptosira mediciana*
		Characium spp.	coccoid Cyanophyta spp. <5 µm	*Gomphonema parvulum*	*Pseudoulvella americana*
		Gomphonema parvulum	*Achnanthes minutissima*	coccoid Cyanophyta spp. 5 - 9.9 µm	*Characium* spp.
		Phormidium spp.	*Achnanthes lanceolata*	*Navicula cryptocephala*	
		Coelosphaerium pallidum	*Eunotia pectinalis*		
			Gomphonema parvulum		
	Su	*Eunotia pectinalis*	*Pseudoulvella americana*	*Characium* spp.	*Microcystis incerta*
		coccoid Cyanophyta spp. <5 µm	*Characium* spp.	*Achnanthes lanceolata*	*Navicula minima*
		Chaetophora elegans	coccoid Chlorophyta spp. 5 - 9.9 µm	coccoid Chlorophyta spp. 5 - 9.9 µm	*Gomphonema parvulum*
		Achnanthes lanceolata	*Achnanthes lanceolata*	*Navicula minima*	*Pseudoulvella americana*

Table 5-124. (cont)

		Common Taxa			
Station	**Season**	**1986**	**1987**	**1988**	**1989**
		Gomphonema parvulum	*Navicula minima*		coccoid Cyanophyta spp. <5 µm
		Navicula minima	*Gomphonema parvulum*		*Achnanthes lanceolata*
	F	*Gomphonema parvulum*	*Gomphonema parvulum*	*Gomphonema parvulum*	coccoid Chlorophyta spp. 5 - 9.9 µm
		Achnanthes lanceolata	*Synedra rumpens*	*Achnanthes lanceolata*	coccoid Chlorophyta spp. <5 µm
		coccoid Chlorophyta spp. 5 - 9.9 µm			*Gomphonema parvulum*
		Pseudoulvella americana			*Navicula cryptocephala*
		Navicula minima			*Eunotia pectinalis*
		Nitzschia kutzingiana			*Navicula minima*
		Eunotia pectinalis			*Oedogonium* spp. small
		Navicula cryptocephala			
340	W	*Pseudoulvella americana*	*Gomphonema parvulum*	*Achnanthes lanceolata*	*Pseudoulvella americana*
		Eunotia pectinalis	coccoid Chlorophyta spp. 5 - 9.9 µm	*Pseudoulvella americana*	coccoid Chlorophyta spp. <5 µm
		Chaetophora elegans	coccoid Chlorophyta colony 1		*Achnanthes lanceolata*
					coccoid Chlorophyta spp. 5 - 9.9 µm
					Cocconeis placentula
	Sp	*Chaetophora elegans*	Cyanophyta colony 2	*Navicula cryptocephala*	*Achnanthes lanceolata*
		Gomphonema parvulum		*Navicula minima*	coccoid Chlorophyta spp. <5 µm
		Achnanthes minutissima		coccoid Chlorophyta spp. 5 - 9.9 µm	*Leptosira medicinana*
		coccoid Chlorophyta spp. 5 - 9.9 µm		*Nitzschia paleacea*	*Gomphonema parvulum*
		Cocconeis placentula		*Characium* spp.	*Characium* spp.
		Characium spp.			*Microcystis incerta*
	Su	*Navicula minima*	*Navicula minima*	*Navicula minima*	coccoid Chlorophyta spp. <5 µm
		coccoid Cyanophyta spp. <5 µm	*Gomphonema parvulum*	coccoid Chlorophyta spp. 5 - 9.9 µm	*Navicula minima*
		Gomphonema parvulum	*Navicula cryptocephala*	*Gomphonema parvulum*	*Gomphonema parvulum*
		Characium spp.	coccoid Chlorophyta spp. 5 - 9.9 µm	*Nitzschia paleacea*	*Characium* spp.
		Achnanthes hungarica		*Lyngbya subtilis*	coccoid Chlorophyta spp. 5 - 9.9 µm
		Achnanthes lanceolata		*Navicula* spp.	*Eunotia pectinalis*
					Nitzschia amphibia
	F	*Lyngbya subtilis*	coccoid Chlorophyta spp. 5 - 9.9 µm	coccoid Chlorophyta spp. 5 - 9.9 µm	coccoid Chlorophyta spp. 5 - 9.9 µm
		Navicula minima	*Ulothrix subtilisma*	*Nitzschia paleacea*	coccoid Chlorophyta spp. <5 µm

Table 5-124. (cont)

		Common Taxa			
Station	**Season**	**1986**	**1987**	**1988**	**1989**
		coccoid Chlorophyta spp. < 5 µm	*Gomphonema parvulum*	*Gomphonema parvulum*	coccoid Cyanophyta spp. <1 µm
		Oedogonium spp. small	*Nitzschia gracilis*	*Cryptomonas erosa*	*Ulothrix subtilisma*
		Gomphonema parvulum	*Nitzschia palea*	*Navicula minima*	*Navicula minima*
		Oscillatoria geminata			*Nitzschia paleacea*
		Navicula cryptocephala			*Eunotia pectinalis*
350	W	*Gomphonema parvulum*	*Pseudouvella americana*	*Achnanthes lanceolata*	coccoid Chlorophyta spp. <5 µm
		Chaetophora elegans	*Gomphonema parvulum*	*Pseudoulvella americana*	coccoid Chlorophyta spp. 5 - 9.9 µm
		Fragilaria vaucheriae	coccoid Chlorophyta spp. 5 - 9.9 µm	coccoid Chlorophyta spp. 5 - 9.9 µm	*Achnanthes lanceolata*
		Achnanthes lanceolata	*Ulothrix subtilisma*		*Cocconeis placentula*
		coccoid Chlorophyta spp. 5 - 9.9 µm	*Characium* spp.		
350	Sp	*Achnanthes lanceolata*	*Achnanthes lanceolata*	*Navicula minima*	coccoid Cyanophyta spp. <5 µm
		Gomphonema parvulum	Cyanophyta colony 2	*Navicula cryptocephala*	*Achnanthes lanceolata*
		Chaetophora elegans	*Gomphonema parvulum*	*Nitzschia amphibia*	*Leptosira medicinana*
		Cocconeis placentula	coccoid Cyanophyta spp. < 5 µm	coccoid Chlorophyta spp. 5 - 9.9 µm	*Characium* spp.
		coccoid Cyanophyta spp. < 5 µm	*Navicula seminulum*	*Characium* spp.	
		Eunotia pectinalis	*Eunotia pectinalis*	*Achnanthes lanceolata*	
			Chaetophora elegans		
	Su	*Achnanthes lanceolata*	*Achnanthes lanceolata*	*Microcystis incerta*	coccoid Cyanophyta spp. <1 µm
		Chaetophora elegans	*Eunotia pectinalis*	*Lyngbya subtilis*	
		Gomphonema parvulum	*Achnanthes hungarica*	Chaetophoraceae (unidentified)	
		Navicula minima	*Navicula cryptocephala*	*Achnanthes lanceolata*	
		Achnanthes hungarica	*Gomphonema parvulum*	*Eunotia pectinalis*	
	F	*Lyngbya subtilis*	*Gomphonema parvulum*	*Microcystis incerta*	coccoid Cyanophyta spp. <1 µm
		Gomphonema parvulum	coccoid Chlorophyta spp. 5 - 9.9 µm	*Gomphonema parvulum*	coccoid Chlorophyta spp. <5 µm
		Schizothrix spp.	*Nitzschia gracilis*	*Anchnanthes lanceolata*	coccoid Chlorophyta spp. 5 - 9.9 µm
		Achnanthes lanceolata		*Navicula minima*	*Gomphonema parvulum*
360	W	*Gomphonema parvulum*	*Gomphonema parvulum*	*Gomphonema parvulum*	*Gomphonema parvulum*
		Nitzschia gracilis	*Pseudouvella americana*	*Navicula minima*	*Achnanthes lanceolata*
		Nitzschia kutzingiana	*Chlamydomonas* spp. 5 - 9.9 µm	*Cocconeis placentula*	
		Fragilaria vaucheriae	coccoid Chlorophyta spp. 5 - 9.9 µm		
		Chaetophora elegans	*Cocconeis placentula*		

Table 5-124. (cont)

		Common Taxa			
Station	**Season**	**1986**	**1987**	**1988**	**1989**
		coccoid Chlorophyta spp. 5 - 9.9 µm *Achnanthes lanceolata*			
	Sp	*Gomphonema parvulum*	*Cocconeis placentula*	*Achnanthes lanceolata*	coccoid Cyanophyta spp. <5 µm
		Achnanthes lanceolata	coccoid Cyanophyta spp. < 5 µm	*Gomphonema parvulum*	*Achnanthes lanceolata*
		cocconeis placentula *Achnanthes minutissima*	*Eunotia pectinalis* *Achnanthes lanceolata* *Gomphonema parvulum*	*Eunotia pectinalis* *Cocconeis placentula* *Microcystis aeruginosa*	*Microcystis incerta* *Eunotia pectinalis*
360	Su	*Achnanthes lanceolata*	*Achnanthes lanceolata*	*Chroococcus minor*	coccoid Chlorophyta spp. <5 µm
		Gomphonema parvulum *Navicula minima*	*Gomphonema parvulum* *Eunotia pectinalis*	*Achnanthes lanceolata*	*Schizothrix* spp. coccoid Cyanophyta spp. <5 µm
		Lyngbya subtillis *Characium* spp.	*Pseudouvella americana* *Navicula cryptocephala* *Navicula minima* *Achnanthes hungarica* *Lyngbya subtillis* Coccoid Chlorophyta spp. 5 - 9.9 µm		*Navicula minima* *Gomphonema parvulum*
	F	*Gomphonema parvulum* *Achnanthes lanceolata*	*Gomphonema parvulum* *Synedra tenera*	*Gomphonema parvulum* *Achnanthes lanceolata*	*Gomphonema parvulum* coccoid Chorophyta spp. <5 µm
				Navicula menisculus	coccoid Chlorophyta spp. 5 - 9.9 µm
				Eunotia pectinalis	*Achnanthes lanceolata* *Navicula minima* *Navicula cryptocephala*
370	W	*Gomphonema parvulum* *Fragilaria vaucheriae*	*Gomphonema parvulum* coccoid Chlorophyta spp. 5 - 9.9 µm	*Navicula minima* *Gomphonema parvulum*	*Gomphonema parvulum* *Achnanthes minutissima*
		Eunotia pectinalis			*Chaetophora elegans* coccoid Chlorophyta spp. 5 - 9.9 µm
	Sp	*Cocconeis placentula*	*Gomphonema parvulum*	*Achnanthes lanceolata*	coccoid Cyanophyta spp. <5 µm
		Achnanthes lanceolata	coccoid Cyanophyta spp. < 5 µm	*Chaetophora elegans*	*Cocconeis placentula*
		Eunotia pectinalis *Chaetophora elegans*	*Lyngbya subtilis* *Chaetophora elegans*	*Cocconeis placentula* coccoid Chlorophyta spp. 5 - 9.9µm *Microcystis incerta* *Eunotia pectinalis*	*Achnanthes Lanceolata* *Letptosira medicinana* *Eunotia pectinalis*

Table 5-124. (cont)

		Common Taxa			
Station	**Season**	**1986**	**1987**	**1988**	**1989**
	Su	*Chaetophora elegans*	*Achnanthes lanceolata*	*Achnanthes lanceolata*	coccoid Cyanophyta spp. <1 µm
		Achnanthes lanceolata	*Chaetophora elegans*	*Gomphonema parvulum*	coccoid Cyanophyta spp. < 5 µm
			Gomphonema parvulum	Chaetophoraceae (unidentified)	*Microcystis incerta*
			coccoid Chlorophyta spp. 5 - 9.9 µm	*Cocconeis fluviatilis*	
			Cocconeis fluviatilis	*Microcystis incerta*	
370	F	*Gomphonema parvulum*	*Gomphonema parvulum*	*Achnanthes lanceolata*	coccoid Cyanophyta spp. <1 µm
		Achnanthes lanceolata	*Synedra tenera*	*Gomphonema parvulum*	coccoid Chlorophyta spp. <5 µm
			Nitzschia gracilis	*Nitzschia paleacea*	*Schizothrix* spp.
			Nitzschia palea	*Eunotia pectinalis*	
400	W	*Gomphonema parvulum*	*Gomphonema parvulum*	*Achnanthes reimeri*	*Gomphonema parvulum*
		Achnanthes minutissima	*Achnanthes minutissima*	*Achnanthes minutissima*	*Achnanthes minutissima*
		Eunotia pectinalis	*Achnanthes reimeri*	*Synedra rumpens*	*Achnanthes reimeri*
		Meridion circulare	*Eunotia pectinalis*	*Gomphonema parvulum*	
		Cocconeis placentula	*Synedra rumpens*		
		Cymbella minuta			
	Sp	*Schizothrix* spp.	*Schizothrix* spp.	*Microcystis incerta*	*Schizothrix* spp.
		Cocconeis placentula	*Gomphonema parvulum*	*Achnanthes lanceolata*	*Achnanthes lanceolata*
		Gomphonema parvulum	*Achnanthes minutissima*	*Chamaesiphon minutus*	*Eunotia pectinalis*
		Navicula capitata		*Chaetophora elegans*	coccoid Chlorophyta spp. <5 µm
		Achnanthes minutissima		*Cocconeis placentula*	*Characium* spp.
		Oscillatoria subtilissima		*Microcystis aeruginosa*	*Navicula cryptocephala*
				Aphanothece saxicola	
				Schizorthrix spp.	
	Su	*Lyngbya subtilis*	*Lyngbya subtilis*	*Lyngbya subtilis*	coccoid Cyanophyta spp. <1 µm
		Achnanthes minutissima	coccoid Cyanophyta spp. < 5 µm	*Microcystis incerta*	*Schizothrix* spp.
		Navicula minima	*Navicula minima*	*Schizothrix* spp.	*Microcystis incerta*
		Nitzschia kutzingiana	*Achnanthes minutissima*	*Navicula cryptocephala*	coccoid Cyanophyta spp. <5 µm
	F	*Lyngbya subtilis*	*Gomphonema parvulum*	*Oscillatoria angustissima*	*Schizothrix* spp.
		Oscillatoria geminata	*Achnanthes minutissima*		coccoid Cyanophyta spp. <1 µm
		Melosira granulata	*Eunotia pectinalis*		coccoid Chlorophyta spp. <5 µm
		Schizothrix spp.			

Macrophytes

Comprehensive Cooling Water Study

Between the shutdown of L Reactor in 1968 and the construction of L Lake in 1984-1985, Steel Creek went through vegetation community successional recovery from the impacts of high flows and temperatures caused by previous L-Reactor discharges. During the CCWS in 1984-1985, four channel, one delta, and two Steel Creek swamp stations were sampled quarterly. Two stations on Meyers Branch, an unimpacted tributary of Steel Creek, also were sampled as controls.

Summary data from the CCWS for Steel Creek and Meyers Branch can be found in Table 5-125. Species diversity appears to be similar between the post-thermal and reference streams, but there are differences between the two swamp stations (Table 5-126, Table 5-127, and Table 5-128); these differences probably can be attributed to Station 33 being in the delta and having an open canopy while Station 35 is in the swamp and has a closed canopy. (These stations are at the same sites as stations used during the L Lake/Steel Creek Biological Monitoring Program. The two sets of sites can be paired by adding a zero to the CCWS station designations. For example, Station 33 in the CCWS and Station 330 in the later Biological Monitoring Program are the same station. Several stations [26, 27] in the CCWS were in the area of the creek converted to L Lake.) The data in Table 5-128 and Table 5-129 demonstrate clear similarities between three (26, 27, 29) of the four stream corridor site macrophyte populations and those of the reference stream (39, 40). These are all in closed-canopy portions of the stream. Corridor station 28 is more similar to the delta and swamp stations, principally because it is in an open-canopy area. Diversity of plant communities is similar for the delta and swamp stations (33, 34, 35) (Table 5-129), but the greater macrophyte area, volume, biomass, and percent cover observed at Station 33 (Table 5-129) can be attributed to its open canopy as opposed to the closed canopy at the other swamp stations.

The CCWS also presented data describing the aquatic habitat of Steel Creek prior to the restart of L Reactor. This included channel morphometry; the volume and density of wood, logs, and sticks; the surface area of trailing vegetation; the volume of trailing roots; and the surface area of debris. This information was included and discussed in the L-Lake/Steel Creek Biological Monitoring Program reports.

Table 5-125. Number of Macrophyte Taxa at Four Steel Creek and Two Meyers Branch Sampling Stations, November 1983-May 1984

Corridor	**Post-thermal**		**Post-thermal Swamp/Delta**		**Meyers Branch**	
	26	**28**[a]	**33**[a]	**35**[a]	**39**	**40**[a]
total number of taxa	28	32	22	32	35	26
taxa growing in stream channel	1	2	9	12	6	2
taxa growing on floodplain	0	18	11	18	0	17
taxa growing in other riparian areas	27	12	2	2	29	7
channel + floodplain taxa	1	20	20	30	6	19

Source: Gladden et al. 1985.

[a] These stations correspond to the L Lake/Steel Creek Biological Monitoring Program Stations 280, 330, 350, and 400, respectively.

Table 5-126. Macrophyte Standing Crop (g AFDW/m^2) at Steel Creek Swamp 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.

	AFWD (g/m^2)	
	Station 35[a]	**Station 35**[a]
Winter		
Mean	5.02	3.21
s	2.75	3.41
CV	19.93	106.03
n	32	41
Spring		
Mean	115.60	31.27
s	69.16	23.13
CV	59.83	73.97
n	75	50
Summer		
Mean	43.82	7.32
s	12.9	6.79
CV	29.5	92.7
n	68	94

Source: Kondratieff and Kondratieff 1984, 1985.

AFDW = ash-free dry weight.

[a] Correspond to L-Lake/Steel Creek Biological Monitoring Program Stations 330 and 350.

Table 5-127. Biomass (g/m^2) and Percent of Total Biomass Contributed by Macrophyte Genera Collected at Steel Creek Stations 33 and 35 During Winter, Spring, and Summer Sampling, November 1983-May 1984

Season	Genus	Biomass (g/m^2)		% of Total Biomass	
		Station 33[a]	Station 35[a]	Station 33	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
	Sparganium[b]	0.00	0.62	0.00	18.49
	Callitriche	0.00	0.16	0.00	4.80
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
	Sparganium[b]	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
	Sparganium[b]	4.11	0.02	9.59	0.27

Source: Kondratieff and Kondratieff 1984.

[a] Correspond to L-Lake/Steel Creek Biological Monitoring Program Stations 330 and 350.

[b] Note that this plant was misidentified as *Vallisneria* and reported as such in the original documents. It is correctly termed *Sparganium* throughout this report.

Table 5-128. Annual Mean and Standard Deviation (s) are Presented for the Following Aquatic Vascular Plant Parameters at Each Mapped Station: Area; Volume; Biomass and Percent Cover, October 1984-September 1985

		Area (m^2/m^2)		Volume (m^3/m^2)		Biomass (g/m^2)		Percent Cover		
Station[a]	Location Steel Creek	Mean	s	Mean	s	Mean	s	Mean	s	Number of Reaches Mapped
26	corridor	0.0019	0.0049	-	-	-	-	0.1848	0.4960	16
27	corridor	0.0001	0.0004	-	-	-	-	0.0122	0.0367	9
28[a]	corridor	0.0423	0.0675	0.0010	0.0015	16.75	28.83	4.026	6.736	16
29[a]	corridor	0.0002	0.0004	<0.0001	<0.0001	0.0855	0.1949	0.0202	0.0430	12
33[a]	delta	0.3958	0.1434	0.1807	0.1349	82.18	48.70	39.61	14.17	20
34[a]	swamp	0.2786	0.2968	0.1196	0.1666	84.01	113.4	29.87	29.85	20
35[a]	swamp	0.2331	0.3229	0.0832	0.1267	59.62	78.83	23.32	32.31	20
39	Myers Branch	0.0001	0.0002	<0.0001	<0.0001	0.0002	0.0007	0.0054	0.0167	20
40[a]	Myers Branch	0.0009	0.0030	0.0002	0.0005	0.0111	0.0331	0.0916	0.2998	20

Source: Firth et al. 1986.

[a] Corresponds to L-Lake/Steel Creek Biological Monitoring Program Stations 280, 290, 330, 340, 350, and 400, respectively.

Table 5-129. The Annual Mean and Standard Deviation (s) for the Following Plant Taxa Parameters: Area; Volume; Biomass; Percent Cover (percent of mapped area covered by species), October 1984-September 1985

	Area (m^2/m^2)		**Volume (m^3/m^2)**		**Biomass (g/m^2)**		**Percent Cover**		
Species	**Mean**	**s**	**Mean**	**s**	**Mean**	**s**	**Mean**	**s**	**Number of Reaches Mapped**
Station 26									
MISC	0.0019	0.0049	-	-	-	-	0.1848	0.4960	16
Station 27									
MISC	0.0001	0.0004	-	-	-	-	0.0122	0.0367	9
Station 28[a]									
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
Station 29[a]									
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[a]									
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
SPA	0.2594	0.1572	0.1140	0.1201	7.665	8.016	0.1103	0.2971	20
Station 34[a]									
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
SPA	0.0087	0.0243	0.0034	0.0094	0.2251	0.6058	0.8746	2.433	20
Station 35[a]									
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
EG	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
LEM	0.0056	0.0108	-	-	0.2057	0.5313	0.5594	1.077	20
MISC	0.0001	0.0002	-	-	-	-	0.0056	0.0218	20

Table 5-129. (cont)

	Area (m^2/m^2)		Volume (m^3/m^2)		Biomass (g/m^2)		Percent Cover		
Species	**Mean**	**s**	**Mean**	**s**	**Mean**	**s**	**Mean**	**s**	**Number of Reaches Mapped**
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
SPA	0.0014	0.0032	0.0004	0.0012	0.0268	0.0764	0.1445	0.3255	20
Station 39									
MISC	<0.0001	0.0001	-	-	-	-	0.0030	0.0134	20
SPA	<0.0001	0.0001	<0.0001	-0.0001	0.0002	0.0007	0.0024	0.0107	20
Station 40[a]									
NU	0.0001	0.0003	<0.0001	0.0001	0.0003	0.0014	0.0076	0.0338	20
SPA	0.0008	0.0030	0.0002	0.0005	0.0108	0.0332	0.0840	0.3002	20

Source: Firth et al. 1986.

[a] Corresponds to the L-Lake/Steel Creek Biological Monitoring Program Stations 280, 290, 330, 340, 350, and 400 respectively.

List of species abbreviations:

ALT	*Alternanthera philoxeriodes*
AZ	*Azolla caroliniana*
BA	*Bacopa* sp.
CAL	*Callitriche heterophyela*
CER	*Ceratophyllum demersum*
EG	*Egeria densa*
HLA	*Hydrolea quadrivalvis*
HY	*Hydrocotyle ranunculoides*
LEM	*Lemna* spp. (and occasional *Spirodela* fronds)
LUD	*Ludwigia* sp.
MISC	Unidentified
MYR	*Myriophyllum aquaticum*
NU	*Nupha luteum*
POL	*Polygonum* spp.
POT	*Potamogeton pusillus*
SPA	*Sparganium* sp.

L-Lake/Steel Creek Biological Monitoring Program

The L-Lake/Steel Creek Biological Monitoring Program monitored the effects of the restart of L Reactor on the macrophytes and aquatic habitat of Steel Creek. During the years 1986 through 1989, this program mapped reaches in the main channels at 12 locations between L-Lake dam and the Savannah River on a semiannual (8 stations) or quarterly (4 stations) basis (See Figure 5-51) (Hooker 1990).

In the years 1990-1992, the program was reduced to four stations sampled annually (Westbury 1993). Variables reported by these studies include: width, depth, surface, and cross-sectional area of the main channel; the surface area, volume, density and importance values of living and non-living woody structures; and the total and species-specific percent cover and biomass of aquatic macrophytes.

The mean channel cross-sectional area of the four stations sampled from 1985 to 1992 is presented in Table 5-130. The cross-sectional area of the main channel at Stations 290, 330, and 370 increased with the start of L Reactor operations in 1986. The channel at Station 350 is separated from the Steel Creek delta by two islands and is only indirectly affected by flow from Steel Creek. Station 350 was influenced by discharge into Pen Branch by K-Reactor operations.

In low-order flowing streams where the riparian canopy shades much of the channel, woody structures provide a major portion of the stable surface area for colonization by periphyton and microhabitat for aquatic organisms. The total surface area of woody structures was lowest at the marsh station (330) in all years of this study (Table 5-131). The increase in surface area at Station 290 is the result of the exposure of previously buried woody structures due to scouring after the re-start of L Reactor. At Station 350, woody structure surface area was reduced after the shutdown due to increased aquatic macrophyte coverage.

The mean percent cover of aquatic vegetation generally increased throughout the study at all stations other than Station 370 (Table 5-132). The percent cover of aquatic plants at Station 370 was low due to the unstable substrate and canopy shading. Increased coverage at Station 290 after the shutdown was due to the increase in coontail (*Ceratophyllum demersum*) (Table 5-133). The percent cover at Stations 330 and 350 increased with the startup and continued after the shutdown due to the invasion of waterweed (*Egeria densa*) (Table 5-133). Waterweed was not found at Station 330 in 1985, and comprised less than 2 percent cover at Station 350 prior to the restart. At the end of the study waterweed covered 85.5% of

Table 5-130. Mean Cross-sectional Area (m^2) of Main Channel in the Summer at Selected Steel Creek Stations, July-September 1985-1992

		Mean Cross-Sectional Area[a] (m^2)							
LOCATION	STATION	1985	1986	1987	1988	1989	1990	1991	1992
Corridor	290	2.23	4.89	5.79	4.41	4.05	4.42	4.42	4.99
Marsh	330	5.37	6.17	8.14	7.63	8.15	6.83	7.72	5.97
Swamp	350	8.01	7.48	5.71	5.32	6.51	6.34	6.54	5.74
Channel	370	17.75	31.07	37.54	22.54	40.79	40.88	61.20	39.63

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[a] Cross-sectional areas were generated from channel width and depth profile data.

Note: Reaches mapped in 1985 may not be the same as those mapped in 1986-1992 for any given station.

Table 5-131. Mean Surface Areas (m^2/m^2) and Relative Importance Values (% of total) of Non-Living Woody Structures at Selected Steel Creek Stations During Summer and Winter in 1986-1989 and Summer 1990-1992

		1986	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
Station	**Woody Structure**	**Mean Wood Surface Area[a] (m^2/m^2)**	**Mean Wood Surface Area[a] (m^2/m^2)**	**Mean Wood Surface Area[a] (m^2/m^2)**	**Mean Wood Surface Area[a] (m^2/m^2)**	**Mean Wood Surface Area[a] (m^2/m^2)**	**Mean Wood Surface Area[a] (m^2/m^2)**	**Mean Wood Surface Area[a] (m^2/m^2)**
290	Logs	0.113	0.136	0.138	0.118	0.097	0.139	0.116
	Sticks	0.053	0.057	0.066	0.080	0.057	0.029	0.041
	Stumps	0.024	0.027	0.037	0.034	0.012	0.026	0.017
	Total	0.190	0.220	0.241	0.232	0.166	0.194	0.174
330	Logs	0.047	0.039	0.081	0.064	0.000	0.000	0.000
	Sticks	0.002	0.001	0.000	0.003	0.000	0.000	0.000
	Stumps	0.030	0.044	0.015	0.014	0.000	0.000	0.000
	Total	0.079	0.084	0.096	0.081	0.000	0.000	0.000
350	Logs	0.137	0.330	0.164	0.177	0.025	0.004	0.015
	Sticks	0.005	0.012	0.023	0.014	0.000	0.000	0.000
	Stumps	0.002	0.006	0.010	0.000	0.000	0.000	0.000
	Total	0.144	0.348	0.197	0.191	0.025	0.004	0.015
370	Logs	0.239	0.361	0.246	0.336	0.152	0.388	0.356
	Sticks	0.024	0.033	0.022	0.024	0.024	0.025	0.046
	Stumps	0.003	0.000	0.001	0.000	0.000	0.000	0.008
	Total	0.266	0.394	0.269	0.360	0.176	0.413	0.410

Source: Hooker 1990; Westbury 1993.

[a] Wood surface area = sum of surface area of nonliving woody structures (m^2)/mapped area of reach (m^2).

Table 5-132. Mean Total Vegetation (percent cover) at Selected Steel Creek Stations during Summer, July-September 1985-1991

		Mean Percent Cover[a]						
Location	**Station[b]**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
Corridor	290	<0.1	0.0	0.3	0.0	4.6	4.5	7.1
Marsh	330	32.6	67.9	55.5	58.4	67.1	71.5	63.1
Swamp	350	15.2	24.3	22.6	58.0	37.4	136.5	142.9
Channel	370	c	20.1	11.6	17.7	15.5	0.2	0.9

Source: Hooker 1990; Westbury 1993.

[a] Mean percent cover = total percent of each mapped channel covered by any aquatic macrophytes.

[b] Note: Stations are the same as those used in CCWS. A zero was added to distinguish the two studies. Thus, Stations 29 and 290 are the same.

[c] Station not sampled for this parameter in 1985.

Table 5-133. Mean Percent Cover of Common Aquatic Macrophyte Taxa (Š 1.0% cover) at Selected Steel Creek Stations, July-September 1985-1992

			Mean Percent Cover[a]							
Location	**Station**	**Taxa**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
Corridor	290	*Alternanthera*	b	c	b	c		1.4		
		Leersia					1.9	1.0		
		Ceratophyllum							4.9	17.2
		Murdania							1.3	
		Egeria								1.5
Marsh	330	*Alternanthera*				2.1				
		Ceratophyllum	15.9	19.0	23.4	19.7	12.1	20.2	12.0	3.7
		Egeria			8.3	25.4	46.7	50.3	50.8	84.8
		Callitriche	2.8							
		Lemna	1.0		3.8					
		Hydrocotyle				2.7				
		Murdannia				1.0				
		Myriophyllum	1.2	1.8						
		Polygonum				2.0	5.5			
		Paspalum		6.4						
		Potamogeton		1.6	1.1					
		Sparganium	10.8	37.1	18.0	5.0	2.2			
Swamp	350	*Ceratophyllum*	8.2	3.1		1.0		1.0		
		Egeria	1.8	18.4	18.6	43.9	24.2	82.6	94.8	71.8
		Hydrocotyle				1.7				
		Lemna	1.9	1.9	1.0	3.9	1.0	34.7	8.7	3.2
		Potamogeton	2.5							
		Sparganium				7.4	11.5	8.5	1.4	4.8
		Azolla							38.1	
		Murdannia								1.5
Channel	370	*Ceratophyllum*	d	5.8	5.3	3.3				
		Egeria		13.4	5.3	13.9	8.4			
		Murdannia					4.2			

Source: Hooker 1990; Westbury 1993.

[a] Mean percent cover =(sum of surface area of taxon [m^2] /mapped area of reach [m^2]) x 100.

[b] No individual taxon had Š 1% cover.

[c] No plant taxa recorded at station.

[d] Station not sampled for these parameters in 1985.

Station 330 and 72% of Station 350. The percent cover at these stations generally increased after the shut-down due to decreased water depth and decreased boat traffic. The percent cover decreased at Station 370 after 1989 due to increased water depth and turbidity as the result of higher Savannah River water levels.

Zooplankton

Introduction

Chimney and Cody (1986) examined the zooplankton communities in several SRS stream systems (including Steel Creek) prior to the construction of L Lake. Bowers (1991) reported on zooplankton sampled at seven locations (Figure 5-57) in Steel Creek from 1986 to 1989, following the construction of L Lake.

Early Effects of L Lake on Steel Creek Zooplankton

During 1985, Rotifera and Cladocera constituted more than 75% of the total number of zooplankton species in the Steel Creek swamp and delta. By 1986, rotifer, cladocera, and copepod species had decreased by about 50%. By 1987, Rotifera was represented by 29 species, 5 more than in 1985. Based only on the number of species, the impoundment of Steel Creek during 1984 and 1985 and the subsequent L-Lake discharge significantly affected the zooplankton taxa in the Steel Creek swamp and delta regions during 1985 and 1986, but recovery by all groups, except cladocerans, as measured by taxa richness had occurred by 1987.

The littoral rotifers dominated the community during 1985 and suffered severe losses during 1986, following impoundment. Those littoral rotifers were replaced by planktonic rotifers from L Lake during 1986, but in 1987, littoral rotifer species returned. Many of the

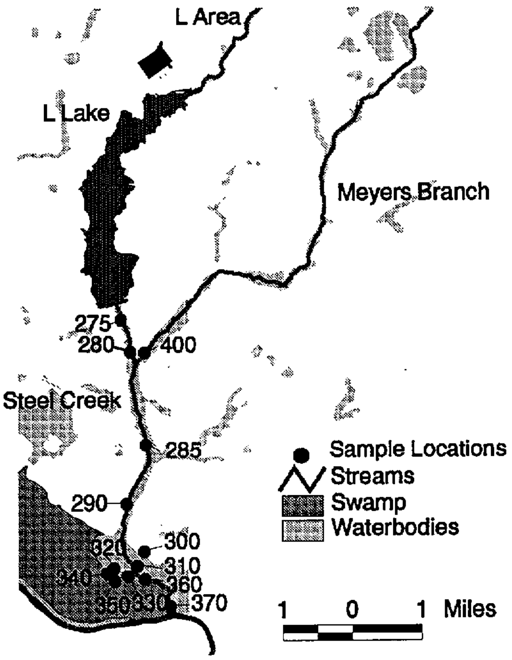

Figure 5-57. Zooplankton Sampling Stations in Steel Creek

original littoral cladoceran species were lost by 1986 and replaced by a single cladoceran, *Chydorus brevilabris*, and several new species of copepods. By 1987, the Steel Creek swamp and delta appeared to be supporting a new, steady-state post-impoundment community structure. However, successional changes were probably not complete in this habitat and the community is expected to continue to change. The disappearance of limnetic zooplankton is common to reaches of streams below reservoirs. Ward's (1975) study on the South Platte River below a large reservoir is a good example. Relative abundances of cladocerans, copepods, and rotifers decreased 79%, 91%, and 61%, respectively, over an 8.5 km (5.2 mi) stretch downstream from the reservoir.

Effect of L Lake Releases on Steel Creek Zooplankton

The abundance, diversity, and turnover of zooplankton populations in Steel Creek reflect zooplankton community composition and population densities in L Lake and flow rates from the L-Lake dam. Whether or not L Reactor was operational, zooplankton were introduced continuously into the corridor of Steel Creek, above the delta and swamp. When L Reactor operated, populations of limnetic zooplankton were introduced into the corridor of Steel Creek at an accelerated rate.

Zooplankton Taxa Found in Steel Creek

A comprehensive list of taxa identified from monthly zooplankton collections in Steel Creek at corridor, swamp, and delta stations during 1984 and 1985 is given in Chimney and Cody (1986). These taxa represented three broad taxonomic categories, including the phylum Rotifera (33 taxa), and within the phylum Arthropoda, the order Cladocera (16 taxa), and the subclass Copepoda (9 taxa).

The most recent sampling has monitored zooplankton populations in Steel Creek and L Lake from 1986 through 1989. Results presented here were obtained by averaging the monthly results from all corridor (stations 275, 280, and 290) and swamp and delta (stations 310, 330, 350, and 370) stations from 1986 to 1989.

Species Densities

Cladoceran densities in the Steel Creek corridor reached their greatest concentrations during May and June for 1986, 1987, and 1988 (Figure 5-58). Thereafter, densities remained low. Cladoceran densities in the corridor region most likely reflect populations originating from L Lake whose numbers significantly decreased after 1988 due to threadfin shad predation. Copepod populations also suffered, but to a lesser degree, from fish predation in L Lake (Figure 5-59). Copepod densities remained greater than 5 organisms/l throughout the study period. Greatest densities were observed during May 1986, May 1987, September 1987, and during the winter of 1988. Variation between years and within each season was considerable due to natural variations and differences in sampling methods. Rotifers also had no pronounced seasonal cycle in the corridor (Figure 5-60). These patterns reflect two features of Steel Creek between L Lake and the swamp. Zooplankton from L Lake are continuously being washed into the corridor, especially when flow rates (>11 m^3/sec) were greatest due to L-Reactor operations. Furthermore, thermal loading into L Lake altered species composition and seasonal population cycles.

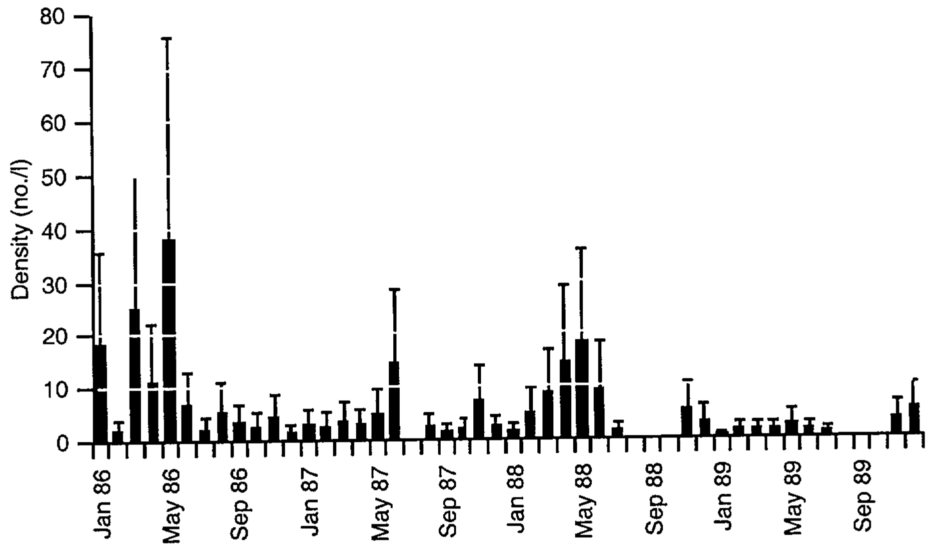

Figure 5-58. Cladoceran Densities Averaged over Steel Creek Corridor Stations, 1986-1989 (There is a difference in scale among the figures in this series.)

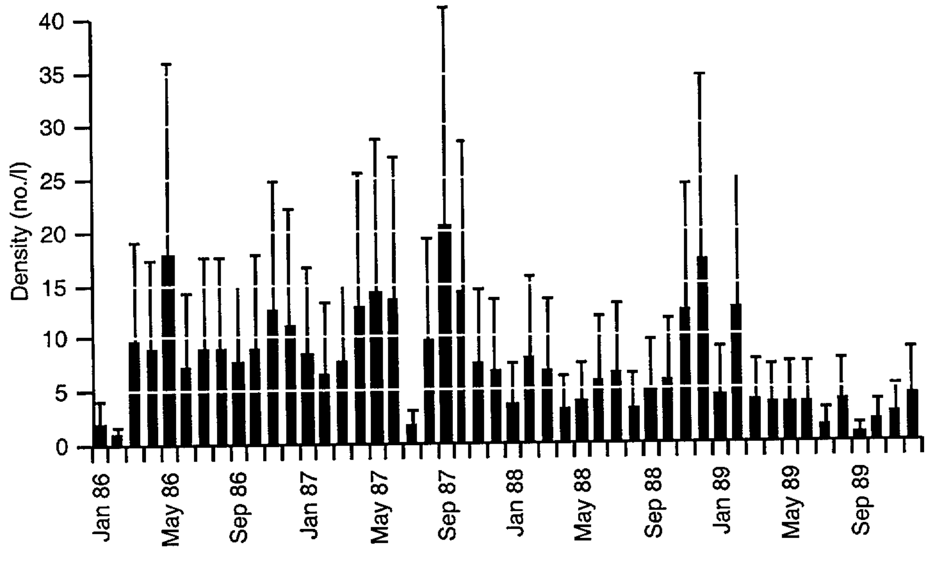

Figure 5-59. Copepod Densities Averaged over Steel Creek Corridor Stations, 1986-1989

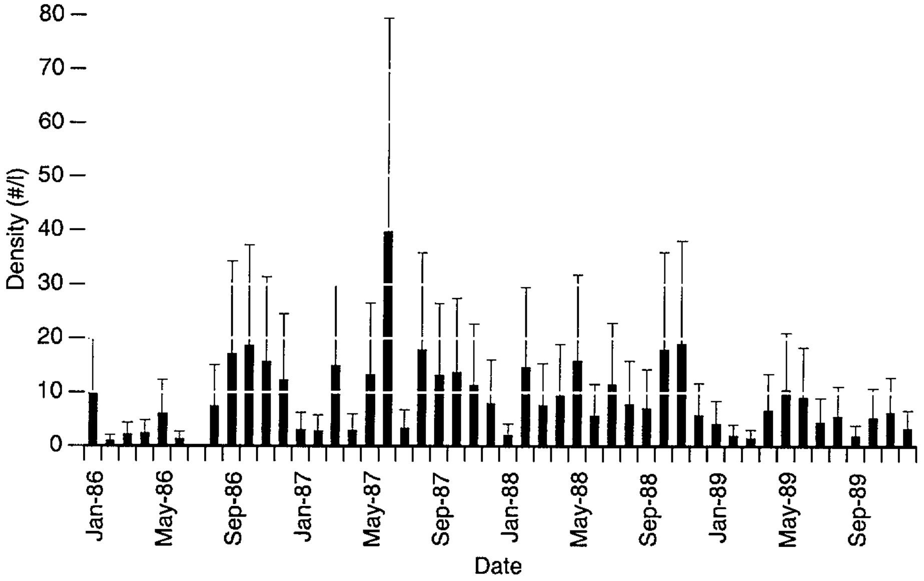

Figure 5-60. Rotifer Densities Averaged over Steel Creek Corridor Stations, 1986-1989

Most of the zooplankton originating in L Lake are consumed by stream predators before reaching the delta and swamp. Significant zooplankton populations in the swamp and delta occur only in slow flowing sections. They do not play a significant role in community metabolism. Cladoceran populations at swamp stations were sporadic throughout the study period with low densities and no marked seasonal trend (Figure 5-61). Copepod densities also did not follow any seasonal pattern, having their greatest abundances several times in any given year (Figure 5-62). Rotifer populations in the swamp had their greatest densities during February through April 1987, a period when all zooplankton groups were abundant (Figure 5-63).

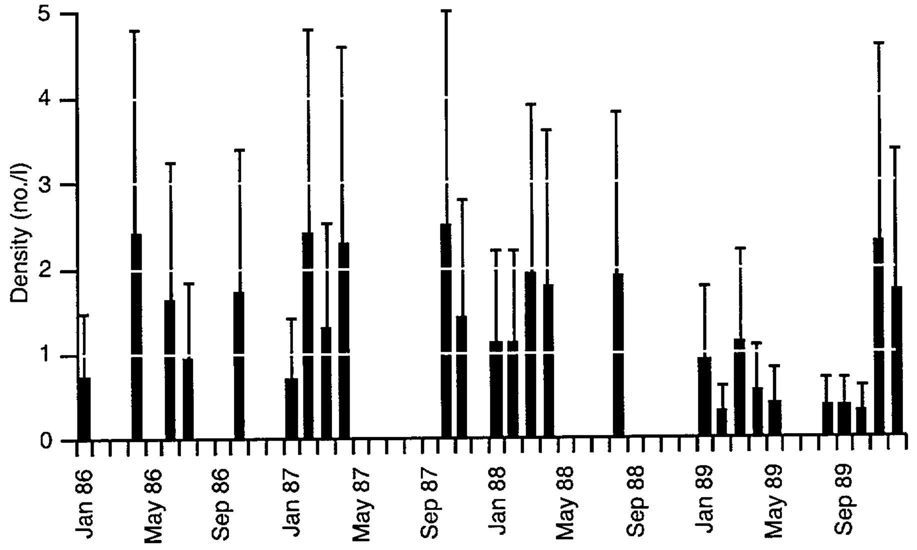

Figure 5-61. Cladoceran Densities Averaged over the Steel Creek Swamp Stations, 1986-1989

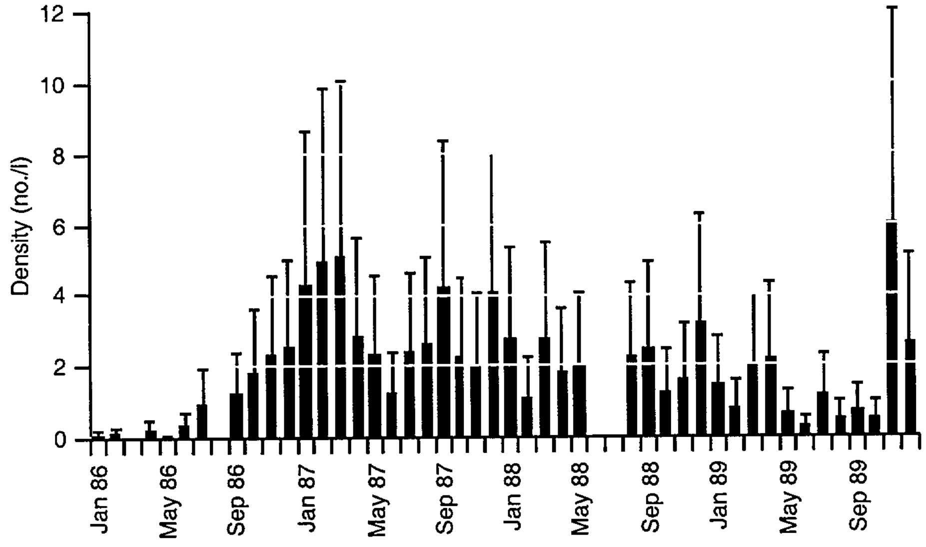

Figure 5-62. Copepod Densities Averaged over the Steel Creek Swamp Stations, 1986-1989

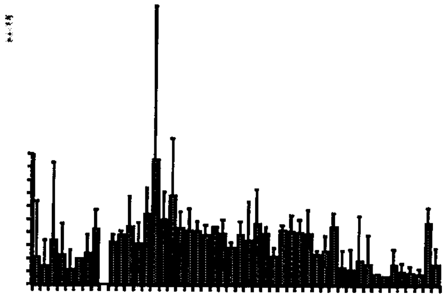

Figure 5-63. Rotifera Densities Averaged over the Steel Creek Swamp Stations, 1986-1989

Macroinvertebrates

Sampling Locations and Methods

Comprehensive Cooling Water Study

Macroinvertebrates were collected at 11 stations in Steel Creek and 2 stations in Meyers Branch in 1983-1985 as part of the CCWS. CCWS data will not be discussed here, because the data collected subsequent to impoundment of Steel Creek are more representative of present conditions. A summary of the CCWS macroinvertebrate data for Steel Creek can be found in Specht (1987).

Clean Water Act Section 316(a) Demonstration and Miscellaneous Studies

From January 1986 through December 1991, macroinvertebrates were collected at up to 12 stations throughout the Steel Creek corridor, marsh and swamp, and lower channel regions and at 1 station in Meyers Branch, a tributary of Steel Creek (Figure 5-64).

Between 1986 and 1989, macroinvertebrates were sampled monthly with Hester-Dendy multiplate samplers at each of the 13 sampling stations. Macroinvertebrate drift and insect emergence were sampled monthly at seven stations. Macroinvertebrates were collected from natural substrates, including snags, macrophytes and sediment cores semiannually at 7 stations and qualitative sampling of natural substrates was conducted semiannually at 13 stations (Lauritsen and Hosey 1990).

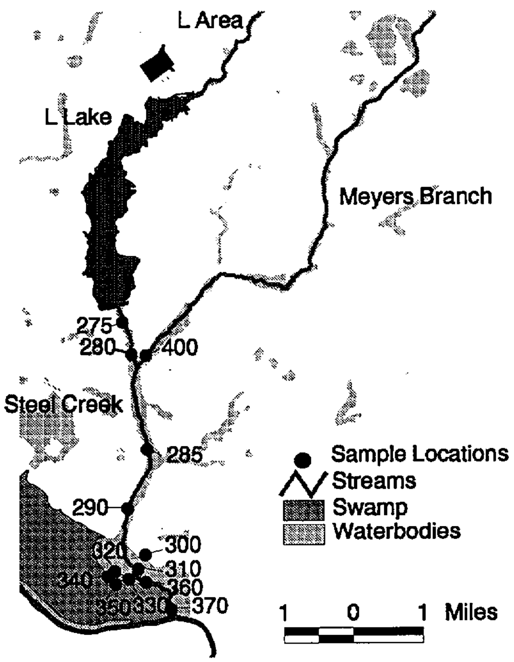

Figure 5-64. Macroinvertebrate Sampling Stations in Steel Creek

In 1990 and 1991, the overall level of effort for macroinvertebrate sampling was reduced. All sampling was restricted to four stations. Hester-Dendy samples, drift, and qualitative dip net samples were collected quarterly at each of the four stations. Natural substrates were sampled semiannually. Emergence continued to be sampled monthly, but beginning in June 1990, a different type of emergence trap was used (Trapp and Hosey 1992). Due to the changes in sampling frequency for most parameters, data from 1990 to 1991 are not directly comparable to the 1986-1989 data. However, for summary purposes, annual means for the data for all six years will be presented.

Macroinvertebrates were sampled during the summer of 1993 at two locations in Steel Creek and at one site on a small tributary of Steel Creek. Hester-Dendy multiplate macroinvertebrate samplers were deployed for one month (Specht 1994).

Macroinvertebrates also were sampled in September 1994 using Hester-Dendy multiplate samplers to develop a biotic index for southeastern streams. While not specifically designed to characterize SRS streams, these data contribute to a better understanding of the streams. Meyers Branch was sampled during this study (Specht and Paller 1995).

Results

Introduction

The small tributary of Steel Creek that was sampled in 1993 receives no discharges from SRS operations. Results indicate that it is perturbed, probably because of low oxygen concentrations that may be due to beaver dams upstream of the sampling location (Specht 1994).

Until 1996, Steel Creek and its major tributary, Meyers Branch, received effluents from nine National Pollutant Discharge Elimination System (NPDES) outfalls in L and P Areas, and the Railroad Yard. In 1996, with the issuance of the new NPDES permit, outfalls were consolidated or eliminated. Presently, only five NPDES outfalls discharge to L Lake and Steel Creek (L-07, L-07A, L-08, P-13 and P-14). Until 1968, Steel Creek received thermal effluents directly from L Reactor and in 1985, L Lake was constructed on the upper reaches of Steel Creek to protect the downstream reaches from thermal effluent.

Steel Creek and Meyers Branch both support diverse and productive macroinvertebrate communities. Macroinvertebrate taxa richness, densities, and biomass in Steel Creek were generally similar to what has been observed in reference streams at SRS, as well as in other southeastern streams. The macroinvertebrate community in the stream corridor downstream from L Lake is strongly influenced by seston inputs from the reservoir. The corridor stations contain high densities and biomass of filter-feeding organisms. The macroinvertebrate communities of the delta and lower creek channel appear to be affected little by the impoundment of Steel Creek, although *Chaoborus* and other lentic species were collected at times, particularly in the drift samples.

The macroinvertebrate community at Road B was sampled in 1993 in a lotic area without flow just upstream from L Lake. It appeared perturbed when compared with the community sampled at Road A, downstream of the L-Lake dam. It had fewer total taxa (29 vs. 49), lower density (717.3 organisms/m^2 vs. 1124 organisms/m^2), and lower biomass (0.057 g AFDW/m^2 vs. 0.1153 g AFDW/m^2) (Specht 1994).

Taxa Richness

Taxa richness (mean number of macroinvertebrate taxa per station) on Hester-Dendy multiplate samplers ranged, except at Road B, from 35 to 103 (Table 5-134). In general, taxa richness was lowest just downstream from L Lake (Stations 275 and 280) and at stream channel Station 360. Taxa richness in Meyers Branch, on the average, was a little higher than at most stations in Steel Creek.

Dominant Taxa

During the six years of sampling between 1986 and 1991, dominant groups of taxa in Steel Creek and Meyers Branch included dipterans (13.0 to 94.2%), caddisflies (1.0 to 46.5%), oligochaetes (0.3 to 36.9%) and mayflies (<0.1 to 37.97%; Table 5-135). Gastropods (snails), isopods, and amphipods were locally abundant in the delta (stations 300-350).

Table 5-134. Mean Number of Macroinvertebrate Taxa/Station Collected from Hester-Dendy Multiplate Samplers in Steel Creek and Meyers Branch, 1986-1994

	Year							
Station	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1993**	**1994**
Road B	-	-	-	-	-	-	29	-
Corridor							-	
275	38	35	39	52	36	-		-
280	41	48	52	53	-	-	-	-
Road A	-	-	-	-	-	-	49	-
285	49	47	61	51	-	-	-	-
290	54	59	57	56	70	103	-	-
Delta								
300	55	49	63	49	-	-	-	-
310	53	46	57	48	-	-	-	-
320	54	54	57	51	-	-	-	-
330	54	60	48	57	69	87	-	-
340	50	55	64	69	-	-	-	-
350	51	51	60	67	57	82	-	-
Channel								
360	36	36	56	45	-	-	-	-
370	41	52	60	60	76	60	-	-
Meyers Branch								
400	56	62	60	54	-	-	-	48
unnamed tributary	-	-	-	-	-	-	39	-

Table 5-135. Relative Abundance (Percent Composition) of Macroinvertebrate Groups in Steel Creek, 1986-1994

	Station															
Year[a]	**275**	**280**	**285**	**290**	**400**	**300**	**310**	**320**	**330**	**340**	**350**	**360**	**370**	**Rd. B**	**Rd. A**	**Unamed trib.**
Oligochaeta																
1986	1.4	4.1	6.5	1.2	0.3	27.1	5.6	5.0	6.8	3.9	1.4	0.5	0.3	-		
1987	4.1	6.8	2.8	1.2	3.2	7.6	5.6	18.1	6.5	8.1	6.7	0.6	1.1	-		
1988	1.8	1.8	1.4	1.4	0.4	7.3	3.1	13.3	4.2	7.0	7.0	3.4	0.6	-		
1989	4.4	2.5	2.4	2.3	1.2	36.9	10.0	22.2	14.3	18.0	9.2	7.9	6.1	-		
1990	5.6	-	-	2.3	-	-	-	-	6.7	-	7.1	-	10.2			
1991	-	-	-	4.8	-	-	-	-	4.7	-	4.8	-	7.5	-		
1993	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	0.0	0.0
1994	-	-	-	-	2.31	-	-	-	-	-	-	-	-	-		
Nematoda																
1986	<0.1	0.1	0.2	0.4	0.2	0.1	0.5	0.7	0.9	0.3	0.4	0.3	<0.1	-		
1987	<0.1	0.1	0.4	0.5	1.0	1.3	1.3	1.4	0.7	0.3	0.4	0.6	0.2	-		
1988	<0.1	<0.1	0.2	0.1	0.2	0.5	0.5	2.9	0.3	1.5	0.7	0.2	<0.1	-		
1989	<0.1	0.1	0.2	0.3	0.4	1.2	0.6	1.1	0.8	0.9	0.5	0.3	0.5	-		
1990	0.4	-	-	1.7	-	-	-	-	1.3	-	8.0	-	5.3	-		
1991	-	-	-	4.6	-	-	-	-	1.9	-	7.3	-	1.1	-		
1993	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	0.0	0.0
1994	-	-	-	-	0.00	-	-	-	-	-	-	-	-	-		
Platyhelminthes																
1986	<0.1	<0.1	0.6	<0.1	<0.1	<0.1	0.9	1.7	0.5	1.7	0.3	0.1	<0.1	-		
1987	<0.1	0.1	<0.1	0.1	<0.1	3.3	2.0	4.5	1.1	4.0	2.0	0.1	0.5	-		
1988	0.3	0.3	0.1	<0.1	<0.1	2.1	0.4	2.3	0.6	0.8	1.2	0.4	0.5	-		
1989	1.0	0.1	<0.1	0.2	0.1	1.3	0.6	2.8	0.7	2.1	2.2	0.3	<0.1	-		
1990	5.6	-	-	0.0	-	-	-	-	0.0	-	2.8	-	2.1	-		
1991	-	-	-	0.0	-	-	-	-	13.0	-	3.6	-	0.0	-		
1993	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	0.0	0.0
1994	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Hirundinea																
1986	<0.1	0.0	<0.1	<0.1	0.0	1.3	0.2	0.3	0.2	0.8	<0.1	0.1	<0.1	-		
1987	<0.1	<0.1	<0.1	<0.1	<0.1	2.3	0.2	0.6	0.4	0.3	0.1	0.6	0.2	-		
1988	<0.1	<0.1	0.1	<0.1	<0.1	0.5	0.4	2.9	0.2	2.2	1.4	<0.1	<0.1	-		
1989	<0.1	<0.1	<0.1	<0.1	0.0	0.7	0.2	0.3	0.2	0.4	0.2	0.2	12.6	-		
1990	0.4	-	-	3.2	-	-	-	-	2.7	-	1.7	-	0.0	-		
1991	-	-	-	0.0	-	-	-	-	1.4	-	2.5	-	0.0	-		
1993	0.0	-	-	-	-	-	-	-	-	-	-	-	-	0.0	0.0	0.95
1994	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Gastropoda																
1986	0.1	0.2	0.8	0.6	1.3	14.3	6.8	8.8	3.5	17.6	2.2	0.9	0.1	-		
1987	1.4	0.3	0.7	0.5	1.6	14.6	8.2	12.8	12.8	11.2	4.1	0.3	0.7	-		
1988	0.5	0.3	1.2	0.4	1.9	7.6	5.4	10.3	2.9	20.1	3.4	1.0	0.7	-		
1989	1.6	0.3	0.4	0.2	2.6	2.4	3.1	24.4	2.0	6.5	3.2	0.5	2.1	-		
1990	1.0	-	-	4.7	-	-	-	-	11.8	-	11.4	-	17.9	-		
1991	-	-	-	2.3	-	-	-	-	8.0	-	13.6	-	3.8	-		
1993	1.69	-	-	-	-	-	-	-	-	-	-	-	-	0.0	1.69	1.43
1994	-	-	-	-	1.15	-	-	-	-	-	-	-	-	-		
Decapoda																
1986	0.0	0.0	0.0	0.0	<0.1	0.0	<0.1	<0.1	0.0	0.0	<0.1	0.0	0.0	-		
1987	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	<0.1	0.0	0.0	0.0	0.0	-		
1988	0.0	0.0	0.0	0.0	<0.1	<0.1	0.4	0.1	0.1	0.1	0.2	0.3	<0.1	-		
1989	<0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	<0.1	<0.1	0.0	0.2	-		
1990	0.0	-	-	0.0	-	-	-	-	1.9	-	0.0	-	0.0	-		
1991	-	-	-	0.4	-	-	-	-	1.5	-	1.0	-	1.1	-		
1993	0.00	-	-	-	-	-	-	-	-	-	-	-	-	0.0	0.0	0.0
1994	-	-	-	-	-	-	-	-	-	-	-	-	-			

Table 5-135. (cont)

	Station															
Year[a]	275	280	285	290	400	300	310	320	330	340	350	360	370	Rd. B	Rd. A	Unamed trib.
Isopoda																
1986	0.0	0.0	<0.1	<0.1	0.0	8.8	4.8	2.2	0.5	0.0	<0.1	<0.1	<0.1	-		
1987	0.0	<0.1	<0.1	<0.1	0.0	6.0	2.5	4.3	1.2	0.1	0.3	0.1	<0.1	-		
1988	0.0	<0.1	<0.1	<0.1	<0.1	8.9	1.5	<0.1	0.9	0.1	0.1	0.2	<0.1	-		
1989	0.0	0.0	<0.1	<0.1	0.0	0.5	0.3	<0.1	0.4	0.0	<0.1	0.1	<0.1	-		
1990	0.0	-	-	0.0	-	-	-	-	11.9	-	1.0	-	2.3	-		
1991	-	-	-	0.2	-	-	-	-	23.7	-	4.6	-	1.5	-		
1993	0.0	-	-	-	-	-	-	-	-	-	-	-	-	0.0	0.0	0.0
1994	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Amphipoda																
1986	<0.1	<0.1	<0.1	0.1	0.1	1.2	13.4	14.4	12.9	2.2	7.1	3.2	0.8	-		
1987	<0.1	0.0	0.0	<0.1	0.1	7.3	12.1	4.1	7.4	1.1	5.6	2.8	2.5	-		
1988	0.0	<0.1	<0.1	<0.1	0.2	13.8	15.3	0.8	16.3	1.1	6.4	12.8	4.3	-		
1989	<0.1	<0.1	<0.1	<0.1	0.3	1.8	12.7	1.3	6.4	1.0	8.6	4.5	3.1	-		
1990	0.8	-	-	0.0	-	-	-	-	16.0	-	13.0	-	12.7	-		
1991	-	-	-	1.0	-	-	-	-	11.0	-	6.4	-	5.1	-		
1993	0.0	-	-	-	-	-	-	-	-	-	-	-	-	0.0	0.0	2.38
1994	-	-	-	-	0.0	-	-	-	-	-	-	-	-	-		
Hydracarina																
1986	<0.1	0.3	1.5	1.8	0.3	0.1	0.5	0.2	0.9	0.4	0.5	0.2	0.2	-		
1987	<0.1	0.6	0.8	2.0	0.7	0.2	0.4	1.2	0.7	0.5	0.5	1.1	0.4	-		
1988	<0.1	0.4	0.5	0.6	0.3	0.8	0.7	0.7	1.3	0.8	0.6	0.9	0.2	-		
1989	0.2	0.2	0.4	0.8	0.4	1.9	1.7	0.3	1.4	0.8	0.8	1.6	1.1	-		
1990	0.4	-	-	6.3	-	-	-	-	9.3	-	2.8	-	3.5	-		
1991	-	-	-	13.8	-	-	-	-	8.1	-	6.4	-	8.1	-		
1993	1.49	-	-	-	-	-	-	-	-	-	-	-	-	0.0	1.49	2.38
1994	-	-	-	-	0.07	-	-	-	-	-	-	-	-	-		
Collembola																
1986	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	<0.1	0.0	0.0	0.0	0.0	0.0	-		
1987	0.0	<0.1	0.0	0.0	0.0	0.0	0.1	<0.1	0.1	0.0	<0.1	0.1	0.0	-		
1988	0.0	0.0	0.0	0.0	0.0	<0.1	<0.1	0.0	0.0	0.0	0.0	0.0	<0.1	-		
1989	0.0	0.0	0.0	0.0	0.0	0.0	0.0	<0.1	0.0	<0.1	0.0	<0.1	0.0	-		
1990	0.0	-	-	3.3	-	-	-	-	3.5	-	0.0	-	1.4	-		
1991	-	-	-	0.2	-	-	-	-	1.6	-	0.8	-	0.0			
1993	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
1994	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Ephemeroptera																
1986	<0.1	0.7	3.5	4.2	6.2	0.7	6.1	3.3	12.0	7.4	6.9	7.4	2.7	-		
1987	<0.1	0.6	1.9	5.1	14.2	2.8	7.7	2.5	11.1	16.3	8.4	15.3	10.3	-		
1988	0.1	2.9	6.3	6.9	15.0	6.5	7.3	3.6	21.1	9.5	7.2	14.8	7.6	-		
1989	0.6	5.0	8.9	4.8	9.7	2.6	5.5	3.8	7.2	7.3	7.4	21.5	13.6	-		
1990	0.4	-	-	14.8	-	-	-	-	4.0	-	6.9	-	10.2	-		
1991	-	-	-	8.1	-	-	-	-	3.8	-	7.8	-	9.6	-		
1993	37.97	-	-	-	-	-	-	-	-	-	-	-	-	10.44	37.97	10.95
1994	-	-	-	-	24.57	-	-	-	-	-	-	-	-	-		

Table 5-135. (cont)

	Station														
Year[a]	**275**	**280**	**285**	**290**	**400**	**300**	**310**	**320**	**330**	**340**	**350**	**360**	**370**	**Rd. B**	**Rd. A**	**Unamed trib.**
Plecoptera																
1986	0.0	<0.1	0.1	0.4	1.3	<0.1	0.0	0.0	<0.1	0.0	0.0	0.0	<0.1	-		
1987	0.0	<0.1	<0.1	0.3	2.9	0.0	0.0	0.0	0.0	<0.1	<0.1	0.0	0.1	-		
1988	0.0	0.1	0.3	0.6	3.8	<0.1	0.0	0.0	<0.1	0.1	<0.1	<0.1	<0.1	-		
1989	<0.1	0.1	0.4	0.4	4.3	<0.1	0.1	0.1	<0.1	0.1	<0.1	0.1	0.1	-		
1990	0.0	-	-	2.4	-	-	-	-	1.6	-	0.0	-	1.4	-		
1991	-	-	-	3.3	-	-	-	-	0.7	-	0.0	-	2.2	-		
1993	0.0	-	-	-	-	-	-	-	-	-	-	-	-	0.0	0.0	0.0
1994	-	-	-	-	1.08	-	-	-	-	-	-	-	-	-		
Coleoptera																
1986	<0.1	0.2	0.7	0.2	2.3	0.2	0.6	0.1	0.4	0.6	0.9	0.5	0.3	-		
1987	<0.1	0.3	0.6	0.2	4.5	0.1	0.2	<0.1	0.3	0.4	1.1	0.9	1.2	-		
1988	<0.1	0.1	0.4	0.1	2.7	0.3	0.1	0.1	0.4	0.8	1.1	1.3	0.9	-		
1989	<0.1	<0.1	0.5	0.3	2.9	0.4	0.1	0.2	0.1	0.7	1.1	1.1	1.4	-		
1990	0.0	-	-	4.8	-	-	-	-	0.4	-	1.9	-	5.3	-		
1991	-	-	-	8.3	-	-	-	-	2.2	-	3.0	-	3.4	-		
1993	11.83	-	-	-	-	-	-	-	-	-	-	-	-	0.0	11.83	0.0
1994	-	-	-	-	1.15	-	-	-	-	-	-	-	-	-		
Trichoptera																
1986	13.5	22.1	6.6	16.2	6.4	1.2	9.3	2.1	6.5	2.6	2.8	9.4	4.3	-		
1987	2.3	13.9	3.5	16.5	8.6	1.0	1.8	2.1	6.8	1.5	2.3	8.7	11.0	-		
1988	3.0	36.0	7.6	17.7	9.1	3.1	3.1	3.8	7.0	3.1	3.2	10.8	6.8	-		
1989	20.2	46.5	19.0	29.9	7.8	6.7	10.4	2.1	8.6	4.6	8.5	5.9	5.3	-		
1990	21.0	-	-	21.9	-	-	-	-	5.9	-	5.9	-	7.5	-		
1991	-	-	-	9.0	-	-	-	-	2.7	-	4.5	-	20.9	-		
1993	10.93	-	-	-	-	-	-	-	-	-	-	-	-	4.36	10.93	3.81
1994	-	-	-	-	1.51	-	-	-	-	-	-	-	-	-		
Odonata																
1986	<0.1	0.0	0.0	<0.1	<0.1	0.8	0.8	1.2	1.5	0.7	0.5	0.1	<0.1	-		
1987	<0.1	<0.1	0.0	<0.1	0.1	1.4	0.7	0.3	0.6	0.6	0.3	0.0	0.0	-		
1988	<0.1	<0.1	<0.1	<0.1	<0.1	1.9	0.7	0.2	0.5	1.1	0.9	0.3	0.2	-		
1989	0.4	-	-	2.1	-	-	-	-	1.3	-	5.2	-	1.0	-		
1990	-	-	-	0.4	-	-	-	-	1.8	-	5.3	-	0.0	-		
1991		-	-	-	-	-	-	-	-	-	-	-	-	-		
1993	0.10	-	-	-	-	-	-	-	-	-	-	-	-	1.40	0.10	0.0
1994	-	-	-	-	0.14	-	-	-	-	-	-	-	-	-		
Diptera																
1986	84.9	72.2	79.2	74.7	81.2	44.0	50.2	59.7	53.1	61.8	76.7	76.7	91.2	-		
1987	91.9	76.2	88.9	73.4	62.5	51.9	56.9	47.9	49.8	55.5	68.1	68.9	71.1	-		
1988	94.2	57.7	81.4	72.0	65.7	45.9	60.7	57.4	44.1	51.0	66.3	53.2	77.7	-		
1989	71.5	44.7	67.3	60.5	69.5	42.3	54.1	40.3	57.4	56.6	57.1	55.2	53.2	-		
1990	63.6	-	-	25.5	-	-	-	-	16.6	-	30.3	-	15.8	-		
1991	-	-	-	41.6	-	-	-	-	13.0	-	27.4	-	35.1	-		
1993	43.84	-	-	-	-	-	-	-	-	-	-	-	-	83.80	35.29	76.19
1994	-	-	-	-	68.02	-	-	-	-	-	-	-	-	-		

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[a] No sampling occurred in 1992.

From 1986 to 1991, the relative abundance of dipterans decreased at most stations, while the relative abundance of oligochaetes, caddisflies, and mayflies increased (Lauritsen and Hosey 1990; Trapp and Hosey 1992).

Although species composition differed somewhat among stations and among years, the most common taxa collected on the multiplate samplers in the Steel Creek corridor included filter-feeding organisms such as *Simulium* (blackflies), tanytarsine and orthoclad chironomids, Coleoptera, mayflies, and net-spinning caddisflies such as *Cheumatopsyche* and *Hydropsyche*. In the delta, amphipods (*Hyalella azteca* and *Gammarus fasciatus*), oligochaetes, caddisflies (*Cheumatopsyche* and *Oxythira*), isopods (*Caecidotea*), gastropods (*Amnicola, Physella, Menetus*, and limpets), mayflies (*Baetis*, *Eurylophella*, and *Stenonema*) and the chironomid groups Tanypodinae, Orthocladiinae, Chironomini, and Tanytarsini were most abundant. Dominant taxa at the channel stations included oligochaetes; the mayfly, *Stenonema*; and orthoclad and tanytarsine chironomids. Chironomids (68.8%) and mayflies (104.4%) dominated the lotic station at Road B.

Densities

The mean annual density of organisms collected from the multiplate samplers ranged from 294.7 organisms/m^2 at delta Station 330 in 1990 to 41,080.3 organisms/m^2 at corridor Station 275 in 1988 (Table 5-136). Macroinvertebrate densities just downstream from the L-Lake dam at Station 275 were always much higher than at the other stations, due to the presence of numerous filter-feeding organisms that fed on the seston inputs flowing into the stream from L Lake. In general, macroinvertebrate densities were higher in the upper stream corridor than in the delta. In the stream channel downstream from the delta, densities were always lower at Station 360 than near the creek mouth (Station 370). In Meyers Branch, macroinvertebrate densities were usually fairly similar to densities in the Steel Creek delta (Table 5-136). Although macroinvertebrate densities at all stations varied considerably among years, no distinct temporal trends were observed during the six-year study (Table 5-136).

Biomass

Macroinvertebrate biomass on the multiplate samplers, as measured by ash-free dry weight/m^2, ranged from 0.001 g AFDW/m^2 at Station 370 in 1990 to 8.220 g AFDW/m^2 at Station 275 in 1988 (Table 5-137). In general, biomass followed the same patterns as density, with the highest biomass usually found at stations in the stream corridor just downstream from the L-Lake dam. No distinct temporal trends were observed.

Drift

Densities

Mean annual densities of macroinvertebrate drift in Steel Creek ranged from 1653.6 organisms/1000 m^3 at Station 330 in 1991 to 35,880.7 organisms/1000 m^3 at this same station in 1990 (Table 5-138). High drift densities were reported at delta Stations 330 and 350 during the spring of 1990. No obvious reason for the high drift densities was reported. Drift could not be collected at these two stations during the spring of 1991 due to low water levels (Trapp and Hosey 1992).

Table 5-136. Mean Annual Macroinvertebrate Densities (no./m^2) on Hester-Dendy Multiplate Samplers in Steel Creek and Meyers Branch, 1986-1994

	Year							
Station	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1993**[a]	**1994**[a]
Road B	-	-	-	-	-	-	717.3	-
Corridor								
275	15,078.1	8,258.5	41,080.3	12,456.5	-	-	-	-
280	-	-	-	-	-	-	-	-
Road A	-	-	-	-	-	-	1,124.0	-
285	3,400.4	2,347.5	3,788.8	2,518.5	-	-	-	-
290	3,113.6	3,635.6	4,376.6	3,849.8	6,535.8	4,277.9	-	-
Delta								
300	1,138.7	732.5	794.7	631.8	-	-	-	-
310	864.5	770.3	892.5	595.3	-	-	-	-
320	1,751.4	1,548.7	870.5	577.6	-	-	-	-
330	889.7	1,202.4	688.7	1,023.8	294.7	695.5	-	-
340	1,086.7	1,032.9	754.3	1,125.9	-	-	-	-
350	1,176.9	880.5	748.1	1,042.7	586.6	722.5	-	-
Channel								
360	486.0	414.2	631.4	410.8	-	-	-	-
370	2,996.3	995.1	1,815.2	635.5	611.7	1,141.1	-	-
Meyers Branch								
400	1,472.7	837.4	818.7	557.9	-	-	-	1,550.8

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[a] Densities are not annual.

Table 5-137. Mean Annual Macroinvertebrate Biomass (AFDW g/m^2) on Hester-Dendy Multiplate Samplers in Steel Creek and Meyers Branch, 1986-1994

	Year							
Station	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1993**[a]	**1994**[a]
Road B	-	-	-	-	-	-	0.0570	-
Corridor								
275	4.634	1.217	8.220	3.575	-	-	-	-
280	1.428	1.033	1.750	2.404	-	-	-	-
Road A	-	-	-	-		-	0.1153	-
285	0.370	0.336	0.611	1.178	--	-	-	-
290	0.335	0.356	0.518	0.493	0.254	0.613	-	-
Delta								
300	0.184	0.107	0.123	0.069	-	-	-	-
310	0.407	0.156	0.338	0.287	-	-	-	-
320	0.551	0.204	0.367	0.768	-	-	-	-
330	0.197	0.220	0.284	0.374	0.097	0.529	-	-
340	0.204	0.145	0.106	0.310	-	-	-	-
350	0.126	0.128	0.185	0.271	0.015	0.008	-	-
Channel								
360	0.323	0.103	0.315	0.351	-	-	-	-
370	0.494	0.289	0.388	0.202	0.001	0.170	-	-
Meyers Branch								
400	0.152	0.110	0.146	0.197	-	-	-	0.1071

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[a] Biomass is not an annual measurement.

AFDW=Ash-free dry weight.

Table 5-138. Mean Annual Density (no./1000 m^3) of Macroinvertebrate Drift in Steel Creek, 1986-1991

	Year					
Station	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
Corridor						
275	1,976.9	4,684.7	3,712.9	3,704.9	-	-
280	4,976.1	5,363.4	5,187.4	1,995.2	-	-
290	3,426.2	6,422.3	2,772.6	1,807.1	2,606.9	4,184.6
Delta						
310	4,741.0	4,639.6	3,793.0	2,908.2	-	-
330	2,669.4	6,216.8	2,083.5	4,361.8	35,880.7	1,653.6
350	3,417.9	3,016.7	1,980.3	1,895.5	26,613.3	3,076.4
Channel						
370	2,696.3	2,974.3	2,100.0	1,758.1	8,111.2	4,718.3

Dominant Species

Dominant taxa collected in the drift included oligochaetes; hydroptilid caddisflies (*Oxyethira* and *Hydroptila*); the mayflies *Baetis*, *Caenis*, and *Stenonema*; the amphipod, *Hyalella azteca*; water mites; blackflies (*Simulium*); the phantom midge, *Chaoborus punctipennis*; and the chironomids *Rheotanytarsus, Cricotopus and Orthocladius.* The taxonomic composition of the drift varied greatly seasonally.

Fish

Introduction

McFarlane (1976) first studied the fish assemblages of Steel Creek. However, extensive sampling began in 1983 and continued through 1985 (Paller et al. 1984, 1985, and 1986a). These studies emphasized ichthyoplankton but also included limited sampling of adult and juvenile fish. Their objective was to assess the importance of spawning habitats in Steel Creek that could be damaged by the planned restart of L Reactor in late 1985.

Fisheries studies were intensified during 1986-1991 to document the effects of thermal effluents released from L Reactor on the Steel Creek fish assemblages. These comparatively extensive studies included both juvenile and adult, and ichthyoplankton sample stations located throughout Steel Creek. The following discussion of fisheries studies in Steel Creek has been divided into two sections: before the L-Reactor restart and after the L-Reactor restart.

Studies Conducted Prior to the Restart of L Reactor

Thermal effluent from L Reactor was discharged directly into Steel Creek during 1954-1968, resulting in the destruction of the cypress-tupelo canopy in portions of the Steel Creek swamp and the stream corridor upstream from the swamp (Gladden et al. 1985). Loss of vegetation cover and high reactor flows also caused erosion in the stream corridor and the deposition of sediments where Steel Creek enters the Savannah River swamp. After reactor discharges ceased in 1968, areas of open-canopy swamp previously impacted by high temperatures and sediment deposition came to support a marsh habitat characterized by an abundance of submerged and emergent macrophytes and woody plants such as willow and buttonbush.

McFarlane (1976) studied the fish assemblage in Steel Creek to determine if it had recovered from previous thermal discharges from L-Reactor. He reported that recovery was "almost complete," based on comparisons of species richness between Steel Creek and nearby unimpacted streams.

Sampling efforts in Steel Creek during 1983-1985 were part of the CCWS, which evaluated the impacts of SRS operations on spawning activity and ichthyoplankton distribution at sites on SRS and in the Savannah River. Special emphasis was placed on Steel Creek because of concerns that it would be affected negatively by the restart of L Reactor after approximately 17 years of nonoperation (with the exception of a brief operational period in the mid-1970s). Ichthyoplankton sampling originally was confined to the mouth of Steel Creek to document the contribution of Steel Creek to the ichthyoplankton assemblages of the Savannah River, but was later expanded to include sample sites in the swamp, marsh, and channel habitats upstream from the stream mouth. Samples also were taken from the Savannah River and Savannah River tributaries to develop a basis for assessing the relative importance of Steel Creek compared with other spawning sites. Ichthyoplankton were collected weekly with paired 0.505-mm mesh nets during daylight from February through July. The number of samples collected was approximately equal among years.

Ichthyoplankton composition in Steel Creek near its confluence with the Savannah River varied among years. Larval minnows (Cyprinidae), larval yellow perch (*Perca flavescens*), larval sunfish/bass (Centrarchidae), and blueback herring (*Alosa aestivalis*) were the most abundant taxa in 1983 (Table 5-139). Species composition was fairly similar in 1984 except that darters replaced yellow perch. However, species composition changed in 1985 when American shad, blueback herring, and darters were the dominant species and minnows and sunfishes were comparatively rare (Paller et al. 1984, 1985, and 1986a).

Table 5-139. Relative Abundance of Ichthyoplankton in Steel Creek, 1983-1985

Species	1983	1984	1985
unidentifiable clupeid		1.1	1.6
blueback herring	14.5	6.9	27.2
American shad	3.2	2.2	33.2
gizzard or threadfin shad		0.5	
pickerel			
minnow	25.0	37.8	4.0
carp			
unidentifiable sucker	1.0	0.8	0.4
spotted sucker	0.5		1.2
catfish or bullhead			
pirate perch	4.7	0.1	
topminnow			
pickerel	0.3	0.1	
brook silversides	1.8	0.9	0.4
striped bass			
unidentifiable sunfish	3.8	9.8	3.6
sunfish (*Lepomis*)	16.3	17.5	1.2
crappie	2.3	3.1	
largemouth bass		0.2	
darter	3.1	17.7	12.0
yellow perch	22.1	0.2	2.0
unidentifiable larvae or eggs	1.7	1.1	13.2
total percent	100.0	100.0	100.0
total larvae and eggs	621	871	250
number ichthyoplankton transported to river x 10^6	77	53	5
mean discharge (m^3/sec)	26	16	9

Source: Paller et al. 1985.

Despite this variability, Steel Creek was consistently one of the most productive Savannah River tributaries in terms of its contribution to the river ichthyoplankton assemblage. This contribution was assessed by determining the number of ichthyoplankton transported from creek to river (Paller et al. 1984, 1985, and 1986a). In 1983, Steel Creek ranked ninth among the 33 major tributaries between river kilometers 47.6 and 301 (River mile 29.6 and 187.1), essentially from Savannah, Georgia, to Augusta, Georgia. (The only creeks with greater ichthyoplankton contributions were in lower reaches of the river.) A similar pattern was observed during 1984 except that only three creeks transported more ichthyoplankton into the Savannah River than Steel Creek. In 1985, more ichthyoplankton were transported to the Savannah River from Steel Creek than from any other tributary under study. The number of ichthyoplankton transported from all creeks was much lower during 1985 than during 1984 or 1983, possibly due to decreased creek discharges (79% lower during 1985 than 1984) or decreased spawning resulting from comparatively low water levels.

Ichthyoplankton transported from Steel Creek raised Savannah River ichthyoplankton levels by an estimated 10% in 1983, 12.8% in 1984, and 2% in 1985 (Paller et al. 1984, 1985, and 1986a). All creeks made minimal contributions in 1985. While creek-to-river transport varied among years, Steel Creek consistently demonstrated high transport in relation to the other creeks in the mid-reaches of the Savannah River. Steel Creek also typically produced more American shad and blueback herring eggs and larvae than most of the other creeks. Relatively high ichthyoplankton transport from Steel Creek during three years with dissimilar hydrological patterns indicated that Steel Creek was an important spawning area compared with other Savannah River tributaries.

Identification of the importance of Steel Creek as a spawning area led to further interest in locating and assessing the spawning and nursery areas in Steel Creek. Fifteen ichthyoplankton sample stations were established throughout Steel Creek (Paller et al. 1986b); most were concentrated in the lower reaches of the creek, which consisted of three main habitats: creek mouth, a channel connecting the creek mouth to the marsh and swamp, and the marsh and swamp. The marsh and swamp consisted of open canopy marsh habitats where previous discharges from L Reactor killed the cypress-tupelo canopy and closed canopy cypress-tupelo swamp. Aquatic macrophytes were abundant in the open canopy areas.

Sampling was conducted weekly from February through July during 1984 and 1985 (Paller 1985, Paller et al. 1986b). Spawning generally began in March, peaked in April and May, then declined through June and July. In 1984, ichthyoplankton densities were approximately comparable in the swamp and marsh and creek mouth; densities further upstream in Steel Creek were relatively low (Paller et al. 1986b). In 1985, densities were highest in the creek mouth but also fairly high in the creek channel and at several locations upstream from the swamp and marsh. However, species composition differed among habitats with American shad, blueback herring, and darters predominating in the creek mouth and channel and minnows and darters predominating further upstream. These data indicated the importance of the creek mouth and creek channel habitats as spawning areas for anadromous fish.

Most of the ichthyoplankton sampling efforts in Steel Creek concentrated on assessing and comparing ichthyoplankton distribution among macrohabitats (i.e., creek mouth, marsh, swamp, upper creek). However, efforts also were made to assess the distribution of ichthyoplankton among microhabitats in portions of the Steel Creek marsh and swamp (Paller 1987). Three microhabitats (macrophyte beds, open channels, and macrophyte bed/open channel interface) were sampled by pumping water through a 0.505-mm mesh net with a trash pump. Samples were taken in the day and at night. The results demonstrated high abundances of a number of taxa (suckers, minnows, pirate perch, and sunfishes) within the macrophyte beds, indicating the importance of this habitat as a spawning or nursery area (Table 5-140). Larvae seldom were found in the open channels except at night. Larvae drifting in the open channels were invariably young and probably originated in the macrophyte beds. Many were undoubtedly transported out of Steel Creek into the Savannah River.

Aho et al. (1986) sampled adult and juvenile fishes by electrofishing in Steel Creek and two other streams to assess the persistence and stability of the fish assemblages in these streams. Steel Creek had slightly higher species richness and diversity than the other streams (Table 5-141). Species richness was highest in the lower reaches of all streams. While limited temporal variability occurred at all sites, there were no consistent differences in degree of variability between sites on Steel Creek or between Steel Creek and the other streams under study.

Aho et al. (1986) also electrofished 12 sample sites in the Savannah River swamp system, three of which were in the Steel Creek marsh and swamp. The number of species and fish density were highest in the Steel Creek marsh where habitat diversity, structural complexity, and primary productivity were high as a result of abundant macrophyte growth and other factors related to the progression of secondary succession. Sites in the Steel Creek marsh were dominated by small-bodied species such as minnows and brook silversides, while larger species were more common in closed canopy areas with less macrophyte growth. While the fish assemblages in the Steel Creek marsh and swamp varied temporally and annually, assemblage stability and persistence of species were generally high with most species repeatedly found over census periods and the rank order of species abundance remaining relatively constant over time.

Studies Conducted Following the Restart of L Reactor

The ecological importance of the lower reaches of Steel Creek led to the decision to build a cooling reservoir that would reduce the temperature of L-Reactor cooling water to environmentally acceptable levels before it entered the lower reaches of Steel Creek. After the restart of L Reactor in late 1985, the emphasis of fisheries studies in Steel Creek was on assessing possible impacts caused by the presence of L Lake and the operation of L Reactor. These studies initially included 14 sample stations throughout Steel Creek, although this number was reduced to four in 1991. Adult and juvenile fish and ichthyoplankton were collected at each sample station.

There was a major change in reactor operations during the 1986-1992 study period that affected environmental conditions in Steel Creek. L Reactor was operated from 1986 to mid-1988, resulting in the discharge of large volumes of water to Steel Creek. However, L Reactor has not operated since July 1988. The shutdown of L Reactor coupled, in some instances, with decreases in natural runoff due to low rainfall, greatly diminished reservoir releases to Steel Creek. Resulting instream changes included diminished depths, current velocities, and habitat volumes.

The Steel Creek sample stations represented a variety of habitats: corridor (the stream reach between the L Lake dam and the marsh and swamp), marsh (the open canopy area

Table 5-140. Fish Collected During the Night in Open Channel, Channel/Macrophyte Bed Interface and Macrophyte Bed Habitats, February-July 1985

	Open Channel				Channel/Macrophyte Bed Interface				Macrophyte Bed				
Species	**E**[a]	**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
unidentified 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	25
brook silversides	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	2	22	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

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[a] Fish life stage: E = egg; P = prolarvae (yolk sac larvae); L = larvae; J = juvenile; and A = adult.

Table 5-141. Percent Composition of Species in the Fish Assemblages Collected from Streams on the SRS

		Stream Sites								
Scientific Name	**Common Name**	**PB1**	**PB2**	**PB3**	**SC1**	**SC2**	**SC3**	**MB1**	**MB2**	**MB3**
Notropis lutipinnis	yellowfin shiner	-	51.7	50.9	53.8	41.1	9.6	59.4	54.7	43.9
Nocomis leptocephalus	bluehead chub	-	9.7	3.0	13.6	13.2	0.2	8.9	8.0	2.0
Hypentilium nigricans	northern hogsucker	-	-	-	11.3	1.7	0.4	0.6	1.0	1.6
Ameiurus nebulosus	brown bullhead	11.7	1.6	0.3	< 0.1	0.1	0.2	0.1	0.1	0.5
Erimyzon spp. (*oblongus* and *sucetta*)	lake and creek chubsucker	13.0	1.6	1.1	0.9	1.5	0.5	1.6	3.2	1.9
Ameiurus natalis	yellow bullhead	3.2	0.7	0.3	0.1	0.6	0.5	-	0.1	0.8
Ameiurus platycephalus	flat bullhead	-	1.5	0.8	2.0	1.2	0.3	0.1	0.5	0.3
Noturus insignis	margined madtom	-	1.1	4.2	0.6	0.4	0.2	1.0	2.2	0.1
Noturus leptacanthus	speckled madtom	-	-	4.8	2.6	3.2	2.3	1.7	1.8	3.1
Noturus gyrinus	tadpole madtom	-	0.7	0.7	0.2	1.4	0.4	0.9	0.1	0.3
Lepomis marginatus	dollar sunfish	19.4	0.7	0.1	0.2	1.5	0.5	1.4	0.5	0.1
Lepomis auritus	redbreast sunfish	0.9	1.5	5.4	7.2	2.7	3.8	2.2	4.0	1.9
Lepomis punctatus	spotted sunfish	1.9	4.4	4.4	0.4	5.9	14.6	1.5	2.4	4.9
Micropterus salmoides	largemouth bass	-	0.1	0.5	0.4	0.8	2.5	-	0.2	0.1
Anguilla rostrata	American eel	0.7	1.3	0.4	1.2	1.2	3.8	0.4	0.9	10.9
Aphredoderus sayanus	pirate perch	7.8	11.5	8.8	0.2	6.4	11.2	10.6	8.9	9.3
Gambusia affinis	mosquitofish	-	-	-	0.8	5.0	1.9	-	0.1	0.2
Esox niger	chain pickerel	-	0.3	0.5	-	-	0.4	-	0.2	0.1
Esox americanus	redfin pickerel	12.3	5.9	0.6	0.2	1.7	0.9	1.4	0.6	1.4
Acantharchus pomotis	mud sunfish	27.2	1.5	-	-	-	< 0.1	-	0.2	0.1
Notropis chalybaeus	ironcolor shiner	-	0.1	-	< 0.1	-	0.7	-	< 0.1	0.1
Etheostoma fricksium	Savannah darter	-	3.4	3.5	0.3	0.4	0.3	2.7	1.8	1.1
Percina nigrofasciata	blackbanded darter	-	-	4.4	2.3	2.3	1.9	0.3	0.7	1.3
Fundulus lineolatus	lined topminnow	-	-	0.1	-	-	< 0.1	-	0.1	-
Etheostoma olmstedi	tessellated darter	-	-	4.6	0.2	4.3	8.6	1.4	4.8	8.8
Notropis cummingsae	dusky shiner	1.9	0.5	0.4	0.1	1.2	23.8	3.5	1.9	4.4
Amia calva	bowfin	-	-	0.1	-	-	-	-	-	-
Semotilus atromaculatus	creek chub	-	-	-	0.1	0.3	-	0.2	-	-
Notropis petersoni	coastal shiner	-	-	-	-	1.9	7.2	-	-	-
Lepomis gulosus	warmouth	-	-	0.1	< 0.1	-	0.2	0.1	0.1	-
Enneacanthus gloriosus	bluespotted sunfish	-	-	-	0.1	-	0.1	-	0.1	-
Elassoma zonatum	banded pygmy sunfish	-	-	0.1	-	-	< 0.1	-	-	-
Etheostoma serriferum	sawcreek darter	-	-	-	-	-	0.2	-	-	-
Notropis emiliae	pugnose minnow	-	-	-	-	-	0.2	-	-	-
Perca flavescens	yellow perch	-	-	-	0.2	-	< 0.1	-	0.1	0.1
Notemigonus crysoleucas	golden shiner	-	-	-	0.2	-	-	-	-	-
Centrarchus macropterus	flier	-	-	-	-	-	< 0.1	-	< 0.1	0.1
Chologaster cornuta	swampfish	-	-	-	-	-	0.9	-	-	0.1
Ameiurus brunneus	snail bullhead	-	0.1	-	-	-	-	-	< 0.1	-
Umbra pygmaea	eastern mudminnow	-	-	0.1	-	0.1	0.1	-	< 0.1	0.1
Minytrema melanops	spotted sucker	-	-	-	0.8	-	0.8	-	-	-
Etheostoma fusiforme	swamp darter	-	-	0.1	-	-	0.3	-	-	0.1

Table 5-141. (cont)

		Stream Sites								
Scientific Name	**Common Name**	**PB1**	**PB2**	**PB3**	**SC1**	**SC2**	**SC3**	**MB1**	**MB2**	**MB3**
Hybopsis rubrifrons	rosyface chub	-	-	-	-	-	< 0.1	-	-	-
Notropis leedsi	bannerfin shiner	-	-	-	-	-	< 0.1	-	-	-
Labidesthes sicculus	brook silverside	-	-	-	-	-	0.2	-	-	-
Enneacanthus chaetodon	blackbanded sunfish	-	-	-	-	-	< 0.1	-	< 0.1	-
Lepomis macrochirus	bluegill	-	0.1	-	-	-	< 0.1	-	-	-
Fundulus chrysotus	gold topminnow	-	-	-	-	-	-	-	-	0.2
Number of collections		5	8	8	7	7	7	4	8	4
Total number of individuals		309	1,519	1,809	2,531	1,174	3,415	1,579	2,823	1,501
Mean relative abundance (no. /100 m^2)		41.2	87.5	51.7	80.3	47.9	62.3	104.5	70.6	44.2

PB = Pen Branch.
SC = Steel Creek.
MB = Meyers Branch.

in the marsh and swamp), swamp (the closed canopy area in the marsh and swamp) and channel (the stream channel between the marsh and swamp and the creek mouth) (Paller et al. 1987). Marked differences in species composition among sample sites were attributed to differences in habitat. In addition, the impacts of reactor operation differed markedly among sites.

Marsh sample stations supported a diverse fauna of primarily small species such as minnows (particularly coastal shiner), sunfishes, and pirate perch (Table 5-142). Other species of importance were brook silversides, chubsuckers, and largemouth bass. Closed canopy swamp stations supported fewer small fishes and more large fishes such as largemouth bass and spotted sucker (Table 5-143). Fish assemblages in the Steel Creek marsh and swamp showed little immediate change following the restart of L Reactor. Exceptions were a possible decrease in the abundance of brook silversides and an increase in the abundance of redbreast sunfish and bluegill. The latter species probably emigrated into the marsh from L Lake, where it was stocked in large numbers. By 1988, it was probable that a reproducing population of bluegill had become established in the Steel Creek marsh/swamp, although there was no sign that this species displaced indigenous swamp species (Heuer and Kissick 1989). Reductions in species richness and the abundance of some taxa in 1988 were associated with reductions in creek flow and depth from the shutdown of L Reactor. Decreases in fish species richness and abundance also could have partly resulted from reduced sampling effort due to program changes and the inaccessibility of some sample stations (Sayers and Mealing 1992).

The greatest impacts of the L-Reactor restart occurred in the stream corridor, the area of the creek closest to the dam. High densities of larvae and, in some cases, juveniles of species common in L Lake were observed immediately below the L-Lake dam. This influx of L-Lake species (in water discharged from L Lake) led to the temporary establishment of bluegill in the stream corridor and possibly permanent establishment of this species in the marsh and swamp as discussed. Other species observed to enter Steel Creek from L Lake were redbreast sunfish and gizzard shad (Heuer and Kissick 1989). While bluegill temporarily attained high numbers at several locations in the corridor and in Meyers Branch, a tributary of Steel Creek, they decreased over time and had no apparent effects on the stream's indigenous fish fauna. Meffe (1991) concluded that the failure of bluegill to establish permanent populations in Meyers Branch was the result of unfavorable habitat and the maintenance of natural flow regimes in this stream.

Additional impacts on the corridor fish assemblage resulted from large increases in current velocity and habitat volume due to the discharge of water from L Lake into Steel Creek. Before and after comparisons indicated a decrease in species typical of small streams, such as darters and some types of minnows (Paller et al. 1987). Species richness declined over time due to the loss of these species and the L-Lake species that colonized the corridor from L Lake as described above (Heuer and Kissick 1989). Fish assemblage structure continued to change following the shut-down of L-Reactor, with sunfishes and largemouth bass composing a larger proportion of the catch than in previous years. Fish abundance also appeared to decline, possibly reflecting lower habitat availability due to reduced flows (Sayers and Mealing 1992).

Table 5-142. Mean Electrofishing Catch Per Unit Effort (CPUE; no./100 m) and Relative Abundance (% Composition) of Common Species in an Open-Canopy Marsh Habitat in the Steel Creek Swamp Before and After the Impoundment of L Lake and Restart of L Reactor, 1983-1988

	Before						**After**					
	1983[a]		**1984**[a]		**1985**[a]		**1986**		**1987**		**1988**	
Taxa	**CPUE**	**%**	**CPUE**	**%**	**CPUE**	**%**	**CPUE**	**%**	**CPUE**	**%**	**CPUE**	**%**
longnose gar	-	-	-	-	-	-	0.17	1.1	0.07	0.3	0.07	0.3
bowfin	0.36	1.5	0.59	1.3	0.72	1.8	0.54	3.4	0.35	1.5	1.05	4.7
American eel	0.10	0.4	0.12	0.3	1.66	4.1	0.16	1.1	0.07	0.3	0.22	1.0
redfin pickerel	0.39	1.7	0.68	1.5	0.22	0.5	0.01	0.1	0.14	0.6	0.44	2.0
chain pickerel	-	-	-	-	-	-	0.39	2.5	0.28	1.2	0.71	3.2
golden shiner	1.50	6.4	1.80	4.0	1.01	2.5	0.44	2.8	1.03	4.4	1.73	7.7
minnow	12.34	52.4	24.22	54.1	10.80	26.4	3.66	23.2	13.83	58.7	3.76	16.7
chubsucker	1.05	4.5	3.02	6.8	2.72	6.7	1.61	10.2	1.11	4.7	2.12	9.4
spotted sucker	0.59	2.5	0.69	1.5	0.67	1.6	0.72	4.6	0.89	3.8	0.63	2.8
pirate perch	0.44	1.9	2.02	4.5	1.96	4.8	0.31	2.0	0.33	1.4	1.05	4.7
mosquitofish	0.78	3.3	0.67	1.5	0.11	0.3	0.62	3.9	0.47	2.0	0.05	0.2
brook silversides	2.11	9.0	4.50	10.0	5.85	14.3	0.38	2.4	0.17	0.7	0.03	0.1
redbreast sunfish	-	-	-	-	-	-	0.32	2.0	0.15	0.6	0.25	1.1
bluegill	-	-	-	-	-	-	0.27	1.7	0.72	3.1	0.97	4.3
spotted sunfish	1.80	7.6	3.08	6.9	10.50	25.7	2.00	12.7	1.29	5.5	4.34	19.3
largemouth bass	2.11	9.0	3.35	7.5	4.71	11.5	3.43	21.8	1.90	8.1	3.00	13.4
blackbanded darter	-	-	-	-	-	-	0.24	1.5	0.24	1.0	0.59	2.6
other	-	-	-	-	-	-	0.44	3.1	0.53	2.1	1.44	6.4
total[b]	23.57	100.2	44.74	99.9	40.93	100.2	15.71	100.0	23.57	100.0	22.46	99.9

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[a] From Aho et al. 1986.

[b] Deviations between arithmetic sum of the column and the indicated total for CPUE and the differences from 100.0 for percent composition are due to rounding.

Table 5-143. Mean Electrofishing Catch Per Unit Effort (CPUE; no./100 m) and Relative Abundance (% Composition) of Common Species in a Closed-Canopy Swamp Habitat in the Steel Creek Swamp Before and After the Impoundment of L Lake and Restart of L Reactor, 1983-1988

	Before						After					
	1983[a]		1984[a]		1985[a]		1986		1987		1988	
Taxa	**CPUE**	**%**	**CPUE**	**%**	**CPUE**	**%**	**CPUE**	**%**	**CPUE**	**%**	**CPUE**	**%**
longnose gar	0.42	4.3	0.94	4.7	2.29	15.1	0.25	2.7	0.21	2.8	0.65	4.9
Florida gar	-	-	-	-	-	-	-	-	-	-	0.56	4.2
bowfin	0.47	4.8	1.36	6.8	0.39	2.6	0.42	4.5	0.19	2.6	0.31	2.3
American eel	0.14	1.4	0.36	1.8	-		0.20	2.1	0.07	0.9	-	-
bizzard shad	0.08	0.8	0.44	2.2	0.28	1.8	0.06	0.6	0.07	0.9	-	-
redfin pickerel	-	-	-	-	-	-	-	-	-	-	-	-
chain pickerel	-		-		-		0.25	2.7	0.21	2.8	0.60	4.5
golden shiner	0.06	0.6	1.11	5.6	0.50	3.3	0.57	6.1	0.31	4.1	0.21	1.6
minnow	1.75	17.9	6.66	33.3	4.34	28.7	2.03	21.5	2.47	33.3	3.32	25.1
chubsucker	0.14	1.4	0.25	1.2	0.17	1.1	0.35	3.7	0.35	4.7	0.79	6.0
spotted sucker	0.73	7.5	1.42	7.1	1.95	12.9	1.24	13.2	0.65	8.8	1.46	11.0
pirate perch	-	-	0.34	1.7	0.28	1.8	0.15	1.6	0.11	1.5	0.15	1.1
lined topminnow	-	-	-	-	-	-	0.01	0.1	-	-	-	-
mosquitofish	0.11	1.1	0.11	0.6	-	-	0.01	0.1	0.18	2.4	-	-
brook silverside	3.84	39.3	2.74	13.7	2.06	13.6	0.39	4.1	0.31	4.1	0.06	0.4
redbreast sunfish	0.08	0.8	0.22	1.1	0.06	0.4	0.06	0.6	0.01	0.2	0.08	0.6
bluegill	-	-	-	-	-	-	0.01	0.1	0.08	1.1	0.10	0.8
redear sunfish	-	-	-	-	-	-	0.17	1.8	-	-	0.24	1.8
spotted sunfish	0.28	2.9	0.59	3.0	0.72	4.8	0.32	3.4	0.36	4.9	0.64	4.8
largemouth bass	1.00	10.2	1.23	6.2	1.05	6.9	1.63	17.3	1.03	13.9	2.12	16.0
yellow perch	0.50	5.1	1.27	6.4	0.66	4.4	0.94	10.0	0.49	6.6	1.24	9.4
blackbanded darter	0.06	0.6	0.39	2.0	0.28	1.8	0.10	1.1	0.11	1.5	0.22	1.7
striped mullet	0.11	1.1	0.56	2.8	0.11	0.7	0.01	0.1	-	-	-	-
other	-	-	-	-	-	-	0.25	2.5	0.17	2.4	0.50	3.8
total[b]	9.77	99.8	19.99	100.2	15.14	99.9	9.42	99.9	7.42	99.5	13.24	100.0

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[a] Adapted from Aho et al. 1986.

[b] Deviations between arithmetic sum of the column and the indicated total for CPUE and the differences from 100.0 for percent composition are due to rounding.

The channel below the marsh and swamp initially experienced increased flows as a result of the discharge of L-Reactor effluent. However, before and after comparisons demonstrated little measurable effect on fish assemblage structure (Paller et al. 1987). The ichthyofauna of the channel remained dominated by largemouth bass, catfish, spotted sunfish, and minnows (Table 5-144), and icthyoplankton collections demonstrated continued use of the channel as a spawning area by the anadromous American shad and blueback herring. Flow reductions following the shutdown of L-Reactor were associated with a shift in dominance to largemouth bass and minnows and a reduction in species richness (Sayers and Mealing 1992). The latter could be the result of reduced habitat availability, but it also coincided with a reduction in sampling effort that could have come from the collection of fewer species.

Table 5-144. Mean Electrofishing Catch Per Unit Effort (CPUE; no./100 m) in the Mouth of Steel Creek Before (1983, 1984, and 1985) and After (1986, 1987, and 1988) the Impoundment of L Lake and Restart of L-Reactor, 1983-1988

	Before			After		
Taxa	**1983**[a]	**1984**[b]	**1985**[c]	**1986**	**1987**	**1988**
longnose gar	-	-	-	0.06	-	0.06
Florida gar	-	0.08	-	-	0.03	-
bowfin	0.63	0.33	0.22	0.22	0.08	0.56
American eel	-	-	-	0.03	0.06	0.11
herring/shad	-	-	-	0.17	-	-
blueback herring	-	-	-	0.03	-	-
American shad	-	-	-	0.06	0.11	0.17
gizzard shad	0.13	-	-	0.11	0.03	-
eastern mudminnow	-	-	-	-	0.03	-
redfin pickerel	-	0.83	-	0.14	-	-
chain pickerel	-	0.08	0.11	0.28	0.11	0.14
minnow	-	-	0.44	2.14	5.44	3.22
creek chubsucker	-	-	-	0.06	-	-
northern hogsucker	-	-	-	-	0.03	0.03
spotted sucker	0.75	0.17	0.11	0.36	0.42	0.56
silver redhorse	0.13	-	-	-	-	0.08
snail bullhead	-	-	0.11	-	-	0.06
brown bullhead	-	-	-	0.03	-	-
flat bullhead	-	-	-	0.06	-	0.14
channel catfish	0.13	-	0.11	-	0.06	0.08
madtom	-	-	-	0.03	-	0.44
pirate perch	0.13	-	0.11	0.19	0.08	-
Atlantic needlefish	-	-	-	0.03	-	0.03
mosquitofish	-	-	-	0.06	-	-
brook silversides	0.25	0.08	0.11	0.61	0.72	0.44
mud sunfish	-	-	-	-	0.03	-
bluespotted sunfish	-	-	0.11	0.14	0.03	-
redbreast sunfish	0.50	0.17	1.22	0.56	0.36	0.42
warmouth	-	-	0.11	0.03	-	-
bluegill	0.25	-	-	0.06	0.78	0.06
dollar sunfish	-	-	-	0.03	-	0.03
redear sunfish	0.13	-	-	0.03	-	0.08
spotted sunfish	2.00	0.33	1.44	1.14	0.44	0.19
largemouth bass	1.25	0.33	0.44	0.67	0.47	0.17
black crappie	-	-	-	0.06	-	-
darter	-	-	-	0.06	-	-
tessellated darter	-	-	-	0.19	0.03	0.03
yellow perch	0.38	0.08	0.22	0.06	0.06	0.03
blackbanded darter	-	-	0.11	0.19	0.17	0.28
striped mullet	-	-	-	-	0.14	0.25
other	-	0.08	0.33	-	0.03	0.11
total[d]	6.66	2.56	5.30	7.83	9.72	7.75

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[a] Paller et al. 1984.

[b] Paller et al. 1985.

[c] Paller et al. 1986.

[d] Any deviations between arithmetic sum of the column and the indicated total for CPUE are due to rounding error.

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5.6 Lower Three Runs

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Drainage Description and Surface Hydrology

General Description

Lower Three Runs is a large blackwater creek that drains about 460 km^2 (178 mi^2) and has a 1012-ha (2500-acre) mainstream impoundment (Section 5.8—Par Pond has a detailed description) on its headwaters (Figure 5-65). From the Par Pond dam, Lower Three Runs flows about 39 km (24 mi) before it enters the Savannah River. The SRS includes the floodplain of Lower Three Runs between the dam and the river. Several other ponds were constructed in the headwaters above Par Pond to improve cooling of the reactor effluent. Pond B, the largest, has an area of about 73 ha (180 acres).

Effluent Contribution

Before construction of Par Pond, effluent cooling water from R Reactor (about 5.66 m^3/sec [200 ft^3/sec]) was discharged through Joyce Branch to Lower Three Runs. In 1964, R Reactor was shut down, and all P-Reactor cooling water was diverted from Steel Creek to Par Pond. P Reactor was shut down in 1988. Historically, SRS operations caused large fluctuations in water volume in Lower Three Runs just downstream from the dam at Par Pond, but groundwater and tributary inputs were sufficient to dampen these fluctuations farther downstream (Firth et al. 1986).

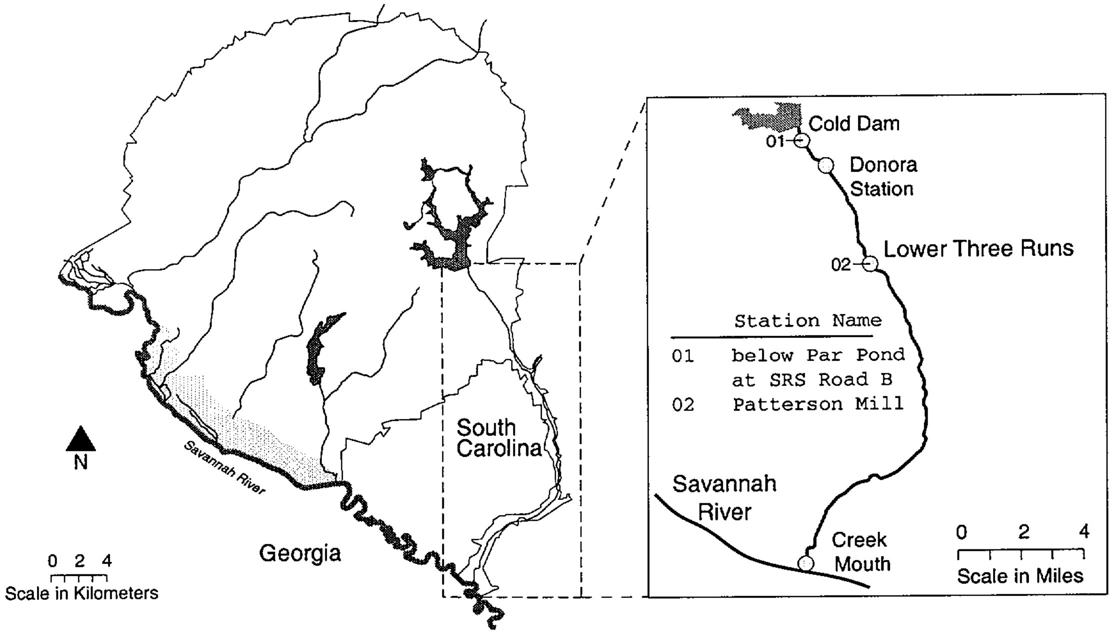

Figure 5-65. Location of Lower Three Runs on SRS

Flow Measurements

The U.S. Geological Survey (USGS) measures flow at several locations on Lower Three Runs. Table 5-145 summarizes flow statistics for Lower Three Runs at Patterson Mill (near Snelling) and below Par Pond. Records for the most downstream station (Lower Three Runs near Snelling) date back to March 1974. In water year 1995, the mean flow of Lower Three Runs at Patterson Mill was 1.7 m^3/s (60 ft^3/s). Over the period of record (water years 1974-1995) at Patterson Mill, the mean flow was 2.4 m^3/s (85.8 ft^3/s); the 7-day low flow was 0.42 m^3/s (15 ft^3/s); and the 7Q10 was 0.45 m^3/s (16 ft^3/s). Figure 5-66 shows the maximum, minimum, and mean daily flows from February 1987 to September 1995 at the station just below the Par Pond dam. The maximum, minimum, and mean daily flows from October 1982 to September 1995 at Patterson Mill are shown in Figure 5-67.

Table 5-145. Flow Summary for Lower Three Runs

			Range									
			Mean		Low		High		7Q10		7-Day Low Flow	
Station Name	**Station Number**	**Period of Record**	**cms[a]**	**cfs[b]**	**cms**	**cfs**	**cms**	**cfs**	**cms**	**cfs**	**cms**	**cfs**
below Par Pond at SRS	02197380	1974-1982, 1987-1995	1.1	38.4	0.02	0.6	6.2	220	0.03	1.2	0.03	0.9
Patterson Mill (near Snelling)	02197400	1974-1995	2.4	85.8	0.37	13	21.0	743	0.45	16	0.42	15

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[a] Cubic meters per second.

[b] Cubic feet per second.

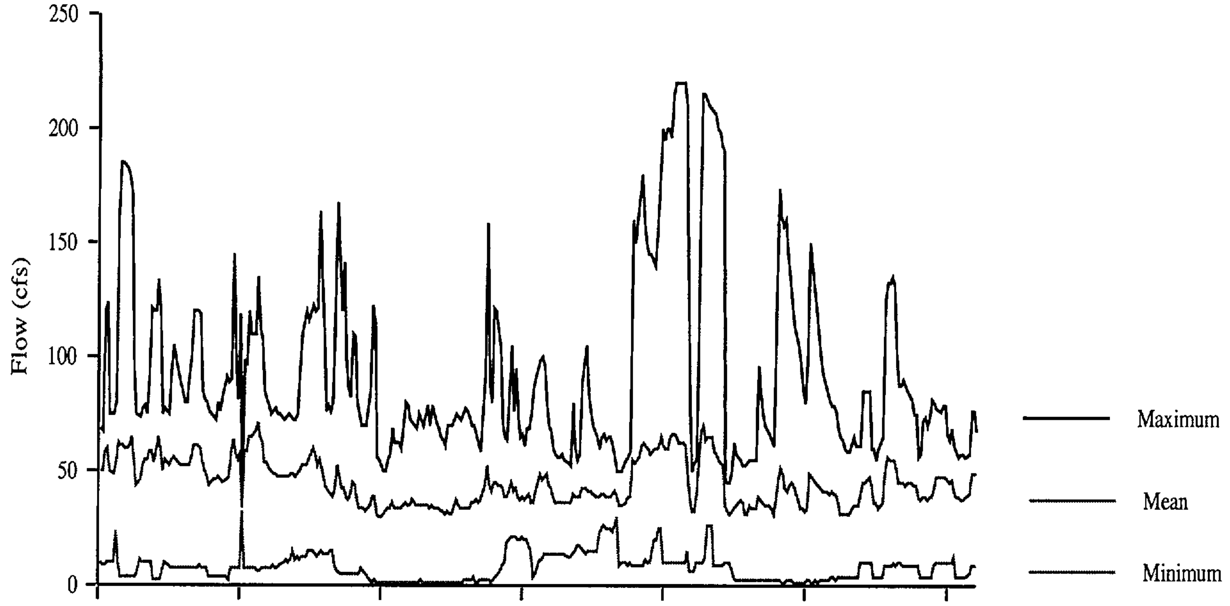

Figure 5-66. Maximum, Mean, and Minimum Flows for Lower Three Runs just below Par Pond dam, February 1987-September 1995

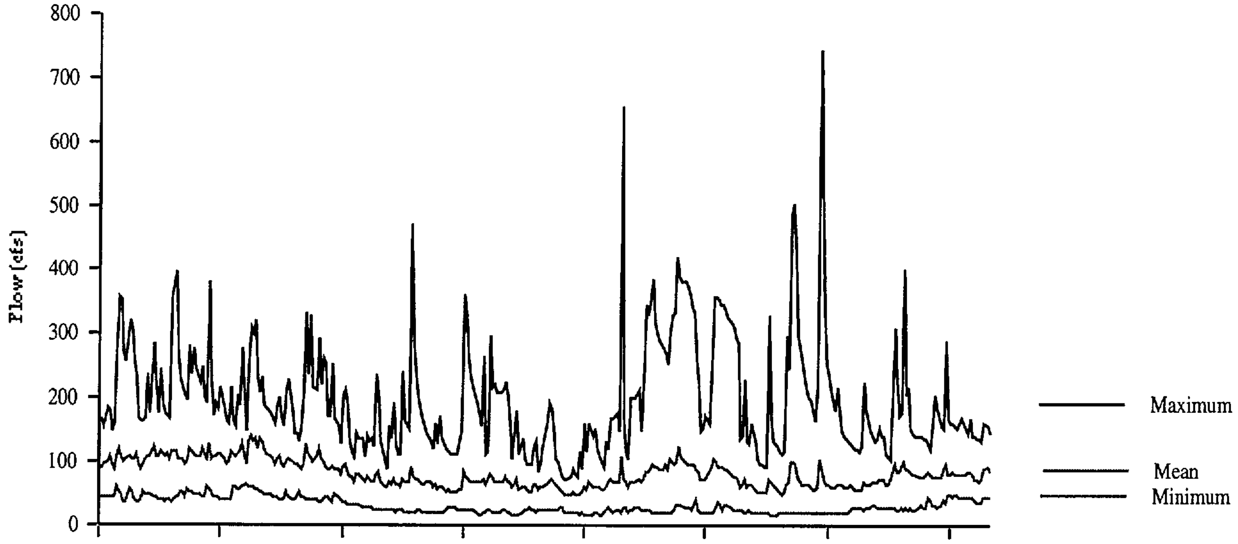

Figure 5-67. Maximum, Mean, and Minimum Flows for Lower Three Runs at Patterson Mill, October 1982-September 1995

Water Chemistry and Quality

Studies and Monitoring

Water-Quality Monitoring

Since 1973, the WSRC Environmental Monitoring Section routinely has monitored the water quality of Lower Three Runs at various locations (below Par Pond and at Patterson Mill). Since 1982, routine monitoring has included only the Patterson Mill station (Figure 5-68; point 02) which currently is sampled monthly for physical and biological parameters and quarterly for metals. Additional samples are collected annually and analyzed for pesticides and PCBs. All routine water quality data reported in the following sections can be found in the annual SRS environmental reports.

Comprehensive Cooling Water Study

The CCWS, conducted from 1983 to 1985, included the following sampling locations for Lower Three Runs (Figure 5-68):

- Lower Three Runs at Road B (01): consists of Par Pond effluents only
- Lower Three Runs at Patterson Mill (02): reflects Par Pond effluents and natural runoff waters from Lower Three Runs tributaries
- Lower Three Runs at U.S. Highway 125 (03): combines cumulative effects of natural runoff from entire Lower Three Runs watershed, just above confluence with the Savannah River

Newman et al. (1986) and Lower (1987) discuss the comprehensive results of CCWS data. Gladden et al. (1985) summarized Lower Three Runs water quality data prior to the

	Station Name
01	Road B
02	Patterson Mill
03	Highway 125

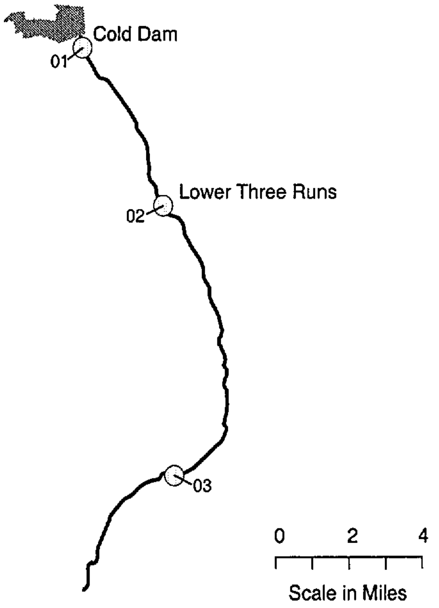

Figure 5-68. Water Chemistry and Quality Sampling Stations for Lower Three Runs

CCWS. The CCWS data in the following sections reflect impacts associated with reactor operation.

The CCWS and routine monitoring show similar water quality results for Lower Three Runs. Because Lower Three Runs has not received direct thermal discharge since 1958, its water quality and chemistry have remained relatively constant.

Priority Pollutant Study

In 1984, a study was conducted to determine the levels of volatile, acid, and base/neutral organic compounds in Lower Three Runs. One location near Road B, was sampled for this study. The results are discussed in the sections that follow and are reported in Lower (1987).

Field Data

Water Temperature

The mean water temperature at sampling locations in Lower Three Runs ranged from 16.0 to 19.3°C (60.8 to 66.7°F) during the CCWS and routine monitoring (Table 5-146). Historic monitoring data indicated slightly higher water temperatures from stream-water samples collected just downstream of Par Pond at Road B. Temperatures at this location

Table 5-146. Lower Three Runs Field Data

	Water Temperature	pH	Stream Maximum Depth (cm)	Stream Velocity (cm/sec)
Lower Three Runs at Road B (CCWS)[a]				
Mean	19.3	6.94	41	34
Range	7.0 - 31.0	5.50 - 8.80	21 - 89	4 - 120
Samples	46	46	28	38
Lower Three Runs at Patterson Mill (CCWS)[a]				
Mean	16.2	7.17	69	19
Range	1.5 - 25.0	5.90 - 8.50	48 - 117	4 - 60
Samples	46	46	30	39
Lower Three Runs at S.C. Highway 125 (CCWS)[a]				
Mean	16.0	7.17	222	11
Range	1.5 - 24.7	6.10 - 8.40	195 - 283	2 - 50
Samples	60	46	19	39
Lower Three Runs at Patterson Mill, 1987-1991[b]				
Mean	18			
Range	7.7 - 29	5.9 - 7.4	NA	NA
Samples	60	60		
Lower Three Runs at Patterson Mill, 1992-1995[c]				
Mean	NA	6.4	NA	NA
Range		5.7 - 7.5		
Samples		48		

NA = Not analyzed.

Blank Spaces = Mean not calculated due to insufficient data in report.

[a] CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).

[b] 1987-1991 = Data taken from Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; and Mikol et al 1988.

[c] Arnett 1993, 1994, 1995, and 1996.

averaged 2°C (3.6°F) higher than other nonthermal or post-thermal surface waters at SRS (Gladden et al. 1985).

pH Measurements

During the CCWS, the pH of Lower Three Runs was circumneutral; with means ranging from 6.94 just below Par Pond to 7.17 at both Patterson Mill and S.C. Highway 125 near the confluence of Lower Three Runs and the Savannah River. The pH ranged from 5.7 to 7.5 during routine monitoring (Table 5-146).

Physical Characteristics and General Chemistry

Dissolved Oxygen

The mean dissolved oxygen concentrations in Lower Three Runs during the CCWS ranged from 7.06 to 7.51 mg/l. From 1987 to 1991, the mean dissolved oxygen concentrations increased to 8.0 mg/l at the Patterson Mill location (Table 5-147). The low mean dissolved oxygen value of 7.06 mg/l measured during the CCWS can be attributed to the higher water temperatures found during the CCWS at the sampling location just below Par Pond. The mean dissolved oxygen concentration from 1992 to 1995 was 8.2 mg/l.

Suspended Solids and Turbidity

Mean turbidity values in Lower Three Runs ranged from 2.8 to 6.3 NTU during the CCWS and routine monitoring. The lowest average (2.8 NTU) was recorded during routine monitoring (1987-1991).

The concentration of suspended solids in Lower Three Runs has not changed substantially since the CCWS (Table 5-147). Mean concentrations ranged from 4.11 to 5.40 mg/l during the CCWS. Routine monitoring has recorded a suspended solids mean concentration of 4.9 mg/l between 1987 and 1991 and a mean concentration of 7.5 mg/l from 1992 to 1995.

Conductivity

Specific conductivity values ranged from 38.9 to 134.8 µS/cm (mean range, 74.1 to 86.3 µS/cm) in Lower Three Runs during the CCWS. From 1987-1995, specific conductance at Patterson Mill has averaged 75 µS/cm with a range of 13-140 µS/cm (Table 5-147).

Table 5-147. Lower Three Runs Physical Characteristics and General Chemistry

	Dissolved Oxygen (mg/l)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Total Suspended Solids (mg/l)
Lower Three Runs at Road B (CCWS)[a]				
Mean	7.06	74.1	6.1	4.11
Range	2.40 - 10.2	56.9 - 134.8	1.2 - 37.0	0.25 - 28.4
Samples	46	38	43	44
Lower Three Runs at Patterson Mill (CCWS)[a]				
Mean	7.51	86.3	3.5	5.40
Range	5.20 - 11.9	46.6 - 125.4	1.1 - 13.5	0.25 - 69.2
Samples	46	38	43	44
Lower Three Runs at S.C. Highway 125 (CCWS)[a]				
Mean	7.30	82.5	6.3	4.43
Range	4.60 - 13.0	38.9 - 119.2	1.4 - 50.0	0.25 - 27.2
Samples	46	38	43	45
Lower Three Runs at Patterson Mill, 1987-1991[b]				
Mean	8.0	75	2.8	4.9
Range	5.8 - 11	13 - 140	0.94 - 38	1 - 34
Samples	60	60	60	60
Lower Three Runs at Patterson Mill, 1992-1995[c]				
Mean	8.2	75	3.34	7.5
Range	4.8 - 11.5	40 - 113	1.1 - 16	1 - 54
Samples	48	48	48	47

NTU = Nephelometric turbidity units.

[a] CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).

[b] 1987-1991 = Data taken from Arnett 1992; Cummins et al. 1990, 1991; Davis et al. 1989; and Mikol et al. 1988.

[c] Arnett 1993, 1994, 1995, and 1996.

Major Anions and Cations

Alkalinity, Chloride, and Sulfate

Concentrations of alkalinity, chloride, and sulfate are in Table 5-148. The mean total alkalinity in Lower Three Runs during the CCWS ranged from 21.8 mg $CaCO_3$/l at the Cold Dam to 35.1 mg $CaCO_3$/l at Patterson Mill. Routine monitoring from 1987 to 1991 has shown a similar mean value at Patterson Mill (31 mg $CaCO_3$/l). Between 1992 and 1995, mean alkalinity was lower, 26.5 mg $CaCO_3$/l. Generally, alkalinity concentrations increased with distance downstream and reflected the alkaline nature of local groundwaters entering Lower Three Runs (Siple 1967; Newman et al. 1986). Furthermore, calcareous deposits underlying portions of the Lower Three Runs streambed (Langley and Marter 1973) likely contribute to the increased alkalinity of the stream water (Gladden et al. 1985).

Table 5-148. Lower Three Runs Major Anions

	Alkalinity (mg CaCO3/1)	**Chloride (mg/l)**	**Sulfate (mg/l)**
Lower Three Runs at Road B (CCWS)[a]			
Mean	21.8	6.17	3.51
Range	12.1 - 63.7	4.90 - 7.40	0.25 - 7.20
Samples	45	45	28
Lower Three Runs at Patterson Mill (CCWS)[a]			
Mean	35.1	3.82	1.85
Range	9.76 - 61.2	2.30 - 5.90	0.04 - 5.75
Samples	45	45	26
Lower Three Runs at S.C. Highway 125 (CCWS)[a]			
Mean	33.6	3.71	0.78
Range	11.9 - 53.6	2.40 - 6.20	0.20 - 3.34
Samples	45	45	26
Lower Three Runs at Patterson Mill, 1987-1991[b]			
Mean	31	5.0	4.5
Range	14 - 60	1.7 - 8.4	0.05 - 12
Samples	60	60	60
Lower Three Rivers at Patterson Mill, 1992-1995[c]			
Mean	26.5	3.6	2.9
Range	2 - 44	1.06 - 13.27	<1 - 6.06
Samples	48	48	48

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[a] CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).
[b] 1987-1991 = Data taken from Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; and Mikol et al. 1988.
[c] Arnett 1993, 1994, 1995, and 1996.

Mean chloride values were higher in Lower Three Runs at Road B (6.17 mg/l) than downstream at S.C. Highway 125 (3.71 mg/l). This is consistent with the higher values measured in Par Pond during the CCWS and the L-Lake/Steel Creek Program (mean range: 5.73 to 6.28 mg/l) (Kretchmer and Chimney 1992). Mean sulfate concentrations followed this same trend. During the CCWS, mean sulfate concentrations ranged from 3.51 mg/l at the Cold Dam to 0.78 mg/l at the downstream station. Between the CCWS and the routine monitoring from 1987 to 1991, the mean sulfate concentration at Patterson Mill increased from 1.85 mg/l to 4.5 mg/l. From 1992 to 1995, the mean chloride value was 3.6 mg/l and the mean sulfate value was 2.9 mg/l.

Calcium, Magnesium, Sodium, and Potassium

The calcium, magnesium, and sodium concentrations (total) measured in Lower Three Runs during the 1987-1995 routine monitoring are similar to the concentrations measured during the CCWS (Table 5-149). Potassium concentrations are not measured during routine monitoring, but were often below the detection limit (0.368 mg/l) during the CCWS.

Table 5-149. Lower Three Runs Major Cations (Total)

	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Aluminum (mg/l)	Iron (mg/l)	Manganese (mg/l)
Lower Three Runs at Road B (CCWS)[a]							
Mean	5.87	1.06	5.24	0.657	0.255	1.54	0.209
Range	3.22 - 19.2	0.901 - 1.29	3.67 - 7.77	<0.368 - 1.69	<0.038 - 1.50	0.265 - 8.40	<0.0004 - 0.760
Samples	39	39	39	39	39	39	16
Lower Three Runs at Patterson Mill (CCWS)[a]							
Mean	11.9	0.800	3.01	0.440	0.380	0.509	0.069
Range	5.20 - 20.9	0.593 - 1.07	1.33 - 5.34	<0.368 - 1.17	0.044 - 1.53	0.181 - 1.59	<0.0004 - 0.188
Samples	39	39	39	39	39	39	16
Lower Three Runs at S.C. Highway 125 (CCWS)[a]							
Mean	11.0	0.781	2.82	1.32	0.454	0.713	0.100
Range	3.65 - 16.6	0.506 - 1.29	1.60 - 9.68	<0.368 - 3.70	0.073 - 1.77	0.283 - 2.66	<0.0004 - 0.309
Samples	39	39	39	39	39	39	16
Lower Three Runs at Patterson Mill, 1987-1991[b]							
Mean							
Range	6.6 - 17	0.67 - 1.0	3.1 - 7.8	NA	<0.01 - 0.18	<0.01 - 0.52	<0.01 - 0.07
Samples	18	18	20		19	20	18
Lower Three Runs at Patterson Mill, 1992-1995[c]							
Mean	9.93	0.72	2.90	NA	0.16	0.44	0.078
Range	5.63 - 14.10	0.478 - 1.19	1.47 - 7.03		<0.01 - 0.73	0.138 - 1.6	0.008 - 0.45
Samples	16	16	16		13	16	15

NA = Not analyzed.

Blank Spaces = Mean not calculated due to insufficient data in report.

[a] CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).

[b] 1987-1991 = Data taken from Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; and Mikol et al. 1988.

[c] Arnett 1993, 1994, 1995, and 1996.

Aluminum, Iron, and Manganese

During the CCWS, mean total aluminum concentrations ranged from 0.255 to 0.454 mg/l. Mean total iron concentrations ranged from 0.509 to 1.54 mg/l and mean total manganese concentrations ranged from 0.069 to 0.209 mg/l. Both iron and manganese concentrations were highest just downstream of Par Pond. Insufficient data prevented the calculation of mean concentrations for the period of routine monitoring between 1987 and 1991. However, the measurement ranges show that the concentrations of aluminum, iron, and manganese have all decreased since the CCWS (Table 5-149). During routine monitoring between 1992 and 1995, mean aluminum concentration was 0.16 mg/l; mean iron concentration was 0.44 mg/l; and mean manganese concentration was 0.078 mg/l.

Nutrients

Phosphorus

All measured forms of phosphorus generally indicate that Lower Three Runs is phosphorus deficient relative to the waters of the Savannah River (Lower 1987). Mean total phosphorus concentrations ranged from 0.037 to 0.053 mg/l during the CCWS (Table 5-150). The mean total phosphorus concentration during routine monitoring had decreased to 0.029 mg/l between 1987 and 1991 and increased to 0.04 mg/l between 1992 and 1995. Mean total orthophosphate concentrations ranged from 0.018 to 0.024 mg/l during the CCWS. Orthophosphate is not measured during routine monitoring.

Table 5-150. Lower Three Runs Nutrients

	Total Phosphorus (mg/l)	Total Orthophosphate (mg/l)	Organic Nitrogen (mg/l)	Total Kjeldahl (mg/l)	Ammonia (mg/l)	Nitrite (mg/l)	Nitrate (mg/l)
Lower Three Runs at Road B (CCWS)[a]							
Mean	0.045	0.018	0.200	0.264	0.086	0.003	0.041
Range	<0.010 - 0.174	<0.001 - 0.118	0.010 - 0.864	0.050 - 0.900	0.012 - 0.620	<0.001 - 0.010	<0.001 - 0.157
Samples	46	41	43	46	46	42	43
Lower Three Runs at Patterson Mill (CCWS)[a]							
Mean	0.037	0.019	0.255	0.275	0.029	0.003	0.090
Range	<0.010 - 0.093	0.003 - 0.042	0.031 - 0.938	0.044 - 0.900	<0.005 - 0.220	<0.001 - 0.005	0.019 - 0.191
Samples	46	41	45	46	46	43	42
Lower Three Runs at S.C. Highway 125 (CCWS)[a]							
Mean	0.053	0.024	0.225	0.257	0.040	0.004	0.124
Range	<0.010 - 0.229	0.005 - 0.039	0.018 - 0.929	0.052 - 0.980	<0.005 - 0.245	<0.001 - 0.035	0.021 - 0.257
Samples	46	41	45	46	46	43	42
Lower Three Runs at Patterson Mill, 1987-1991[b]							
Mean	0.029				0.072		0.10
Range	0.01 - 0.16	NA	NA	NA	<0.01 - 1.4	NA	<0.02 - 1.1
Samples	60				60		60
Lower Three Runs at Patterson Mill, 1992-1995[c]							
Mean[d]	0.04	NA	0.125[e]	NA	0.08	NA	0.22[f]
Range	ND - 0.04		0.03 - 0.36		ND - 0.21		0.13 - 0.35
Samples	12		24		33		24

NA = Not analyzed.

ND = None detected.

Blank Spaces = Mean not calculated due to insufficient data in report.

[a] CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).

[b] 1987-1991 = Data taken from Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; and Mikol et al. 1988.

[c] Arnett 1993, 1994, 1995, and 1996.

[d] All nondetectable quantities were excluded from the calculation of means.

[e] Nitrite + nitrate, 1992-1993.

[f] 1994-1995.

Nitrogen

During the CCWS, mean concentrations for organic nitrogen and total Kjeldahl nitrogen ranged from 0.200 to 0.255 mg/l and 0.257 to 0.275 mg/l, respectively (Table 5-150). Mean ammonia concentrations ranged from 0.029 to 0.086 mg/l. Mean nitrite concentrations ranged from 0.003 to 0.004 mg/l and mean nitrate concentrations ranged from 0.041 to 0.124 mg/l. Concentrations measured during routine monitoring for ammonia fell within these ranges. Mean nitrate concentration between 1992 and 1995 was 0.22 mg/l. Organic nitrogen, total Kjeldahl nitrogen, and nitrite are not measured during routine monitoring.

Trace Elements

Table 5-151 summarizes trace element concentrations measured in Lower Three Runs. Low-level concentrations of trace element were measured during the CCWS. The detection limits used during routine monitoring are higher than those used in the CCWS. As is generally the case with SRS thermal, nonthermal, and post-thermal waters, low trace element concentrations, reflecting Savannah River concentrations, were found in Lower Three Runs (Lower 1987).

Table 5-151. Lower Three Runs Trace Elements (Total)

	Arsenic (μg/l)	Cadmium (μg/l)	Chromium (μg/l)	Copper (μg/l)	Lead (μg/l)	Nickel (μg/l)	Zinc (μg/l)
Lower Three Runs at Road B (CCWS)[a]							
Mean	2.4	0.67	7.3	3.0	1.5	6.8	9.7
Range	<0.4 - 10.5	<0.04 - 4.70	<0.4 - 47.0	<0.4 - 5.5	<0.4 - 4.3	<0.4 - 59.9	<0.4 - 60.0
Samples	16	16	16	16	16	16	16
Lower Three Runs at Patterson Mill (CCWS)[a]							
Mean	1.6	0.37	7.0	2.5	1.2	8.1	5.8
Range	<0.4 - 6.8	<0.04 - 2.30	<0.4 - 56.0	<0.4 - 5.5	<0.4 - 4.7	<0.4 - 61.3	<0.4 - 30.0
Samples	16	16	16	16	16	16	16
Lower Three Runs at S.C. Highway 125 (CCWS)[a]							
Mean	2.0	0.45	4.6	2.5	1.4	3.0	4.8
Range	<0.4 - 7.8	<0.04 - 3.1	<0.4 - 30.0	<0.4 - 5.2	<0.4 - 5.7	<0.4 - 8.2	<0.4 - 21.5
Samples	16	16	16	16	16	16	16
Lower Three runs at Patterson Mill, 1987-1991[b]							
Mean							
Range	NA	<10	<10 - <50	<10 - 16	<3 - <100	<10 - 60	<10 - 20
Samples		20	20	20	20	19	20
Lower Three Runs at Patterson Mill, 1992-1995[c]							
Mean[d]	NA	<10	<15	<16	<4	<30	15
Range		ND - <10	ND - <20	ND - 180	ND - 13	ND - <50	ND - 31
Samples		4	4	9	6	4	8

NA = Not analyzed.
ND = None detected.
Blank Spaces = Mean not calculated due to insufficient data in report.
[a] CCWS = Comprehensive Cooling Water Study (Newman et al. 1986).
[b] 1987-1991 = Data taken from Arnett et al. 1992; Cummins et al. 1990, 1991; Davis et al. 1989; and Mikol et al. 1988.
[c] Arnett 1993, 1994, 1995, and 1996.
[d] All nondetectable quantities were excluded from the calculations of means.

Organic Carbon

In Lower Three Runs, mean total organic carbon concentrations measured during the CCWS increased from 5.4 mg/l downstream of the Par Pond overflow to 8.2 mg/l at the S.C. Highway 125 crossing. This latter mean concentration was the highest found in all waters of onsite streams (Newman et al. 1986).

Priority Pollutants

Concentrations of all 88 volatile, acid, and base/neutral organic compounds tested in Lower Three Runs at Road B never exceeded the lower limits of detection. Lower (1987) documents the results of this study.

Pesticides, Herbicides, and PCBs

The WSRC Environmental Monitoring Section collects a sample annually from Lower Three Runs and analyzes it for pesticides, herbicides, and PCBs. From 1987 to 1995, concentrations of all analytes in Lower Three Runs were below analytical detection limits.

Lower (1987) reports the results of analyses for pesticides, herbicides, and PCBs from 1982 to 1985, and results from 1967 to 1981 can be found in Gladden et al. (1985). During these periods, concentrations also were near or below detection limits at all locations.

Chemical, Including Radionuclide, and Toxicity Assessment Studies

No chemical or toxicity assessment studies have been done on Lower Three Runs.

Algae

The algae of Lower Three Runs have not been studied with the exception of two stations that were sampled for periphyton as part of the CCWS conducted during 1984-1985. Periphyton biomass during this study reportedly was similar to that of Upper Three Runs (Specht 1987).

Macrophytes

The only data dealing with aquatic macrophytes in Lower Three Runs comes from the CCWS (Specht 1987) and was collected during the 1984-1985 sampling period. This data may not be representative of the current state of the macrophyte populations in Lower Three Runs.

Summary data from the CCWS appears in Table 5-152 (Specht 1987). Station 42, located just downstream from Par Pond dam, shows macrophyte development. This is probably attributable to less overstory cover and flow fluctuations from Par Pond. The other two stations show little (Station 43; at S.C. Highway 125) and no (Station 53; Stinson Bridge) macrophyte development. This is probably from extensive shading by the riparian tree canopy.

It is possible that the riparian vegetation structure has been altered by the change in flow regimes brought about first by the shutdown of P Reactor and then by Par Pond drawdown.

Table 5-152. The Annual Mean, Number of Reaches Mapped During Year (N) and Standard Deviation (s), October 1984-September 1985

	Area (m^2/m^2)		**Volume (m^3/m^2)**		**Biomass (g/m^2)**		**Percent Cover**		
Species	**Mean**	**s**	**Mean**	**s**	**Mean**	**s**	**Mean**	**s**	**N**
				Station 42 (downstream of Par Pond dam)					
Callitriche heterophylla	0.0002	0.0008	<0.0001	<0.0001	0.0005	0.0021	0.0180	0.0805	20
Ceratophyllum demersum	0.0025	0.0042	0.0003	0.0005	0.3474	0.5316	0.2540	0.4207	20
unidentified	0.0022	0.0087	-	-	-	-	0.2226	0.8693	20
Myriophyllum aquaticum	0.0003	0.0011	<0.0001	<0.0001	0.0068	0.0201	0.0343	0.1148	20
Polygonum spp.	0.0004	0.0016	-	-	0.1890	0.7137	0.0420	0.1580	20
Potamogeton pusillus	0.0270	0.0558	0.0011	0.0028	1.369	3.373	2.696	5.578	20
Sparganium sp.[a]	0.0008	0.0032	0.0003	0.0011	0.0159	0.0685	0.0818	0.3200	20
				Station 53 (Stinson Bridge) No vegetation in mapped channel					
				Station 43 (S.C. Highway 125)					
unidentified	0.0049	0.0184	-	-	-	-	0.4851	1.839	20
Nuphar luteum	0.0011	0.0040	<0.0001	<0.00011	0.0284	0.1121	0.0578	0.1996	20

Source: Firth et al. 1986.

[a] Misidentified as *Vallisneria* in source documents.

Zooplankton

No data are available on the zooplankton of Lower Three Runs.

Macroinvertebrates

Sampling Locations and Methods

Lower Three Runs receives no National Pollutant Discharge Elimination System (NPDES) discharges directly, but receives overflow from Par Pond. Since 1996, the only NPDES discharge that Par Pond received is from PP-1, which consists of small amounts (< 1 gpm) of rinsewater and backwash from a manganese greensand filter system in the Par Pond Laboratory next to the pumphouse.

Macroinvertebrates were collected at three stations in Lower Three Runs from November 1983 through September 1985 as part of the CCWS (Figure 5-69). Macroinvertebrates were collected from Hester-Dendy multiplate samplers, leaf bags, and drift. Macroinvertebrates also were collected in the mouth of Lower Three Runs from October 1982 through September 1983 using Hester-Dendy multiplate samplers and drift nets. Specht (1987) describes details of sampling methods. Macroinvertebrates were sampled during the summer of 1993 at two locations in Lower Three Runs below the Par Pond dam. Hester-Dendy multiplate macroinvertebrate samplers were deployed for one month (Specht 1994).

Macroinvertebrates also were sampled in September 1994 at Road B, just below the Par Pond dam, in order to develop a biotic index for southeastern streams using Hester-Dendy multiplate samplers. While not specifically designed to characterize SRS streams, these data contribute to a better understanding of them.

1983-1985, 1993, 1994

	Station Name
01	Road B
02	Donora Station
03	Patterson Mill
04	Upstream of SR 66, Stinson Bridge
05	Creek Mouth

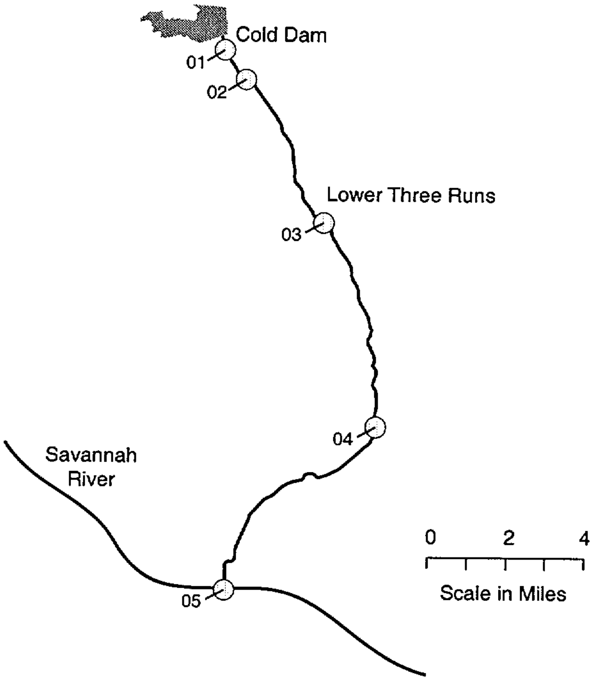

Figure 5-69. Macroinvertebrate Sampling Locations for Lower Three Runs

Results

Community Composition

Par Pond greatly influenced the macroinvertebrate community just downstream from the Par Pond dam (Station 01). Of the 34 stream sampling stations that were sampled for macroinvertebrates using Hester-Dendy multiplate samplers during the CCWS, this station had by far the highest density of macroinvertebrates (5549.8 organisms/m^2; Table 5-153). The high density was due in part to large numbers of Tanytarsini chironomids, which composed 39% of the organisms collected from the multiplate samplers. Other abundant taxa at Station 01 included the chironomid groups Orthocladiinae (15.0%), Chironomini (9.6%), and Tanypodinae (3.3%); hydropsychid caddisflies (3.7%); and Simuliidae (blackflies; 1.7%; Firth et al. [1986]). Many of these macroinvertebrates are filter-feeders that fed on the seston inputs from Par Pond.

In 1994, immediately below the dam, density was 2171.0 organism/m^2 (Table 5-153). Dominant taxa included Hirudinea (leeches; 40%) and the dipteran midges Chironomini (40%), Orthocladiinae (7%), and Tanypodinae (7%). There were few collector-filterers. These data were collected during the Par Pond drawdown and dam repair and reflect the disturbed nature of the stream at that time (Specht and Paller 1995).

Downstream at Station 04 in 1983-1985, densities were comparable to those at many other CCWS stations, averaging 743.5 organisms/m^2 (Table 5-153). Common taxa at Station 04 included the chironomid groups Chironomini (19.7%), Tanytarsini (17.6%), and Orthocladiinae (17.2%); the stonefly, *Perlesta placida* (5.2%); the mayflies *Ephemerella invaria* (6.5%) and *Stenonema modestum* (2.4%); and the caddisfly *Cheumatopsyche* (2.9%; Firth et al. [1986]).

Macroinvertebrate density in the mouth of Lower Three Runs (Station 05) was higher than at Station 04, averaging 1932.3 organisms/m^2 (Table 5-153). Chironomids made up 84% of the macroinvertebrates collected from multiplates in the mouth of the creek. Other common taxa included the mayfly *Stenonema modestum* (5.2%) and the caddisfly *Cheumatopsyche* (3%; Chimney and Cody [1986]).

Table 5-153. Average Macroinvertebrate Density, Biomass, Taxa Per Sampler, and Total Taxa Collected from Hester-Dendy Multiplate Samplers in Lower Three Runs

Parameter	01[a]	01[b]	02[c]	03[c]	04[a]	05[a,d] Creek Mouth
Density (no./m^2)	5,549.8	2,171.0	2,511.7	1,528.5	743.5	1,932.3
Biomass (g AFDW/m^2)	0.549	0.1012	0.3183	0.1427	0.411	0.159
Mean Number of Taxa/Sampler	12.6	14.2	21.4	32.2	17.6	13.8
Total Number of Taxa Collected	56	23	32	53	67	50

Source: Firth et al. 1986; Chimney and Cody 1986; Specht 1994; and Specht and Paller 1995.

AFDW = Ash free dry weight.

[a] Sampled from November 1983-September 1985.

[b] One-time sample in 1994.

[c] One-time sample in 1993.

[d] Sampled from October 1982-September 1983.

In 1993, the macroinvertebrate community at Donora Station, 1.5 km (0.9 mi) below the Par Pond dam, appeared to be influenced by Par Pond. There were large numbers of collector-filterers (58.76%) and relatively high densities of organisms (2511.7 organisms/m^2). Filter-feeding caddisflies (52.27%) and orthoclad chironomids (23.49%) numerically dominated the community. Mayflies also were relatively common (8.59% of the organisms collected). Collector-filterers often are found in high numbers below reservoir outfalls, where they feed on the high concentrations of suspended organic matter.

The Patterson Mill station had greater numbers of mayflies (12.94%), Tanytarsini (22.73%) and Chironomini (21.71%) chironomids, and fewer caddisflies (7.97%). Density was 1528.5 organisms/m^2. Lower Three Runs is influenced by Par Pond but maintains a productive and reasonably diverse community (Specht 1994).

Biomass

Macroinvertebrate biomass declined downstream during the CCWS, averaging 0.549 g/m^2 at Station 01, 0.411 g/m^2 at Station 04, and 0.159 g/m^2 in the creek mouth (Table 5-153). This trend held true for the 1993 and 1994 sampling, with the exception of the station just below the Par Pond dam, which was affected by the construction activities associated with dam repair. In more recent studies macroinvertebrate biomass was 0.1012 g/m^2 just below the dam (1994), 0.3183 g AFDW/m^2 at Donora Station (1993), and 0.1427 g AFDW/m^2 at Patterson Mill (1993). These values are substantially lower than the values reported from the CCWS.

Taxa Richness

During the CCWS at Station 01, an average of 12.6 taxa was collected per sampler and 56 taxa were collected during the two-year sampling program, while downstream at Station 04, taxa richness was higher, with a mean of 17.6 taxa per sampler and 67 taxa collected (Table 5-153). In the creek mouth, an average of 13.8 taxa was found on the multiplate samplers, while 50 taxa were collected (Table 5-153). In 1993 and 1994, there was an average of 14.2 taxa per sampler and a total of 23 taxa collected just below the dam, an average of 21.4 taxa per sampler and a total of 32 taxa collected at Donora Station, and an average of 32.2 taxa per sampler and a total of 58 taxa at the most downstream station (Table 5-153). Lower Three Runs is influenced by Par Pond but maintains a productive and reasonably diverse community (Specht 1994).

These results suggest that taxa richness may have increased over the past 10 years, as evidenced by increases in the mean number of taxa collected/sampler. However, the total number of taxa collected was lower in 1993 and 1994, because these data represent single sampling periods, rather than monthly sampling over a longer time period. Species that are rare or occur seasonally are usually less likely to be collected unless sampling is conducted over an extended period of time.

Fish

Introduction

Fisheries sampling in Lower Three Runs has not been as extensive as in most other SRS streams, although two sampling programs have been conducted. The first, during 1984-1985, was part of the CCWS, which was designed to generate information concerning the effects of thermal discharge from nuclear-reactor operation on SRS streams. This sampling effort included ichthyoplankton sampling at several sites between the mouth and the Par Pond dam (Paller et al. 1986). The second, conducted during the summer of 1990, was part of an effort to assess fish community structure in SRS streams. This program consisted of electrofishing for adult and juvenile fish at several sample sites between the lower reaches of Lower Three Runs and the Par Pond dam plus two sample stations in tributaries of Lower Three Runs.

Comprehensive Cooling Water Study

Sampling Methods

Sampling efforts during the CCWS emphasized the abundance and distribution of ichthyoplankton (Paller et al. 1986). Samples were collected with 0.5 mm, 0.5 m diameter plankton nets. There were three sampling stations in 1984, one in the Par Pond tailwaters, one near Road A (approximately two-thirds of the distance from Par Pond to the Savannah River), and one in the mouth of Lower Three Runs (Figure 5-70). There were seven sample stations in 1985, three in the Par Pond tailwaters, one in the creek mouth, and three between the creek mouth and the tailwaters (Figure 5-70). Samples were collected during the main spawning period for most SRS fishes, February-July 1984 and March-July 1985.

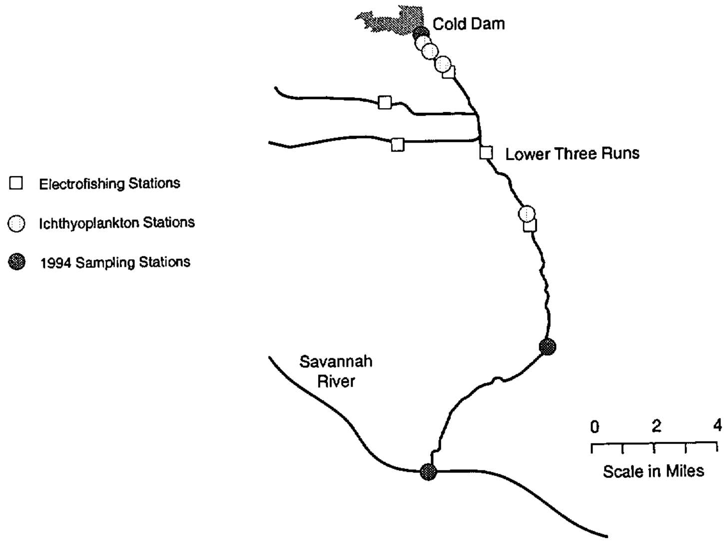

Figure 5-70. Fish Sampling Stations for Lower Three Runs

1984 Sampling Program

Most of the 1483 ichthyoplankters collected during 1984 were taken from a tailwater pool just downstream from the Par Pond dam. Densities averaged 625 organisms/1000 m^3 in the tailwaters compared with 14 organisms/1000 m^3 at Road A and 24 organisms /1000 m^3 in the creek mouth. Most of the larvae collected in the Par Pond tailwaters were sunfish and bass, crappie, and yellow perch that probably were spawned in Par Pond and entered Lower Three Runs in Par Pond overflow. Sampling in Par Pond (Paller and Saul 1986) indicated that all three taxa were abundant there (Paller et al. 1986).

1985 Sampling Program

As in 1984, most of the 446 ichthyoplankton collected from Lower Three Runs during 1985 were collected at the sample stations in the Par Pond tailwaters (Figure 5-70). Minnows and darters numerically dominated the tailwater samples early in the spawning season. However, as the season progressed, crappie, sunfish/bass, and brook silversides became increasingly common. Ichthyoplankton densities rapidly declined to comparatively low levels within 400-500 m (1312-1640 ft) of the Par Pond dam, suggesting that ichthyoplankton conveyed from Par Pond to Lower Three Runs were not transported far downstream. Ichthyoplankton collected from the four sample stations downstream of the Par Pond tailwaters consisted primarily of darters, sunfish, and suckers, species typical of most streams on SRS (Paller et al. 1986).

Comparison of 1984 and 1985 Sampling Programs

Comparisons between 1984 and 1985 indicate that ichthyoplankton densities were fairly similar in the lower half of Lower Three Runs during both years. However, densities in the Par Pond tailwaters were approximately five times higher during 1984 than 1985. The higher densities during 1984 probably were caused by greater discharge from Par Pond into Lower Three Runs during that year, as observed by field personnel (Paller et al. 1986).

Stream Fisheries Characterization Study

Electrofishing samples were collected from two first-to-second-order tributaries of Lower Three Runs near the crossings of Road B-6 and B-6.4. Both tributaries were small, sand bottom streams. They were heavily shaded, and the predominant instream structure consisted of snags and woody debris. The fish assemblages in these streams were numerically dominated by small species including pirate perch, shiners, small sunfishes, darters, madtoms, bullheads, and redfin pickerel. These taxa are typical of unimpacted first and second order streams in and around the vicinity of SRS (Paller 1992).

Electrofishing samples also were collected from three locations on Lower Three Runs: near Donora Station, Patterson Mill, and Stinson Bridge. Creek width ranged from 5-10 m (16-33 ft) at Donora Station to 10-15 m (33-49 ft) at Stinson Bridge. Snags and brush provided the dominant instream structure, although aquatic macrophytes were at some stations. The Stinson Bridge sample yielded few fish because it was collected during a high-water period. The other samples were more representative. The Donora Station fish assemblage was dominated by sunfishes (primarily redbreast and spotted sunfish) followed by shiners, pirate perch, and a variety of other taxa. The fish assemblage at the wider, deeper Patterson Mill station was dominated by larger species, including spotted sucker, largemouth bass, and creek chubsucker. This transition from a mixed fauna of medium- and small-sized species, most of which are generalized insectivores, at stream sites of moderate size (i.e., Donora Station) to a fauna dominated by larger benthic insectivorous and piscivorous species at wider, deeper stream sites (i.e., Patterson Mill) is typical in southeastern coastal plain streams (Paller 1992).

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5.7 L Lake

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Drainage Description and Surface Hydrology

General Description

L Lake was formed in 1985 by impounding the headwaters of Steel Creek. L Lake extends about 7 km (4.3 mi) along the Steel Creek valley from the embankment above South Carolina Highway 125 (SRS Road A) to just above SRS Road B (Figure 5-71). The lake width averages about 600 m (0.4 mi), reaching a maximum of about 1200 m (0.8 mi) (DOE 1984). At a normal pool elevation of 58 m (190 ft) above mean sea level, the dam impounds about 31 million m^3 of water and covers about 4.185 km^2 or 418 ha (reported as 1034 acres, nominally 1000 acres) (U.S. Army Corps of Engineers 1987). Table 5-154 contains information on physical characteristics of the basin.

DOE anticipates that pumping Savannah River water into L Lake will be discontinued. The only water the lake would receive would be surface runoff and groundwater recharge. L Lake would recede over approximately 10 years, eventually returning to the Steel Creek flow at the bottom of the lake bed. Erosion control measures would be applied to minimize the adverse effects of exposed sediments (DOE 1997).

L Lake both gains and loses water from the surrounding groundwater system. Groundwater flows into L Lake at the upstream end, from the very top, above Road B to approximately one-fourth of the distance to the dam on the west side of the reservoir and to approximately one-half to two-thirds of the distance to the dam on the east side. L Lake loses water to the groundwater system along the remainder of the shoreline (Hiergesell 1997).

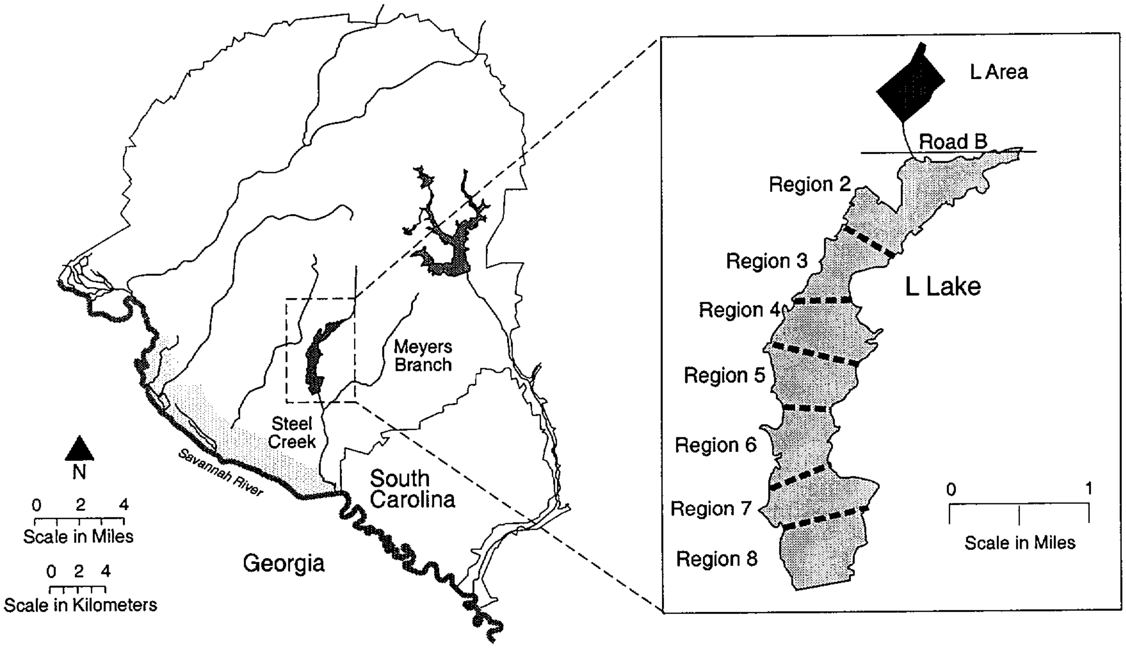

Figure 5-71. Location of L Lake on SRS

Table 5-154. Physical Characteristics of L Lake

Physiographic Province	Maximum Depth (m)	Mean Depth (m)	Surface Area (km^2)	Volume (x 10^8 m^3)	Residence Time (days)	Shoreline Length (km)	Shoreline Development Ratio
Coastal Plain	19.8	8	4.2	0.31	14-33	2.1	0.3

Source: Bowers 1992.

L Lake Dam

Description

The L-Lake dam is approximately 7.2 km (4.5 mi) above the mouth of Steel Creek and about 0.8 km (0.5 mi) north of South Carolina Highway 125. The dam consists of a main embankment of rolled fill construction, with a lower embankment (saddledike) extending from the right abutment and a service bridge leading to an intake tower extending from the left abutment. The main embankment is about 670 m (0.4 mi) long with a 12-m (39-ft) crest width. The unpaved emergency spillway has a sill elevation of 60 m (197 ft) above mean sea level. A 60-cm (2-ft) thick concrete cutoff wall is on the upstream toe of the main dam to minimize seepage under the dam. The saddle dike is about 520 m (0.3 mi) long with a 12-m (59-ft) crest width. The maximum height of the saddle dike is 3.7 m (12 ft) (U.S. Army Corps of Engineers 1987).

Outlet Structure

The outlet structures for the lake consist of a multigate intake tower, a prefabricated concrete conduit, and a stilling basin in the valley of the left abutment (U.S. Army Corps of Engineers 1987). Water passes through the intake tower and the conduit and is discharged into the stilling basin before being released to Steel Creek. The discharge intake structure was designed to pass the volume of the L-Reactor cooling water flow, the P-Area process water flow, and ambient Steel Creek flow through the dam and to serve as the principal means of flood control.

The system of eight gates in the dual wet well tower regulates the reservoir water level. Two gates near the bottom of the lake (lower gates or emergency gates) and two gates 3 m (10 ft) below the normal pool elevation (upper gates) can be opened to let water into the wet wells. These gates are either fully opened or closed. Under normal operating conditions, both lower gates are closed, and both upper gates are open. The lower gates can be opened to release water if the lake level gets too high.

Effluent Contribution

Originally, L-Reactor cooling water entered L Lake directly through an effluent canal situated north to south on the north shore of the lake. In 1986, a diversion dike was built to divert the flow into the upper, northeastern portion of the lake to increase the lake's cooling efficiency.

L Lake stratified during the spring and summer due to climatic factors, as is typical of most southeastern lakes and reservoirs. However, stratification occasionally occurred during the winter due to density differences between thermal reactor discharges and underlying lake waters. L Lake received thermal effluent from November 1985 to June 1986, December 1986 to June 1987, and January 1988 to June 1988. Temperatures in excess of 40°C (104°F) occurred near the L-Reactor outfall during periods of reactor operation. However, the maximum recorded water temperature in Regions 4-8 (Figure 5-71) was approximately 34°C (93°F) in June 1986. This temperature was approximately 2°C (3.6°F) higher than the maximum temperatures in southeastern reservoirs with no thermal inputs. The highest recorded 24-hour mean temperature in Regions 4-8 was 32°C (90°F). While the highest absolute temperatures occurred in June, the greatest temperature differences occurred during the winter and early spring when L-Lake waters were elevated as much as 5°C (9°F) above ambient. Littoral zone temperatures exhibited little consistent spatial variation within the study area (Regions 4-8).

Flow and Temperature Measurements

The volume of water released from the dam is controlled by the two service gates at the base of the wet wells. Water flows through both upper gates into the two wet wells and through the service gates into the concrete conduit. Flow through service gates can vary from about 2 m^3/sec (71 ft^3/sec) to 29 m^3/sec (1024 ft^3/sec) per gate. Service gates are not operated with an opening of less than about 15 cm (6 in) to avoid cavitation. To release flows less than 2 m^3/sec (71 ft^3/sec), such as the minimum flows required during reactor shutdown, two 46-cm- (18-in) diameter knife gates can be opened. The knife gates can release flows ranging from about 0.3 m^3/sec (10.5 ft^3/sec) to 2 m^3/sec (70 ft^3/sec) to Steel Creek (du Pont 1985).

A control system electronically monitors the reservoir level and the discharge water temperature and volume. If the computerized operating system should fail, these data can be visually monitored and the gates manually operated at the dam site (du Pont 1985).

Water Chemistry and Quality

Studies and Monitoring

L-Lake water quality was monitored regularly between the completion of the reservoir in 1985 and 1991 to meet environmental regulatory requirements associated with the restart of L Reactor. The monitoring was driven primarily by Section 316(a) of the Clean Water Act. L Lake is not monitored as part of the SRS routine water quality monitoring program.

L Lake was divided into eight regions by expected thermal gradients in order to assess the impact of thermal discharge on the L-Lake ecosystem. (Region 1 was above Road B and was not sampled.) Water quality sampling was initiated in November 1985 in regions 4-8 (Figure 5-71). The data collected during periods of reactor shutdown are more representative of current and expected future conditions at a later successional stage of L Lake. See Gladden et al. (1988).

Kretchmer and Chimney (1992) report the results of L-Lake water quality from November 1985 to December 1991. The following subsections summarize that report.

This discussion emphasizes data from 1988-1991, the period after L-Reactor was shut down (no thermal input to the lake), but when river water continued to be pumped into the lake. A one-time sampling was done in September 1995 to analyze for total mercury, gamma emissions, gross alpha emissions, nonvolatile beta emissions and U.S. Environmental Protection Agency (EPA) target analyte list metals (Paller 1996).

Field Data

Temperature

Thermal effluent from L Reactor induced periods of temporary thermal stratification in L Lake during the fall and winter of 1985-1987. However, the effect of this phenomenon on water quality appeared to be minimal, and the water column quickly returned to isothermal conditions with the cessation of reactor activities. Stratification of the lake during the summer was largely attributed to normal climatic heating and was well established by April of each year. Fall turnover usually began in September or October and was completed by November (Kretchmer and Chimney 1992).

pH Measurements

From 1988 to 1991, pH values in L Lake varied from 4.9 to 10.1; and from 1985 to 1987 the range of values was 5.2 to 9.7 (Table 5-155). The pH changes in the water column did not appear to be closely related to the establishment or collapse of thermal stratification, but were thought to be more correlated with the intensity of phytoplankton primary productivity.

Table 5-155. Water Quality Data (Range of Values) for L Lake, November 1985-December 1991

	Temperature (°C)	Dissolved Oxygen (mg/l)	pH	Conductance (µS/cm)	Tot. Diss. Solids (mg/l)	Tot. Sus. Solids (mg/l)	Tot. Org. Carbon (mg/l)
L Lake, 1985-1987[a]							
Region 4	10.8 - 33.6	0.1 - 10.1	5.6 - 9.5	64 - 133	25 - 91	1 - 41	1 - 13
Region 5	10.9 - 30.2	0.1 - 11.0	5.9 - 9.6	64 - 112	32 - 91	1 - 13	3 - 11
Region 6	10.9 - 31.1	0.1 - 11.8	5.6 - 9.6	61 - 117	40 - 76	1 - 17	3 - 11
Region 7	10.9 - 32.2	<0.1 - 11.9	5.2 - 9.6	61 - 120	27 - 88	1 - 39	3 - 10
Region 8	10.7 - 29.8	0.1 - 11.0	5.5 - 9.7	61 - 111	25 - 82	<1 - 13	3 - 12
L Lake, 1988-1991[b]							
Region 4[c]	6.4 - 32.6	<0.1 - 11.4	4.9 - 9.9	53 - 146	38 - 97	<1 - 11	1 - 13
Region 5	8.5 - 31.0	<0.1 - 12.7	5.4 - 9.9	41 - 122	18 - 90	<1 - 11	<1 - 15
Region 6[c]	9.5 - 31.4	0.1 - 10.7	6.0 - 10.0	67 - 120	30 - 87	<1 - 20	1 - 9
Region 7	8.5 - 37.1	<0.1 - 13.0	5.3 - 10.1	41 - 143	17 - 95	<1 - 11	<1 - 12
Region 8[c]	10.2 - 30.8	0.1 - 10.7	5.5 - 10.1	61 - 112	34 - 90	<1 - 11	<1 - 12

	Diss. Org. Carbon (mg/l)	Tot. Inorg. Carbon (mg/l)	Alkalinity (mg $CaCO_3$/l)	Ortho-phosphate (mg/l)	Tot. Phosphorus (mg/l)	Nitrite (mg/l)	Nitrate (mg/l)
L Lake, 1985-1987[a]							
Region 4	1 - 11	1 - 21	14.5 - 39.5	<0.005 - 0.654	0.018 - 0.698	<0.001 - 0.036	<0.01 - 0.660
Region 5	2 - 9	1 - 15	12.7 - 50.9	<0.005 - 0.561	0.024 - 0.557	<0.001 - 0.020	<0.01 - 0.276
Region 6	3 - 9	1 - 13	11.0 - 34.0	<0.005 - 0.489	0.018 - 0.484	<0.001 - 0.022	<0.01 - 0.269
Region 7	3 - 8	1 - 17	14.8 - 34.8	<0.005 - 0.573	0.014 - 0.584	<0.001 - 0.025	<0.01 - 0.758
Region 8	2 - 8	1 - 12	15.0 - 32.7	<0.005 - 0.413	0.020 - 0.423	<0.001 - 0.022	<0.01 - 0.304
L Lake, 1988-1991[b]							
Region 4[c]	1 - 16	1 - 19	8 - 41	<0.005 - 0 816	0.025 - 0.864	<0.001 - 0.092	<0.01 - 0.334
Region 5	1 - 17	1 - 15	6 - 35	<0.005 - 0.570	0.026 - 0.572	<0.001 - 0.021	<0.01 - 0.318
Region 6[c]	1 - 10	2 - 14	9 - 34	<0.005 - 0.520	0.026 - 0.523	<0.001 - 0.019	<0.01 - 0.331
Region 7	<1 - 8	1 - 16	5 - 35	<0.005 - 0.536	0.024 - 0.542	<0.001 - 0.076	<0.01 - 0.369
Region 8[c]	2 - 10	2 - 10	9 - 33	<0.005 - 0.447	0.025 - 0.447	<0.001 - 0.017	<0.01 - 0.409

	Ammonia (mg/l)	Tot. Inorg. Nitrogen (mg/l)	Silica (mg/l)	Tot. Aluminum (mg/l)	Diss. Aluminum (mg/l)	Tot. Calcium (mg/l)	Diss. Calcium (mg/l)
L Lake, 1985-1987[a]							
Region 4	<0.01 - 2.72	<0.01 - 2.73	1.8 - 10.5	<0.1 - 0.42	<0.1 - 0.18	2.12 - 5.09	2.08 - 4.94
Region 5	<0.01 - 2.27	<0.01 - 2.28	1.5 - 10.5	<0.1 - 0.37	<0.1 - 0.17	2.53 - 5.15	2.53 - 4.81
Region 6	<0.01 - 1.86	0.01 - 1.87	1.0 - 10.4	<0.1 - 0.57	<0.1 - 0.25	2.09 - 5.25	2.08 - 4.78
Region 7	<0.01 - 2.21	0.01 - 2.22	0.6 - 10.4	<0.1 - 0.79	<0.1 - 0.27	1.87 - 5.25	1.76 - 4.79
Region 8	<0.01 - 1.67	<0.01 - 1.72	0.4 - 10.2	<0.1 - 1.03	<0.1 - 0.94	2.39 - 4.91	2.68 - 4.76
L Lake, 1988-1991[b]							
Region 4[c]	<0.01 - 2.08	<0.01 - 2.12	3.0 - 9.7	<0.1 - 0.93	<0.1 - 0.17	0.97 - 4.93	0.95 - 5.04
Region 5	<0.01 - 1.74	<0.01 - 1.76	2.9 - 9.5	<0.1 - 0.64	<0.1 - 0.20	0.99 - 4.61	1.01 - 4.58
Region 6[c]	<0.01 - 1.48	<0.01 - 1.49	2.8 - 9.7	<0.1 - 0.54	<0.1 - 0.20	0.85 - 4.51	0.91 - 4.55
Region 7	<0.01 - 1.70	<0.01 - 1.72	2.9 - 9.7	<0.1 - 0.69	<0.1 - 0.17	1.02 - 4.78	1.05 - 4.65
Region 8[c]	<0.01 - 1.89	<0.01 - 1.91	2.7 - 10.0	<0.1 - 0.75	<0.1 - 0.20	1.03 - 4.76	0.97 - 4.52

Table 5-155. (cont)

	Tot. Iron (mg/l)	Diss. Iron (mg/l)	Tot. Magnesium (mg/l)	Diss. Magnesium (mg/l)	Tot. Manganese (mg/l)	Diss. Manganese (mg/l)	Tot. Potassium (mg/l)
L Lake, 1985-1987[a]							
Region 4	0.052 - 11.60	<0.020 - 11.60	1.04 - 1.69	1.01 - 1.76	<0.02 - 2.60	<0.02 - 2.50	1.10 - 2.06
Region 5	0.101 - 8.94	<0.020 - 8.66	1.20 - 2.00	1.12 - 1.95	<0.02 - 1.88	<0.02 - 1.93	1.17 - 1.96
Region 6	0.078 - 7.78	<0.020 - 7.30	0.97 - 1.54	1.02 - 1.53	<0.02 - 8.46	<0.02 - 7.80	0.86 - 4.59
Region 7	0.070 - 5.30	<0.020 - 5.51	1.08 - 1.68	1.12 - 1.67	<0.02 - 1.57	<0.02 - 1.53	0.95 - 2.27
Region 8	0.087 - 6.90	<0.02 - 5.44	1.19 - 1.57	1.18 - 1.58	<0.02 - 1.83	<0.02 - 1.90	1.00 - 4.20
L Lake, 1988-1991[b]							
Region 4[c]	0.060 - 9.15	<0.020 - 9.51	0.94 - 1.68	0.93 - 1.60	<0.02 - 1.76	<0.02 - 1.83	0.49 - 5.1
Region 5	0.032 - 7.29	<0.020 - 7.01	0.74 - 1.62	0.96 - 1.64	<0.02 - 2.00	<0.02 - 1.53	0.90 - 2.12
Region 6[c]	0.037 - 5.79	<0.020 - 5.96	0.86 - 1.54	0.94 - 1.55	<0.02 - 1.38	<0.02 - 1.49	0.71 - 2.7
Region 7	0.024 - 5.63	<0.020 - 5.64	0.72 - 1.52	0.97 - 1.65	<0.02 - 2.00	<0.02 - 1.34	0.86 - 2.0
Region 8[c]	<0.020 - 4.56	<0.020 - 4.58	0.90 - 1.62	0.10 - 1.66	<0.02 - 1.26	<0.02 - 1.26	0.78 - 1.88

	Diss. Potassium (mg/l)	Tot. Sodium (mg/l)	Diss. Sodium (mg/l)	Chloride (mg/l)	Hydrogen Sulfide (mg/l)	Sulfate (mg/l)
L Lake, 1985–1987[a]						
Region 4	1.10 - 1.94	5.92 - 11.19	5.44 - 11.19	6 - 9	<0.1 - 0.3	2 - 6
Region 5	0.97 - 1.94	7.21 - 13.00	7.19 - 13.30	6 - 13	<0.1 - 0.4	2 - 6
Region 6	0.82 - 2.89	6.89 - 12.40	6.81 - 13.40	6 - 9	<0.1 - 0.4	2 - 6
Region 7	1.05 - 2.15	7.06 - 11.30	6.76 - 11.20	6 - 10	<0.1 - 0.6	2 - 6
Region 8	0.94 - 4.55	6.18 - 10.84	6.96 - 11.03	6 - 11	<0.1 - 0.6	2 - 7
L Lake, 1988-1991[b]						
Region 4[c]	0.86 - 2.26	8.88 - 14.40	7.28 - 13.80	5.3 - 11.7	<0.1 - 0.1	2 - 10
Region 5	0.61 - 2.1	4.02 - 14.10	7.38 - 14.10	3.2 - 11.6	<0.1 - 0.3	2 - 10
Region 6[c]	0.63 - 2.9	6.90 - 13.80	7.37 - 13.70	5.2 - 11.0	<0.1 - 0.3	1 - 9
Region 7	0.69 - 2.1	4.10 - 14.20	7.39 - 13.80	4.3 - 11.6	<0.1 - 0.5	2 - 10
Region 8[c]	0.83 - 2.1	6.67 - 14.30	7.21 - 14.40	5.1 - 13.8	<0.1 - 0.7	1 - 9

Source: Kretchmer and Chimney 1992.

[a] L Reactor operated during parts of these years.

[b] L Reactor ceased operation in June 1988.

[c] Sampling was discontinued in 1990.

Physical Characteristics and General Chemistry

Dissolved Oxygen

Changes in dissolved oxygen concentrations throughout the water column from 1985 to 1989 often coincided with the establishment and subsequent collapse of thermal stratification. Oxygen usually decreased in the deeper strata during periods of reactor-induced stratification, but quickly recovered to higher levels when the reactor shut down and the water column remixed. From 1988 to 1991, dissolved oxygen concentrations ranged from <0.1 to 13 mg/l in Region 7 (Table 5-155). This maximum, measured in 1991, was higher than any value previously reported.

Suspended Solids

Total suspended solids concentrations ranged from <1 to 20 mg/l from 1988 to 1991 (Table 5-155). These concentrations were somewhat lower than the concentrations measured in either 1985, 1986, or 1987. The higher concentrations during 1985, 1986, and 1987 may reflect the settling out of high total suspended solids loads in the reactor effluent in the upper regions of L Lake. Turbidity was not measured as part of this study.

Conductivity

Mean conductivity values in L Lake during 1991 ranged from 45 to 91 µS/cm. These mean values were 10 to 20 µS/cm lower than in 1990, which in turn were 10 to 20 µS/cm lower than in previous years. The highest conductivity values generally were recorded at the lake bottom during the fall of each year. No consistent regional differences in water column conductivity were noted for any year.

Major Anions and Cations

Alkalinity, Chloride, and Sulfate

From 1988 to 1991, alkalinity ranged from 5 to 41 mg $CaCO_3$/l (Table 5-155). This range was lower than observed in previous years. Alkalinity values were usually highest in the summer or fall and lowest in the winter. Chloride measurements ranged from 3.2 to 13.8 mg/l and sulfate concentrations ranged from 1 to 10 mg/l from 1988 to 1991 (Table 5-155). These chloride and sulfate measurements were similar to those first observed in 1985, 1986 and 1987.

Calcium, Magnesium, Sodium, and Potassium

Concentrations of total calcium, magnesium, and potassium were similar during all years of the study (Table 5-155). Concentrations of total sodium measured from 1988 to 1991 were slightly higher than those measured in 1985, 1986, and 1987. Ranges of concentrations for sodium during the 1988 to 1991 period were 4.02 to 14.4 mg/l, and during 1985, 1986, and 1987 sodium concentration ranges were 5.92 to 13 mg/l (Table 5-155).

Aluminum, Manganese, and Iron

Mean total aluminum concentrations in 1985, 1986, and 1987 were generally slightly greater than the detection limit of 0.1 mg/l. Means and ranges of individual aluminum values in 1988, 1989, 1990, and 1991 were similar, and generally lower than those in 1985, 1986, and 1987 (Table 5-155).

Total manganese ranged from <0.02 mg/l to 2.0 mg/l from 1988 to 1991. These concentrations were similar to those measured during 1985, 1986, and 1987 with the exception of one measurement at Region 6 (8.46 mg/l). The remaining manganese concentrations ranged from <0.02 to 2.6 mg/l during the 1985-1987 period (Table 5-155).

Throughout the years of the study, there was considerable variation in the magnitude of means and ranges of individual concentrations of iron (Table 5-155). However, the iron concentrations were similar during all years of the study.

Nutrients

Phosphorus

L Lake acted as an effective nutrient sink and retained most of the total phosphorus and orthophosphorus imported into it. L Reactor effluent had mean total phosphorus concentrations, ranging between 60 and 246 µg/l from 1985 to 1989 (Kretchmer and Chimney 1992). Concentrations of total phosphorus and orthophosphate measured in L Lake ranged from 0.014 to 0.864 mg/l and from <0.005 to 0.816 mg/l, respectively, during all years of the study (Table 5-155).

Nitrogen

L Lake acted as a nutrient sink and retained most of the nitrite, nitrate, and ammonia imported into it. However, L Lake usually exported more total Kjeldahl nitrogen than was present in the reactor effluent waters. Concentrations of nitrogen species measured in L Lake ranged as follows: nitrite, <0.001 to 0.092 mg/l; nitrate, <0.001 to 0.758 mg/l; and ammonia, <0.01 to 2.72 mg/l (Table 5-155).

Regional Lakes Study

In September 1988 and 1989, 10 South Carolina reservoirs were intensively sampled for trophic status, community structure, and biologically balanced community criteria. Based on the results of this study, L Lake had nitrogen and phosphorus concentrations that characterized a eutrophic system (Bowers 1992).

Trace Elements

The L Lake/Steel Creek Biological Monitoring Program did not measure for trace elements (arsenic, cadmium, chromium, copper, lead, nickel, and zinc).

Organic Carbon

Total organic carbon concentrations were similar throughout all years of the study, with ranges of <1 to 15 mg/l (Table 5-155).

Priority Pollutants, Pesticides, Herbicides and PCBs

L Lake is not sampled for priority pollutants, perticides, herbicides or PCBs.

Chemical, Including Radionuclide, and Toxicity Assessment Studies

During the early period of P- and L-Reactor operations, radioactive materials, chiefly cesium-137, were released into Steel Creek where they became sequestered in the sediments on the Steel Creek floodplain and later became inundated when L Lake was filled. While not associated with reactor operations, elevated concentrations of mercury have been recorded in SRS streams and reservoirs.

In 1995, near-surface and near-bottom water samples were collected from the centers of Regions 2, 4, 6, and 8 in L Lake. Radionuclide contaminants were not detected in the four surface water samples. However, cesium-137 (arithmetic mean of 3.01 pCi/l) and alpha-emitting radionuclides (arithmetic mean of 0.49 pCi/l) were in measurable levels in one of the four bottom water samples (Paller 1996), reflecting the contamination of the Steel Creek watershed during reactor operations prior to the construction of L Lake. Cesium-137 remobilizes from sediments under anoxic conditions (Alberts et al. 1987); this is the likely mechanism responsible for the observed elevated cesium-137 concentration.

Several metals, notably iron and manganese, were in much higher concentrations in bottom water samples than in top water samples, reflecting thermal stratification at the time of sampling and dissolution of these metals from the sediments into the anoxic bottom waters of L Lake. None of the metals exceeded EPA acute toxicity screening values for the protection of organisms in surface waters. However, the detection limits for several metals (cadmium, lead, mercury, and silver) were above the chronic toxicity screening values, making it impossible to definitely eliminate them as potential constituents of concern. Iron and beryllium concentrations exceeded their chronic toxicity screening values (Paller 1996).

Sediments

Both P and L Reactors released thermal effluents to Steel Creek in the past. Between 1955 and 1978, approximately 284 curies of cesium were released to Steel Creek. Because cesium has a strong affinity for sediments, the majority of the released material was adsorbed to the sediments and deposited with them in the Steel Creek floodplain. An inventory of the sediments at 1991 decay-corrected concentrations estimated that 8 curies of cesium were upstream of L Reactor, 30 curies were between L Reactor and the Steel Creek delta, 20 curies were in the delta, and 8 curies were in lower Steel Creek, between the delta and the creek mouth (Brisbin 1974; Gladden et al. 1985; Carlton et al. 1992).

In the summers of 1995 and 1996 the Savannah River Technology Center (SRTC) sampled the sediments of L Lake to identify radioactive and metal contaminants in the lake bed. Sampling was done in several phases.

Phase 1 sampled the surface sediments (0-0.3-m [0-1-ft] depth) at 45 L-Lake locations distributed along the old streambed and floodplain and upslope of the submerged floodplain. Two depths (0-0.3 m [0-1 ft] and 0.3-1.3 m [1-4 ft]) were sampled at 13 reference locations. The sediments were analyzed for all EPA Target Analyte List (TAL) metals (except cyanide), gross alpha activity, nonvolatile beta activity, gamma-pulse height, plutonium alpha series isotopes, and uranium alpha series isotopes. Metals results were compared to the EPA screening criteria to determine potential contaminants of concern.

Phase 2 sampled sediment cores in the L-Lake basin for the same constituents sampled in Phase 1. Core intervals were 0-0.3 m (0-1 ft), 0.3-1.2 m (1-4 ft), and 1.2-2.4 m (4-8 ft). Phase 3 measured gamma-emitting radionuclides (mainly cesium-137 and cobalt-60) *in situ* with an underwater High Purity Germanium detector.

The L-Lake cesium-137 activity is primarily located in the submerged Steel Creek floodplain (Figure 5-72). The collective sediment data show most cobalt-60:cesium-137 ratios near 1-2%, but ranging up to 6% in several locations. The higher ratios are found primarily in the vicinity of the L-Reactor discharge canal, but some of the high ratios are evident further downstream in the submerged Steel Creek floodplain (Dunn 1996).

The following metals exceeded their screening criteria in some L-Lake stream/floodplain surface sediments: mercury, copper, lead, zinc, nickel, and chromium. Mercury, copper, and lead also exceeded their screening criteria at reference locations on the SRS and in nonfloodplain L-Lake sediments (Table 5-156) (Dunn et al. 1996a). Cadmium, chromium, and mercury exceeded screening criteria in the deeper sediments at four locations, only one of which was in the floodplain (Dunn et al. 1996b).

Of the radionuclides analyzed, concentrations of actinium-228, cesium-137, cobalt-60, lead-212, uranium-233/234, uranium-238, gross alpha, and nonvolatile beta in all of the L-Lake surface sediment types were higher than those in reference soils. A comparison of the means of concentrations of cesium-137, cobalt-60, uranium-233/234, uranium-238, gross alpha, and nonvolatile beta in the old Steel Creek stream channel and floodplain with the means in other sediments and the reference soils infers a statistically significant ($P \leq 0.05$) difference between concentrations in the old channel and floodplain and in the other and reference sediments. Plutonium-239/240 and uranium-235, while detected in measurable concentrations, were not elevated relative to concentrations in the reference soils.

Phase 2 results (deeper cores) showed statistically significant differences between concentrations in the old Steel Creek channel and floodplain and those in other sediments or reference soils for cesium-137, uranium-238, gross alpha, and nonvolatile beta activity. Actinium-228, lead-212, and uranium-233/234 were found in measurable concentrations but there was no difference between locations. Cobalt-60 was not detected in the majority of samples. Plutonium-239/240 and uranium-235 were at activities detected in measurable concentrations, but results were not elevated relative to background reference concentrations (Dunn et al. 1996b).

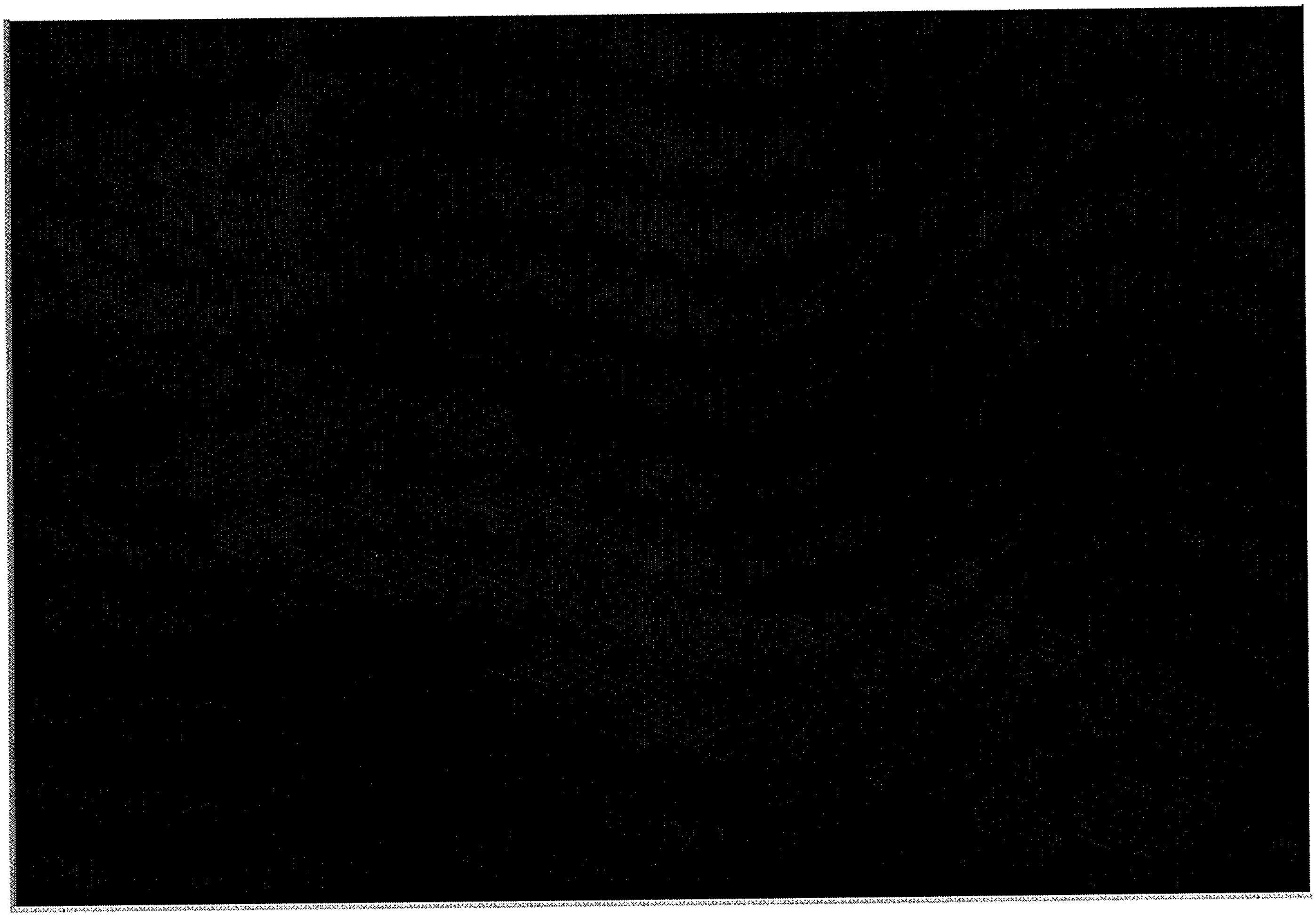

Figure 5-72. Cesium-137 Surface Model Based on 1995 and 1996 Data (Source: Dunn 1996)

Table 5-156. Metal Concentrations Found in L-Lake Surface Sediment Samples that Exceeded EPA Region IV Screening Criteria for Potential Constituents of Concern

Phase	Analyte	Sample Category	Analytical result	Units	Screening Value
1	Mercury	Other submerged sediments	131	µg/kg	130
1	Mercury	Other submerged sediments	365	µg/kg	130
1	Mercury	Other submerged sediments	178	µg/kg	130
1	Copper	Other submerged sediments	298,000	µg/kg	18,700
1	Lead	Other submerged sediments	42,800	µg/kg	30,200
1	Mercury	Reference soil	258	µg/kg	130
1	Copper	Reference soil	19,700	µg/kg	18,700
1	Lead	Reference soil	59,800	µg/kg	30,200
1	Mercury	Stream/floodplain	210	µg/kg	130
1	Copper	Stream/floodplain	26,500	µg/kg	18,700
1	Lead	Stream/floodplain	35,900	µg/kg	30,200
1	Nickel	Stream/floodplain	16,300	µg/kg	15,900
1	Chromium	Stream/floodplain	56,100	µg/kg	52,300
1	Copper	Stream/floodplain	39,200	µg/kg	18,700
1	Lead	Stream/floodplain	56,400	µg/kg	30,200
1	Nickel	Stream/floodplain	18,200	µg/kg	15,900
1	Zinc	Stream/floodplain	137,000	µg/kg	124,000
1	Copper	Stream/floodplain	26,900	µg/kg	18,700
1	Lead	Stream/floodplain	49,900	µg/kg	30,200
1	Copper	Stream/floodplain	32,700	µg/kg	18,700
1	Lead	Stream/floodplain	51,500	µg/kg	30,200
1	Copper	Stream/floodplain	32,100	µg/kg	18,700
1	Lead	Stream/floodplain	42,900	µg/kg	30,200
2	Cadmium[a]	Lakebed	1,090	µg/kg	1,000
2	Chromium[a]	Lakebed	160,000	µg/kg	52,300
2	Mercury[b]	Floodplain	189	µg/kg	130
2	Mercury[c]	Lakebed	174	µg/kg	130

Sources: Dunn et al. 1996a and b.

[a] In 0.3-1.2 m (1-4 ft) segment.

[b] In 0-0.3 m (0-1 ft) segment.

[c] In 0.3-1.2 m (1-4 ft) segment.

Deep sediment cores (0-2.4 m [0-8 ft]) collected from L Lake in 1995 were sampled for metals and radionuclides. Mercury was detected at the 0.3-0.6 m (1-2 ft) depth in one L-Lake segment. The cores had concentrations of cobalt-60, cesium-137, plutonium-238, plutonium-239/240, and strontium-90 (Koch et al. 1996).

Algae

Phytoplankton

Phytoplankton samples were collected monthly in L Lake from 1986 through 1991. Regions 4 through 8 were sampled during 1986-1989, while only Regions 5 and 8 were sampled in 1990-1991 (Figure 5-71). This sampling was conducted to determine species composition and abundance expressed as densities of organisms, biovolumes, chlorophyll *a*, dry weight, and ash-free dry weight. Primary productivity of the phytoplankton also was measured. Detailed methods and results can be found in Carson (1992). Data from 1986-1987 have been previously summarized in compliance documents (Gladden et al. 1988; Wike et al. 1989); and the data for 1986-1989 were more recently summarized in a technical report by Bowers (1991).

Phytoplankton Establishment After the Construction of L Lake

The phytoplankton communities of newly created reservoirs are frequently unstable for the first few years, and this disequilibrium phase may have been confounded in L Lake by the sporadic operation of L Reactor at decreasing power levels during 1986-1988 (Figure 5-73). For example, substantial blooms of the nuisance blue green alga *Microcystis aeruginosa* during the first two years of the lake's existence (Figure 5-73; Gladden et al. 1988) appeared to be related to the pumping of heated, relatively nutrient-rich secondary cooling water effluent (derived from the Savannah River) into L Lake. This nutrient enrichment resulted in phosphorus concentrations that were among the highest recorded in southeastern lakes (Carson 1992). Extremely high chlorophyll *a* and primary productivity levels also were observed concurrently with peak reactor operation during the spring of 1986.

Current Status of L Lake Phytoplankton

With the cessation of reactor operations in 1988, and the natural sucession process, the L-Lake phytoplankton community stabilized and was much more typical of other southeastern reservoirs in 1990 and 1991. Annual trends for species richness, primary productivity, chlorophyll *a*, and relative abundance of major algal groups are shown in Figure 5-74 through Figure 5-78, respectively. Comprehensive species lists from the six-year study appear in Table 5-157 and Table 5-158.

Periphyton

Periphyton sampling was conducted monthly in Regions 4-8 of L Lake (Figure 5-71) from 1986 through 1989 using periphytometers and sediment cores. Periphyton parameters that were studied included taxonomy and abundance of organisms expressed in terms of densities and biovolumes, dry weight and ash-free dry weight, chlorophyll *a*, and primary productivity. Detailed methods and results can be found in Chimney et al. (1990). Data from 1986-1987 have been previously summarized in compliance documents by Gladden et. al. (1988) and Wike et al. (1989).

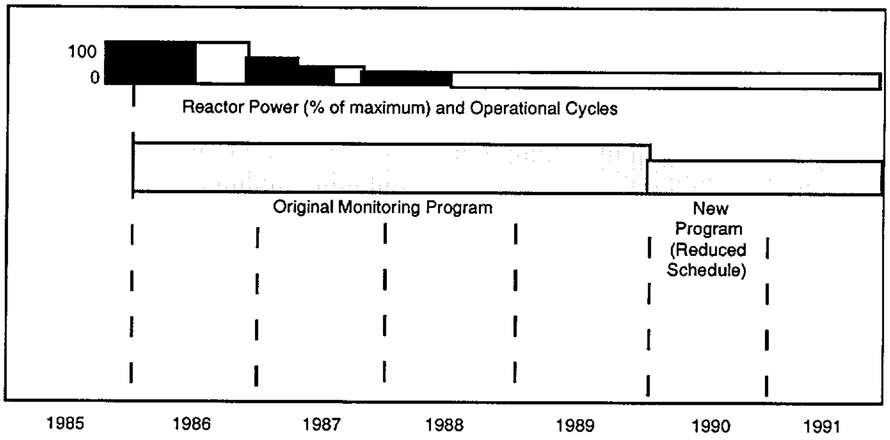

Figure 5-73. L-Reactor Operation and L-Lake Monitoring History

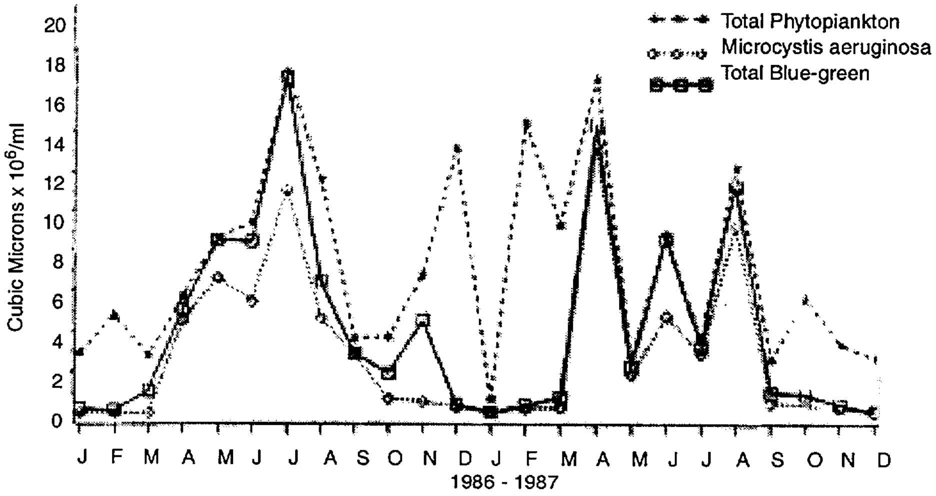

Figure 5-74. Mean Phytoplankton Biovolume in the Pelagic Zone of Regions 4-8 in L Lake, January 1986-December 1987 (Source: Gladden et al. 1988).

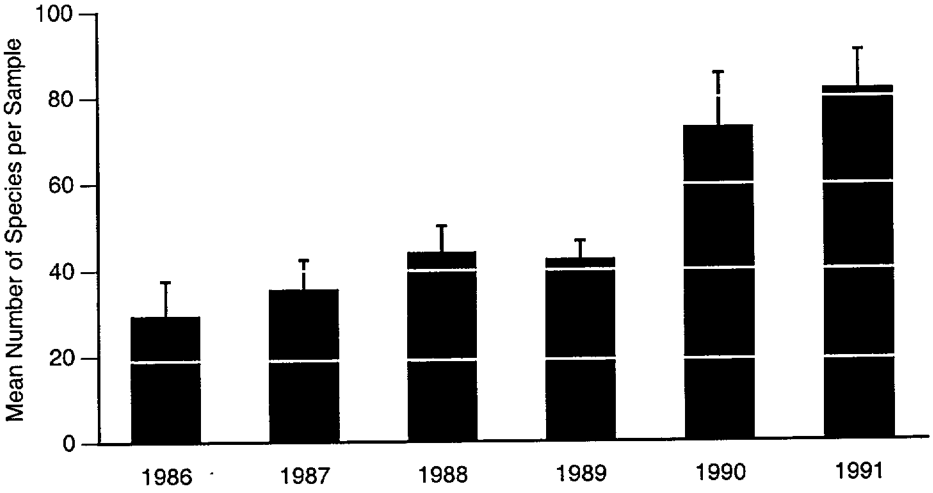

Figure 5-75. Mean Algae Species Richness (±SD) in L Lake.

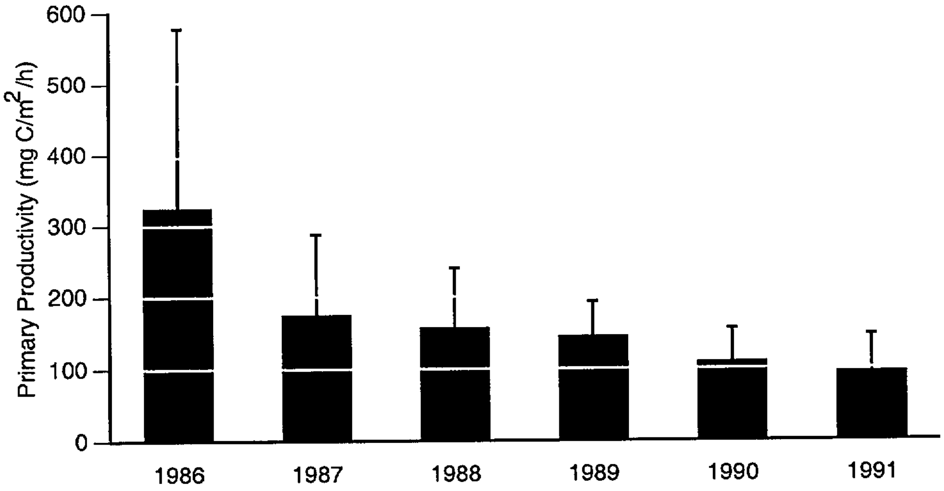

Figure 5-76. Mean Integrated Primary Productivity (±SD) in L Lake

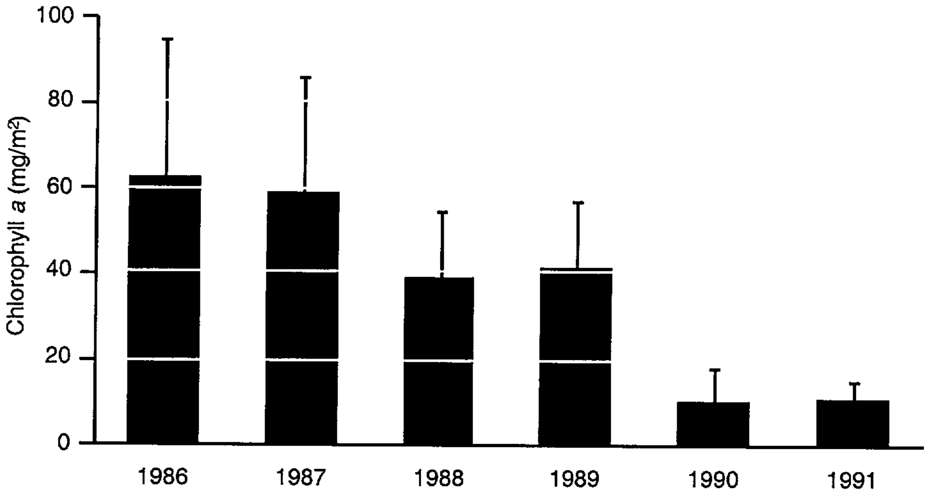

Figure 5-77. Mean Integrated Chlorophyll *a* (±SD) in the Mixed Layer of L Lake

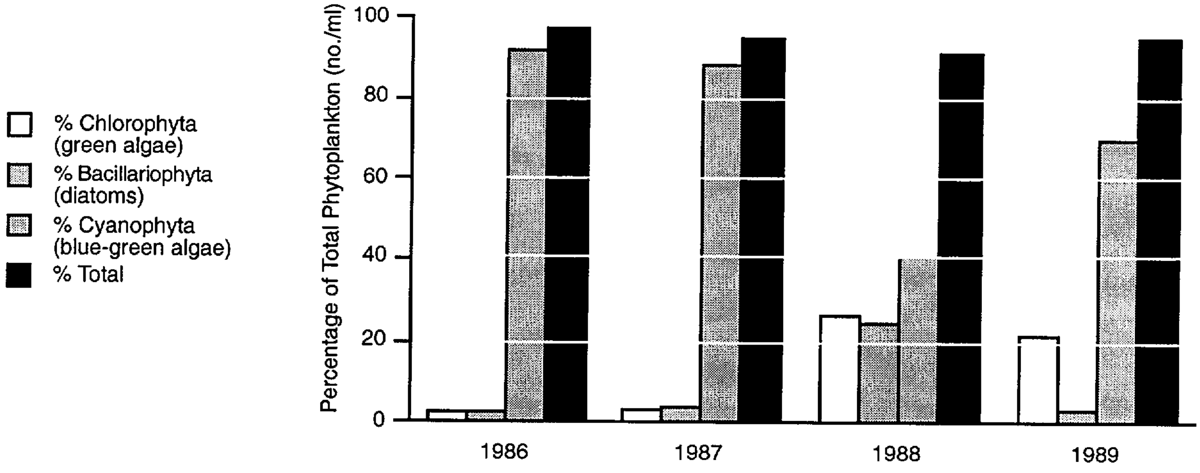

Figure 5-78. Percent Abundance of Blue-Green Algae, Green Algae, and Diatoms in L Lake

Table 5-157. Phytoplankton Taxa Collected from L-Lake Pelagic Zone Sampling Stations, January 1986-December 1989.

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8
Division Bacillariophyta					
Achnanthes exigua			X	X	
Achnanthes lanceolata var. *apiculata*	X	X			
Achnanthes minutissima	X	X	X	X	X
Asterionella formosa				X	X
Attheya zachariasi	X	X	X	X	X
Capartogramma crucicula	X				
Cyclostephanos tholiformis	X	X	X	X	X
Cyclotella atomus	X	X	X	X	X
Cyclotella meneghiniana	X	X	X	X	X
Cyclotella pseudostelligera	X	X	X	X	X
Cyclotella stelligera	X	X	X	X	X
Cymbella minuta	X				X
Cymbella tumida	X				
Eunotia pectinalis		X			
Eunotia zasuminensis		X			
Fragilaria crotonensis		X	X	X	X
Fragilaria virescens					X
Gomphonema parvulum	X	X	X	X	X
Gyrosigma acuminatum				X	
Gyrosigma spencerii	X	X	X	X	X
Melosira ambigua	X	X	X	X	X
Melosira distans	X	X	X	X	X
Melosira granulata	X	X	X	X	X
Melosira granulata var. *angustissima*	X	X	X	X	X
Melosira varians	X	X	X	X	X
Navicula capitata		X			
Navicula confervacea	X	X	X	X	X
Navicula cryptocephala	X	X	X	X	X
Navicula cuspidata	X				
Navicula decussis	X	X	X	X	X
Navicula luzonensis			X		
Navicula minima	X	X			
Navicula rhynchocephala var. *germainii*		X			
Navicula spp.	X	X	X		X
Nitzschia acicularis	X	X	X	X	X
Nitzschia agnita	X	X	X	X	X
Nitzschia amphibia	X		X	X	X
Nitzschia capitellata	X				
Nitzschia fonticola	X	X	X	X	X
Nitzschia gracilis	X	X	X	X	X
Nitzschia holsetica	X	X	X	X	X
Nitzschia intermedia		X			
Nitzschia palea	X	X	X	X	X
Nitzschia paleacea	X	X	X	X	X
Nitzschia spp.		X	X		
Pinnularia spp.				X	
Pinnularia viridis					X
Rhizosolenia eriensis	X	X	X	X	X

Table 5-157. (cont)

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8
Rhizosolenia longiseta	X	X	X	X	X
Skeletonema potamos	X	X	X	X	X
Stephanodiscus sp. 2	X	X	X	X	X
Surirella robusta	X	X		X	X
Synedra delicatissima	X		X	X	X
Synedra parasitica		X			
Synedra planktonica	X	X	X	X	X
Synedra rumpens	X	X	X	X	X
Synedra tenera	X	X	X	X	X
Synedra ulna	X	X	X	X	X
Synedra ulna var. *oxyrhynchus*	X				
Division Chlorophyta					
Actinastrum hantzschii	X	X	X	X	X
Ankistrodesmus falcatus	X	X	X	X	X
Ankistrodesmus spiralis	X	X	X	X	X
Arthrodesmus octocornis			X		
Carteria sp. 1				X	
Carteria spp.	X	X	X	X	X
Chaetophora elegans					X
Characium spp.	X	X	X	X	X
Chlamydomonas spp. < 5 µm	X	X	X	X	X
Chlamydomonas spp. 5 - 9.9 µm	X	X	X	X	X
Chlamydomonas spp. 10 - 15 µm	X	X	X	X	X
Chlamydomonas spp. > 15 µm	X	X	X	X	X
chlorobacteria < 2 µm		X			
chloroflagellate spp. < 5 µm	X	X	X	X	X
chloroflagellate spp. 5 - 9.9 µm	X	X	X	X	X
Closteriopsis longissima	X				X
Closterium aciculare	X	X	X		X
Closterium acutum	X	X	X	X	X
Closterium cornu	X		X		
Closterium gracile	X	X	X	X	X
Closterium moniliferum	X				
Closterium parvulum	X				
coccoid Chlorophyta spp. < 5 µm	X	X	X	X	X
coccoid Chlorophyta spp. 5 - 9.9 µm	X	X	X	X	X
coccoid Chlorophyta spp. 10 - 15 µm					X
Coelastrum microporum	X	X	X	X	X
Coelastrum reticulatum	X	X	X	X	X
Coelastrum sphaericum	X	X	X	X	X
Coronastrum aestivale	X	X	X	X	X
Cosmarium botrytis			X		
Cosmarium contractum	X	X	X	X	X
Cosmarium depressum	X	X	X	X	X
Cosmarium granatum				X	
Cosmarium regnellii		X			
Cosmarium reniforme					X
Cosmarium tenue	X	X	X	X	X
Crucigenia crucifera	X	X	X	X	X
Crucigenia quadrata	X	X	X	X	X

Table 5-157. (cont)

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8
Crucigenia tetrapedia	X	X	X	X	X
Desmidium swartizii			X		
Dictyosphaerium ehrenbergianum	X	X	X		
Dictyosphaerium pulchellum	X	X	X	X	X
Didymocystis fina	X	X	X	X	X
Elakatothrix viridis	X	X	X	X	X
Euastrum binale	X	X	X	X	X
Eudorlna elegans			X		
Franceia ovalis	X	X	X	X	X
Gloeocystis planctonica	X	X	X	X	X
Golenkinia radiata	X	X	X	X	X
Gonium pectorale	X	X	X	X	X
Keratococcus raphidioides	X	X	X	X	X
Kirchneriella lunaris	X	X	X	X	X
Kirchneriella obesa	X	X	X		X
Lagerheimia citriformis			X	X	X
Lagerheimia genevensis	X	X	X	X	X
Lagerheimia subsalsa	X	X	X	X	X
Leptosira mediciniana			X		
Micractinium pusillum	X	X	X	X	X
Monoraphidium circinale	X	X	X	X	X
Monoraphidium sp. 1	X	X	X	X	X
Mougeotia spp.		X	X	X	X
Oedogonium spp. large	X	X	X	X	X
Oocystis parva	X	X	X	X	X
Oocystis pusilla	X	X	X	X	X
Pandorina charkowiensis	X	X	X	X	X
Pandorina morum	X	X	X	X	X
Pediastrum duplex	X	X	X	X	X
Pediastrum tetras	X	X	X	X	X
Pleurotaenium ehrenbergii		X			
Polyedriopsis spinulosa	X	X	X	X	X
Scenedesmus acuminatus	X	X	X	X	X
Scenedesmus acutus	X	X	X	X	X
Scenedesmus bernardii	X				
Scenedesmus bicaudatus	X	X	X	X	X
Scenedesmus brasiliensis	X	X	X	X	X
Scenedesmus brevispina	X				
Scenedesmus denticulatus	X	X	X	X	X
Scenedesmus dimorphus	X	X	X	X	X
Scenedesmus ecornis	X	X	X	X	X
Scenedesmus opoliensis	X	X	X	X	X
Scenedesmus perforatus	X				
Scenedesmus producto-capitatus	X	X	X	X	X
Scenedesmus quadricauda	X	X	X	X	X
Scenedesmus sp.				X	
Scenedesmus spinosus	X	X	X	X	X
Schroederia setigera	X	X	X	X	X
Selenastrum minutum	X	X	X	X	X

Table 5-157. (cont)

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8
Selenastrum westii	X	X	X	X	X
Spermatozoopsis exultans	X	X	X	X	X
Sphaerocystis schroeteri	X	X	X	X	X
Spirogyra spp.					X
Staurastrum alternans		X			
Staurastrum chaetoceras	X	X	X	X	X
Staurastrum cingulum	X	X	X	X	X
Staurastrum excavatum	X	X	X	X	X
Staurastrum gracile	X	X	X	X	
Staurastrum hexacerum					X
Staurastrum leptocladum	X	X	X	X	X
Tetraedron caudatum	X	X	X	X	X
Tetraedron gracile	X	X	X	X	X
Tetraedron minimum	X	X	X	X	X
Tetraedron sp.			X		X
Tetraedron trigonum	X	X	X	X	X
Tetrastrum heteracanthum	X	X	X	X	X
Tetrastrum staurogeniaeforme	X	X	X	X	X
Treubaria setigerum	X	X	X	X	X
Treubaria triappendiculata	X	X	X	X	X
Ulothrix tenerrima	X	X	X		
Division Chrysophyta					
Chromulina spp. < 5 µm	X	X	X	X	X
Chromulina spp. 5 - 9.9 µm	X	X	X	X	X
chrysoflagellate spp. < 5 µm	X	X	X	X	X
chrysoflagellate spp. 5 - 9.9 µm	X	X	X	X	X
chrysophyte unidentified sp. 2	X	X	X	X	X
Chrysosphaerella longispina		X			
coccoid Chrysophyta spp. < 5 µm	X	X	X	X	X
coccoid Chrysophyta spp. 5 - 9.9 µm	X	X	X	X	X
coccoid Chrysophyta spp. 10 - 15 µm	X	X	X	X	
Dinobryon divergens		X	X	X	X
Dinobryon sp. 1	X	X	X	X	
Mallomonas caudata	X	X	X	X	X
Mallomonas pseudocoronata	X	X		X	
Mallomonas sp. 3	X		X	X	
Mallomonas spp.	X				
Mallononas tonsurata	X	X	X	X	X
Microglena cordiformis	X	X	X	X	X
Ochromonas spp. < 5 µm	X		X		
Ophiocytium capitatum		X			
Paraphysomonas spp.			X	X	X
Salpingoeca spp.	X	X	X	X	X
Synura uvella	X	X	X	X	X
Division Cryptophyta					
Cryptomonas erosa	X	X	X	X	X
Cryptomonas marsonii	X	X	X	X	X
Cryptomonas rostratiformis	X	X	X	X	X
Rhodomonas minuta	X	X	X	X	X
Rhodomonas minuta var. *nannoplanctonica*	X	X	X	X	X

Table 5-157. (cont)

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8
Division Cyanophyta					
Anabaena planctonica	X	X	X	X	X
Anabaena spiroides	X	X	X	X	X
Anabaena spp.	X	X	X	X	X
Anabaena subcylindrica	X	X	X	X	X
Anabaena visconsinense	X		X		
Anabaenopsis raciborskii	X	X	X	X	X
Anabaenopsis sp. 1	X	X	X	X	X
Aphanizomenon flos-aquae	X	X	X	X	X
Aphanocapsa elachista			X	X	X
Aphanothece nidulans	X	X	X	X	X
Aphanothece saxicola		X	X		X
Chroococcus lacustris		X	X	X	X
Chroococcus minutus	X	X	X	X	X
Chroococcus sp. 1		X	X		
coccoid Cyanophyta spp. < 5 µm	X	X	X	X	X
coccoid Cyanophyta spp. 5 - 9.9 µm	X	X	X	X	X
Coelosphaerium naegelianum	X	X	X	X	X
Coelosphaerium pallidum	X	X	X	X	X
Dactylococcopsis sp. 1	X	X	X	X	X
Lyngbya limnetica	X	X	X	X	X
Lyngbya sp. 1	X	X	X		
Lyngbya spp.		X		X	
Lyngbya subtilis		X		X	
Mastigocladus laminosus	X	X	X	X	X
Merismopedia glauca				X	
Merismopedia minima	X	X	X	X	X
Merismopedia tenuissima	X	X	X	X	X
Microcystis aeruginosa	X	X	X	X	X
Microcystis incerta	X	X	X	X	X
Oscillatoria acutissima	X	X	X	X	X
Oscillatoria amphibia	X	X	X	X	X
Oscillatoria anguina		X			
Oscillatoria angustissima	X	X	X	X	X
Oscillatoria geminata	X	X	X	X	X
Oscillatoria limnetica	X	X	X	X	X
Oscillatoria limosa	X				
Oscillatoria ornata	X	X	X	X	X
Oscillatoria sp. 1	X		X	X	
Oscillatoria spp.	X	X	X	X	X
Oscillatoria subtilissima		X	X	X	X
Oscillatoria tenuis	X	X	X		X
Phormidium molle	X				
Phormidium sp. 1	X	X	X	X	X
Phormidium spp.	X	X	X	X	X
Rhabdoderma sp. 1		X	X	X	X
Rhabdoderma sp. 2	X	X	X	X	X
Schizothrix sp. 1	X	X	X	X	X
Schizothrix spp.	X	X	X	X	X

Table 5-157. (cont)

Taxon	Reg 4	Reg 5	Reg 6	Reg 7	Reg 8
Division Euglenophyta					
Euglena acus	X	X	X	X	
Euglena minuta	X	X	X	X	X
Euglena spp.	X	X	X	X	X
Phacus longicauda			X		
Phacus monilata	X	X	X	X	X
Phacus spp.	X	X	X	X	X
Trachelomonas hispida	X	X	X	X	X
Trachelomonas stokesiana	X	X	X		
Trachelomonas volvocina	X	X	X	X	X
Division Pyrrhophyta					
Ceratium hirundinella	X	X	X	X	X
Gymnodinium ordinatum	X	X	X	X	X
Gymnodinium sp. 1	X	X	X	X	X
Gymnodinium spp.	X	X	X	X	X
Peridinium inconspicuum	X	X	X	X	X
Peridinium sp.	X	X			X
Peridinium sp. 1	X	X	X	X	X
Peridinium volzii	X		X		

Table 5-158. Phytoplankton Collected from Regions 5 and 7 in L Lake and in Par Pond, January-December 1990 and 1991

Taxon	1991 L Lake Region 5	1991 L Lake Region 7	1991 Par Pond	1990 L Lake Region 5	1990 L Lake Region 7	1990 Par Pond
Bacillariophyta						
Achnanthes minutissima	X	X	X	X	X	X
Asterionella formosa	X	X	X	X	X	X
Attheya zachariasi	X	X	X	X	X	X
Cyclostephanos tholiformis	X	X	X	X	X	X
Cyclotella atomus	X	X	X			
Cyclotella pseudostelligera	X	X	X	X	X	X
Cyclotella stelligera	X	X	X	X	X	X
Eunotia zasuminensis	X	X	X	X	X	X
Fragilaria capucina					X	
Fragilaria crotonensis	X	X	X			X
Gomphonema parvulum					X	
Melosira ambigua	X	X	X	X	X	X
Melosira distans	X	X	X	X	X	X
Melosira distans var. *tenella*	X	X	X			
Melosira granulata	X	X	X	X	X	X
Melosira herzogii					X	
Melosira varians	X	X		X	X	X
Navicula cryptocephala	X	X	X	X	X	
Navicula decussis		X				
Nitzschia acicularis	X	X	X	X	X	X
Nitzschia agnita	X	X	X	X	X	
Nitzschia holsetica	X	X	X	X	X	X
Rhizosolenia eriensis	X	X	X	X	X	X
Rhizosolenia longiseta		X				
Skeletonema potamos	X	X				
Stephanodiscus sp. 2		X		X	X	
Synedra delicatissima	X	X	X	X	X	X
Synedra planktonica	X	X	X	X	X	X
Synedra rumpens	X	X	X	X	X	X
Synedra sp. 1	X	X	X			
Synedra spp.	X	X	X			
Synedra tenera	X	X	X	X	X	X
Synedra ulna	X	X	X	X	X	X
Tabellaria fenestrata	X	X	X			
Chlorophyta						
Actinastrum hantzschii	X	X			X	
Ankistrodesmus falcatus	X	X	X	X	X	X
Ankistrodesmus spiralis	X	X	X	X	X	X
Arthrodesmus bifidus var. *latidivergens*	X					
Carteria spp.		X				
Characium spp.	X	X	X			
Chlamydomonas spp. 10 - 15 µm	X	X			X	
Chlamydomonas spp. 5 - 9.9 µm	X	X	X	X	X	X
Chlamydomonas spp. < 5 µm	X	X	X	X	X	X
Chlamydomonas spp. > 15 µm	X	X				
chloroflagellate spp. 5 - 9.9 µm	X	X	X	X	X	
chloroflagellate spp. < 5 µm	X	X	X	X	X	

Table 5-158. (cont)

Taxon	1991 L Lake Region 5	1991 L Lake Region 7	1991 Par Pond	1990 L Lake Region 5	1990 L Lake Region 7	1990 Par Pond
Chlorogonium sp.		X		X	X	
Closteriopsis sp.			X			
Closterium acutum	X	X	X	X	X	X
Closterium gracile	X		X	X	X	X
Closterium kutzingii			X			
Coccoid chlorophyta spp. 10 - 15 µm	X					
Coccoid chlorophyta spp. 5 - 9.9 µm	X	X	X	X	X	X
Coccoid chlorophyta spp. < 5 µm	X	X	X	X	X	X
coccoid chlorophyte colony #1	X					
Coelastrum microporum	X	X	X	X	X	X
Cosmarium corbula		X				
Cosmarium regnesi var. *montanum*	X	X	X	X	X	
Cosmarium tenue	X	X	X	X	X	X
Crucigenia crucifera	X	X	X	X	X	X
Crucigenia quadrata	X					
Crucigenia tetrapedia	X	X	X	X	X	X
Dictyosphaerium ehrenbergianum	X					
Dictyosphaerium pulchellum	X	X	X	X	X	X
Didymocystis fina	X	X	X	X	X	X
Elakatothrix gelatinosa			X			
Elakatothrix viridis	X	X	X	X	X	X
Euastrum binale	X	X	X	X	X	X
Eudorina elegans	X				X	
Franceia ovalis	X	X	X	X	X	X
Gloeocystis planctonica	X	X	X			X
Golenkinia radiata	X	X	X	X	X	X
Gonium pectorale	X	X		X	X	
Keratococcus raphidioides	X	X		X	X	
Kirchneriella lunaris	X	X	X	X	X	X
Kirchneriella microscopia				X	X	X
Kirchnerlella obesa				X		
Lagerheimia citriformis	X					
Lagerheimia genevensis	X	X	X	X	X	X
Lagerheimia subsalsa				X	X	
Micractinium pusillum	X	X	X	X	X	X
Monoraphidium circinale	X	X	X	X	X	
Monoraphidium sp. 1		X				
Mougeotia spp.	X	X	X	X	X	X
Oedogonium spp. large			X			
Oocystis parva	X	X	X	X	X	X
Oocystis pusilla	X	X	X	X	X	X
Pandorina charkowiensis	X	X		X	X	X
Pandorina morum				X	X	
Pediastrum biradiatum longecornutum		X				
Pediastrum duplex	X			X	X	X
Pediastrum tetras	X	X	X	X	X	X
Quadrigula closterloides	X	X	X			X

Table 5-158. (cont)

Taxon	1991 L Lake Region 5	1991 L Lake Region 7	1991 Par Pond	1990 L Lake Region 5	1990 L Lake Region 7	1990 Par Pond
Scenedesmus acuminatus	X	X	X	X	X	X
Scenedesmus bicaudatus	X	X	X	X	X	
Scenedesmus denticulatus	X	X	X	X	X	X
Scenedesmus ecornis	X	X	X	X	X	X
Scenedesmus opoliensis	X	X	X	X	X	
Scenedesmus quadricauda	X	X	X	X	X	X
Scenedesmus sp.	X		X			X
Scenedesmus spinosus	X	X	X	X	X	X
Schroederia setigera	X			X		
Selenastrum minutum	X	X	X	X	X	X
Spermatozoopsis exultans	X	X	X	X	X	X
Sphaerocystis schroeteri	X	X	X	X	X	X
Spondylosium papillosum	X	X	X			
Staurastrum anatinum			X			
Staurastrum chaetoceras	X	X	X	X	X	X
Staurastrum cingulum			X			X
Staurastrum cuspidatum	X	X	X		X	X
Staurastrum excavatum		X				
Staurastrum gracile	X	X				X
Staurastrum laeve						X
Staurastrum leptocladum			X			
Staurastrum pentacerum			X			
Staurastrum smithii	X	X	X	X	X	X
Staurastrum sp. 1			X			X
Staurastrum sp. 2	X	X	X			
Tetraedron caudatum	X	X	X	X	X	X
Tetraedron gracile	X	X	X	X	X	
Tetraedron minimum	X	X	X	X	X	X
Tetrastrum heteracanthum	X	X		X	X	
Treubaria setigerum	X	X	X	X	X	X
Treubaria triappendiculata	X	X	X	X	X	
Westella botryoides					X	
Westella sp. 1			X			
Cyanophyta						
Anabaena spiroides				X	X	X
Anabaena spp.	X	X	X	X	X	X
Anabaenopsis raciborskii	X	X	X	X	X	X
Anabaenopsis sp. 1	X	X		X	X	X
Aphanothece saxicola				X	X	X
Aphanothece sp. 1	X	X	X	X	X	X
Chroococcus dispersus var. *minor*	X	X				
Chroococcus minimus	X	X		X	X	X
Chroococcus minutus	X			X		
Chroococcus sp. 1	X	X	X			
coccoid cyanophyta spp. < 5 µm	X	X	X	X	X	X
Coelosphaerium kuetzingianum			X			
Coelosphaerium naegelianum	X					

Table 5-158. (cont)

Taxon	1991 L Lake Region 5	1991 L Lake Region 7	1991 Par Pond	1990 L Lake Region 5	1990 L Lake Region 7	1990 Par Pond
Coelosphaerium pallidum		X				
Dactylococcopsis sp. 1	X	X	X	X	X	X
Lyngbya limnetica	X	X	X	X	X	X
Mastigocladus laminosus				X	X	X
Merismopedia minima			X	X	X	
Merismopedia tenuissima	X	X	X		X	
Microcystis aeruginosa		X				
Microcystis incerta	X	X	X	X	X	X
Oscillatoria limnetica	X	X	X	X	X	X
Oscillatoria tenuis			X			X
Phormidium frigidum				X	X	
Raphidiopsis curvata		X		X		
Synechococcus elongatus	X	X	X			
Cryptophyta						
Cryptomonas erosa	X	X	X	X	X	X
Cryptomonas marsonii	X	X	X	X	X	X
Cryptomonas rostratiformis	X	X	X	X	X	X
Rhodomonas minuta	X	X	X	X	X	X
Chrysophyta						
chrysoflagellate spp. 10 - 15 µm	X	X		X	X	X
chrysoflagellate spp. 5 - 9.9 µm	X	X	X	X	X	X
chrysoflagellate spp. < 5 µm	X	X	X	X	X	X
coccoid chrysophyta spp. 10 - 15 µm	X					
coccoid chrysophyta spp. 5 - 9.9 µm	X	X	X	X	X	X
coccoid chrysophyta spp. < 5 µm	X	X	X	X	X	X
Dinobryon bavaricum	X	X	X	X	X	
Dinobryon divergens	X	X	X	X	X	X
Mallomonas akrokomos		X	X			
Mallomonas caudata	X	X	X	X	X	X
Mallomonas crassisquama	X	X	X			
Mallomonas spp.	X	X				
Mallomonas tonsurata	X	X	X	X	X	X
Microglena cordiformis	X	X	X	X	X	X
Ophiocytium capitatum			X			
Synura sp. 1	X	X	X			
Synura uvella	X	X	X	X	X	X
Pyrrhophyta						
Ceratium hirundinella	X	X	X	X	X	X
Gymnodinium ordinatum	X	X	X	X	X	X
Gymnodinium spp.	X	X	X	X	X	X
Peridinium cinctum			X			
Peridinium inconspicuum	X	X	X	X	X	X

Table 5-158. (cont)

Taxon	1991 L Lake Region 5	1991 L Lake Region 7	1991 Par Pond	1990 L Lake Region 5	1990 L Lake Region 7	1990 Par Pond
Peridinium sp. 1	X	X	X	X	X	
Peridinium umbonatum		X				
Peridinium wisconsinense	X	X	X			X
Euglenophyta						
Euglena spp.	X	X	X	X	X	X
Phacus longicauda	X	X	X			
Phacus monilata	X	X	X	X	X	X
Phacus spp.			X	X	X	X
Trachelomonas hispida	X	X	X	X	X	X
Trachelomonas volvocina	X	X	X	X	X	X

L Reactor Impacts

Impacts of L-Reactor operations on the periphyton community of L Lake were not apparent. There were no consistent regional relationships among periphyton grown on artifical substrates and, although the periphyton in sediment cores varied regionally in terms of species composition, there was no gradient among regions indicative of varying degrees of thermal pollution.

Quantities of total periphyton (Figure 5-79) and primary productivity (Figure 5-80 and Figure 5-81) indicated a trend in the attached algae toward less fluctation and reduced peaks with reservoir aging (and the termination of L Reactor operations). However, chlorophyll *a* and dry weight values on both periphytometers and in sediment cores did not show any discernible pattern over the four-year study period (Figure 5-82 and Figure 5-83). Densities and biovolumes of blue-green algae (Figure 5-84 and Figure 5-85) showed a tendency toward reduced temporal and spatial variation and a general reduction in biomass. The relative abundance of blue-green algae was substantially lower in 1988 and 1989 compared to 1986 and 1987 (Chimney et al. 1990). Both reservoir aging and reductions in thermal and nutrient additions to the reservoir as a result of cessation of reactor operations are likely to have contributed to the diminishing quantities of blue-green algae observed over the four-year study period.

List of the important periphyton taxa (making up >5% of the total in a given sample) identified during the study period appear in Table 5-159 through Table 5-162.

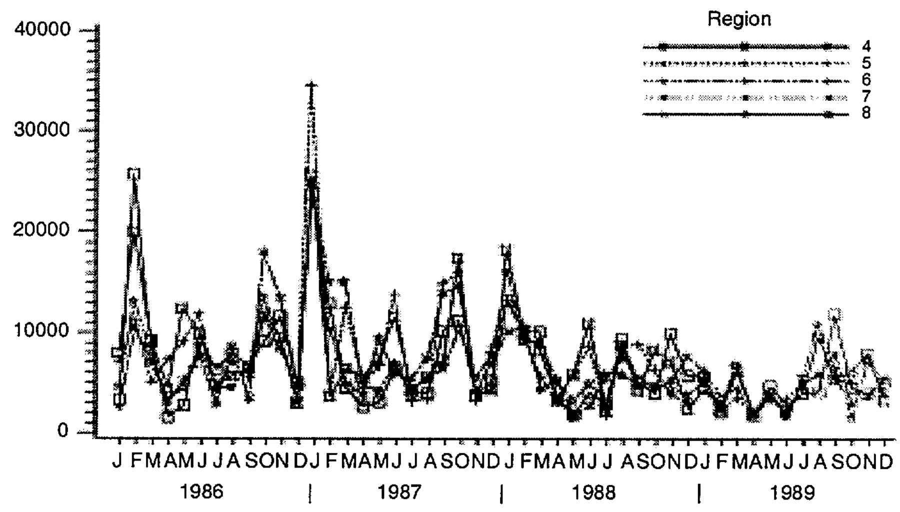

Figure 5-79. Mean Total Periphyton Densities (organisms/mm^2) on Periphytometer Slides from L-Lake Sampling Stations in Regions 4-8, January 1986-December 1989

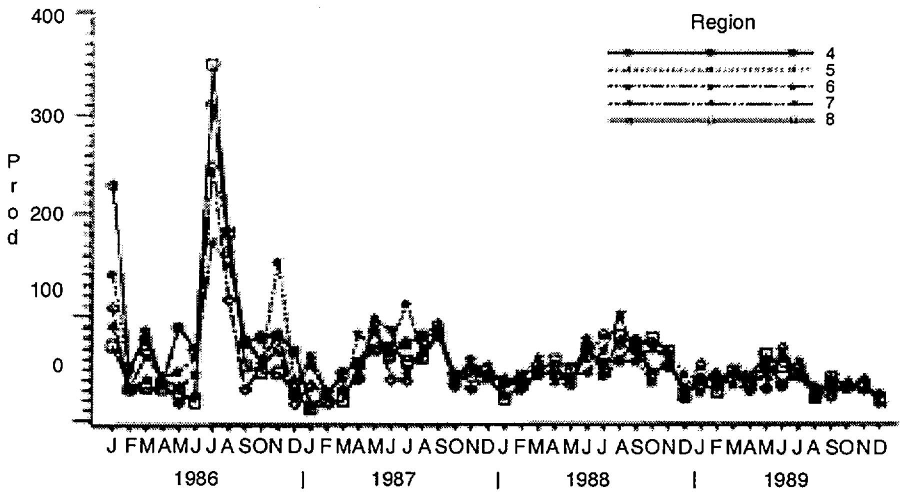

Figure 5-80. Mean Periphyton Primary Productivity Per Hour (mg C/m^2/h) from L-Lake Littoral Sampling Stations in Regions 4-8, January 1986-December 1989

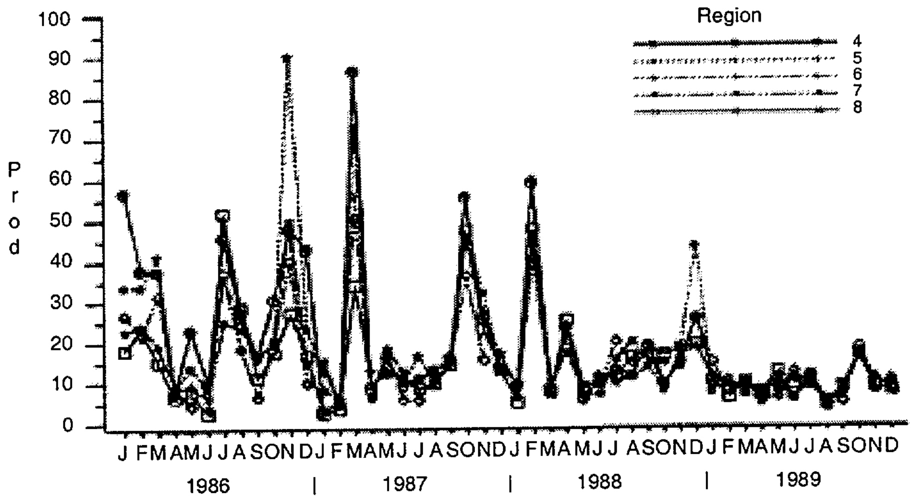

Figure 5-81. Mean Periphyton Primary Productivity Per Unit of Light (mg C/m^2/E) from L-Lake Littoral Sampling Stations in Regions 4-8, January 1986-December 1989

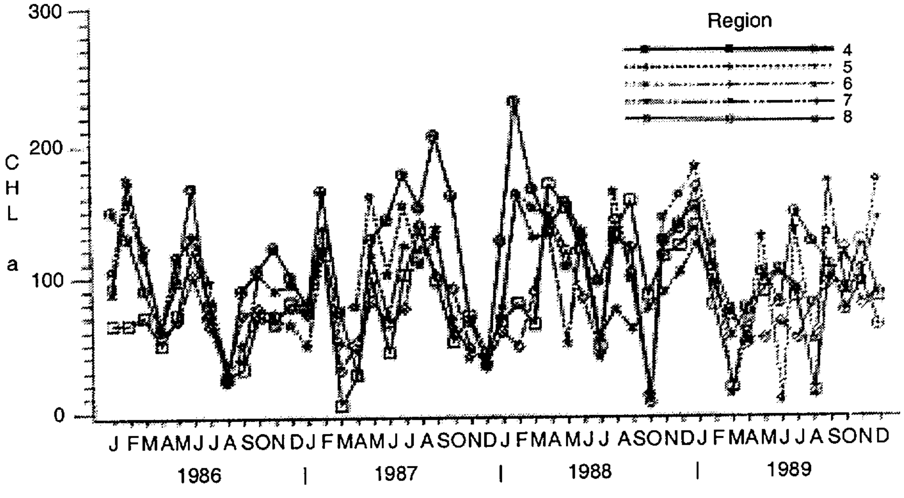

Figure 5-82. Mean Periphyton Chlorophyll *a* (mg/m^2) in Sediment Cores from L-lake Littoral Sampling Stations in Region 4-8, January 1986-December 1989

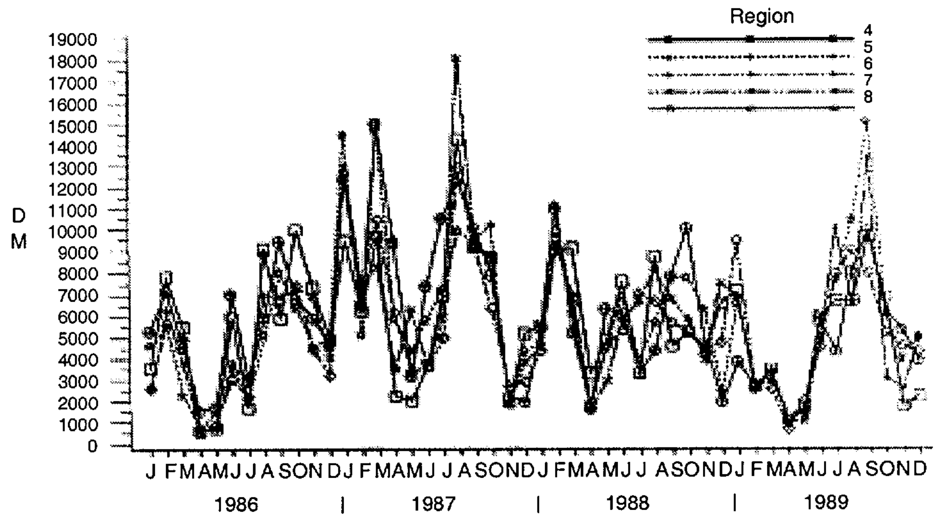

Figure 5-83. Mean Periphyton Dry Weight (mg/m^2) on Periphytometer Slides from L-Lake Littoral Sampling Stations in Regions 4-8, January 1986-December 1989

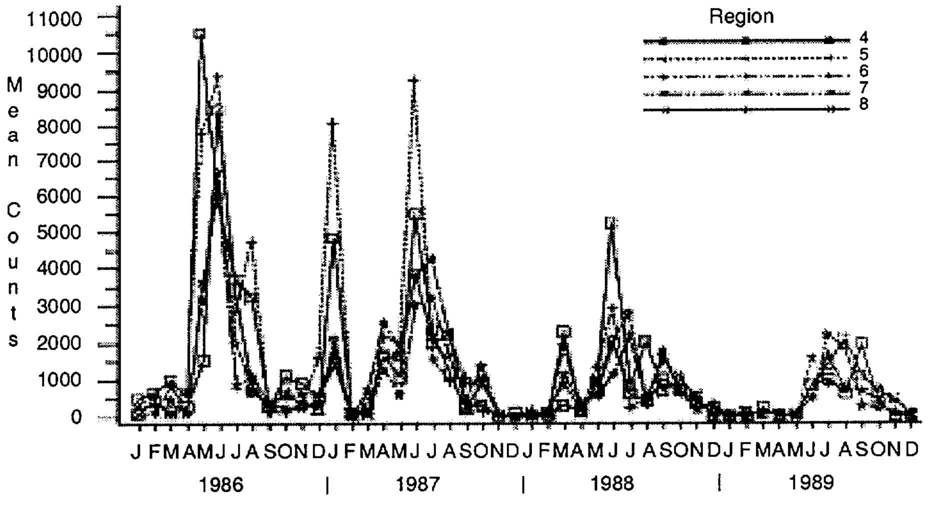

Figure 5-84. Mean Densities of Cyanophyta (no./mm^2) on Periyphytometer Slides from L-Lake Littoral Sampling Stations in Regions 4-8, January 1986-December 1989

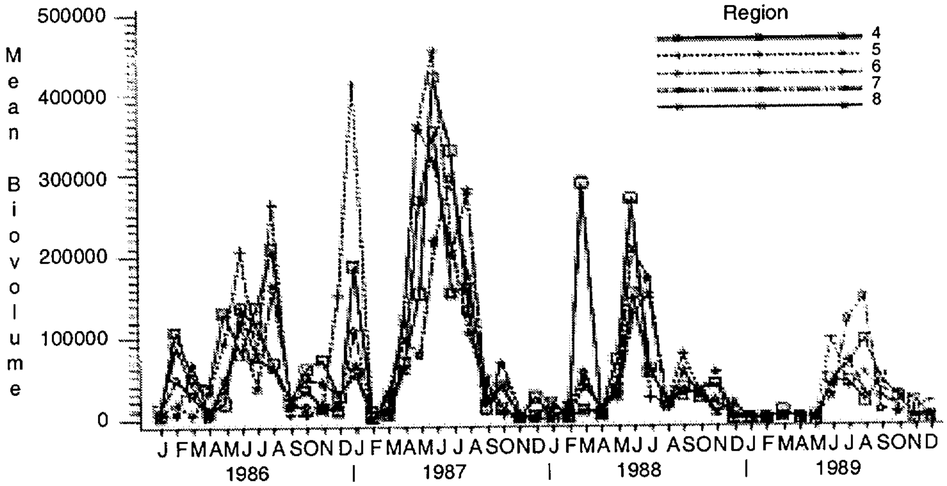

Figure 5-85. Mean Biovolumes of Cyanophyta ($\mu m^3 \times 10^3/mm^2$) from L-Lake Littoral Sampling Stations in Regions 4-8, January 1986-December 1989

Table 5-159. Numerically Dominant (>5% of the total in the sample) Periphyton Taxa in Sediment Cores from L-Lake Littoral Zone Sampling Stations, Regions 4-8, January 1986-December 1989

Year	Division[a]	Taxon	No. samples in which dominant
1986	Baci	*Navicula decussis*	44
	Baci	*Melosira granulata*	36
	Baci	*Navicula cryptocephala*	32
	Cyan	*Microcystis aeruginosa*	27
	Chlo	*Scenedesmus denticulatus*	17
	Chlo	*Scenedesmus dimorphus*	15
	Baci	*Navicula lateropunctata*	13
	Baci	*Synedra rumpens*	12
	Baci	*Nitzschia amphibia*	10
	Baci	*Achnanthes minutissima*	8
	Chlo	*Ankistrodesmus spiralis*	8
	Baci	*Achnanthes exigua*	6
	Baci	*Nitzschia paleacea*	5
1987	Baci	*Navicula decussis*	53
	Baci	*Melosira granulata*	36
	Cyan	*Microcystis aeruginosa*	36
	Chlo	*Scenedesmus denticulatus*	32
	Baci	*Navicula cryptocephala*	19
	Cyan	coccoid Cyanophyta spp. <5 μm	18
	Chlo	*Ankistrodesmus spiralis*	17
	Baci	*Achnanthes lanceolata* var.*apiculata*	7

Table 5-159. (cont)

Year	Division[a]	Taxon	No. samples in which dominant
	Chlo	*Scenedesmus dimorphus*	6
	Chlo	coccoid Chlorophyta spp. 5 - 9.9 µm	5
	Cyan	*Lyngbya subtilis*	5
	Cyan	*Microcystis incerta*	5
1988	Baci	*Navicula decussis*	54
	Chlo	*Scenedesmus denticulatus*	38
	Baci	*Achnanthes exigua*	35
	Baci	Achnanthes lanceolata	29
	Chlo	*Ankistrodesmus spiralis*	25
	Cyan	*Microcystis aeruginosa*	22
	Baci	*Achnanthes lanceolate* var. *apiculata*	20
	Baci	*Navicula cryptocephala*	18
	Chlo	*Scenedesmus dimorphus*	14
	Baci	*Fragilaria virescens*	10
	Baci	*Navicula minima*	9
	Baci	*Melosira granulata*	8
	Chlo	coccoid Chlorophyta spp. 5 - 9.9 µm	7
	Chlo	*Scenedesmus quadricauda*	7
	Baci	*Achnanthes minutissima*	7
	Cyan	*Microcystis incerta*	7
	Baci	*Fragilaria construens*	6
	Cyan	*Merismopedia glauca*	5
1989	Baci	*Navicula decussis*	45
	Baci	*Achnanthes exigua*	36
	Chlo	*Scenedesmus denticulatus*	30
	Chlo	*Scenedesmus dimorphus*	30
	Cyan	*Microcystis aeruginosa*	29
	Cyan	*Microcystis incerta*	21
	Baci	*Achnanthes lanceolata*	20
	Baci	*Fragilaria construens*	20
	Chlo	*Ankistrodesmus spiralis*	17
	Baci	*Navicula minima*	16
	Chlo	coccoid Chlorophyta spp. < 5 µm	13
	Baci	*Fragilaria pinnata*	12
	Baci	*Navicula cryptocephala*	9
	Baci	*Synedra rumpens*	7
	Baci	*Achnanthes minutissima*	6
	Cyan	coccoid Cyanophyta spp. <5 µm	6
	Cyan	*Merismopedia glauca*	6

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[a] Baci = Bacillariophyta; Chlo = Chlorophyta; Cyan = Cyanophyta.

Table 5-160. Volumetrically Dominant (>5% of the total sample) Periphyton Taxa in Sediment Cores from L-Lake Littoral Zone Sampling Stations, Regions 4-8, January 1986-December 1989

Year	Division[a]	Taxon	No. samples in which dominant
1986	Baci	*Melosira granulata*	49
	Baci	*Navicula decussis*	43
	Baci	*Melosira varians*	27
	Baci	*Navicula cryptocephala*	25
	Cyan	*Microcystis aeruginosa*	15
	Baci	*Navicula lateropunctata*	14
	Baci	*Nitzschia amphibia*	9
	Baci	*Navicula cuspidata*	6
	Baci	*Navicula viridula*	6
	Baci	*Navicula capitata*	5
	Chlo	*Oedogonium* spp. large	5
	Baci	*Pinnularia acrosphaeria*	5
1987	Baci	*Melosira granulata*	55
	Baci	*Navicula decussis*	51
	Baci	*Achnanthes lanceolata* var. *apiculata*	27
	Baci	*Melosira varians*	18
	Baci	*Navicula cryptocephala*	14
	Cyan	*Microcystis aeruginosa*	14
	Baci	Navicula viridula	12
	Chlo	*Scenedesmus denticulatus*	11
	Baci	*Nitzschia amphibia*	5
	Baci	*Nitzschia gracilis*	5
1988	Baci	*Navicula decussis*	57
	Baci	*Achnanthes lanceolata* var. *apiculata*	50
	Baci	*Melosira granulata*	
	Baci	*Melosira varians*	24
	Baci	*Achnanthes lanceolata*	21
	Baci	*Achnanthes exigua*	13
	Baci	*Navicula cryptocephala*	13
	Baci	*Epithemia adnata*	14
	Baci	*Fragilaria virescens*	11
	Baci	*Nitzschia amphibia*	6
	Chlo	*Scenedesmus denticulatus*	5
	Baci	*Navicula viridula*	5
	Baci	*Rhopaidoia gibba*	5
1989	Baci	*Navicula decussis*	56
	Baci	*Melosira varians*	35
	Baci	*Achnanthes lanceolata* var. *apiculata*	25
	Baci	*Achnanthes lanceolata*	24
	Baci	*Achnanthes exigua*	21
	Baci	*Fragilaria construens*	15
	Cyan	*Microcystis aeruginosa*	15
	Chlo	*Scenedesmus denticulatus*	14
	Baci	*Navicula cryptocephala*	13
	Baci	*Epithemia adnata*	10
	Baci	*Cymbella tumida*	5

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[a] Baci = Bacillariophyta; Chlo = Chlorophyta; Cyan = Cyanophta.

Table 5-161. Numerically Dominant (>5% of the total sample) Periphyton Taxa on Periphytometer Slides from L-Lake Littoral Zone Sampling Stations, Regions 4-8, January 1986-December 1989

Year	Division[a]	Taxon	No. samples in which dominant
1986	Baci	*Achnanthes minutissima*	37
	Chlo	*Chaetophora elegans*	28
	Baci	*Synedra rumpens*	24
	Baci	*Gomphonema parvulum*	18
	Chlo	*Characium* spp.	11
	Cyan	*Chamaesiphon minimus*	10
	Cyan	coccoid Cyanophyta spp. < 5 μm	10
	Chlo	coccoid Chlorophyta spp. 5 - 9.9 μm	8
	Cyan	*Lyngbya subtilis*	7
	Baci	*Melosira varians*	7
	Chlo	*Chlamydomonas* spp. 5 - 9.9 μm	6
	Cyan	*Phormidium* sp. 1	6
	Cyan	*Phormidium* spp.	6
	Baci	*Navicula decussis*	5
	Cyan	*Rhabdoderma sigmoidea*	5
1987	Baci	*Achnanthes minutissima*	51
	Cyan	*Lyngbya subtilis*	33
	Cyan	coccoid Cyanophyta spp. 5 - 9.9 μm	22
	Chlo	*Chaetophora elegans*	16
	Baci	*Navicula decussis*	16
	Baci	*Synedra rumpens*	10
	Chlo	coccoid Chlorophyta spp. 5 - 9.9 μm	9
	Cyan	coccoid Cyanophyta spp. < 5 μm	8
	Chlo	*Oedogonium* spp. sm	8
	Baci	*Gomphonema gracile*	6
	Baci	*Achnanthes exigua*	5
	Chlo	*Characium* spp.	5
	Chlo	*Chlamydomonas* spp. 5 - 9.9 μm	5
	Baci	*Gomphonema parvulum*	5
	Chlo	*Scenedesmus denticulatus*	5
1988	Baci	*Achnanthes minutissima*	59
	Chlo	coccoid Chlorophyta spp. 5 - 9.9 μm	33
	Cyan	*Lyngbya subtilis*	33
	Baci	*Navicula decussis*	13
	Cyan	*Microcystis incerta*	12
	Baci	*Achnanthes exigua*	10
	Baci	*Navicula minima*	10
	Chlo	*Characium* spp.	10
	Chlo	*Scenedesmus denticulatus*	9
	Cyan	*Calothrix* sp. 1	8
	Baci	*Gomphonema gracile*	7
	Chlo	*Chlamydomonas* spp. 5 - 9.9 μm	7
	Chlo	*Chaetophora elegans*	6
	Cyan	coccoid Cyanophyta spp. 5 - 9.9 μm	6
	Baci	*Nitzschia paleacea*	5
	Baci	*Synedra rumpens*	5
1989	Baci	*Achnanthes minutissima*	60
	Chlo	coccoid Chlorophyta spp. < 5 μm	24

Table 5-161. (cont)

Year	Division[a]	Taxon	No. samples in which dominant
	Baci	*Synedra rumpens*	23
	Cyan	*Lyngbya subtilis*	22
	Baci	*Gomphonema parvulum*	14
	Chlo	coccoid Chlorophyta spp. 5 - 9.9 µm	12
	Chlo	*Chlamydomonas* spp. 5 - 9.9 µm	11
	Chlo	*Oedogonium* spp. small	10
	Baci	*Gomphonema gracile*	9
	Chlo	*Scenedesmus denticulatus*	8
	Cyan	coccoid Cyanophyta spp. < 5 µm	7
	Baci	*Cocconeis placentual*	5

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[a] Baci = Bacillariophyta; Chlo = Chlorophyta; Cyan = Cyanophyta.

Table 5-162. Volumetrically Dominant (>5% of the total sample) Periphyton Taxa on Periphytometer Slides from L-Lake Littoral Zone Sampling Stations, Regions 4-8, January 1986-December 1989

Year	Division[a]	Taxon	No. samples in which dominant
1986	Baci	*Achnanthes minutissima*	33
	Chlo	*Chaetophora elegans*	29
	Baci	*Gomphonema parvulum*	28
	Chlo	*Oedogonium* spp. large	22
	Baci	*Synedra rumpens*	20
	Baci	*Synedra ulna*	18
	Baci	*Melosira varians*	17
	Chlo	coccoid Chlorophyta spp. 5 - 9.9 µm	16
	Baci	*Gomphonema gracile*	12
	Cyan	*Chomoesiphon minimus*	9
	Baci	*Melosira granulata*	8
	Baci	*Gomphonema subclavatum*	7
	Baci	*Navicula cryptocephala*	7
	Cyan	coccoid Cyanophyta spp. < 5 µm	6
	Baci	*Gomphonema rhombicum*	5
	Chlo	*Spirogyra* spp.	5
1987	Baci	*Cymbella tumida*	37
	Baci	*Achnanthes minutissima*	31
	Baci	*Gomphonema gracile*	22
	Baci	*Melosira varians*	17
	Cyan	coccoid Cyanophyta spp. 5 - 9.9 µm	17
	Baci	*Navicula decussis*	10
	Chlo	*Chaetophora elegans*	15
	Baci	*Gomphonema subclavatum*	14
	Chlo	*Spirogyra* spp. sm	12
	Chlo	coccoid Chlorophyta spp. 5 - 9.9 µm	10
	Baci	*Epithemia adnata*	9
	Baci	*Synedra ulna*	8
	Baci	*Synedra rumpens*	7
	Baci	*Synedra tenera*	7

Table 5-162. (cont)

Year	Division[a]	Taxon	No. samples in which dominant
	Baci	*Gomphonema truncatum*	6
	Baci	*Melosira granulata*	6
	Chlo	*Oedogonium* spp. small	6
	Chlo	*Spirogyra* spp. large	6
	Baci	*Gomphonema parvulum*	5
	Chlo	*Chlamydomonas* spp. 5 - 9.9 µm	5
	Cyan	*Lyngbya subtillis*	5
1988	Baci	*Achnanthes minutissima*	29
	Baci	*Cymbella tumida*	24
	Chlo	coccoid Chlorophyta spp. 5 - 9.9 µm	18
	Baci	*Melosira varians*	18
	Baci	*Navicula decussis*	10
	Baci	*Epithemia adnata*	13
	Chlo	*Spirogyra* spp. large	13
	Baci	*Gomphonema parvulum*	11
	Baci	*Achnanthes exigua*	10
	Baci	*Gomphonema gracile*	9
	Baci	*Cocconeis placentula*	8
	Chlo	*Scenedesmus denticulatus*	8
	Chlo	*Chaetophora elegans*	6
	Chlo	*Oedogonium* spp. large	5
	Baci	*Nitzschia paleacea*	5
1989	Baci	*Achnanthes minutissima*	36
	Baci	*Gomphonema parvulum*	25
	Chlo	*Spirogyra* spp. large	23
	Baci	*Melosira varians*	21
	Baci	*Cymbella tumida*	17
	Baci	*Gomphonema truncatum*	16
	Baci	*Gomphonema gracile*	15
	Baci	*Cocconeis placentula*	10
	Chlo	*Chlamydomonas* spp. 5 - 9.9 µm	
	Chlo	coccoid Chlorophyta spp. 5 - 9.9 µm	
	Baci	*Synedra rumpens*	9
	Baci	*Epithemia adnata*	6
	Chlo	*Oedogonium* spp. large	6
	Baci	*Synedra ulna*	5

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[a] Baci = Bacillariophyta; Chlo = Chlorophyta; Cyan = Cyanophyta.

Macrophytes

L-Lake aquatic macrophytes are not covered in this section, but in Chapter 6—Wetlands and Carolina Bays of SRS.

Zooplankton

Taylor et al. (1993) described zooplankton succession in L Lake for the first three years of the reservoir's existence. During 1986 and 1987, larger macrozooplankton, *Daphnia parvula*, *Daphnia retrocurva*, *Diaphanosoma brachyurum*, *Diaptomus pallidus*, and *Diaptomus dorsalis*, were dominant species. *Bosmina longirostris*, the smallest of the cladocerans, was most abundant during 1988. During the third year of the study, loricate rotifers (*Keratella* spp., *Polyarthra* spp., and *Kellicottia bostoniensis*), *Synchaeta stylata*, and *Conochilus unicornis* dominated the zooplankton assemblage. Size-selective predation by the threadfin shad (*Dorosoma petenense*) was responsible for this shift in community structure.

L-Lake total macrozooplankton, mainly zooplankton crustacea (cladocerans, copepods) and total microzooplankton (rotifers and protozoans) reached their greatest abundance during the summers of 1988 and 1989 (Figure 5-86). Numerically, the protozoans dominated zooplankton communities in L Lake. However, copepod and cladoceran densities reveal the striking effect of size-selective predation in L Lake (Figure 5-87). During 1986 and 1987, when densities of the planktivorous threadfin shad were low, these larger, more easily seen and thus more vulnerable species existed in the lake. However as threadfin shad, voracious consumers of large zooplankton (Drenner and McComas 1980; Drenner et al. 1984; Prophet and Frey 1987) increased, they began to drive their preferred prey to extinction in the lake. By 1990, copepod and cladoceran were nonexistent in the open waters of L Lake.

At the species level, these temporary extinctions were even more apparent (Figure 5-88). Only *Paracyclops* and *Diaphonosoma* remained at detectable densities and for plausible reasons. *Diaphonosoma* is large and easily seen by planktivorous fish, but this inshore littoral species rarely is found in deeper waters where the threadfin shad feed. Therefore, its behavior significantly reduces predation by a pelagic predator. *Paracyclops* is the smallest of the macrozooplankton and is not as easily detected by the shad. In summary, the size structure and density of zooplankton in L Lake reflected intense planktivorous predation. No large species were collected in open water. Decreases in shad abundance during 1990 and 1991 may be a result of decreases in zooplankton densities.

Another factor that affects macrozooplankton abundance is the presence of the phantom midge, *Chaoborus punctipennis* (Haven 1990). Haven (1990) noted that during periods of high *C. punctipennis* abundance, preferred prey such as soft-bodied rotifers and small cladocerans disappear, while loricate rotifers and larger cladocerans coexist with the predator.

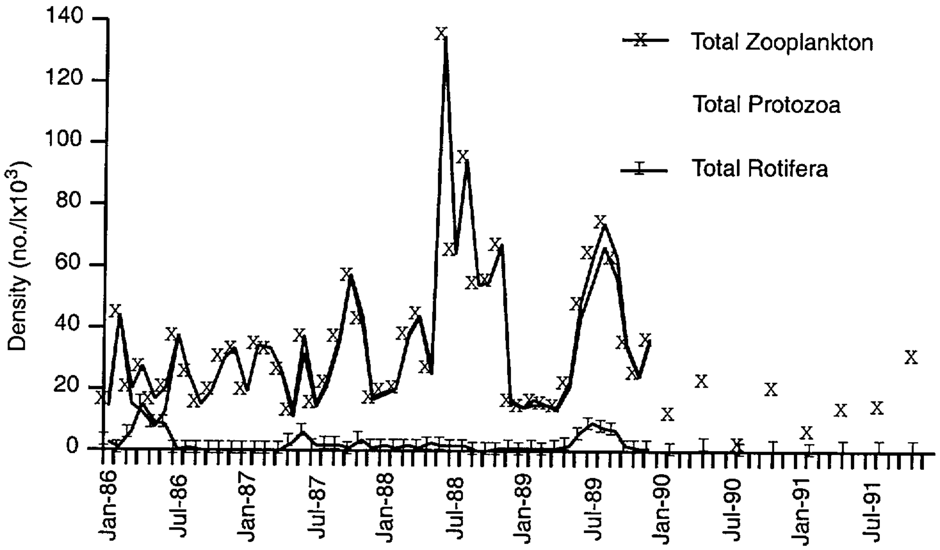

Figure 5-86. Protozoa and Rotifera in L Lake.

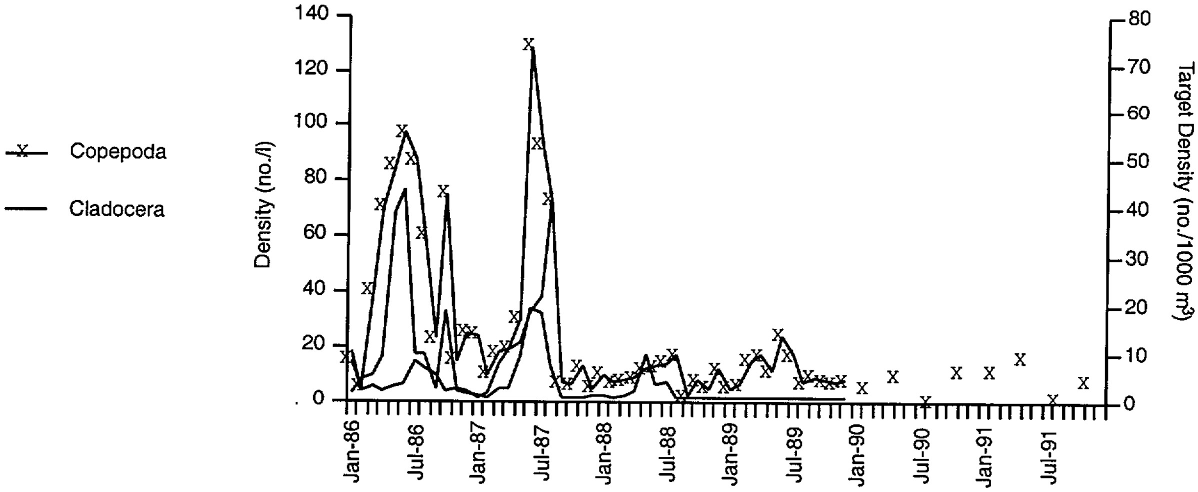

Figure 5-87. Cladocera and Copepoda in L Lake.

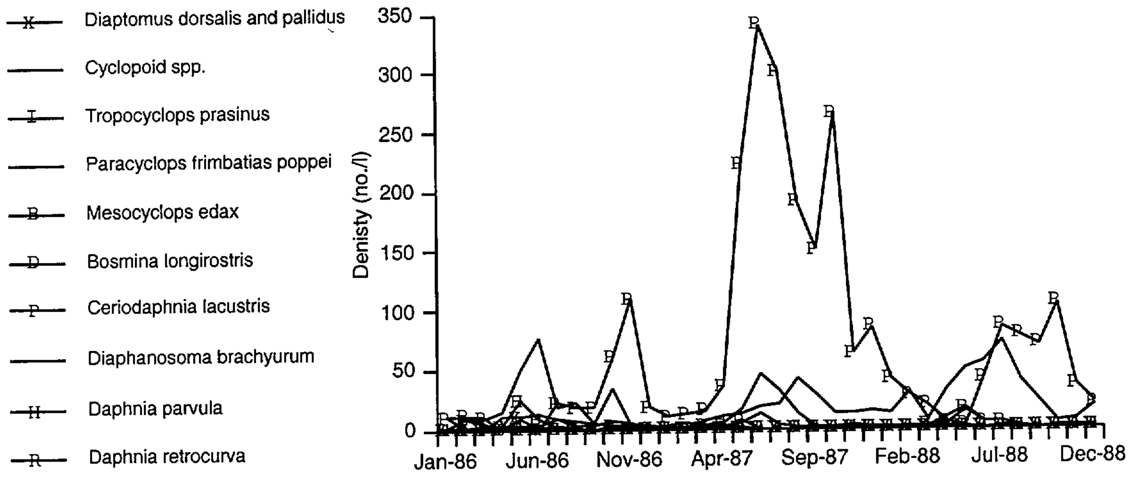

Figure 5-88. Zooplankton species in L Lake.

In L Lake, *C. punctipennis* reached its greatest abundance during the summer and fall of 1987, 1989, 1990, and 1991. Protozoans, due to their small size, are not thought to be important *C. punctipennis* prey. Densities of protozoans appeared positively correlated to *C. punctipennis*. Rotifera densities declined in L Lake after 1989, but were not correlated to midge abundance maxima. Cladocerans also declined in L Lake after 1988. This pattern suggests that *C. punctipennis* may be preying extensively on small species. Maximum abundances of *Chaoborus* co-occurred with cladoceran densities during 1987 and 1988 and slightly behind cladocera densities during 1989. Copepod densities, like those of cladocerans, declined after 1988, most likely due to fish predation.

Macroinvertebrates

Sampling Locations and Methods

Clean Water Act Section 316(a) Demonstration

From January 1986 through December 1989, macroinvertebrates were collected in Regions 4 through 8 of L Lake (Figure 5-71). Meroplankton was sampled monthly at night using vertical plankton tows. The benthic littoral community was sampled monthly at two depths (2 and 4 m [6.5 and 13 ft]) using a ponar grab sampler. Emerging adult insects were collected during one week of every month from floating emergence traps placed in each region. In addition, littoral habitats were sampled qualitatively on a quarterly basis in each region using a D-frame dip net.

Beginning in January 1990, the overall level of effort for the macroinvertebrate sampling program was reduced. All macroinvertebrate sampling was limited to Regions 5 and 7. Meroplankton and insect emergence were sampled monthly. Ponar samples were collected quarterly at 1-, 2-, and 4-m (3-, 6.5-, and 13-ft) depths. Qualitative dip net sampling was continued quarterly in Regions 5 and 7. Details of sampling methods for 1986-1989 can be found in Lauritsen (1990), and details of 1990-1991 methods can be found in Trapp (1992).

1995 Sampling

In September 1995, 72 macroinvertebrate grab samples were collected from 4 transects in Region 5 and 4 transects in Region 7. Along each transect, three replicate samples were collected at water depths of 1-, 2-, and 4-m (3-, 6.5-, and 13-ft) using a petite ponar dredge. To facilitate comparison, samples were collected in the same locations as were sampled in 1988 and 1989 (Specht 1996).

Results

Clean Water Act 316(a) Demonstration

Meroplankton

As in most lakes, the meroplankton community of L Lake was always overwhelmingly dominated by the phantom midge (*Chaoborus punctipennis)*, which made up 94.3 to 99.9% of the organisms collected annually in the meroplankton samples. Other macroinvertebrate taxa that commonly were collected in the plankton nets included the oligochaetes *Stylaria lacustris, Nais behningi,* and *Nais variabilis*; the amphipod *Hyalella azteca;* and several genera of chironomids (Trapp 1992). Meroplankton densities during the six-year period ranged from 17,168.6 organisms/1000 m^3 in Region 8 in 1986 to 206,486.4 organisms/1000 m^3 in Region 4 in 1987 (Table 5-163). Meroplankton densities at all stations were lowest in 1986 and highest in 1987 (Table 5-163). Meroplankton biomass had a similar temporal pattern, with low biomass in 1986, followed by high biomass in 1987 as the lake community became more established. During the six-year period, mean annual meroplankton biomass ranged from 1.630 g/1000 m^3 at Region 8 in 1986 to 15.371 g/

Table 5-163. Meroplankton Densities (no./1000 m^3) in L Lake, 1986-1991

	Region				
Year	**4**	**5**	**6**	**7**	**8**
1986	26,727.7	29,377.5	20,985.3	24,008.8	17,168.6
1987	206,486.4	181,274.3	157,701.5	137,218.2	112,996.5
1988	87,700.1	72,417.6	58,342.9	47,005.7	36,152.8
1989	130,247.6	124,361.5	106,123.7	96,569.3	78,433.8
1990	-	86,318.5	-	107,487.1	-
1991	-	82,206.0	-	97,921.6	-

Source: Trapp 1992.

1000 m^3 in Region 5 in 1987 (Table 5-164). Meroplankton density and biomass were generally lowest in Region 8.

Benthic Macroinvertebrates

Dominant Taxa and Taxa Richness

The littoral benthic macroinvertebrate community of L Lake was dominated numerically by oligochaetes including *Lumbriculus variegatus*, *Limnodrilus hoffmeisteri*, *Nais communis*, and *Aulodrilus* sp.; turbellarians; the amphipod *Hyalella azteca*; and several genera of chironomids, including *Chironomus*, *Dicrotendipes*, and *Ablabesmyia*. In most regions, the fewest taxa (9.3 to 11.6 taxa) were collected during the first year of sampling when the littoral community was first becoming established; the most were collected in 1989 (14.4 to 17.3 taxa; Table 5-165). Taxa richness in 1990 and 1991 was somewhat lower than in 1989 (Table 5-165). In general, taxa richness varied considerably with depth, between sampling stations within the same region, among regions and among seasons (Trapp 1992). However, no consistent pattern was discernible for any of these parameters.

Densities

Benthic densities were also lowest in 1986, ranging from 3955.5 to 4471.6 organisms/m^2 (Table 5-166). The density of organisms in most regions peaked in 1988 or 1989, with densities of approximately 10,000 to 12,000 organisms/m^2 occurring in all regions except Region 8, where the maximum mean annual densities in 1988 and 1989 were 8948.1 and 7617.4 organisms/m^2, respectively. Densities in 1991 were substantially lower for both Regions 5 and 7, averaging fewer than 7000 organisms/m^2. The density patterns exhibited in L Lake are typical of those reported for many new reservoirs, with densities peaking in the third or fourth year, and then declining somewhat as the ecosystem approaches equilibrium.

Table 5-164. Meroplankton Biomass (g AFDW/1000 m^3) in L Lake, 1986-1991

	Region				
Year	**4**	**5**	**6**	**7**	**8**
1986	2.024	2.567	2.009	2.024	1.630
1987	14.072	15.371	12.941	12.279	10.741
1988	5.807	3.869	4.034	2.443	2.553
1989	5.758	5.237	4.656	4.516	4.658
1990	-	4.930	-	7.115	-
1991	-	3.862	-	7.467	-

Source: Trapp 1992.
AFDW=Ash-free dry weight

Table 5-165. Annual Mean Number of Macroinvertebrate Taxa Collected from Ponar Dredge Samples in L Lake, 1986-1991

	Region				
Year	**4**	**5**	**6**	**7**	**8**
1986	11.6	10.4	12.2	10.1	9.3
1987	11.8	11.1	11.5	10.3	10.2
1988	15.3	14.7	14.0	12.9	11.8
1989	17.3	16.3	17.3	16.1	14.4
1990	-	15.1	-	15.7	-
1991	-	13.0	-	14.1	-

Source: Trapp 1992.

Table 5-166. Benthic Macroinvertebrate Density (no./m^2) in L Lake, 1986-1991

	Region				
Year	**4**	**5**	**6**	**7**	**8**
1986	4,091.9	4,072.8	4,471.6	3,955.5	3,955.8
1987	8,066.4	8,676.3	8,481.9	8,503.2	7,672.5
1988	10,773.1	11,029.6	11,694.1	11,017.4	8,948.1
1989	10,933.1	9,897.5	11,762.3	10,671.4	7,617.4
1990	-	10,601.6	-	11,713.1	-
1991	-	6,586.2	-	6,966.7	-

Source: Trapp 1992.

Biomass

Benthic biomass followed a similar trend, with low biomass (<1 g/m^2), reported for all regions during 1986, followed by a gradual increase in 1987 and 1988 (Table 5-167). Biomass in all regions peaked in 1989 or 1990, with standing crops as high as 17.182 g/m^2 reported. Biomass in 1991 was somewhat lower than in the previous two years. Biomass in Region 8 was always substantially lower than in the other regions, ranging from 0.749 to 2.094 g/m^2. Benthic habitat in Region 8 was poorer than that of the other regions of the lake, primarily due to the presence of large areas of hard-packed clay, which provided a poor substrate for most species of macroinvertebrates. The biomass pattern exhibited in L Lake is typical of that reported for many new reservoirs, with biomass peaking in the third or fourth year, and then declining somewhat as the ecosystem approaches equilibrium.

Emergence Traps

Emergence traps were used in L Lake to document successful reproduction of aquatic insects in the reservoir and to collect taxa that might be missed by other sampling methods. The majority of the insects collected from the emergence traps were chironomids. The most prevalent taxa included *Glyptotendipes* spp., *Procladius sublettei, Cricotopus* sp., *Nanocladius* sp., *Ablabesmyia* sp., *Labrundinia* spp., *Tanytarsus* spp., and *Cladotanytarsus viridiventris* (Lauritsen 1990; Trapp 1992). Other dipterans caught in the traps included *Chaoborus punctipennis*, Ephydridae, and Ceratopogonidae. Mayflies and caddisflies also were collected in low numbers (Lauritsen 1990). As expected, emergence rates were typically highest during the spring and summer (Trapp 1992). Annual mean emergence rates during the six-year period ranged from 0.62 insects/m^2/day in Region 5 in 1991 to 36.47 insects/m^2/day in Region 4 in 1988. Emergence rates were fairly comparable in 1986 through 1989, but were much lower in 1990 and 1991 probably due to a change in the design of the emergence traps (Trapp 1992).

1995 Sampling

Sixty-seven macroinvertebrate taxa were collected during the 1995 sampling. The most dominant taxa in most samples were oligochaetes (32.8-69.7%) and the amphipod, *Hyalella azteca* (5.6-30.9%; Table 5-168 and Table 5-169). The mean number of taxa collected per replicate ranged from 12.58 to 16.83. Taxa richness in Regions 5 and 7 was similar. In general, fewer taxa were collected at the deeper depths. Densities of organisms was somewhat higher in Region 5 (8622 to 18,826 organisms/m^2) than in Region 7 (7184 to 11,628 organisms/m^2). Densities decreased with increasing depth. Macroinvertebrate biomass was also higher in Region 5 at the 1- and 2-m (3- and 6.5-ft) depths (51.6 and 80.5 g/m^2, respectively) than in Region 7 (12.2 and 27.4 g/m^2, respectively), but the biomass of samples from the 4-m (13-ft) depth in Region 7 was somewhat higher than that at 4 m (13 ft) in Region 5.

The composition of the L-Lake macroinvertebrate community has changed considerably since it was last sampled in the late 1980s. The relative abundance of Chironomini midges has declined substantially, while amphipods, oligochaetes, Tanytarsini midges, Turbellaria, bivalves, and the phantom midge (*Chaoborus punctipennis*) have increased in abundance. Amphipods exhibited the greatest increase in relative abundance. This shift in structure is due, at least in part, to the development of aquatic macrophyte beds in L Lake. The L-Lake macroinvertebrate community is similar to those of many other southeastern reservoirs (Specht 1996).

Table 5-167. Benthic Macroinvertebrate Biomass (g AFDW/m^2) in L Lake, 1986-1991

	Region				
Year	**4**	**5**	**6**	**7**	**8**
1986	0.768	0.907	0.764	0.755	0.749
1987	1.307	1.421	1.248	1.449	1.255
1988	1.322	4.227	2.790	3.177	2.074
1989	17.182	13.554	6.829	5.180	2.094
1990	-	16.424	-	11.520	-
1991	-	10.142	-	4.183	-

Source: Trapp 1992.
AFDW = ash-free dry weight.

Table 5-168. Summary of L-Lake Ponar Sample Data: Mean Values for Region 5 at 1-, 2-, and 4-m (3-, 6.5-, and 13-ft) Depths, September 1995

	Depth (m)		
Samples	**1**	**2**	**4**
General			
Taxa richness	24.50	21.75	20.50
Mean number/m^2	18,825.65	15,524.28	8,622.33
Number of replicates	3	3	3
Mean number taxa/replicate	16.75	13.67	13.83
Biomass (g AFDW/m^2)	51.63	80.52	10.79
Percent relative abundance of major taxa (number)			
Turbellaria	4.19	5.46	2.83
Nemertea	0.81	0.10	0.00
Nematoda	1.38	6.94	1.13
Annelida-Oligochaeta	69.70	40.27	33.67
Annelida-Hirudinea	0.45	0.22	0.78
Amphipoda	5.57	30.94	22.68
Hydracarina	0.90	0.38	0.05
Ephemeroptera	0.05	0.10	0.03
Odonata	0.73	0.17	0.07
Lepidoptera	0.03	0.00	0.00
Trichoptera	0.82	1.23	0.48
Coleoptera	0.00	0.00	0.00
Diptera-Ch. Chironomini	0.80	0.81	17.57
Diptera-Ch. Orthocladiinae	0.09	0.06	0.25
Diptera-Ch. Pseudochironomini	0.15	0.04	0.00
Diptera-Ch. Tanypodinae	1.30	0.64	1.83
Diptera-Ch. Tanytarsini	5.56	4.69	5.32
Diptera-other	0.34	1.54	10.04
Mollusca-Bivalvia	6.37	6.13	3.21
Mollusca-Gastropoda	0.74	0.26	0.05
Total	100.00	100.00	100.00
Percent relative abundance-functional feeding group (number)			
Collector-filterers	6.85	6.95	3.34
Collector-gatherers	88.63	89.03	82.32
Herbivores	0.24	0.08	0.00
Predators	3.54	3.67	14.29
Scrapers	0.74	0.26	0.05
Shredders	0.00	0.00	0.00
Total	100.00	100.00	100.00
Percent relative abundance-functional feeding group (biomass)			
Collector-filterers	87.32	97.60	90.38
Collector-gatherers	8.05	1.68	7.94
Herbivores	0.01	0.00	0.00
Predators	4.15	0.63	1.45
Scrapers	0.47	0.09	0.23
Shredders	0.00	0.00	0.00
Total	100.00	100.00	100.00

Table 5-168. (cont)

	Depth (m)		
Samples	**1**	**2**	**4**
Mean percent relative abundance of dominant taxa (>5% in one or more samples)			
Nematoda	1.38	6.94	1.13
Dugesia tigrina	3.31	4.30	2.58
Oligochaeta	69.70	40.27	33.67
Hyalella azteca	5.57	30.94	22.68
Chaoborus sp.	0.00	1.16	9.28
Cladotanytarsus sp.	4.94	4.44	4.72
Glyptotendipes paripes	0.00	0.14	14.17
Corbicula sp.	6.37	6.05	3.10

Source: Specht 1996.

Table 5-169. Summary of L-Lake Ponar Sample Data: Mean Values for Region 7 at 1-, 2-, and 4-m (3-, 6.5-, and 13-ft) Depths, September 1995

	Depth		
Samples	**1**	**2**	**4**
General			
Taxa richness	27.25	22.25	20.00
Mean number/m^2	11,627.91	7,510.54	7,184.14
Number of replicates	3	3	3
Mean number taxa/replicate	16.83	12.58	12.67
Biomass (g AFDW/m2)	12.18	27.38	16.61
Percent relative abundance of major taxa (number)			
Turbellaria	1.79	0.69	2.87
Nemertea	0.27	0.00	0.00
Nematoda	1.97	5.71	4.41
Annelida-Oligochaeta	56.70	44.69	32.77
Annelida-Hirudinea	0.30	0.46	0.52
Amphipoda	20.55	28.99	23.82
Hydracarina	0.06	0.42	0.06
Ephemeroptera	0.07	0.17	0.09
Odonata	1.57	0.38	0.14
Lepidoptera	0.00	0.00	0.00
Trichoptera	1.17	2.30	0.59
Coleoptera	0.10	0.00	0.00
Diptera-Ch. Chironomini	1.23	3.37	5.38
Diptera-Ch. Orthocladiinae	0.80	0.36	0.13
Diptera-Ch. Pseudochironomini	2.11	0.35	0.04
Diptera-Ch. Tanypodinae	2.71	0.66	1.38
Diptera-Ch. Tanytarsini	2.33	3.08	4.19
Diptera-other	0.58	0.90	18.32
Mollusca-Bivalvia	4.18	5.83	4.79
Mollusca-Gastropoda	1.52	1.63	0.51
Total	100.00	100.00	100.00

Table 5-169. (cont)

	Depth		
Samples	**1**	**2**	**4**
Percent relative abundance of functional feeding group (number)			
Collector-filterers	5.17	7.46	5.22
Collector-gatherers	89.40	87.35	73.42
Herbivores	0.20	0.58	0.04
Predators	3.72	2.98	20.81
Scrapers	1.52	1.63	0.51
Shredders	0.00	0.00	0.00
Total	100.00	100.00	100.00
Percent relative abundance of functional feeding group (biomass)			
Collector-filterers	66.18	68.10	83.19
Collector-gatherers	22.67	20.71	13.23
Herbivores	0.05	0.69	0.02
Predators	8.24	3.09	2.83
Scrapers	2.86	7.40	0.74
Shredders	0.00	0.00	0.00
Total	100.00	100.00	100.00
Mean percent relative abundance of dominant taxa (>5% in one or more samples)			
Nematoda	1.97	5.71	4.41
Dugesia tigrina	1.68	0.69	2.60
Oligochaeta	56.70	44.69	32.77
Hyalella azteca	20.55	28.99	23.82
Polycentropus sp.	1.00	1.56	0.44
Chaoborus sp.	0.06	0.05	17.76
Cladotanytarsus sp.	3.02	2.55	4.03
Glyptotendipes paripes	0.43	1.02	3.57
Corbicula sp.	2.72	4.85	3.76
Sphaerium sp.	1.46	0.97	1.02

Source: Specht 1996.

Fish

Introduction

The L-Lake fish community was sampled extensively from January 1986 to December 1989; this sampling began approximately two months after the lake was filled in November 1985. Somewhat less-extensive sampling continued from January 1990 through December 1992 and November and December 1995. Both adult and larval fish assemblages were sampled. The extensive sampling program on L Lake provided an unusually complete database documenting the development of the fish community and the relationship between the fish community and other trophic levels. Most of the following discussion is based on research reported in Paller et al. (1992).

Sampling Methods

The lower end of L Lake was divided longitudinally into five sampling regions (Regions 4-8) (Figure 5-71). Distributed throughout these regions were 20 electrofishing sample stations that were sampled from January 1986 to December 1989. The number of stations was reduced to 8 from January 1990 to December 1992. Each sample station consisted of a 100-m (330-ft) transect parallel to the shoreline following the 1-m (3.3-ft) depth contour. Electrofishing samples also were collected from artificial reefs in Regions 4-8. Electrofishing was conducted at night monthly from January 1986 to December 1990 and quarterly thereafter.

Ichthyoplankton were collected during darkness with paired 0.5-m diameter, 0.505 mm mesh plankton nets. From January 1986-December 1989, collections were made weekly during February-July and biweekly during the remaining months. During January 1990-December 1992, collections were made weekly from February-August. Temperature, dissolved oxygen concentration, pH, and conductivity were routinely measured *in situ* at the same times and locations where fish samples were collected. Paller et al. (1992) has more information on fisheries sampling methodologies.

Hydroacoustic methods were used to document the abundance of pelagic fishes. This technology was particularly useful in monitoring threadfin shad abundance. (Paller et al. 1988 has further details).

Artificial Stocking Program

L Lake was stocked with approximately 40,000 juvenile (20-30 mm [0.75-1 in]) bluegill in the fall of 1985 and approximately 4000 juvenile largemouth bass in the spring of 1986.

Physical and Chemical Conditions in L Lake

L Lake stratified during the spring and summer due to climatic factors, as is typical of most southeastern lakes and reservoirs. However, stratification occasionally occurred during the winter due to density differences between thermal reactor discharges and underlying lake waters. L Lake received thermal effluent during November 1985-June 1986, December 1986-June 1987 and January 1988-June 1988. Temperatures in excess of 40°C (104°F) occurred near the L-Reactor outfall during periods of reactor operation. However, the maximum recorded water temperature in Regions 4-8 was approximately 34°C (93°F), in June 1986. This temperature was approximately 2°C (3.6°F) higher than the maximum temperatures in southeastern reservoirs without thermal inputs. The highest recorded 24-hour mean temperature in Regions 4-8 was 32°C (90°F). While the highest temperatures occurred in June, the highest above ambient occurred during the winter and early spring when L Lake waters were elevated as much as 5°C (9°F). Littoral zone temperatures exhibited little consistent spatial variation within the study area (Regions 4-8).

When L Lake stratified, hypolimnetic waters became anoxic; however, the epilimnion remained oxygenated throughout this study. The lowest 24-hour mean dissolved oxygen concentration in the littoral and epilimnetic waters of L Lake was approximately 5 mg/l and the minimum recorded concentration was approximately 3 mg/l. None of the other 36 water-quality variables monitored in the littoral zone of L Lake reached levels detrimental to warm-water fishes.

Species that Failed to Colonize L Lake

Most of the 28 species of fish in the reach of Steel Creek that was impounded to create L Lake failed to colonize the reservoir. At least seven of the species that failed to colonize L Lake are known to prefer sites with relatively fast flowing water; they are tesselated darter (*Etheostoma olmstedi*), blackbanded darter (*Percina nigrofasciata*), Savannah darter (*Etheostoma fricksium*), bluehead chub (*Nocomis leptocephalus*), speckled madtom (*Noturus leptacanthus*), northern hogsucker (*Hypentilium nigricans*), and yellowfin shiner (*Notropis lutipinnis*) (Meffe and Sheldon 1988). Other species that did not colonize L Lake from Steel Creek may have had other types of habitat requirements that were not met in L Lake. For example, chain pickerel (*Esox niger*), redfin pickerel (*Esox americanus*), and eastern mudminnow (*Umbra pygmaea*) require aquatic vegetation for successful reproduction, and spotted sucker (*Minytrema melanops*) generally require riffle areas. Neither habitat was present in L Lake when initial colonization was occurring. None of the preceding species was collected from L Lake in more than trace numbers; they may have avoided L Lake because of unsuitable habitat or entered L Lake but failed to successfully reproduce. Therefore, the first stage of colonization was controlled by the habitat requirements of the species that occupied Steel Creek prior to impoundment.

Successful Early Colonists of L Lake

Early Colonists

Only eight species of fish found in Steel Creek before it was impounded entered L Lake in substantial numbers: mosquitofish (*Gambusia affinis*), brook silversides (*Labidesthes sicculus*), coastal shiner (*Notropis petersoni*), golden shiner (*Notemigonus chrysoleucas*), creek chubsucker (*Erimyzon oblongus*) dollar sunfish (*Lepomis marginatus*), redbreast sunfish and spotted sunfish (*Lepomis punctatus*) (Table 5-170). These eight species can be divided into three groups: those that did not reproduce in L Lake, those that reproduced but did not persist, and those that persisted.

Table 5-170. Electrofishing Catch Rates Over Time in L Lake. Only Dominant Taxa and Catch Rates ≥ 0.1 Fish/Minute are Shown

	1986						1987						1988						
Species	**Jan Feb**	**Mar Apr**	**May Jun**	**Jul Aug**	**Sept Oct**	**Nov Dec**	**Jan Feb**	**Mar Apr**	**May Jun**	**Jul Aug**	**Sept Oct**	**Nov Dec**	**Jan Feb**	**Mar Apr**	**May Jun**	**Jul Aug**	**Sept Oct**	**Nov Dec**	**Number fish**
mosquitofish	2.0	0.1	0.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	922
creek chubsucker	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	68
brook silversides	0.3	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	158
coastal shiner	1.5	1.0	1.2	0.5	0.6	0.2	0.3	-	-	-	-	-	-	-	-	-	-	-	1,905
golden shiner	0.9	0.3	1.0	0.2	0.1	0.2	0.2	0.1	-	-	-	-	-	-	-	-	-	-	1,025
dollar sunfish	0.3	0.3	0.2	0.2	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	456
spotted sunfish	0.6	0.2	0.5	0.3	0.3	0.1	0.5	0.1	0.1	0.1	0.1	0.1	0.1	-	-	-	-	-	926
redbreast sunfish	3.4	0.8	1.7	4.9	8.9	6.8	3.9	4.5	7.3	7.0	7.1	7.1	6.0	7.0	5.8	4.2	5.6	5.3	26,737
bluegill	0.1	-	0.1	32.2	52.0	44.7	23.4	11.2	22.7	14.7	12.0	19.8	16.9	11.0	6.6	5.6	8.3	13.1	79,105
largemouth bass	-	-	0.3	0.5	0.6	1.1	0.5	0.9	0.9	1.1	1.5	1.2	0.9	0.8	0.6	0.8	0.9	0.8	3,512
warmouth	-	-	-	-	-	-	-	-	0.1	0.1	0.1	0.1	-	0.1	0.1	0.1	0.1	0.2	274
flat bullhead	-	-	-	-	-	0.1	0.1	0.1	-	-	0.1	0.1	0.1	0.4	-	0.1	0.1	0.1	283
gizzard shad	-	-	-	-	-	-	-	-	-	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.2	0.1	377
threadfin shad	-	-	-	-	-	-	-	-	0.1	0.4	9.8	2.4	0.4	1.5	4.7	13.5	13.5	3.7	13,399

Source: Paller et al. 1992.

Species that Did Not Reproduce in L Lake

The creek chubsucker and brook silversides, although collected from L Lake as adults, probably did not reproduce based on an inability to collect larvae or juveniles of either species. These species quickly decreased in abundance after L Lake was filled and were virtually absent from the electrofishing catches by March 1986 and May 1986, respectively (Table 5-170).

Species that Reproduced but Did Not Persist in L Lake

Mosquitofish, golden shiner, coastal shiner, dollar sunfish, and spotted sunfish were able to reproduce but did not persist in L Lake or declined over time to low numbers (Table 5-170). Large schools of mosquitofish were observed swimming along the shoreline of L Lake as it was filling in late 1985. Electrofishing catches for this species were relatively high in January 1986 but decreased in February and March (Figure 5-89). Catch rates again increased in April and May 1986 as fish that were spawned in the spring (Figure 5-90) were recruited into the population. In June, however, numbers of mosquitofish declined precipitously, leading to the disappearance of this species from L Lake by late 1986.

Coastal shiner and golden shiner were comparatively abundant in L Lake during January through May 1986 (Table 5-170, Figure 5-89) and successfully reproduced during this period as indicated by the collection of larvae (Figure 5-90). Larvae could not have drifted into L Lake from Steel Creek because Regions 4-8 of L Lake were separated from Steel Creek by a thermal barrier (>40°C [104°F]) created by the discharge of reactor effluent at the upper end of L Lake. Despite their ability to reproduce, numbers of coastal shiners and golden shiners decreased sharply after May 1986, and both species disappeared from L Lake by mid-1987.

Dollar sunfish and spotted sunfish were relatively abundant during early 1986 but subsequently decreased in abundance (Table 5-170, Figure 5-89). Dollar sunfish persisted until mid-1987, and spotted sunfish persisted in small numbers through the end of the study. Spotted sunfish and dollar sunfish were able to reproduce in L Lake, as indicated by the collection of relatively small individuals (under 80 mm [3 in]) after June 1986. (Juveniles collected prior to this may have been spawned in Steel Creek while L Lake was filling.)

Species that Persisted in L Lake

Of the eight species that initially dominated the L Lake fish community, only redbreast sunfish increased in number. Unlike the aforementioned species, redbreast sunfish were recruited in large numbers in the summer of 1986, causing the electrofishing catch rate for this species to double or triple from spring levels (Table 5-170, Figure 5-91). Recruitment also was observed in 1987 and 1988. By 1988, this species had stable population with substantial numbers of individuals of all sizes from juvenile through adult.

Decline of the Early Colonists

Five species of fish established reproducing populations and initially dominated the L Lake fish community, but later declined as related above. It is unlikely that this decline was caused by harsh abiotic conditions because critical water-quality variables, including dissolved oxygen concentration and temperature, did not reach levels in the littoral or epilimnetic portions of Regions 4-8 that were likely to be lethal to the early colonists.

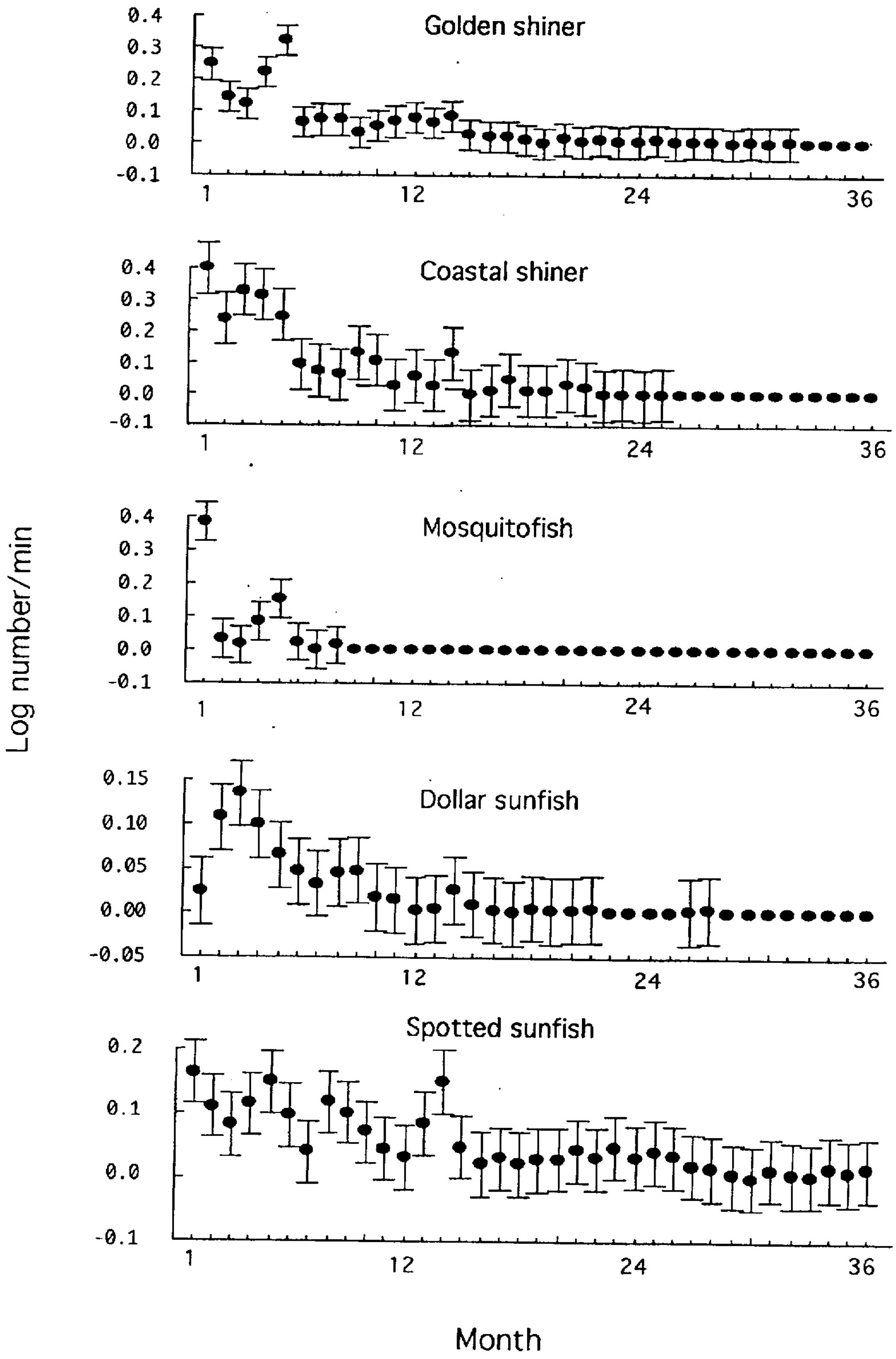

Figure 5-89. Mean Electrofishing Catch Rates (Logarithmically Transformed) of Five Species of Fish that Colonized L Lake but then Declined, January 1986-December 1988 (Source: Paller et al. 1992)

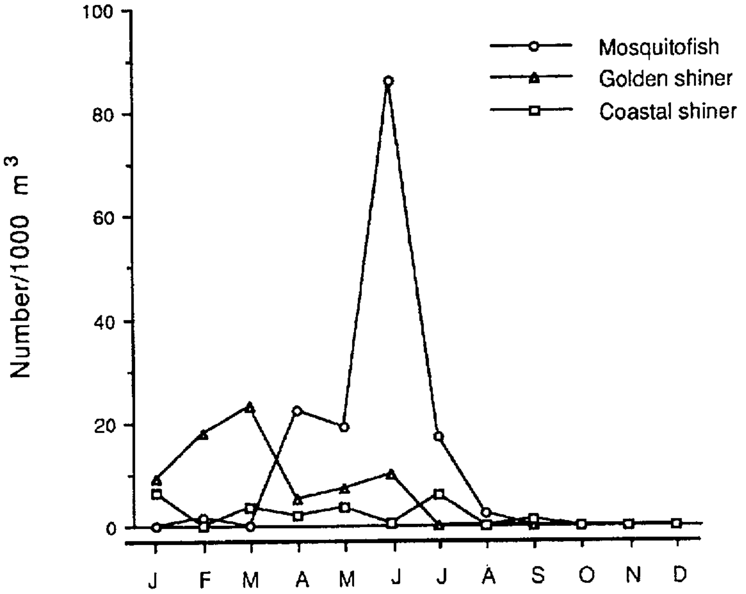

Figure 5-90. Mean Larval Fish Densities (no./1000 m^3) in Regions 4-8 of L Lake during 1986 as Indicated by Plankton Net Tows (Source: Paller et al. 1992)

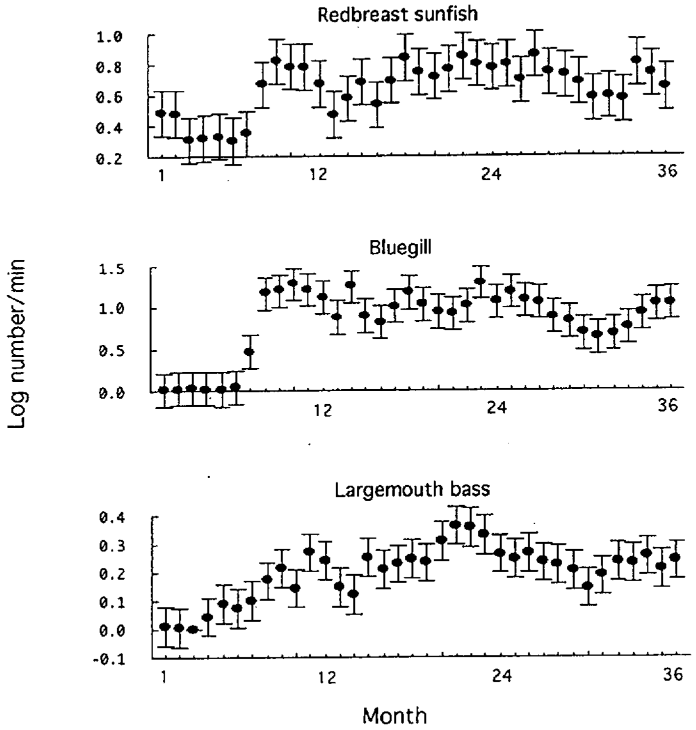

Figure 5-91. Mean Electrofishing Catch Rates (Logarithmically Transformed) of Three Species of Fish that Persisted After Entering L Lake, January 1986-December 1988 (Source: Paller et al. 1992)

The decline of most of the species that initially colonized L Lake coincided with the establishment and increase in numbers of other species of fish. Catch per unit effort of largemouth bass increased substantially beginning in April 1986 as fish stocked earlier in the spring and those spawned in L Lake early in 1986 grew to catchable size (Table 5-170; Figure 5-91). This increase in largemouth bass abundance began just before the abrupt decline of several of the initial colonists, and the monthly average electrofishing catch rate of largemouth bass was inversely correlated with the monthly average catch rates of the early colonists that later declined (i.e., dollar sunfish, spotted sunfish, coastal shiner, mosquitofish, and golden shiner summed) (Pearson $r=-0.78$, $P\leq0.05$).

Bluegill catch per unit effort increased greatly in August 1986 due to the recruitment of large numbers of juvenile fish (Figure 5-91). The juvenile bluegill collected during the summer of 1986 were the progeny of fish stocked in L Lake in November 1985 and of the small numbers of bluegill that may have been present before stocking. Other species that became established in L Lake during 1987 and 1988 were threadfin shad (*Dorosoma petenense*), gizzard shad (*Dorosoma cepedianum*), warmouth (*Lepomis gulosus*), and flat bullhead (*Ameiurus platycephalus*) (Table 5-170). Larvae of some of these fish may have been transported to L Lake in unheated water pumped to the reservoir from the Savannah River during summer reactor outages.

By 1988, the initial fish fauna of Regions 4-8 of L Lake, with the exception of redbreast sunfish, had been replaced by later arriving species (Table 5-170). The only events that closely coincided with the decline of the unsuccessful early colonists were relatively sudden increases in the size of largemouth bass, bluegill, and redbreast sunfish populations. This concurrence of events, coupled with an absence of negative changes in the abiotic environment, indicates that interactions between the early colonists and the rapidly expanding species were responsible for the community changes observed during 1986.

Fish Assemblages Upstream from Regions 4-8

High temperatures (>40°C [104°F]) precluded the survival of fish above Regions 4-8 during periods of reactor operation. However, during the extended summer reactor outages, which lasted approximately six months, temperatures decreased to ambient levels, permitting fish from Regions 4-8 to invade the upper portion of L Lake. When L Reactor was restarted in the fall, large numbers of these fish were killed by elevated temperatures (Paller et al. 1988). There was no indication, however, that these fish kills affected community structures in the lower portion (Regions 4-8) of L Lake.

Recent Status of the L-Lake Fish Community

Largemouth bass, bluegill, redbreast sunfish, and threadfin shad dominated the L-Lake fish community between 1987 and sometime after 1992. The most important trends in the fish community in recent years involve changes in the abundances of these species and interactions between the dominant fish species and lower trophic levels, particularly zooplankton. The latter have been documented by Taylor et al. (1993), who described zooplankton succession in L Lake during the three years following impoundment. During 1986 and 1987, larger macrozooplankton dominated the zooplankton assemblage. However, during 1988, *Bosmina longirostris*, the smallest of the cladocerans, was the most abundant macrozooplankton, and loricate rotifers dominated the zooplankton assemblage. Size-selective predation by threadfin shad was implicated in this shift in community structure.

Several of the dominant fish taxa in L Lake have declined in abundance from previous levels. After reaching peak population densities in 1988, threadfin shad densities have declined to low levels (Figure 5-92). Threadfin shad were not collected in 1995. Bluegill and redbreast sunfish numbers also have declined from earlier levels (Figure 5-92). Decreases in bluegill and redbreast sunfish numbers were associated with changes in condition (a measure of weight in relation to length) and size distribution (Sayers and Mealing 1992). There are several possible reasons for these changes, including predatory and competitive interactions and changes in the primary productivity of L Lake.

In 1995, brook silversides (*Labidesthes sicculus*) and coastal shiner (*Notropis petersoni*), which were rare in the reservoir after summer of 1986, were again common. Yellow perch (*Perca flavescens*) and chain pickerel (*Esox niger*), which had never before been common, were numerically important members of the fish assemblage, and threadfin shad (*Dorosoma petenense*), which were very common between 1987 and 1989, were absent (Paller 1996).

It is probable that these changes in the L-Lake fish community are largely the result of predation and competition among species with the outcome of these processes strongly influenced by the changing physical and chemical environment in L Lake. The most important of these changes appears to have been the proliferation of aquatic vegetation in L Lake. Also, cessation of reactor operations reduced nutrient loading from Savannah River water input to the reservoir and the maintenance of ambient water temperatures throughout the reservoir throughout the year.

Currently, the L-Lake fish community includes at least 19 species with the most abundant being brook silversides, yellow perch, bluegill, redbreast sunfish, coastal shiner, largemouth bass, chain pickerel, and spotted sunfish. These species are generally common in southeastern reservoirs with abundant aquatic vegetation. Most or all of these species appear to have successfully reproducing and self-sustaining populations in L Lake (Paller 1996).

Contaminant Levels in L-Lake Fish

The geometric mean total mercury concentration in L-Lake largemouth bass (whole fish) collected in 1995 was 351 μg/kg of body weight. Total mercury concentrations increased significantly with fish size, reflecting bioaccumulation in older fish. The geometric mean total mercury concentration in bluegill and redbreast sunfish from L Lake in 1995 averaged 70 and 76 μg/kg, respectively. Mercury contamination is common in fish taken from SRS water bodies that receive or received input from the Savannah River. The mercury concentrations in largemouth bass from L Lake are similar to those found in largemouth bass collected from the Savannah River (1992-1994 mean of 557 μg/kg).

The geometric mean cesium-137 concentration in L-Lake largemouth bass (whole fish) was 0.62 pCi/g. Body burdens were not significantly related to fish size. Geometric mean concentrations in bluegill and redbreast sunfish were 0.16 pCi/g and 0.18 pCi/g, respectively (Paller 1996).

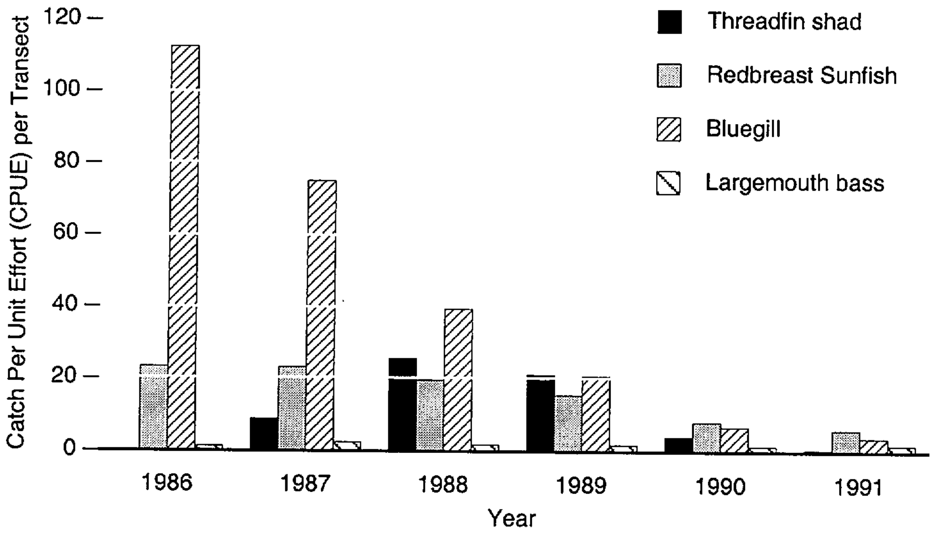

Figure 5-92. Mean Annual Catch Per Unit Effort from Electrofishing Transects in L Lake, 1986-1991

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