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BIOLOGICAL MONITORING OF UPPER THREE RUNS CREEK, SAVANNAH RIVER PLANT, AIKEN COUNTY, SOUTH CAROLINA. FINAL REPORT ON MACROINVERTEBRATE STREAM ASSESSMENTS FOR F/H AREA ETF EFFLUENT DISCHARGE, JULY 1987 - FEBRUARY 1990 (U)

by

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Westinghouse Savannah River Company
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Aiken, South Carolina 29808

This is a Technical Report proposed for approval

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D. B. Moore-Shedrow, Section Manager
Authorized Derivative Classifier

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Publication Date: October 1991

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SAVANNAH RIVER SITE
AIKEN, SC 29808

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ENWRIGHT
ENVIRONMENTAL

BIOLOGICAL MONITORING OF UPPER THREE RUNS CREEK,

SAVANNAH RIVER PLANT, AIKEN COUNTY, SOUTH CAROLINA

FINAL REPORT ON

MACROINVERTEBRATE STREAM ASSESSMENTS FOR
F/H AREA ETF EFFLUENT DISCHARGE

JULY 1987 - FEBRUARY 1990

REPORT TO: WESTINGHOUSE SAVANNAH RIVER COMPANY,
AIKEN COUNTY, SOUTH CAROLINA

REPORT DATE: MARCH 1990

E2CL

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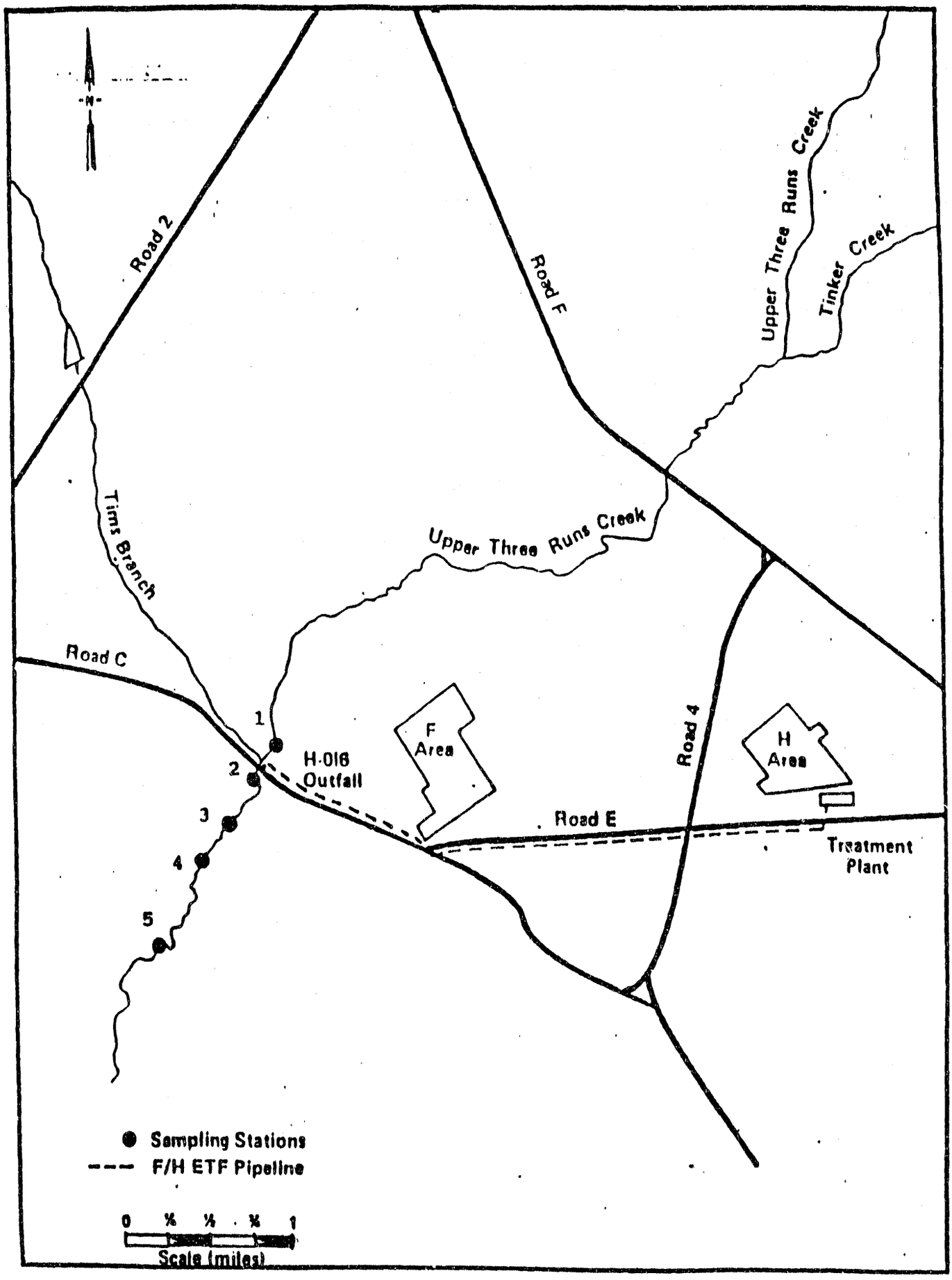
I. Introduction

In anticipation of the fall 1988 start up of effluent discharges into Upper Three Runs Creek by the F/H Area Effluent Treatment Facility of the Savannah River Site, Aiken, SC, a two and one half year biological study was initiated in June 1987. Upper Three Runs Creek is an intensively studied fourth order stream known for its high species richness. Designed to assess the potential impact of F/H area effluent on the creek, the study includes qualitative and quantitative macroinvertebrate stream surveys at five sites (see map), chronic toxicity testing of the effluent, water chemistry and bioaccumulation analysis.

This final report presents the results of both pre-operational and post-operational qualitative and quantitative (artificial substrate) macroinvertebrate studies. Six quantitative and three qualitative studies were conducted prior to the initial release of the F/H ETF effluent and five quantitative and two qualitative studies were conducted post-operationally.

Five sites were sampled, including one site upstream of the Road C bridge (near the Aquatic Ecology Laboratory) and four sites downstream of the Road C bridge. The discharge point, for the H-016 effluent release beginning October 22, 1988, is at Road C.

Map of Sampling Sites - Quantitative Macroinvertebrate Sampling of Upper Three Runs Creek, Savannah River Plant, Aiken County, South Carolina. July 1987 - April 1989.



II. Methods

A. Sampling

1. Multiplate Samplers/Quantitative

Five replicate multiplate samplers were set in the stream at each site on a quarterly schedule as follows:

Samplers Set	Samplers Retrieved	# Days Exposure
June 10, 1987	July 8, 1987	28
Sept 16, 1987	Oct 16, 1987	30
Jan 28, 1988	Feb 26, 1988	29
Mar 29, 1988	Apr 26, 1988	28
June 7, 1988	July 8, 1988	31
September 7, 1988	October 5, 1988	28
December 6, 1988	January 4, 1989	29
March 15, 1989	April 11, 1989	27
June 19, 1989	July 18, 1989	29
September 28, 1989	October 24, 1989	26
December 27, 1989	January 29, 1990	35

Each sampler was comprised of 14 circular plates with a diameter of 7.5 cm and thickness of 0.3 cm (area: 0.12 M^2). The plates were made of masonite board and were separated by masonite board spacers. A metal bolt through the plates and spacers held each assembly together.

Samplers were suspended in the water by rope from floats; each sampler being approximately 25 cm below the water surface. Proceeding from left to right when facing up stream replicates A through E were placed at equal spacing across the stream. Similar flow regimes were selected in determining exact site location.

Samplers were retrieved by swiftly lifting each sampler from the water, placing it in a labelled zip-lock type plastic bag and cutting the support rope. Approximately 500 ml of stream water was placed in each bag as well as a site and replicate label. Bags with samplers were placed in a cooler with ice to chill the samples until processing in the laboratory.

2. Qualitative Sampling

Qualitative sampling was conducted on a semi-annual basis, on the following dates: November 25, 1987, March 29, 1988, October 4, 1988, March 15, 1989 and October 24, 1989. Three samples of 500 cm^3 were collected at each site including a) snag/vascular plant habitat, b) sand habitat c) detritus/mud/leaf pack habitat. Samples were collected with the use of an aquatic dip net (used for sweeping, bottom sampling, and as a kick net), a U.S. Standard #30 brass sieve, a white collecting pan and hand collecting of various substrates such as moss, bark, and stick/log scrapings. Approximateley 15 minutes of sampling effort was expended at each site. Each sample was placed in a 500 ml plastic labelled container, with 80% ethanol for a fixative. A storm event preceeding October 4, 1988 sampling made access to the streambed and snag habitats difficult due to high water levels.

3. Field Chemical Parameters

At each site measurements were taken of dissolved oxygen (ppm), pH and temperature (C). Dissolved oxygen was measured with a YSI Model 54ARC D.O. meter with a YSI Model A77003 probe. The meter was recalibrated according to the elevation scale/calibration knob and temperature at each site. A Fisher Model 607 pH meter with a probe was used to measure pH. The meter was calibrated, using pH 7 standard buffer solution, at each site.

Temperature readings were made with a Fisher brand mercury thermometer with 1°C gradations. Conductivity was analyzed using a YSI Salinity-Conductivity-Temperature meter (Model 33). All readings were made 2-6" below the water surface and recorded in a bound field record book.

4. Water Chemistry Analysis

Samples for chemical analysis were taken at each site as grab samples just below the water surface. Containers and sample volumes are listed below:

Sampler Container	Volume	Parameters	Preservative
Glass, amber	250 ml	Res Cl	none
Plastic	1/2 gallon	cond, TSS, Hard, Alk, NO2	none
Plastic	250 ml	O-PO4	none
Glass, amber	250 ml	Sediment Hg	W/HNO3
Plastic	500 ml	Metals	W/HNO3
Plastic	500 ml	Dis. Metals	none
Plastic	1/2 gallon	NO3, NH3, T-PO4	W/HNO3
Glass, amber	1 liter	Kerosene, TBP	none

After collection, samples were placed in coolers, chilled with ice and returned to the laboratory.

5. Sediment Analysis

Grab samples of mud/sand were placed in 200 ml glass amber bottles at each site. Samples were collected from sediment in erosional stream zones. Each sample bottle was labelled, chilled with ice and returned to the laboratory.

B. Sample Processing

1. Multiplate Samplers/Quantitative

Each sampler and the contents of the sampler bag were placed in a white collecting pan. Samplers were disassembled and each plate and spacer was scraped/brushed to remove all organisms. Subsequently the contents of each collecting pan were rinsed in a U.S. Standard #30 sieve (to remove sediment) and placed back in the pan. All organisms in the pan were then placed in labelled vials of 80% ethanol preservative, using an illuminated magnifier to facilitate sorting.

2. Qualitative Sampling

Sorting qualitative samples involved processing each sample container in approximately five 100 cm^3 portions until each container was completed. Each portion was placed in a U.S. Standard #30 sieve, rinsed with tap water and transferred to a white collecting pan. Macroinvertebrates were removed from the pan with the aid of an illuminated magnifier and placed in

C. Water Chemistry Analysis

Chemical analyses were conducted according to the procedures in "Methods for Chemical Analysis of Water and Wastes" (EPA 600 4/79-020) and are referenced, along with detection limits and preservatives, as follows:

Parameter	EPA Method #	Detection Limit	Preservative
pH	150.1	0.1 Units	On-Site Analysis
Dissolved Oxygen	360.1	0.1 mg/l	On-Site Analysis
Temperature	170.1	1°C	On-Site Analysis
Specific Conductance	120.1	10 umhos/cm	None
Total Hardness	130.2	1 mg/l	None
Alkalinity	310.1	1 mg/l	None
Total Suspended Solids	160.2	1 mg/l	None
Total Residual Chlorine	330.1	0.1 mg/l	None
Nitrate (As N)	352.1	0.1 mg/l	H_2SO_4 to pH <2.0
Nitrite (As N)	354.1	0.02 mg/l	None
Ammonia (As N)	350.3	0.01 mg/l	H_2SO_4 to pH <2.0
Total Phosphorus (As P)	365.2	0.01 mg/l	H_2SO_4 to pH <2.0
(Ortho Phosphate (As P)	365.2	0.01 mg/l	Filter on Site
Chromium	218.2	0.005 mg/l	HNO_3 to pH <2.0
Copper	220.2	0.005 mg/l	HNO_3 to pH <2.0
Lead (Furnace)	234.2	0.005 mg/l	HNO_3 to pH <2.0
Manganese	234.2	0.005 mg/l	HNO_3 to pH <2.0
Mercury (water)	245.1	0.005 mg/l	HNO_3 to pH <2.0
Mercury (sediment)	245.3	50 ug/kg	HNO_3 to pH <2.0
Sodium	273.1	0.002 mg/l	HNO_3 to pH <2.0
Uranium	711 B	0.001 mg/l	HNO_3 to pH <2.0
Zinc	289.1	0.005 mg/l	HNO_3 to pH <2.0
* Kerosene	SPE/GC	0.1 mg/l	Qt. Amber Glass with Teflon Lined Lid
* Tributyl Phosphate	SPE/GC	0.05 mg/l	Qt. Amber Glass with Teflon Lined Lid
Tritium	Liquid Scintillation	MCI/L	None

* Solid Phase Extraction GC Analysis Method as Provided by DuPont SRP.

D. Macroinvertebrate Identification

Each vial of sorted organisms was emptied into a glass petri dish (3" diameter) with 80% ethanol and examined under a WILD M3 stereomicroscope at 16x magnification. Organisms were initially separated by order for most taxa and family for true flies (Diptera). After species identification, organisms collected by multiplate were returned to the labelled vials for biomass determination, except for voucher specimens. One to three organisms of each species collected in the survey were placed in the Enwright Laboratories reference collection, as voucher specimens. Some midges, black flies and annelids were mounted on slides with CMC-10, and examined with a WILD M20 compound microscope (400X Power). A list of references used for identification is given below:

Taxon	References
Annelida	
Polychaeta	Klemm, 1985
Hirudinea	Klemm, 1985
Oligochaeta	Klemm, 1985
Gastropoda	Thompson, 1984
	Pennak, 1978
Pelecypoda	Pennak, 1978
Cladocera, Copepoda, Ostracoda	Pennak, 1978
	Fitzpatrick, 1983
Isopoda	Williams (EPA), 1972
	Fitzpatrick, 1983
Amphipoda	Holsinger (EPA) 1972
	Fitzpatrick, 1983
Decapoda	Fitzpatrick, 1983
Hydracarina	Pennak, 1978
Collembola	Merritt & Cummins, 1984
Ephemeroptera	Berner & Pescador, 1988
	Brigham et al, 1982
	Needham, Taver, Hsu 1935
	Lewis, 1974 (EPA670/4-74-6)
	Morihara & McCafferty, 1979

Taxon	Reference
Odonata	Brigham et al, 1982
	Merritt & Cummins, 1984
	Needham & Westfall, 1955
Plecoptera	Brigham et al, 1982
	Merritt & Cummins, 1984
	Claasen, 1931
Hemiptera	Brigham et al, 1982
	Merritt & Cummins, 1984
Megaloptera, Neuroptera	Brigham et al, 1982
Lepidoptera	Brigham et al, 1982
	Ross, 1944
	Schefter & Wiggins 1986
	Wiggins, 1977
	Merritt & Cummins, 1984
Coleoptera	Brigham et al, 1982
	Merritt & Cummins 1984
	Usinger, 1959
Diptera	McAlpine et al, 1981
	Johannsen, 1934-37
	Brigham et al, 1982
	Merritt & Cummins, 1984
Simuliidae	Snoddy & Noblet, 1976
Chironomidae	Wiederholm, 1983
	Wiederholm, 1986
	Brigham et al, 1982
	Merritt & Cummins, 1984
	Oliver & Roussel, 1983
Ablabesmyia	Roback, 1981
Conchapelopia, Meropelopia	Roback, 1981
Rheopelopia, Thienemannimyia	Roback, 1981
Brillia	Oliver & Roussel, 1986
Parachaetocladius, Doithrix	Saether & Sublette 1983
Eukiefferiella, Tvetenia	Bode, 1983
Nanocladius	Saether, 1977
Nilotanypus	Roback, 1985
Pseudorthocladius	Saether & Sublette 1983
Unniella	Caldwell, 1986
Rheocricotopus	Saether, 1985
Orthocladius	Soponis, 1977
Dicrotendipes	Epler, 1987
Tribelos, Phaenopsectra	Grodhaus, 1987

E. <u>Biomass (AFDW)</u>

After macroinvertebrate species identification, organisms were separated by functional group for each site and placed in labelled vials. All five replicates per site were combined. As some midges were placed on microscope slides, they were initially excluded from biomass processing. Each sample for each functional group at each site was dried, at 105°C, weighed and subsequently placed in a weighed crucible at 550°C for ashing (30 minutes in thermolyne furnace). This was followed by 30 minutes in the dessicator for equlibration to room temperature. Subsequently the crucibles were re-weighed, the initial dry weight subtracted and the ash-free dry weights calculated. An enumerated sample of midges (all subfamilies combined) was separately ashed and weighed to calculate an average "midge weight". This factor was multiplied by the number of midges for each functional group and the biomass corrected accordingly. Weight determinations were made with a Mettler AE200 electronic balance reading to four places (0.0001g).

F. Data Analysis

A number of methods to evaluate the data obtained in qualitative and quantitative macroinvertebrate assessments have been developed. Several approaches to analyzing the data are used in this report. These approaches concern the richness, density, evenness, pollution tolerance, % composition by major taxonomic group, biomass, functional group analysis, dominant species and community structure.

Community richness is the total number of species collected at a site. Pollution by an effluent discharge generally reduces the number of species (Weber, 1973). A mean density of organisms is calculated per M^2. When depressed, the mean density can reflect the effects of toxic pollutants (Weber, 1973). When elevated, it can suggest nutrient enrichment (Weber, 1973).

Community evenness is based upon the concept that a stream unaffected by pollution will support many species of macroinvertebrates, each represented by a few organisms, whereas a stream impacted by organic pollution will have only a few tolerant species with large numbers of organisms (Weber, 1973). Organisms intolerant to such organic pollution are killed or drift downstream to a more tolerable habitat. With toxic wastes, a similar phenomenon occurs, except that the reduction in the numbers of intolerant species occurs with a decrease in the species population (Weber, 1973). Two indices involving evenness are used; diversity and equitability. Both are computed using the Shannon-Weaver function and the Margalef measure, as described by the U.S. EPA (1973). Species diversity is an index taking into account the number of species and the distribution of individual organisms within a sampled segment of waterway. In severely polluted water, diversity usually is less than one (Weber, 1973). In unpolluted water, it is higher and may attain three or four. The higher the diversity the less stressful the aquatic environment to the organisms contained therein (Weber, 1973).

consideration with an idealized community. Such a community is found in unpolluted habitats where many species are present, few are relatively abundant in individuals, and several are represented within the community by only a few individuals. Equitability has been found to be a more sensitive test of environmental stress than diversity (Weber, 1973). Levels above 0.5 are indicative of good water quality (Weber, 1973). Although these evenness indices are designed primarily for use with quantitative studies, they can also be useful in analyzing qualitative data.

Community pollution tolerance evaluates the macroinvertebrate community based upon the concept that certain taxa of aquatic organisms are considered to be more pollution intolerant than others. Such taxa include most species of mayflies, caddisflies and stoneflies, as well as, certain species of beetles (e.g., some elmids), midges (e.g., Pottastia) and Megaloptera (Hilsenhoff, 1987). Other taxa are more tolerant of pollution, including dragonfly nymphs, true bugs and fly larvae (including many species of midges) (Hilsenhoff, 1987). Two ways of measuring pollution tolerance are provided here; the biotic index and EPT index. A biotic index gives an indication of the average pollution tolerance of organisms present at a stream site. Each species is given a tolerance rating between 0 and 10, with 0 indicating a very intolerant organism and 10 an organism with high tolerance of pollution. The biotic index used here was produced by Hilsenhoff (1987) and designed for northern streams. It has been modified slightly for several midge species to account for known tolerances in this region. The EPT index is simply the total number of species at a site which are in the pollution intolerant orders Ephemeroptera (mayflies), Plecoptera (stoneflies) or Trichoptera (caddisflies).

Functional Group Analysis involves classifying each species by feeding strategy, calculating the percentage by total number of organisms and by biomass in each group and comparing those percentages between sites. Species are assigned to a functional group based upon information by Merritt & Cummins (1984).

Functional groups include shredders (herbivores and detritivores), scrapers, predators, piercer-herbivores and collectors (filterers and gatherers). In as much as piercer-herbivors never comprised $\geq$ 1% of the total number or biomass of organisms at any site/date combination, this category is ignored in discussion of functional groups. A shift in the proportions of the functional groups between sites may reflect the presence of a pollution source or changes in the trophic structure of the ecosystem. It must however, be carefully analyzed as a difference in habitat can also produce a shift.

Dominant species in common is a comparison of the ten most commonly collected organisms between data sets to determine how many of the same species are found in common.

Results of each method of data analysis are discussed separately, then summarized. As might be expected for this type of data, none of the data sets proved to be normally distributed. A square root transformation of the data (y + 1/2) failed to achieve normality. Therefore all data was analyzed by non-parametric methods for paired data, using a significance level of p=0.05. Comparisons of means of pre-operational data to post-operational data were accomplished using Wilcoxon's Signed Rank Test (Gilbert, 1987) to compare the corresponding seasons of 1987 - 1989. Data were also analyzed by combining post-operational data for each site and comparing sites using Friedman's Test (Gilbert, 1987). For the percent composition by major taxonomic group and functional group analysis, each group was separately subjected to Wilcoxon's Signed Rank Test and Friedman's Test. Pre-operational mean values were calculated to include all data through October 1988. Data after October 1988 were considered post-operational. Results of statistical analyses are provided in Appendix E.

* Most indices were compared using the pre-operational and post-operational mean at each site. Functional Group Analysis and percent composition by major taxonomic group were compared.

III. Results

A. Species Richness (Figure III A; Tables III Ai, III Aii)

A total of 247 species of aquatic macroinvertebrates have been collected during biological monitoring of Upper Three Runs Creek at the five study sites. This total represents eleven quantitative (multiplate artificial substrate) sampling periods and five qualitative sampling periods. Quantitative sampling has yielded 179 species, or 72% of the total. 68 species (28%) were collected only by qualitative sampling. Comparison of pre-operational quantitative data with post operational quantitative data showed a substantial reduction in the mean number of species collected per sampling period (for all sites) from 42.5 to 33.9. Analysis of the data by Wilcoxin's Signed Rank Test (Appendix E) indicated that the difference in the means was significant ($p=0.05$) This trend toward lower species was noted in all seasons. In both 1988 and 1989 species richness reached maximum in the spring (April).

With the exception of site 2, a slight decrease in species richness was noted at downstream sites, as compared with site 1. Analysis of the data by Friedman's Test indicated the difference among sites was not significant. Qualitative sampling yielded a total of 201 species pre-operationally and 167 species post-operationally Analysis of the qualitative data by Wilcoxon's Signed Rank Test showed no significant difference between the mean number of species collected per site pre-operationally (60.0) and post-operationally (56.0). Nevertheless, the same trend of decreased richness post-operationally for quantitative data did appear to be present for qualitative data.

The average number of species collected per replicate (all sites) exhibited the same pattern as the species richness data, when comparing pre-operational and post-operational collecting periods.

During pre-operational collection periods a mean of 20.5 species per replicate were collected. Post-operational sampling yielded 15.4 species per replicate. Analysis by Wilcoxon's Signed Rank Test (Appendix E) indicated the mean number of species per replicate did decrease significantly ($p=0.05$) during the post-operational sampling periods. The mean number of species per replicate ranged from a low of 8.6 at site 5 in July 1989 to a maximum of 29.8 at site 4 in April 1988. Analysis of the data by Friedman's Test indicates that differences in the mean number of species collected per site during post-operational sampling were not significant ($p=0.05$).

A change in the species richness of the macroinvertebrate community of Upper Three Runs Creek did appear to take place post-operationally. This reduction in species richness was noted at all sites including the control site (1). The trend toward lower species richness began with the July 1988 quarter, during which there was a 15% reduction in the mean value for all sites as compared to July 1987. As the trend was noted even at the control site, it does not appear attributed to the discharge of F/H ETF effluent into the creek.

TABLE III A1

Species Richness
Quantitative and Qualitative Sampling
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Pre-Operational Data

QUANTITATIVE SAMPLING (5 Replicate Multiplate Artificial Substrate Samplers)
(All Replicates Combined)

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Total	Mean	Std.Dev.
Jun - Jul 87	36	15	56	50	47	74	16.8	7.3
Sep - Oct 87	39	13	31	31	37	67	36.8	1.6
Jan - Feb 88	35	51	45	52	45	80	45.6	6.8
Mar - Apr 88	57	57	56	48	53	89	54.2	3.8
Jun - Jul 88	37	38	36	46	43	71	10.0	4.3
Sep - Oct 88	29	31	36	32	27	61	31.6	3.6
Total (Pre-operational)**	86	100	105	95	95	146	96.2	7.0
Mean	38.8	44.7	43.8	43.2	42.0	74.2	42.5	
Std. Dev. (Pre-Operational)*	9.2	7.1	10.5	8.4	5.8	8.2	7.9	
Mean	35.2	36.2	33.6	31.6	32.8	60.2	33.9	
Std. Dev. (Post-Operational)**	3.6	10.4	7.3	6.7	9.0	9.0	7.3	

QUALITATIVE SAMPLING

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Total
November 1987	40	71	66	65	67	139
March 1988	79	76	59	96	63	168
October 1988	45	55	41	45	34	106
Mean	55	67	55	69	55	138
Total	114	132	112	125	101	201

TABLE III A1

Species Richness
Quantitative and Qualitative Sampling
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Post-Operational Data

QUANTITATIVE SAMPLING (5 Replicate Multiplate Artificial Substrate Samplers)
(All Replicates Combined)

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Total	Mean	Std.Dev.
Dec 88 - Jan 89	39	37	38	37	38	65	37.8	0.8
Mar - Apr 89	38	54	14	40	15	73	11.2	6.2
Jun - Jul 89	34	31	29	24	22	55	28.0	4.9
Sep - Oct 89	30	29	26	30	27	58	28.4	1.8
Dec 89 - Jan 90	35	30	31	27	32	50	31.0	2.9
Total (Post-operational)**	52	66	58	56	58	97	58.0	5.1
Mean	35.2	36.2	33.6	31.6	32.8	60.2	33.9	
Std. Dev. (Post-operational)**	3.6	10.4	7.3	6.7	9.0	9.0	7.3	
Mean	38.8	44.7	43.8	43.2	42.0	74.2	42.5	
Std. Dev. (Pre-Operational)*	9.2	7.4	10.5	8.4	5.8	8.2	7.9	

QUALITATIVE SAMPLING

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Total
March 1989	78	81	80	83	73	146
October 1989	30	27	32	39	37	71
Mean	51	51	56	61	55	109
Total	95	90	97	95	96	167

*Includes all sampling periods up to and including October 1988.
**Includes all sampling periods after October 1988.

FIGURE III Ai: Species Richness, Quantitative Macroinvertebrate Sampling of Upper Three Runs Creek, Savannah River Site, Aiken County, South Carolina. July 1987 - January 1990.

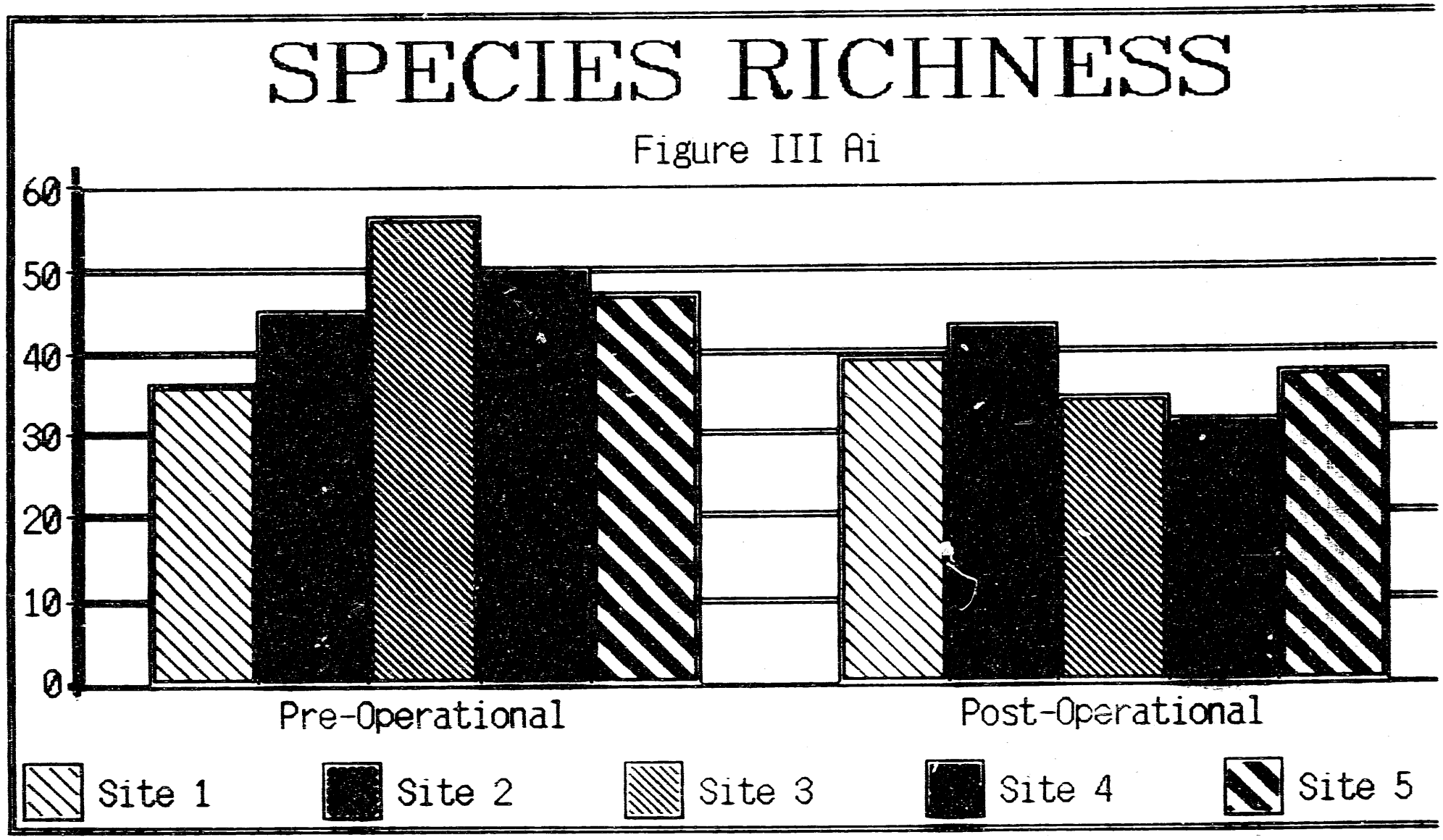


TABLE III A.i

Average # of Species per Replicate
Quantitative Sampling
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Pre - Operational Data

QUANTITATIVE SAMPLING (5 Replicate Multiplate Artificial Substrate Samplers)

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	Std.Dev.
Jun- Jul 87	17.0	21.8	29.2	26.0	25.4	23.9	4.7
Sep - Oct 87	20.8	22.0	16.6	15.6	16.8	18.4	2.8
Jan - Feb 88	16.6	26.1	22.1	22.4	23.8	22.3	3.6
Mar - Apr 88	28.0	29.4	26.8	29.8	27.6	28.3	1.3
Jun - Jul 88	16.8	16.8	16.6	18.6	19.2	17.6	1.2
Sep - Oct 88	10.8	12.8	12.6	15.8	10.8	12.6	2.0
Mean	18.3	21.5	20.7	21.4	20.6	20.5	
Std. Dev. (Pre-Operational)**	5.7	6.1	6.5	5.8	6.2	5.5	
Mean	16.0	16.2	15.6	14.6	14.8	15.4	
Std. Dev. (Post-Operational)***	5.1	5.6	4.7	3.6	5.8	5.1	

Standard Deviation for Mean # of Species / Replicate at Each Site

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5
Jun- Jul 87	5.1	5.9	4.4	10.1	3.8
Sep - Oct 87	4.9	2.3	3.2	3.3	8.3
Jan - Feb 88	7.0	4.2	5.9	5.8	2.8
Mar - Apr 88	2.8	4.2	7.4	5.5	3.9
Jun - Jul 88	3.0	4.3	3.8	7.0	4.7
Sep - Oct 88	5.9	5.8	2.4	3.7	1.3

** Includes all sampling periods up to and including October 1988.
*** Includes all sampling periods after October 1988.

TABLE III Aii

Average # of Species per Replicate
Quantitative Sampling
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Post Operational Data

QUANTITATIVE SAMPLING (5 Replicate Multiplate Artificial Substrate Samplers)

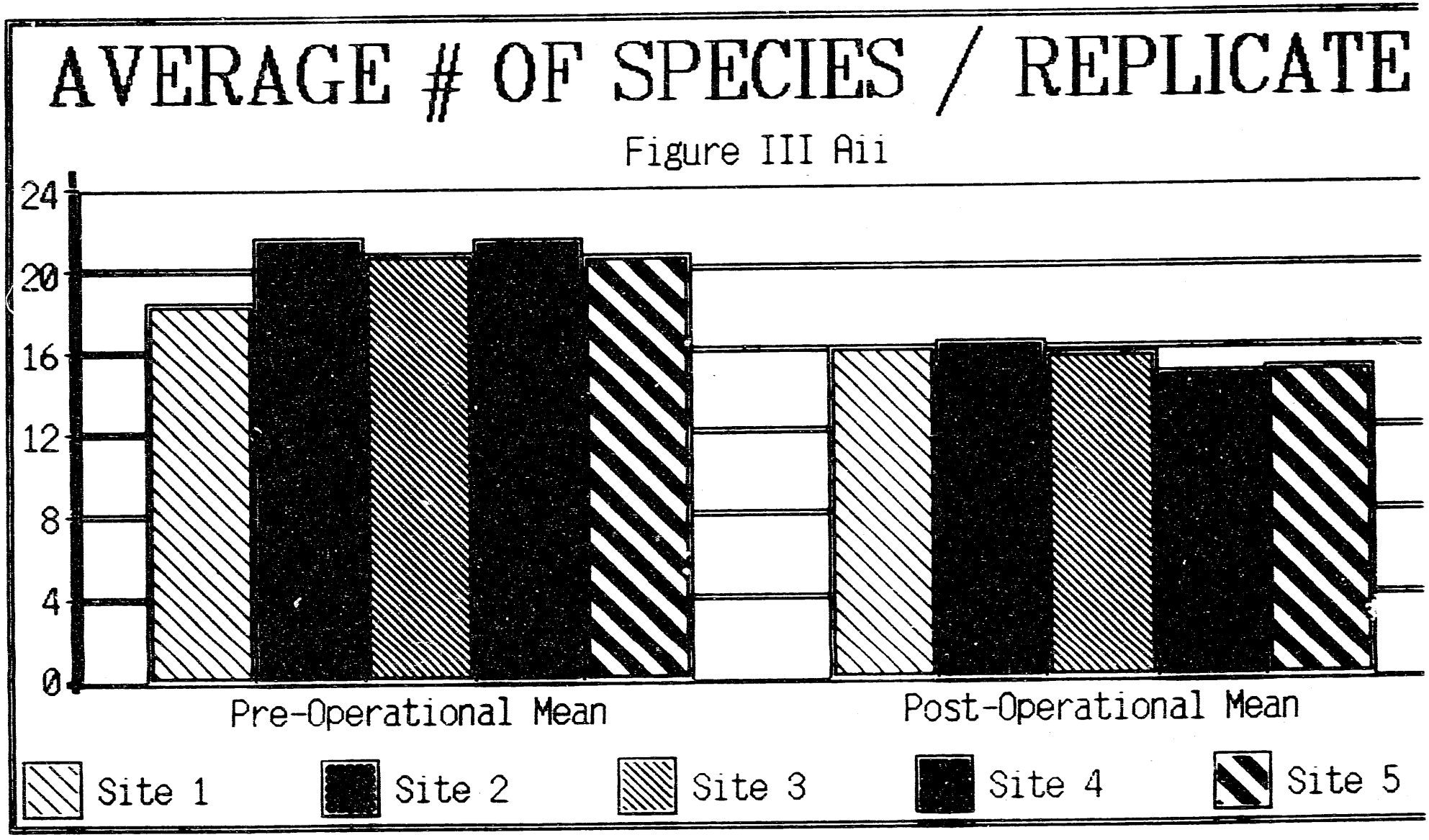
Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	Std.Dev.
Dec 88 - Jan 89*	20.4	19.6	18.4	17.8	19.2	19.1	1.0
Mar - Apr 89	21.0	24.0	22.2	18.6	22.0	21.6	2.0
Jun - Jul 89	12.6	12.0	11.2	10.6	8.6	11.0	1.5
Sep - Oct 89	9.0	10.6	11.1	14.4	9.6	11.0	2.1
Dec 89 - Jan 90	16.8	14.6	14.6	11.6	14.4	14.4	1.8
Mean	16.0	16.2	15.6	14.6	11.8	15.4	
Std. Dev. (Post-Operational)***	5.1	5.6	4.7	3.6	5.8	5.1	
Mean	18.3	21.5	20.7	21.4	20.6	20.5	
Std. Dev. (Pre-Operational)**	5.7	6.1	6.5	5.8	6.2	5.5	

Standard Deviation for Mean # of Species / Replicate at Each Site

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5
Dec 88 - Jan 89*	4.6	3.9	9.3	6.4	2.3
Mar - Apr 89	1.7	11.5	3.3	7.7	3.8
Jun - Jul 89	3.1	5.3	4.8	4.4	2.6
Sep - Oct 89	3.2	2.7	3.6	1.8	2.1
Dec 89 - Jan 90	2.8	0.9	2.2	2.7	1.2

* Only 4 replicates were retrieved at Site 4 during Dec 88 - Jan 89.
** Includes all sampling periods up to and including October 1988.
*** Includes all sampling periods after October 1988.

FIGURE IV Aii: Species Richness, Quantitative Macroinvertebrate Sampling of Upper Three Runs Creek, Savannah River Site, Aiken County, South Carolina. July 1987 - January 1988.



B. Total # of Organisms/Mean Density of Organisms per M^2

(Tables III Bi, III Bii; Figure III B)

A total of 5,330 aquatic macroinvertebrates were collected at the five sites over the five post-operational quantitative sampling periods. This represented an average of 1066.0 organisms per sampling period and an average of 213.2 organisms per site. The number of organisms collected per site reached a maximum of 469 at site 2 during January 1989 sampling and a minimum of 71 at site 1 during October 1989 sampling. The mean number of organisms/site was higher during pre-operational collection periods 369.2.

Analysis by Wilcoxon's Signed Rank Test indicated a significant difference in the mean number of organisms collected pre-operationally and post-operationally ($p=0.05$; Appendix E). This trend was observed for all seasons. During post-operational sampling, the mean number of organisms collected per site ranged from 183.4 at site 5 to 242.6 at site 3. Only the mean for site 5 (183.4) was lower than the control site. Analysis by Friedman's Test was conducted and no significant differences among sites were encountered.

The total number of organisms collected qualitatively also declined in post-operational sampling. This was true of both October 1989, as compared to October 1988 and November 1987, and of March 1989 as compared to March 1988. No significant decreases in population numbers was noted at downstream sites as compared to the control.

The mean density of organisms per site during post-operational sampling was 348.5 organisms/m2, ranging from 118.3 organisms/m2 at site 1 during October 1989 to 750.4 organisms/m2 at site 3 during January 1989. As the density is directly related to the number of organisms collected, the trends noted for the total number of organisms were also noted for density.

Data on the total number and density of macroinvertebrates collected at Upper Three Runs Creek showed no evidence of any impact upon the community by the F/H area ETF discharge.

TABLE III B1

Total # of Organisms per Site
Quantitative and Qualitative Sampling
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Pre-Operational Data

QUANTITATIVE SAMPLING (5 Replicate Multiplate Artificial Substrate Samplers)
(All Replicates Combined)

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Total	Mean	Std.Dev.
Jun - Jul 87	241	300	527	423	413	1904	380.8	112.1
Sep - Oct 87	733	699	260	230	346	2268	453.6	243.6
Jan - Feb 88	267	599	461	539	274	2140	428.0	151.9
Mar - Apr 88	555	501	542	632	670	2900	580.0	69.1
Jun - Jul 88	207	174	242	252	275	1150	230.0	39.7
Sep - Oct 88	152	141	101	197	122	713	142.6	36.1
Total (Pre-operational)*	2155	2111	2133	2273	2100	11075	2215.0	129.0
Mean	359.2	402.3	355.5	378.8	350.0	1845.8	369.2	
Std. Dev. (Pre-operational)*	230.9	231.2	180.1	180.6	184.3	793.3	182.7	
Mean	201.2	233.8	242.6	205.0	183.4	1066.0	213.2	
Std. Dev. (Post-Operational)**	126.8	146.4	158.9	86.1	109.8	612.9	119.2	

QUALITATIVE SAMPLING

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Total
November 87	123	498	258	458	215	1552
March 88	325	489	285	778	245	2122
October 88	147	233	212	210	83	885
Mean	198	407	252	482	181	1520
Total	595	1220	755	1446	543	4559

*Includes all sampling periods up to and including October 1989.
**Includes all sampling periods after October 1989.

TABLE III Bi

Total # of Organisms per Site
Quantitative and Qualitative Sampling
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Post-Operational Data

QUANTITATIVE SAMPLING (5 Replicate Multiplate Artificial Substrate Samplers)
(All Replicates Combined)

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Total	Mean	Std.Dev.
Dec 88 - Jan 89	343	442	469	271	303	1828	365.6	86.5
Mar - Apr 89	328	335	352	319	299	1633	326.6	19.6
Jun - Jul 89	104	126	130	138	93	591	118.2	18.9
Sep - Oct 89	71	122	120	175	80	568	113.6	41.3
Dec 89 - Jan 90	160	144	142	122	142	710	142.0	13.5
Total (Post-operational)**	1006	1169	1213	1025	917	5330	1066.0	122.2
Mean	201.2	233.8	242.6	205.0	183.4	1066.0	213.2	
Std. Dev. (Post-operational)**	126.8	146.4	158.9	86.1	109.8	612.9	119.2	
Mean	359.2	402.3	355.5	378.8	350.0	1845.8	369.2	
Std. Dev. (Pre-Operational)*	230.9	231.2	180.1	180.6	184.3	793.3	182.7	

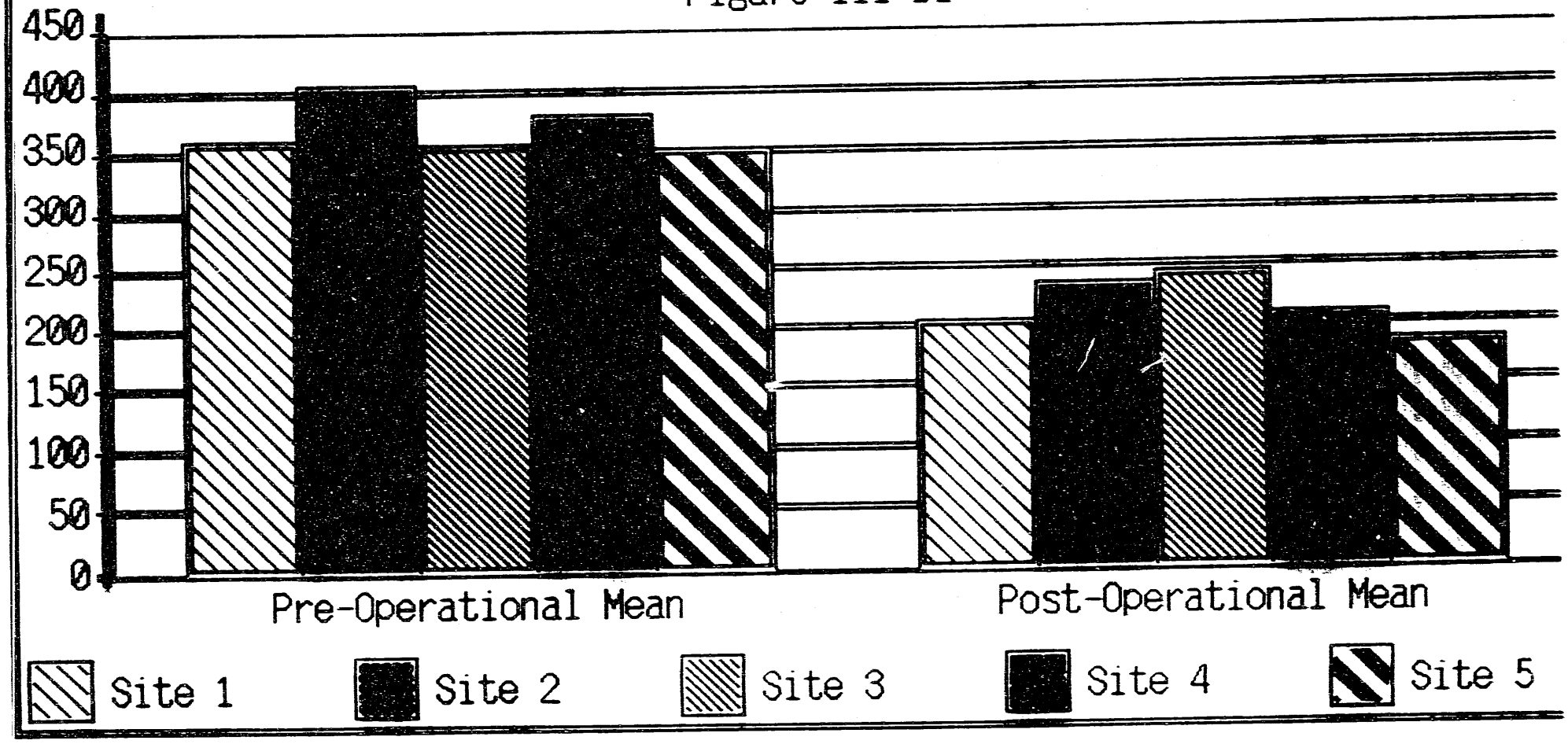
QUALITATIVE SAMPLING

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Total
March 1989	447	465	435	336	261	1944
October 1989	94	146	169	118	102	629
Mean	271	306	302	227	182	1287
Total	541	611	604	454	363	2573

*Includes all sampling periods up to and including October 1989.
**Includes all sampling periods after October 1989.

TOTAL # OF ORGANISMS PER SITE

Figure III Bi



TOTAL # OF ORGANISMS PER SITE

Figure III Bii

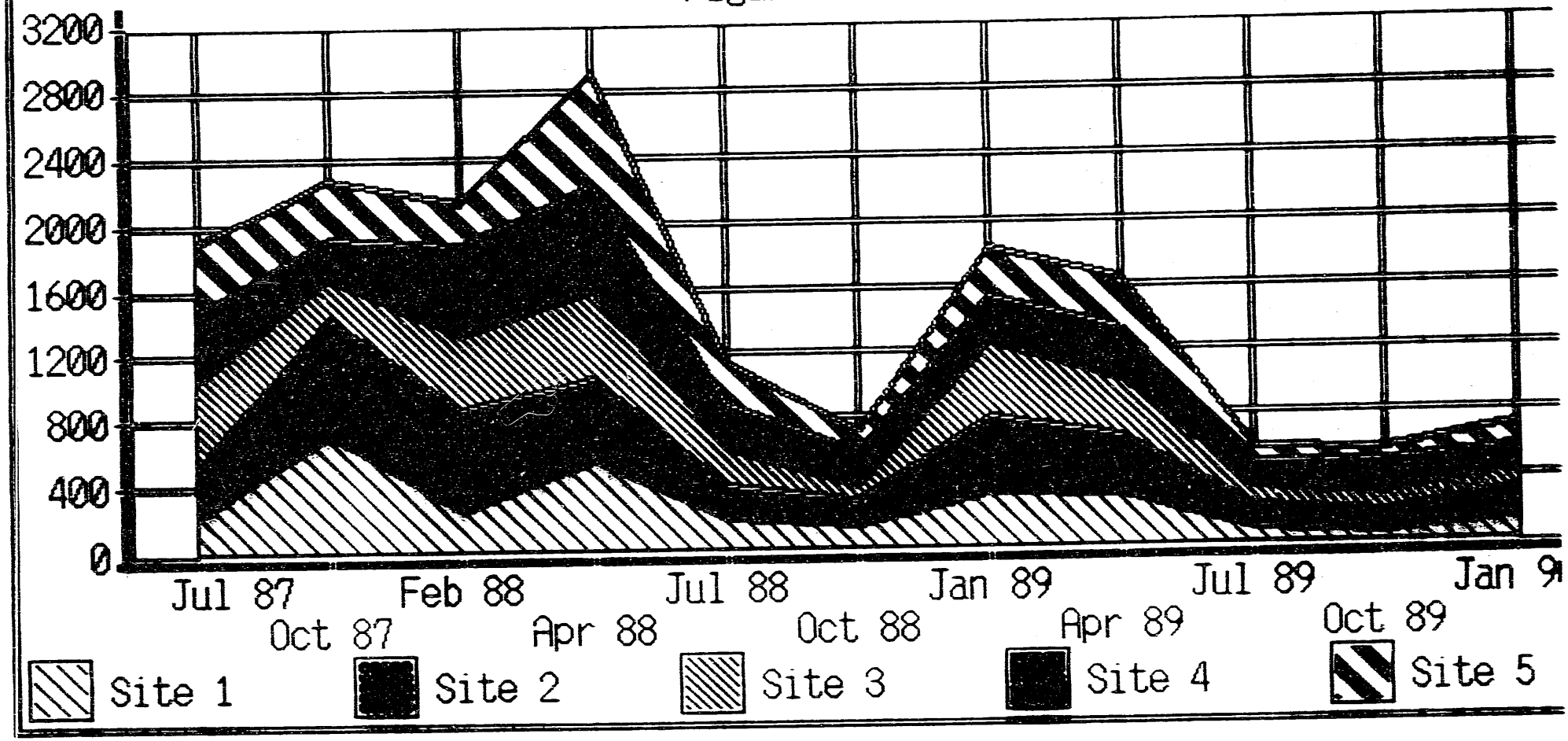


TABLE III B1i

Mean Density of Organisms per M^2
Quantitative Sampling
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Pre - Operational Data

QUANTITATIVE SAMPLING (5 Replicate Multiplate Artificial Substrate Samplers)

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	Std.Dev.
Jun- Jul 87	385.6	480.0	843.2	676.8	660.8	609.3	179.4
Sep - Oct 87	1172.8	1118.4	416.0	368.0	553.6	725.8	389.7
Jan - Feb 88	127.2	958.4	737.6	862.4	138.1	684.8	213.0
Mar - Apr 88	888.0	801.6	867.2	1011.2	1072.0	928.0	110.6
Jun - Jul 88	331.2	278.1	387.2	403.2	140.0	368.0	63.6
Sep - Oct 88	243.2	225.6	161.6	315.2	211.2	231.4	55.8
Mean	574.7	643.7	568.8	606.1	562.7	591.2	
Std. Dev. (Pre-Operational)**	369.5	370.0	288.1	288.9	290.9	253.0	
Mean	338.4	379.3	393.4	333.7	297.6	318.5	
Std. Dev. (Post-Operational)***	189.5	229.7	249.7	132.8	172.3	191.1	

** Includes all sampling periods up to and including October 1988.
*** Includes all sampling periods after October 1988.

TABLE III Bii

Mean Density of Organisms per M^2
Quantitative Sampling
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Post Operational Data

QUANTITATIVE SAMPLING (5 Replicate Multiplate Artificial Substrate Samplers)

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	Std.Dev.
Dec 88 - Jan 89*	518.8	707.2	750.1	433.6	184.8	585.0	138.3
Mar - Apr 89	524.8	536.0	563.2	510.0	478.4	522.5	31.4
Jun - Jul 89	233.3	210.0	216.7	230.0	155.0	209.0	31.7
Sep - Oct 89	118.3	203.3	200.0	291.7	133.3	189.3	68.8
Dec 89 - Jan 90	266.7	240.0	236.7	203.3	236.7	236.7	22.5
Mean	338.1	379.3	393.4	333.7	297.6	318.5	
Std. Dev. (Post-Operational)***	189.5	229.7	249.7	132.8	172.3	191.1	
Mean	574.7	643.7	568.8	606.1	562.7	591.2	
Std. Dev. (Pre-Operational)**	369.5	370.0	288.1	288.9	290.9	253.0	

* Only 4 replicates were retrieved at Site 4 during Dec 88 - Jan 89.
** Includes all sampling periods up to and including October 1988.
*** Includes all sampling periods after October 1988.

C. <u>% Composition by Major Taxonomic Group</u>

(Table IIICi, IIICii, Figure IIICi)

As was noted in pre-operational quantitative sampling, the macroinvertebrate community of Upper Three Runs Creek was found to be dominated by midges (Table IIICi). The degree of dominance by midges post-operationally (50.1%) was less than observed pre-operationally (63.1%). This substantial decrease, when analyzed by Wilcoxon's Signed Rank Test, was found not to be significant. In general, the proportion of midges was lowest during summer (July) sampling. However, the proportion of midges remained suppressed, as compared with pre-operational sampling, from July 1989 to January 1990. Qualitative sampling indicated a similar pattern, with the percentage of midges decreasing to a low of 34.3% in October 1989. Whereas the percentage of midges decreased post-operationally, the percentage of stoneflies and caddisflies increased. Plecoptera comprised 13.8% of all the organisms collected post-operationally as compared to 9.3% pre-operationally. Trichoptera increased from 8.2% pre-operationally to 12.4% post-operationally.

It can be seen there is no shift away from the more intolerant orders of aquatic insects (e.g. Ephemeroptera, Plecoptera and Trichoptera) to more tolerant orders such as Diptera. In fact, the proportion of mayflies, stoneflies and caddisflies increased from 27.1% pre-operationally to 34.7% post-operationally.

Comparison of percent composition by major taxonomic group among sites showed some differences but no clear trends. The proportion of non-chironomid diptera was higher at site 4. Habitat differences and flow regimes may account for the difference. No clear impacts attributable to the F/H Area ETF discharge were noted.

Analysis of the percent composition by major taxonomic group indicates a balanced community with no evidence of impacts from the F/H ETF discharge.

TABLE III C4

cent Composition by Major Taxonomic Group
ted by Date and Site - Quantitative Sampling
er Three Runs Creek
annah River Site, Aiken County, South Carolina
- Operational Data

ted by Date

ling Date	Jul 87	Oct 87	Feb 88	Apr 88	Jul 88	Oct 88	Pre-Operational Mean*
emeroptera	12.6	2.3	15.8	7.0	9.3	2.2	9.6%
ecoptera	4.5	3.1	14.3	10.3	13.6	12.1	9.3%
ichoptera	8.7	2.9	3.6	7.7	25.0	12.6	8.2%
leoptera	8.8	0.4	0.5	1.1	17.9	3.8	5.2%
tera (Non-Chir.)	7.5	6.3	1.2	3.6	3.9	5.2	1.3%
ironomidae	57.4	84.8	64.5	67.1	30.0	62.7	63.1%
her	0.5	0.2	0.1	0.2	0.3	1.4	0.2%

rted by Site (Pre-Operational)

te	Site 1	Site 2	Site 3	Site 4	Site 5	Post-Operational Mean**	Pre-Operational Mean*
hemeroptera	7.5%	7.6%	11.5%	9.1%	6.7%	8.5%	9.6%
ecoptera	7.0%	10.0%	10.3%	9.2%	8.5%	13.8%	9.3%
ichoptera	7.1%	6.5%	8.0%	9.2%	10.6%	12.4%	8.2%
leoptera	2.6%	4.7%	8.3%	4.0%	4.9%	7.1%	5.2%
ptera (Non-Chir.)	6.9%	3.4%	2.3%	4.9%	5.1%	7.6%	4.3%
ironomidae	68.8%	67.4%	59.2%	63.1%	64.0%	50.1%	63.1%
her	0.1%	0.4%	0.4%	0.5%	0.2%	0.4%	0.2%

ludes all sampling periods up to and including October 1988.
ncludes all sampling periods after October 1989.

TABLE III C1

cent Composition by Major Taxonomic Group
ted by Date and Site - Quantitative Sampling
er Three Runs Creek
annah River Site, Aiken County, South Carolina
t - Operational Data

ted by Date

pling Date	Jan 89	Apr 89	Jul 89	Oct 89	Jan 90	Post-Operational Mean**	Pre-Operational Mean*
emeroptera	1.5	7.2	11.5	8.8	19.2	8.5%	9.6%
coptera	12.5	10.1	13.5	11.8	26.8	13.8%	9.3%
choptera	7.4	9.7	20.3	25.3	11.8	12.4%	8.2%
eoptera	0.5	9.9	31.6	3.1	0.6	7.1%	5.2%
tera (Non-Chir.)	1.3	11.7	1.1	15.1	3.1	7.6%	1.3%
ronomidae	70.8	51.0	16.1	34.7	34.9	50.1%	63.1%
er	0.0	0.1	2.3	0.9	0.3	0.4%	0.2%

rted by Site (Post-Operational)

e	Site 1	Site 2	Site 3	Site 4	Site 5	Post-Operational Mean**	Pre-Operational Mean*
hemeroptera	11.6%	8.5%	6.3%	6.2%	9.4%	8.5%	9.6%
ecoptera	12.1%	13.8%	13.4%	15.0%	14.6%	13.8%	9.3%
ichoptera	9.7%	13.4%	11.9%	14.4%	11.7%	12.4%	8.2%
leoptera	2.6%	8.3%	6.8%	8.7%	6.0%	7.1%	5.2%
ptera (Non-Chir.)	4.4%	3.8%	4.1%	15.5%	11.0%	7.6%	4.3%
ironomidae	59.1%	51.6%	57.0%	40.0%	46.8%	50.1%	63.1%
her	0.5%	0.6%	0.5%	0.2%	0.5%	0.4%	0.2%

cludes all sampling periods up to and including October 1988.
ncludes all sampling periods after October 1989.

TABLE III C.1.

Percent Composition by Major Taxonomic Group
Sorted by Date and Site - Qualitative Sampling
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Pre - Operational Data

November 1987

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Mean
Ephemeroptera	17.9%	12.5%	24.1%	4.1%	18.1%	13.2%
Plecoptera	15.4%	7.2%	6.6%	5.5%	17.7%	8.7%
Trichoptera	28.5%	20.1%	11.6%	7.4%	5.6%	13.5%
Coleoptera	1.6%	1.2%	1.5%	1.1%	1.9%	1.4%
Diptera (Non-Chir.)	15.4%	4.5%	7.0%	11.4%	1.7%	7.8%
Chironomidae	17.1%	51.2%	45.7%	69.0%	40.0%	51.5%
Other	1.1%	3.2%	3.2%	1.5%	12.0%	3.9%

March 1988

Site	Site 1	Site 2	Site 3	Site 4	Site 5	Mean
Ephemeroptera	15.2%	13.4%	4.6%	7.7%	15.4%	10.6%
Plecoptera	10.9%	16.0%	20.6%	16.6%	17.0%	16.1%
Trichoptera	6.5%	24.3%	18.1%	24.9%	6.6%	19.0%
Coleoptera	5.3%	1.2%	3.5%	2.4%	2.3%	2.7%
Diptera (Non-Chir.)	5.6%	4.3%	5.3%	5.7%	1.2%	5.1%
Chironomidae	54.0%	39.3%	45.4%	40.2%	47.9%	43.6%
Other	2.5%	1.5%	2.5%	2.5%	6.6%	2.9%

October 1988

Site	Site 1	Site 2	Site 3	Site 4	Site 5	Mean
Ephemeroptera	4.8%	2.2%	4.3%	5.2%	3.6%	4.0%
Plecoptera	0.7%	3.9%	7.1%	10.5%	10.8%	6.3%
Trichoptera	27.9%	26.2%	21.2%	24.8%	12.1%	23.6%
Coleoptera	3.4%	4.7%	3.8%	3.3%	2.4%	3.7%
Diptera (Non-Chir.)	15.0%	8.6%	17.0%	8.1%	22.9%	12.9%
Chironomidae	39.5%	50.6%	43.4%	45.2%	25.3%	43.4%
Other*	8.7%	3.8%	3.2%	2.9%	22.9%	6.1%

*Predominantly Gastropoda.

TABLE III Cii

nt Composition by Major Taxonomic Group
d by Date and Site - Qualitative Sampling
Three Runs Creek
nah River Site, Aiken County, South Carolina
- Operational Data

1989

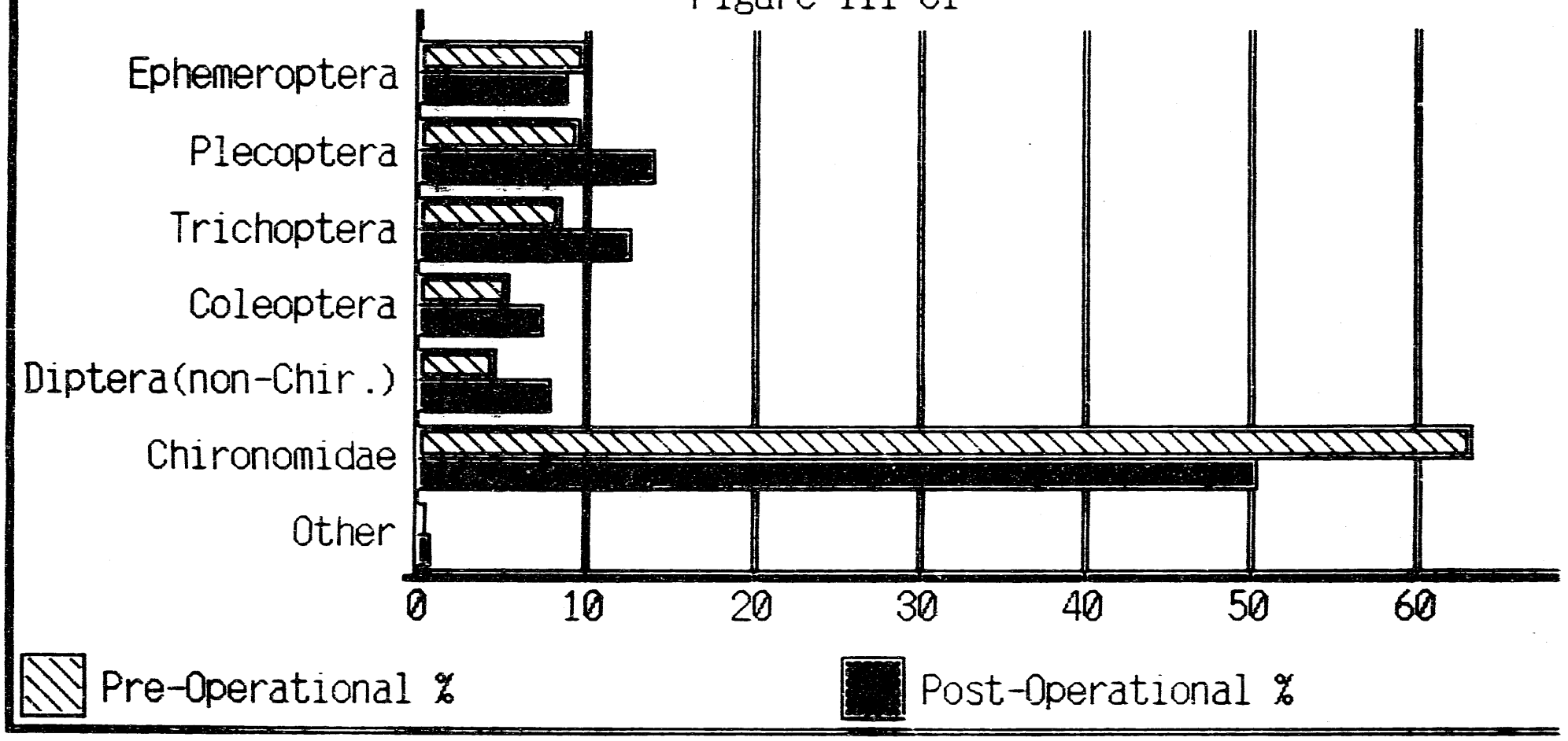
ling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Mean
meroptera	10.7%	9.9%	7.8%	7.7%	10.3%	9.3%
optera	16.3%	17.2%	16.8%	22.3%	14.9%	17.5%
hoptera	6.7%	15.9%	7.8%	14.9%	9.6%	11.0%
optera	1.2%	3.4%	2.5%	5.7%	3.1%	3.2%
era (Non-Chir.)	5.4%	4.5%	12.9%	8.0%	13.4%	8.4%
onomidae	57.5%	44.5%	51.0%	37.2%	46.0%	47.9%
r	2.2%	4.6%	1.2%	4.2%	2.7%	2.7%

ber 1989

	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	Post Operational Mean
meroptera	14.9%	4.8%	5.9%	7.6%	9.8%	8.0%	9.0%
coptera	3.2%	2.7%	8.3%	8.5%	5.9%	5.9%	14.7%
choptera	29.8%	25.3%	11.8%	22.0%	12.8%	19.7%	13.1%
coptera	3.2%	3.4%	1.8%	2.5%	2.9%	2.7%	3.1%
tera (Non-Chir.)	8.5%	4.1%	8.3%	22.9%	9.8%	10.3%	8.9%
ronomidae	27.7%	43.2%	32.0%	25.4%	42.2%	34.3%	44.6%
stacea	1.1%	0.0%	21.3%	4.2%	5.9%	7.6%	1.9%
lusca	9.6%	13.7%	6.5%	4.2%	9.8%	8.7%	2.1%
er	2.1%	3.8%	4.7%	2.7%	1.0%	2.8%	2.7%

% COMPOSITION BY TAXONOMIC GROUP

Figure III Ci



D. <u>Eveness: Diversity and Equitability</u> (Tables III Di, III Dii; Figures III Di, III Dii)

Diversity values on the post-operational data averaged 4.27, a slight decrease from the pre-operational mean, which was 4.46. Both pre-operationally and post-operationally the diversity index was high, indicative of an even community not dominated by only a few commmon species. Rather, there is a good distribution of common species, moderately abundant species and uncommon species. Analysis by Wilcoxon's Signed Rank Test (Appendix E) indicates a significant difference in the mean diversity of organisms collected post-operationally as compared to pre-operational data. Pre-operational values ranged from a low of 3.95 at site 1 in October, 1989 to a maximum of 4.93 at site 4 in July, 1987. Post-operational values ranged from a low of 3.72 at site 3 in July, 1989 to a maximum of 5.01 at site 2 in April, 1989. A Friedman's statistical analysis conducted on the post-operational data showed no significant difference in diversity among sites (Appendix E), although sites 2-5 did have lower diversity values than site 1. Diversity values correlated with species richness on a seasonal basis, reaching a minimum in July and October 1989. Even the relatively low values, however, showed good diversity.

Equitability at the five sites averages 0.79 pre-operationally and 0.86 post-operationally. Analysis by Wilcoxon's Signed Rank Test (Appendix E) is indicative of no significant differences in the mean equitability of the sites during the post-operational sampling periods. A Friedman's test conducted on the data showed no changes in equitability among sites (Appendix E).

In overall view, the eveness of the macroinvertebrate community at all sites is good, with no indication of any degredation of water quality either post-operationally or at any downstream site.

TABLE III Di

Shannon Weaver Diversity Indices
Quantitative Sampling
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Pre - Operational Data

QUANTITATIVE SAMPLING (5 Replicate Multiplate Artificial Substrate Samplers)

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	Std.Dev.
Jun- Jul 87	4.33	4.72	4.70	4.93	4.74	4.68	0.22
Sep - Oct 87	4.11	4.13	4.29	4.19	4.23	4.19	0.07
Jan - Feb 88	4.17	4.49	4.28	4.17	4.32	4.29	0.13
Mar - Apr 88	4.83	4.92	4.80	4.72	4.70	4.79	0.09
Jun - Jul 88	4.57	4.68	4.44	4.67	4.50	4.57	0.10
Sep - Oct 88	3.95	4.27	4.71	4.27	4.01	4.21	0.30
Mean	4.33	4.51	4.54	4.49	4.42	4.16	
Std. Dev. (Pre-Operational)**	0.32	0.30	0.23	0.32	0.28	0.25	
Mean	4.42	4.34	4.13	4.16	4.28	4.27	
Std. Dev. (Post-Operational)***	0.10	0.40	0.31	0.23	0.31	0.30	

* Includes all sampling periods up to and including October 1988.
** Includes all sampling periods after October 1988.

TABLE III Di

Shannon Weaver Diversity Indices
Quantitative Sampling
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Post Operational Data

QUANTITATIVE SAMPLING (5 Replicate Multiplate Artificial Substrate Samplers)

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	Std.Dev.
Dec 88 - Jan 89*	4.41	4.29	4.14	4.42	4.31	4.31	0.11
Mar - Apr 89	4.44	5.01	4.50	4.32	4.60	4.57	0.26
Jun - Jul 89	4.56	4.18	3.72	3.87	3.83	4.03	0.34
Sep - Oct 89	4.28	3.92	3.97	3.99	4.13	4.06	0.15
Dec 89 - Jan 90	4.40	4.32	4.34	4.22	4.54	4.36	0.12
Mean	4.42	4.34	4.13	4.16	4.28	4.27	
Std. Dev. (Post-Operational)***	0.10	0.40	0.31	0.23	0.31	0.30	
Mean	4.33	4.54	4.54	4.49	4.42	4.46	
Std. Dev. (Pre-Operational)**	0.32	0.30	0.23	0.32	0.28	0.25	

Only 4 replicates were retrieved at Site 4 during Dec 88 - Jan 89.
** Includes all sampling periods up to and including October 1988.
*** Includes all sampling periods after October 1988.

DIVERSITY INDICES

Figure III Di

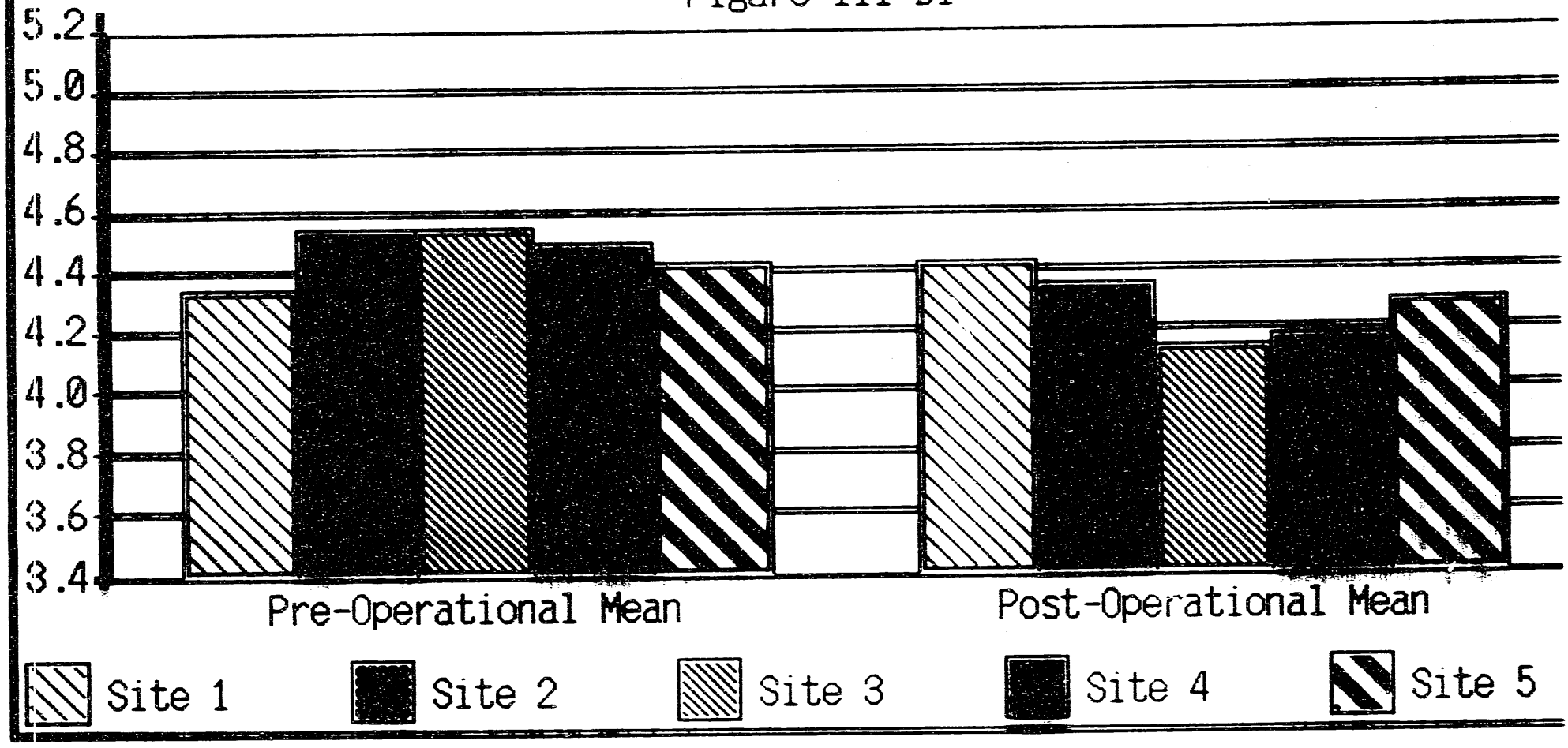


TABLE III Dii

Equitability Indices
Quantitative Sampling
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Pre - Operational Data

QUANTITATIVE SAMPLING (5 Replicate Multiplate Artificial Substrate Samplers)

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	Std.Dev.
Jun- Jul 87	0.83	0.87	0.70	0.92	0.83	0.83	0.08
Sep - Oct 87	0.64	0.60	0.85	0.90	0.76	0.75	0.13
Jan - Feb 88	0.74	0.63	0.63	0.50	0.63	0.63	0.09
Mar - Apr 88	0.77	0.80	0.75	0.81	0.74	0.77	0.03
Jun - Jul 88	0.95	1.00	0.89	0.83	0.77	0.89	0.09
Sep - Oct 88	0.76	0.72	1.08	0.88	0.85	0.86	0.14
Mean	0.78	0.77	0.82	0.81	0.76	0.79	
Std. Dev. (Pre-Operational)**	0.10	0.15	0.16	0.16	0.08	0.09	
Mean	0.91	0.85	0.78	0.83	0.90	0.86	
Std. Dev. (Post-Operational)***	0.13	0.09	0.15	0.11	0.13	0.12	

** Includes all sampling periods up to and including October 1988.
*** Includes all sampling periods after October 1988.

TABLE III Di i

ability Indices
itative Sampling
Three Runs Creek
nah River Site, Aiken County, South Carolina
Operational Data

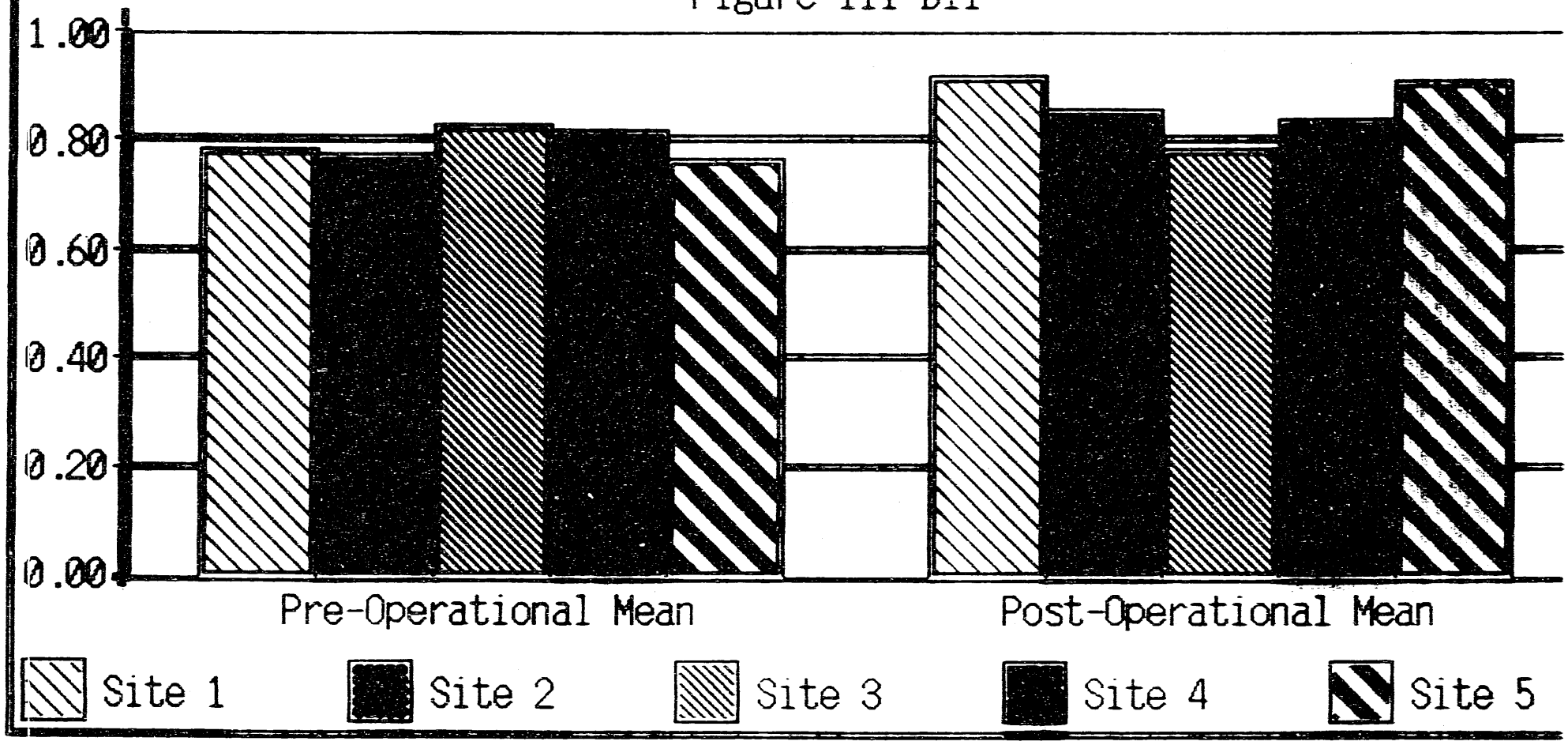
ITATIVE SAMPLING (5 Replicate Multiplate Artificial Substrate Samplers)

ing Date	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	Std.Dev.
88 - Jan 89*	0.76	0.78	0.62	0.78	0.74	0.74	0.07
- Apr 89	0.84	0.89	0.77	0.73	0.80	0.81	0.06
- Jul 89	1.09	0.87	0.66	0.88	0.95	0.89	0.16
- Oct 89	0.97	0.76	0.88	0.77	0.96	0.87	0.10
89 - Jan 90	0.89	0.97	0.97	1.00	1.06	0.98	0.06
	0.91	0.85	0.78	0.83	0.90	0.86	
Dev.	0.13	0.09	0.15	0.11	0.13	0.12	
t-Operational)***							
	0.78	0.77	0.82	0.81	0.76	0.79	
Dev.	0.10	0.15	0.16	0.16	0.08	0.09	
-Operational)**							

4 replicates were retrieved at Site 4 during Dec 88 - Jan 89.
udes all sampling periods up to and including October 1988.
ludes all sampling periods after October 1988.

EQUITABILITY INDICES

Figure III Dii



E. Total Biomass (g/m2)

(Table IIIEi; Figure IIIEI)

The total biomass as ash-free dry weight (AFDW) averaged 0.4439g post-operationally as compared to 0.4041g pre-operationally. Pre-operational means ranged from 0.2930g at site 4 to 0.5391g at site 3. Post-operational means ranged from 0.3096g at site 4 to 0.6126g at site 2.

Total biomass values were quite variable from each site/date combination to each other site/date combination. The patchy distribution of large perlid and pteronarcyd stoneflies accounts for most of this variability, especially in the spring quarter. Lowest biomass values were obtained in the summer and fall, when most mayfly and stonefly nymphs, the largest organisms inhabiting the multiplate samplers, are in early instars. The increase in biomass post-operationally was not significant when analyzed by Wilcoxon's Signed Rank Test. It is of interest that the decreases in species richness and population numbers noted post-operationally were not accompanied by a decrease in biomass.

Although biomass increased at site 2 post-operationally, as contrasted to site 1, it decreased at sites 3-5. The differences among sites (post-operational data) were not significant, except for the decrease at site 4.

A comparison of biomass values obtained at each site indicated no clear trend associated with the F/H Area ETF effluent discharge.

TABLE III E1

Total Biomass (AFDW in g/m2)
Quantitative Sampling
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Pre - Operational Data

QUANTITATIVE SAMPLING (5 Replicate Multiplate Artificial Substrate Samplers)

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	Std.Dev.
Jun- Jul 87	0.1120	0.2712	0.2152	0.1123	0.1347	0.1691	0.0711
Sep - Oct 87	0.2106	0.5138	0.2424	0.1675	0.2938	0.2916	0.1321
Jan - Feb 88	0.3282	0.4144	0.3911	0.4867	0.8299	0.4901	0.1982
Mar - Apr 88	1.1550	0.7107	0.9030	0.5171	0.4277	0.7427	0.2945
Jun - Jul 88	0.4226	0.2616	0.6826	0.2050	0.5064	0.4156	0.1921
Sep - Oct 88	0.0434	0.2224	0.7998	0.2694	0.2414	0.3153	0.2850
Mean	0.3836	0.3990	0.5391	0.2930	0.4057	0.4041	
Std. Dev. (Pre-Operational)**	0.4024	0.1881	0.2952	0.1700	0.2464	0.1990	
Mean	0.5231	0.6126	0.4048	0.3096	0.3695	0.4439	
Std. Dev. (Post-Operational)***	0.2800	0.2808	0.1677	0.0728	0.2036	0.2334	

** Includes all sampling periods up to and including October 1988.
*** Includes all sampling periods after October 1988.

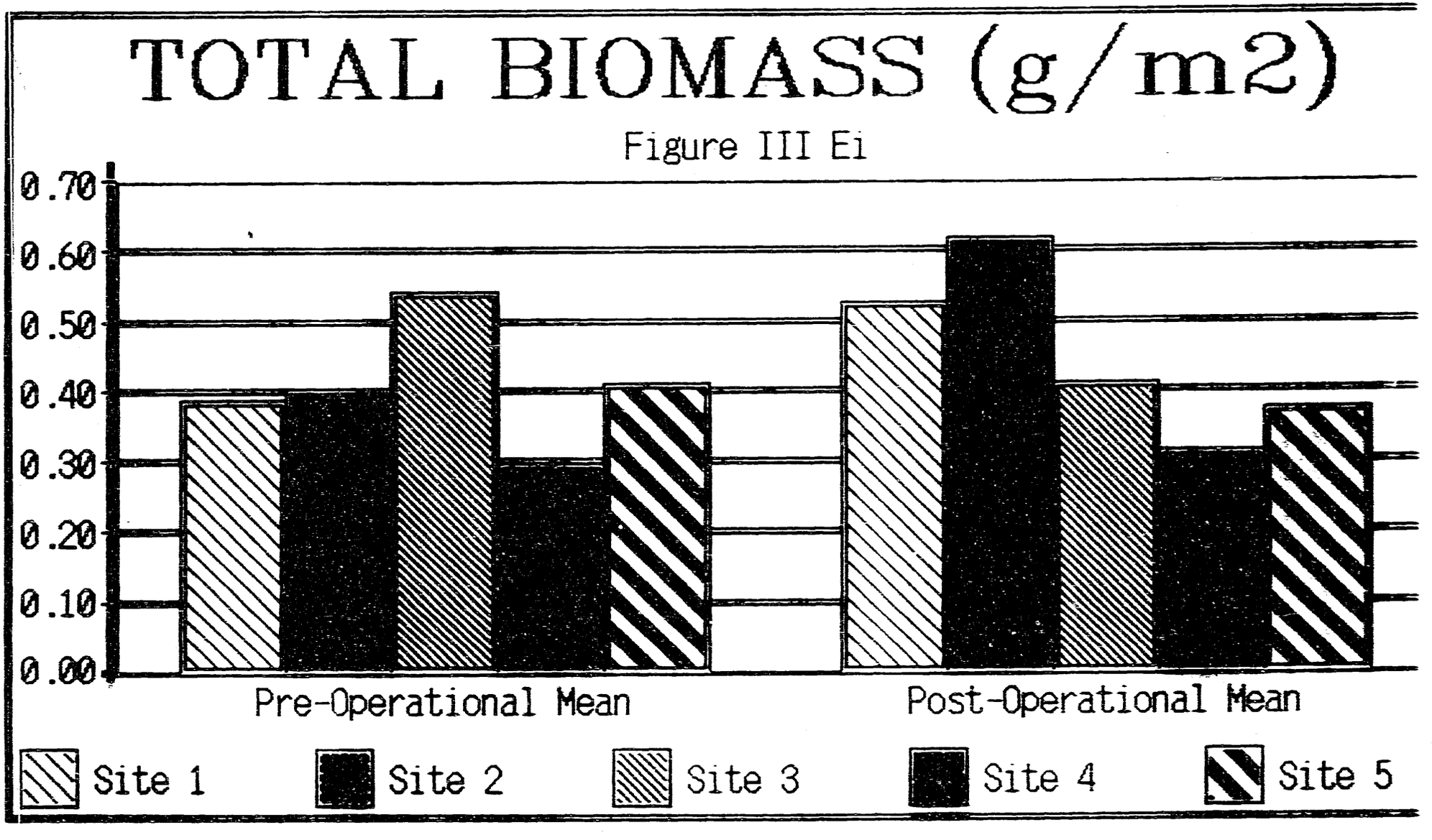
TABLE III E1

Total Biomass (AFDW in g/m2)
Quantitative Sampling
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Post Operational Data

QUANTITATIVE SAMPLING (5 Replicate Multiplate Artificial Substrate Samplers)

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	Std.Dev.
Dec 88 - Jan 89*	0.6976	0.6003	0.5058	0.3898	0.4514	0.5290	0.1219
Mar - Apr 89	0.4162	0.5755	0.3346	0.2507	0.3933	0.3941	0.1199
Jun - Jul 89	0.2682	0.5118	0.1637	0.2440	0.1388	0.2653	0.1479
Sep - Oct 89	0.3091	0.3053	0.4175	0.2771	0.2112	0.3040	0.0746
Dec 89 - Jan 90	0.9242	1.0700	0.6025	0.3865	0.6528	0.7272	0.2709
Mean	0.5231	0.6126	0.4048	0.3096	0.3695	0.4439	
Std. Dev. (Post-Operational)***	0.2800	0.2808	0.1677	0.0728	0.2036	0.2334	
Mean	0.3836	0.3990	0.5391	0.2930	0.4057	0.4011	
Std. Dev. (Pre-Operational)**	0.4024	0.1881	0.2952	0.1700	0.2464	0.1990	

* Only 4 replicates were retrieved at Site 4 during Dec 88 - Jan 89.
** Includes all sampling periods up to and including October 1988.
*** Includes all sampling periods after October 1988.


TOTAL BIOMASS (g/m2)
Figure III Ei
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Pre-Operational Mean
Post-Operational Mean
Site 1
Site 2
Site 3
Site 4
Site 5

F. Pollution Tolerence: Biotic Index and EPT Index

(Tables IIIFi, IIIFii, Figures IIIFi, IIIFii)
The average biotic index for all sites and dates combined post-operationally, calculated on the multiplate sampling data was 4.44 (Table IIIFi). This value was significantly lower than the value for pre-operational data (4.96). The lower value reflects a more pollution intolerant community after initiation of effluent releases. According to Hilsenhoff (1987) these values represent a good level of water quality (low biotic index values indicate good water quality). During pre-operational sampling values were lowest in July and highest in October. Post-operationally, the biotic index decreased over time, irrespective of seasons. The multiplate sampling data were most sensitive to midge populations, especially orthoclads and chiromomini midges, which were larger in pre-operational collections. Reduced numbers of Polypedium, Rheocricotopus and Orthocladius were the major contributing factors resulting in lower biotic indices. Post-operationally, the Friedman's Test shows significant differences among the sites (Appendix E). This was most notable at site 4, which was found to have a macroinvertebrate community with a significantly better (lower) biotic index than other sites. As both spatial and temporal comparisons indicated an improved biotic index downstream/post-operationally, no impact by F/H area effluent is observed.

The post-operational EPT indices for multiplate sampling at the five sites ranged from a low of 10 to a maximum of 20 (Table IIIFii). No significant differences were noted among sites when the data are subjected to Friedman's test (Appendix E). There was a slight non-significant increase in the EPT index from the pre-operational mean of 13.8 to the post-operational mean of 14.7. Qualitative sampling portrayed the opposite trend, with EPT values decreasing from a mean of 18.9 pre-operationally to 17.6 post-operationally. The highest EPT ratings occurred in the winter and spring, when species richness among the ephemerellid mayflies and perlodid stoneflies was at a peak. The values are indicative of good water quality for macroinvertebrate community of Upper Three Runs Creek. No indication of an impact by the F/H area ETF effluent was noted.

TABLE III F1

Biotic Indices
Quantitative Sampling
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Pre - Operational Data

QUANTITATIVE SAMPLING (5 Replicate Multiplate Artificial Substrate Samplers)

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	Std.Dev.
Jun- Jul 87	4.56	4.73	5.31	5.00	4.81	4.88	0.29
Sep - Oct 87	5.52	5.91	5.35	5.51	5.29	5.52	0.24
Jan - Feb 88	5.18	5.30	5.12	5.33	4.90	5.17	0.17
Mar - Apr 88	5.17	4.88	4.84	4.92	5.20	5.00	0.17
Jun - Jul 88	4.50	4.64	4.38	4.60	4.49	4.52	0.10
Sep - Oct 88	5.63	4.66	4.18	5.11	3.80	4.68	0.73
Mean	5.09	5.02	4.86	5.09	4.75	4.96	
Std. Dev. (Pre-Operational)**	0.47	0.50	0.49	0.33	0.55	0.36	
Mean	4.64	4.50	4.70	4.16	4.23	4.44	
Std. Dev. (Post-Operational)***	0.33	0.57	0.33	0.34	0.55	0.47	

QUALITATIVE SAMPLING

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Average by Date
November 1987	4.49	5.10	4.45	4.88	4.54	4.69
March 1988	5.01	4.88	4.75	4.74	4.73	4.82
October 1988	6.13	5.33	4.44	4.92	4.92	5.15

** Includes all sampling periods up to and including October 1988.
*** Includes all sampling periods after October 1988.

TABLE III Fi

Biotic Indices
Quantitative Sampling
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Post Operational Data

QUANTITATIVE SAMPLING (5 Replicate Multiplate Artificial Substrate Samplers)

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	Std.Dev.
Dec 88 - Jan 89*	5.10	5.21	5.12	4.59	5.04	5.01	0.24
Mar - Apr 89	1.69	1.89	1.83	1.38	1.09	1.58	0.31
Jun - Jul 89	1.13	1.53	1.79	1.13	1.40	1.46	0.21
Sep - Oct 89	1.73	3.91	1.18	3.93	1.10	1.23	0.36
Dec 89 - Jan 90	1.21	3.91	1.27	3.75	3.54	3.95	0.31
Mean	1.64	1.50	1.70	1.16	1.23	1.14	
Std. Dev. (Post-Operational)***	0.33	0.57	0.33	0.34	0.55	0.47	
Mean	5.09	5.02	1.86	5.09	1.75	1.96	
Std. Dev. (Pre-Operational)**	0.17	0.50	0.19	0.33	0.55	0.36	

QUALITATIVE SAMPLING

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Average by Date
March 1989	4.71	4.94	4.86	4.84	5.59	4.99
October 1989	5.50	5.47	5.44	4.20	5.21	5.19

* Only 4 replicates were retrieved at Site 4 during Dec 88 - Jan 89.

** Includes all sampling periods up to and including October 1988.

*** Includes all sampling periods after October 1988.

BIOTIC INDICES

Figure Fi

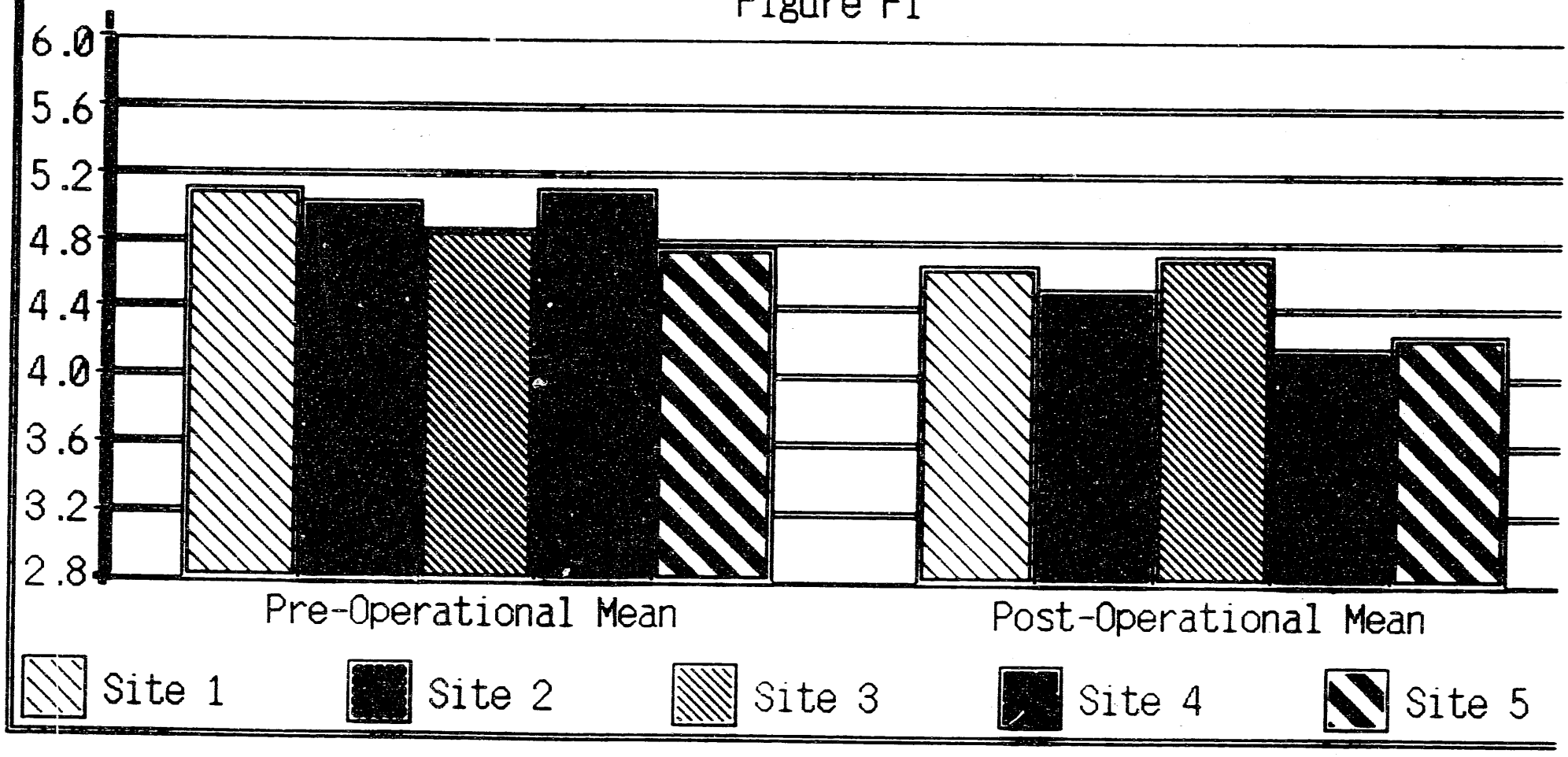


TABLE III Fii

EPT Index
Quantitative and Qualitative Sampling
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Pre-Operational Data

QUANTITATIVE SAMPLING (5 Replicate Multiplate Artificial Substrate Samplers)
(All Replicates Combined)

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	Std.Dev.
Jun - Jul 87	11	14	17	18	14	14.8	2.8
Sep - Oct 87	8	11	11	8	7	9.0	1.9
Jan - Feb 88	12	19	19	18	17	17.0	2.9
Mar - Apr 88	17	23	21	18	18	20.0	3.2
Jun - Jul 88	14	15	13	13	15	14.0	1.0
Sep - Oct 88	8	10	9	8	5	8.0	1.9
Mean	11.7	15.3	15.5	13.8	12.7	13.8	
Std. Dev. (Pre-operational)*	3.4	4.7	5.1	4.5	4.3	4.8	
Mean	15.2	15.2	14.2	14.4	14.4	14.7	
Std. Dev. (Post-Operational)**	1.9	3.9	3.0	1.1	4.3	3.1	

QUALITATIVE SAMPLING

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	Std.Dev.
November 1987	16	20	18	21	17	18.4	2.1
March 1988	27	28	23	36	21	27.0	5.8
October 1988	10	14	12	11	10	11.4	1.7
Mean	17.7	20.7	17.7	22.7	16.0	18.9	7.4

*Includes all sampling periods up to and including October 1988.
**Includes all sampling periods after October 1988.

TABLE III F1i

EPT Index
Quantitative and Qualitative Sampling
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Post-Operational Data

QUANTITATIVE SAMPLING (5 Replicate Multiplate Artificial Substrate Samplers)
(All Replicates Combined)

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	Std.Dev.
Dec 88 - Jan 89	16	18	18	15	20	17.1	1.9
Mar - Apr 89	16	19	11	13	16	15.6	2.3
Jun - Jul 89	17	11	13	11	10	13.0	2.7
Sep - Oct 89	12	11	10	16	10	11.8	2.5
Dec 89 - Jan 90	15	17	16	14	16	15.6	1.1
Mean	15.2	15.2	14.2	14.1	14.1	14.7	
Std. Dev. (Post-Operational)**	1.9	3.9	3.0	1.1	1.3	3.1	
Mean	11.7	15.3	15.5	13.8	12.7	13.8	
Std. Dev. (Pre-Operational)*	3.1	4.7	5.1	4.5	1.3	4.8	

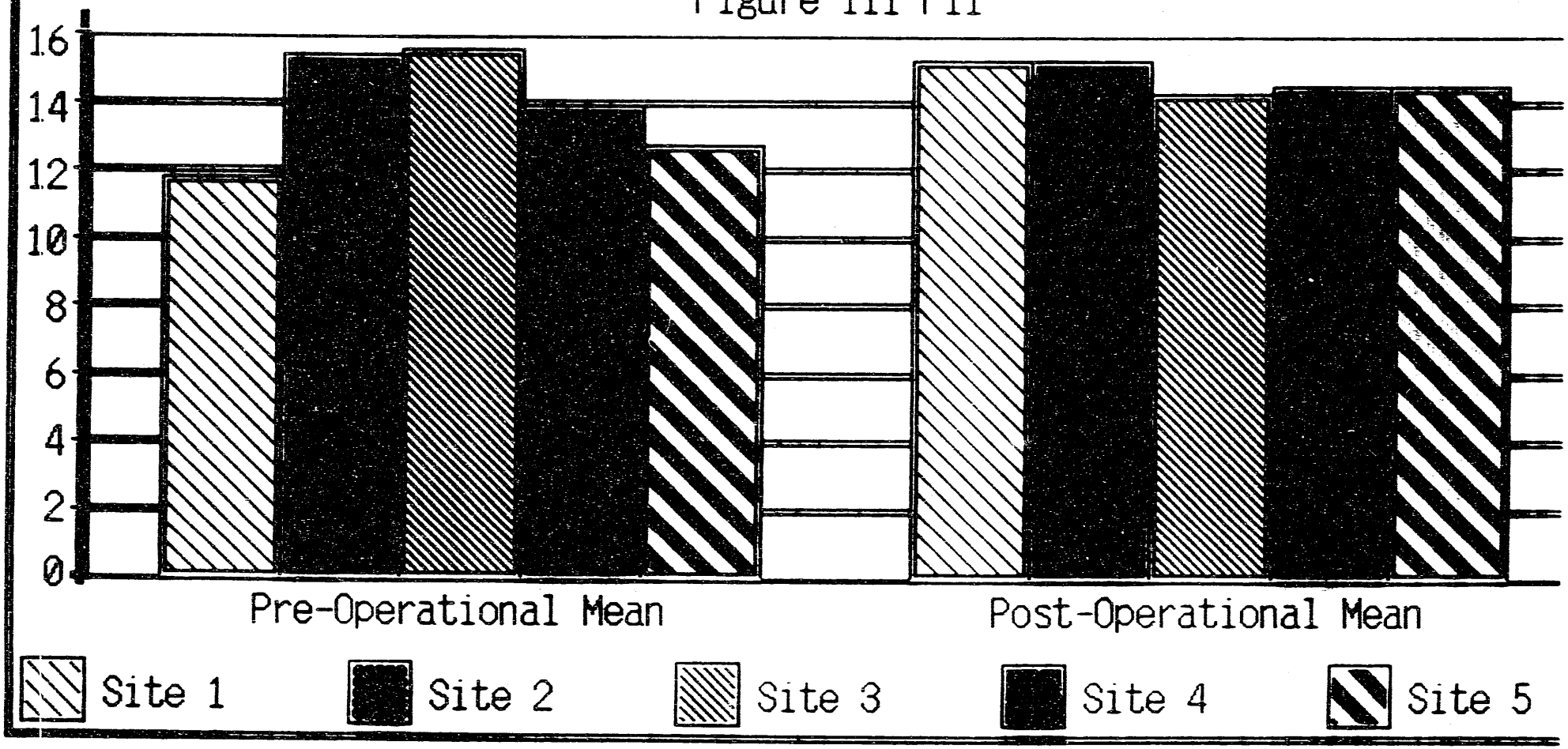
QUALITATIVE SAMPLING

Sampling Date	Site 1	Site 2	Site 3	Site 4	Site 5	Mean	Std. Dev.
March 1989	24	24	26	26	18	23.6	3.3
October 1989	11	8	9	14	13	11.6	2.9
Mean	19.0	16.0	17.5	20.0	15.5	17.6	7.4

*Includes all sampling periods up to and including October 1988.
**Includes all sampling periods after October 1988.

EPT INDICES

Figure III Fii



G. <u>Functional Group Analysis</u> (Tables VIGi - IIIGii; Figures IIIGi, IIIGxi, Appendix G)

Functional post-operational group analysis, based upon the total number of organisms quantitatively collected per site, portrayed a community dominated by collectors (62%). This was a slight decrease from the pre-operational dominance of collectors (65%). Although the proportion of collectors did not vary significantly when comparing pre-operational and post-operational results, the balance of gatherers and filterers did shift. In all seasonal comparisons across the ETF start-up date (except February 1988 vs. January 1989 and July 1988 vs. July 1989) the percentage of collector-gatherers significantly decreased post-operationally. Conversely, in fall comparisons and winter comparisons the percentage of collector-filterers significantly increased. The decrease in collector-gatherers seems to be correlated with the smaller numbers of orthoclad midges collected after February 1988. Predators increased post-operationally, increasing from 17.0% to 19.4% (all seasons combined). Analysis by Wilcoxon's Signed Rank Test indicated that the increase was significant for all seasonal comparisons across the ETF start-up date except July 1988 vs. July 1989 and October 1988 vs. October 1989. Scrapers (grazers) constituted 8.1% of the community pre-

operationally and 9.7% post-operationally. Seasonal comparisons using Wilcoxon's Signed Rank Test demonstrated significant differences in the proportion of scrapers pre- and post-operationally, except October 1988 vs. October 1989. Shredders remained relatively constant in proportion, ranging from 9.8% pre-operationally to 9.1% post-operationally. Among shredders, however, herbivores comprised a smaller percentage post-operationally (decreasing fro 8.9% to 5.5%) and detritivores a larger percentage (increasing from 0.9% to 3.6%). It is worth noting that fewer significant differences were noted when comparing functional group proportions between July and October 1988 data sets and post-operational data sets than other pre-post-operational combinations. This suggests that, as noted for density calculations, the shift in the data occurred prior to the F/H ETF area start-up, which occurred in late October 1988. In other words, there was not so much difference in the trophic structure of the community between seasons after June 1988 as there was across the July 1988 temporal boundary.

Comparisons of functional groups (based on numbers of organisms) among sites showed some interesting trends. In particular, collector-gatherers were less dominant downstream and collector-filterers increased. This is opposite the spatial trend noted pre-operationally. The proportions of predators increased slightly at downstream sites, although the increase was noted both pre- and post-operationally. Shredder-herbivors also increased in proportion post-operationally. Analysis by Friedman's Test confirmed the lack of significant differences post-operationally for any functional group among sites.

Post-operational functional group analysis based upon percentage by biomass was similar to pre-operational results in finding the community to be dominated by predators. (61%). Scrapers were the second largest functional group by biomass (15%), followed by shredders (13%) and collectors (11%). Comparison of pre-operational to post-operational biomass data showed a similar pattern to the functional group analysis by population numbers, with decreases in collecter-gatherers and increases in collector-filterers. However, the population of predators decreased significantly. Comparisons of biomass data among sites showed smaller percentages of collector-gatherers downstream while collector-filterers increased. Unlike the functional group analysis by population number data, predators did not increase at downstream sites and neither did shredders.

Post-operational sampling revealed significant changes in the functional group proportions as compared to the same season's pre-operational data. These changes appeared to occur prior to October 1988 and involved lessened populations and biomass of orthoclad midges. There was also, however, a shift in the trophic structure of the community downstream of the F/H area ETF effluent discharge. Of greatest concern is the increase in proportions of collector-filterers, coupled with a decrease in proportion of collector-gatherers, noted both for population data and biomass data. Although not drastic, the shift is significant and could suggest minor nutrient enrichment in the stream, (increasing fine particulate organic matter (FPOM)). Other causes, such as slight habitat differences or natural variability could also account for the shift. In the absence of inter-site differences in species richness or other measured indices, it would be premature to overemphasize this shift and its possible correlation to the F/H area ETF effluent discharge.

TABLE III C11

unctional Group Analysis by Site
uantitative Sampling: Post-operational Data
oper Three Runs Creek
avannah River Site, Aiken County, South Carolina
re - Operational Data

QUANTITATIVE SAMPLING (5 Replicate Multiplate Artificial Substrate Samplers)
(All Replicates Combined)

unctional Group	Site 1	Site 2	Site 3	Site 4	Site 5	Pre-Operational Overall % of Total **	Post-Operational Overall % of Total *
Collector-Gatherers							
% by Pop. #	18.7%	50.1%	16.8%	11.1%	17.0%	17.5%	37.6%
% by Biomass	8.5%	8.9%	7.1%	8.1%	5.2%	7.8%	3.5%
Collector-Filterers							
% by Pop. #	22.3%	11.6%	13.5%	19.5%	18.1%	17.5%	21.2%
% by Biomass	5.2%	5.5%	6.3%	7.5%	10.5%	6.1%	7.5%
Predators							
% by Pop. #	15.1%	18.7%	16.9%	17.6%	17.0%	17.0%	19.1%
% by Biomass	76.1%	70.6%	67.0%	65.3%	62.3%	70.6%	60.6%
Scrapers							
% by Pop. #	5.5%	7.1%	11.6%	8.1%	7.5%	8.1%	9.7%
% by Biomass	5.5%	8.0%	8.9%	11.3%	15.1%	9.7%	15.0%
Shredder-Herbivores							
% by Pop. #	7.8%	8.8%	9.9%	9.2%	8.1%	8.9%	5.5%
% by Biomass	2.5%	3.1%	0.8%	3.0%	1.2%	2.0%	6.5%
Shredder-Detritivores							
% by Pop. #	0.6%	0.8%	1.2%	1.2%	1.7%	0.9%	3.6%
% by Biomass	2.2%	3.9%	10.6%	4.5%	5.1%	3.8%	6.9%

* Includes all sampling periods up to and including October 1988.
** Includes all sampling periods after October 1988.

TABLE III GIII

Functional Group Analysis by Site
Quantitative Sampling: Post-operational Data
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Post-Operational Data

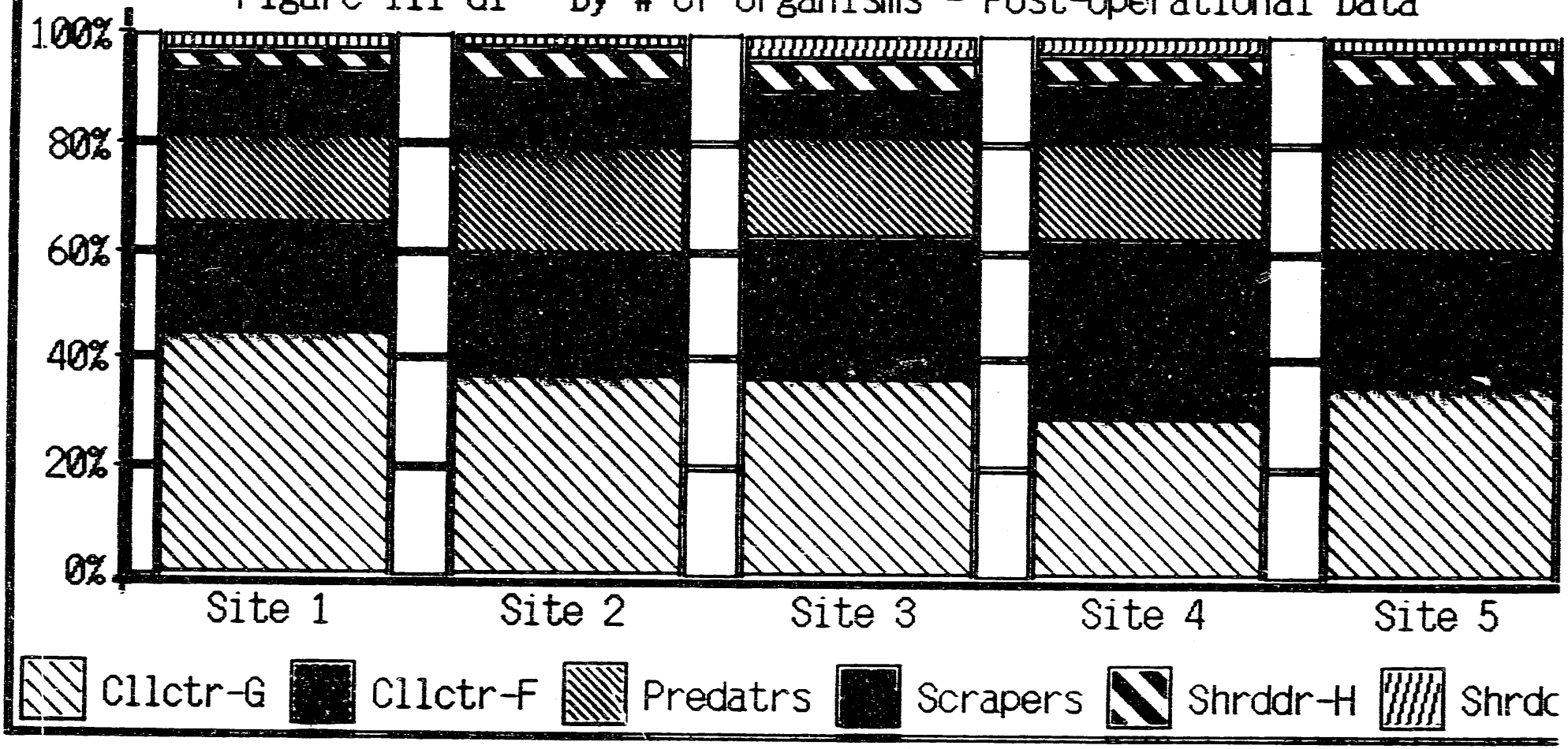
QUANTITATIVE SAMPLING (5 Replicate Multiplate Artificial Substrate Samplers)
(All Replicates Combined)

Functional Group	Site 1	Site 2	Site 3	Site 4	Site 5	Post-Operational Overall % of Total **	Pre-Operational Overall % of Total *
Collector-Gatherers							
% by Pop. #	15.2%	17.1%	38.8%	29.7%	15.7%	17.6%	17.4%
% by Biomass	1.1%	1.7%	1.5%	5.3%	1.1%	2.5%	7.8%
Collector-Filterers							
% by Pop. #	19.7%	22.2%	27.3%	22.5%	21.5%	21.2%	17.5%
% by Biomass	2.9%	6.8%	6.0%	7.0%	6.2%	7.5%	6.1%
Predators							
% by Pop. #	17.1%	20.7%	19.9%	18.7%	20.8%	19.1%	17.0%
% by Biomass	59.9%	56.7%	75.0%	63.2%	53.5%	60.6%	70.6%
Scrapers							
% by Pop. #	10.6%	10.8%	7.8%	10.0%	9.5%	9.7%	8.1%
% by Biomass	11.7%	16.6%	10.1%	11.0%	16.9%	15.0%	9.7%
Shredder-Herbivores							
% by Pop. #	3.9%	6.2%	6.3%	5.1%	6.1%	5.5%	8.9%
% by Biomass	9.9%	8.7%	2.3%	1.5%	9.1%	6.5%	2.0%
Shredder-Detritivores							
% by Pop. #	3.1%	2.9%	1.9%	1.0%	3.3%	3.6%	0.9%
% by Biomass	8.6%	7.5%	4.8%	6.0%	9.9%	6.9%	3.8%

* Includes all sampling periods up to and including October 1988.
** Includes all sampling periods after October 1988.

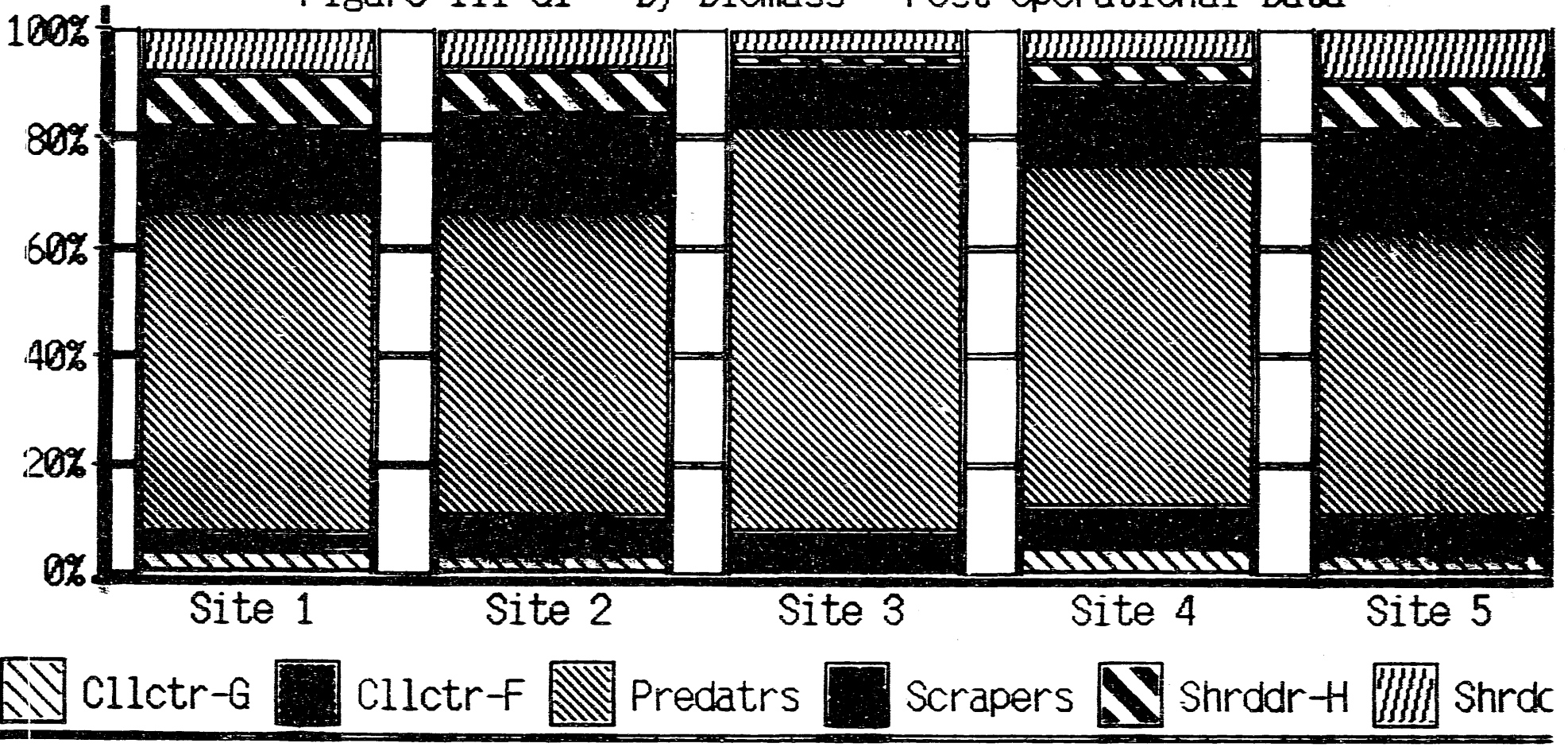
FUNCTIONAL GROUP ANALYSIS – BY SITE

Figure III Gi - By # of Organisms - Post-Operational Data



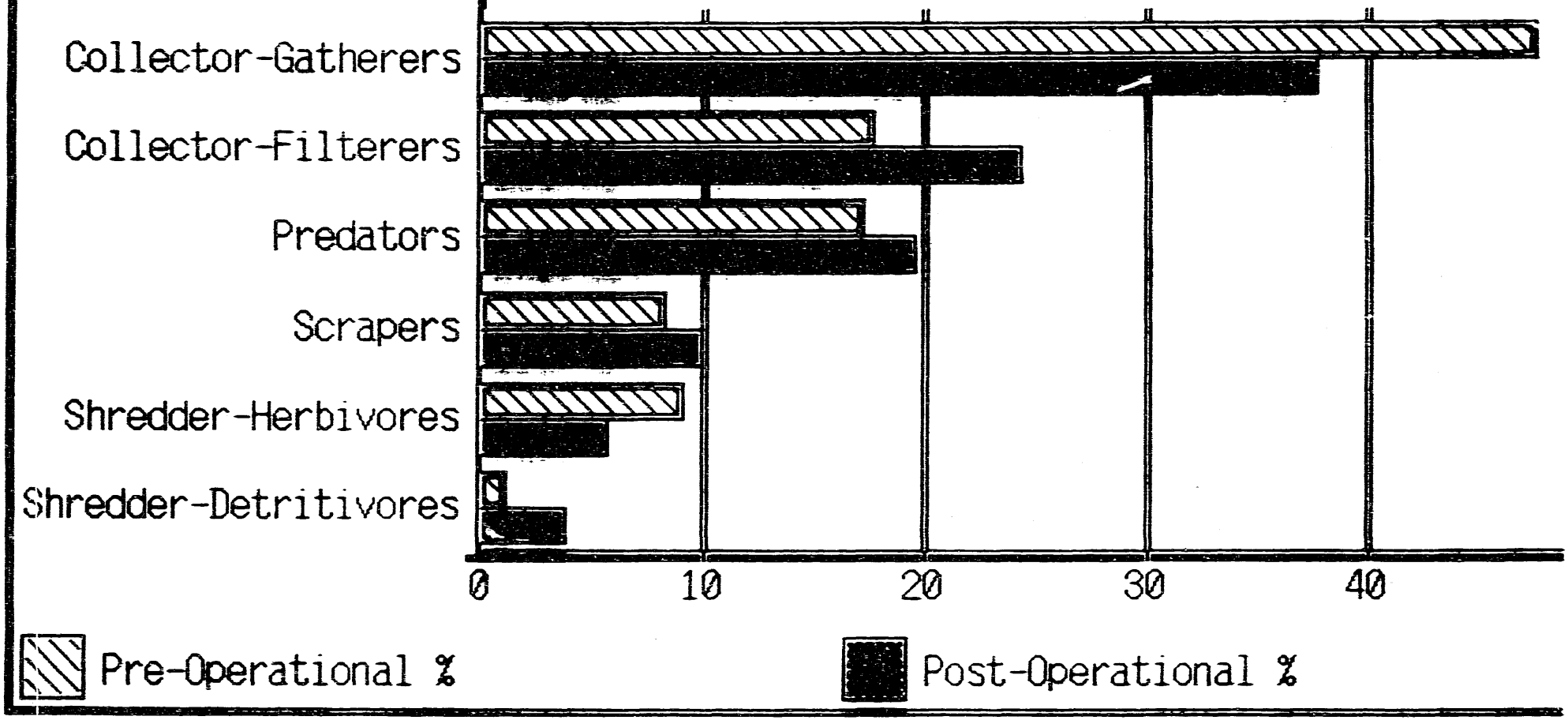
FUNCTIONAL GROUP ANALYSIS – BY SITE

Figure III Gi - By Biomass - Post-Operational Data



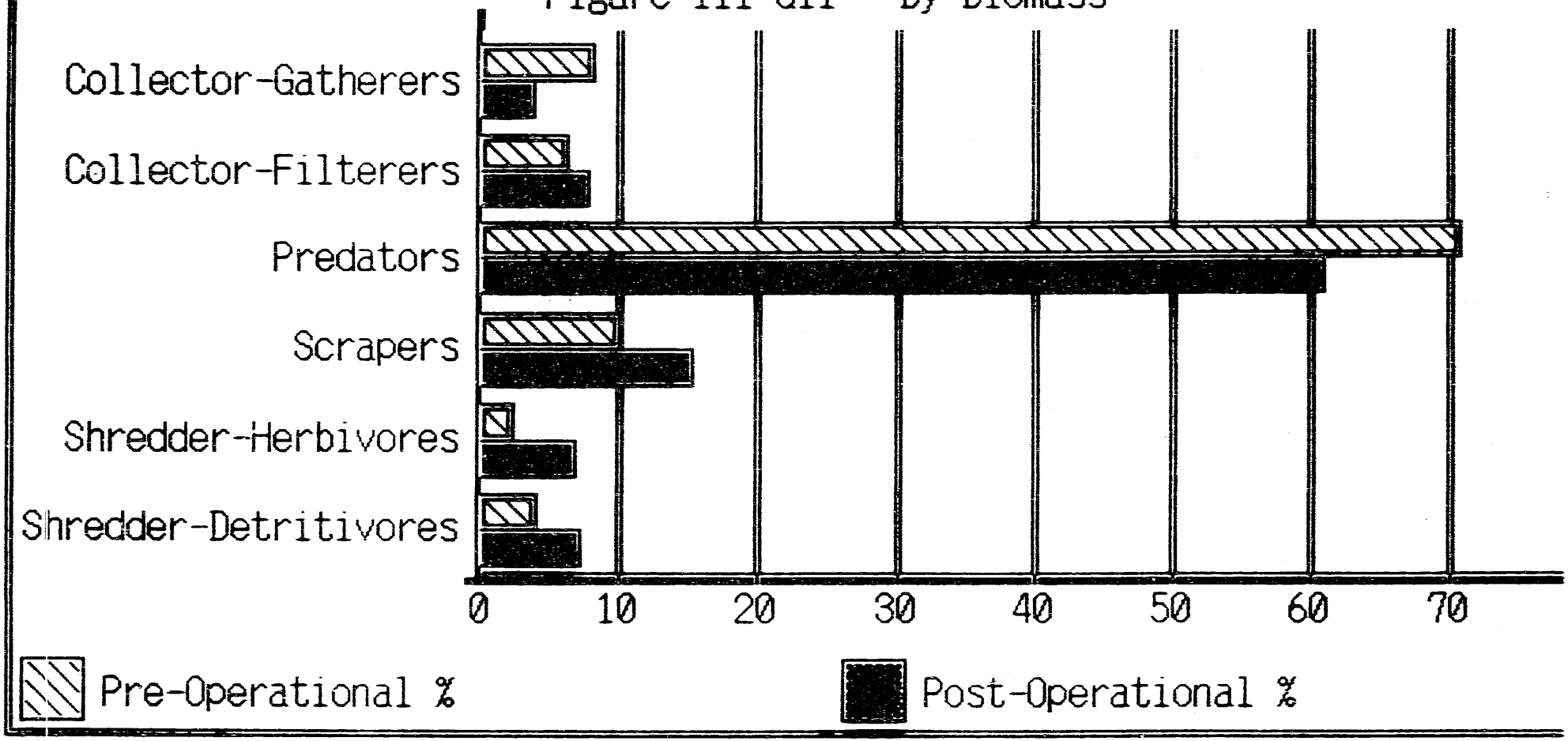
FUNCTIONAL GROUP ANALYSIS – BY DATE

Figure III Gii - By # of Organisms



FUNCTIONAL GROUP ANALYSIS – BY DATE

Figure III Gii - By Biomass



Due to the rheophilic/snag habitat bias of artificial substrate sampling, other habitats within the stream are under-represented, particularly sediment-dwelling organisms and neuston (surface)

H. Dominant Species and Community Structure

Throughout the study, the macroinvertebrate community colonizing the multiplate artificial substrate samplers was dominated by rheophilic, snag habitat species, particularly orthoclad midges.

The most commonly collected species was Rheocricotopus robacki and the second most common species was Polypedilum convictum. Non-chironomid species among the most commonly collected included black flies (Simulium dixiense/jonesi), caddisflies (Hydropsyche elissoma) and mayflies (Stenonema modestum/smithae and Heptagenia Flavescens) and stoneflies (Acroneuria abnormis). The ten most commonly collected species at the five sites were as follows:

Quantitative Sampling Pre-Operational Dominant Species	#	Post-Operational Dominant Species	#
Rheocricotopus robacki	1291	Rheocricotopus robacki	524
Thienemanniella fusca	803	Polypedilum convictum	464
Polypedilum convictum	617	Hydropsyche elissoma	386
Tvetenia discoloripes	511	Rheotanytarsus distinctissimus	296
Hydropsyche elissoma	477	Simulium dixiense/jonesi	285
Rheotanytarsus distinctissimus	441	Tvetenia discoloripes	221
Stenonema modestum/smithae	388	Orthocladius curtiseta	216
Simulium dixiense/jonesi	377	Stenonema modestum/smithae	201
Cricotopus vierriensis	309	Corynoneura sp. 3	173
Heptagenia flavescens	308	Acroneuria abnormis	132

Although the list varies from site to site, no pronounced shifts in dominants among sites was noted.

Due to the rheophilic/snag habitat bias of artificial substrate sampling, other habitats within the stream are under-represented, particularly sediment-dwelling organisms and neuston (surface) dwelling organisms. Qualitative sampling can give a more balanced overall view of the community in all habitats of the lotic system. A list of species collected post-operationally by qualitative sampling methods, representing non-snag habitats at all sites is presented below:

Sand Community

Agarodes libalis
Bezzia sp. 7
* Cladotanytarsus sp.
Cryptochironomus blarina
C. fulvus gp.
Dolania americana
Genus nr. Kloosia
Haploperla brevis
Paracladopeelma undine
Paracladopelma doris
Paralauterborniella nigrohalteralis
* Rheosmittia
Robackia claviger

Neuston/Pelagic Community

Dineutus ciliatus
* Dineutus discolor
Rhagovelia obesa

Sediment/Leaf Pack Community

* Hexagenia limbata
* Acerpenna pygmaeus
* Paraleptophlebia guttata
Enallagma sp.
Gomphus lividus
Hagenius brevistylus
Lepidostoma sp.
Leuctra sp.
Perlinella drymo
Sialis sp.
Anisocentropus pyraloides
Lepidostoma sp.
* Phylocentropus
Hydroporus pilatei
Sperchopsid tesselatus
Atrichopogon
Bezzia sp. 2,6
Crysops sp.
Culicoides sp.
Erioptera/Ormosia
Hextoma (E.) cinerea
* Palpomyia sp. 1,5
Pilaria
Sphaerium sp.

* A. mallochi
Ablabesmyia janta
Conchapelopia
Clinotanypus pinguis
Heterotrissocladius marcidus
Labrundinia pilosella

* Microtendipes spp.
Pagastiella ostansa
Paramerina sp.
* Polypedilum halterale
* Polypedilum scalaenum
Psectrocladius (Meso.) sp.
Paratendipes nudisquama
Stempellinella sp.
Tanytarsus sp. XVII
Tribelos jucundus
Caecidotea sp.
Cambarinae
Palaemonetes
Spirosperma sp.
Tubificidae
* Gillia altilis
Viviparis subpurpureum

* Dominant Species

Qualitative sampling indicated that the sediment dwelling species are equally abundant to the snag habitat species. Thus, the dominant species noted in qualitative sampling are distinctly different than were found by artificial substrate sampling, which primarily sampled snag habitat species. Sediment/leaf pack habitat may be estimated at approximately 30% of the streambed area, as compared to 60% sand habitat and 10% snag habitat. Each of the three habitat types was sampled equally. A review of the qualitative data by habitat (Appendix B) shows the highest species richness and organism density to be found in the snag habitat and the lowest species richness and organism density in the sand habitat. Field observations indicated that site 1 included less snag and sediment/leaf pack habitat than the other sites and site 5 included a greater proportion of sediment/leaf pack habitat than the other sites. The ten most common species collected pre-operationally and post-operationally are as follows:

Qualitative Sampling Pre-Operational Dominant Species	#	Post-Operational Dominant Species	#
Hydropsyche elissoma	315	Hydropsyche elissoma	178
Tribelos jucundus	255	Conchapelopia sp.	129
Polypedilum convictum	237	Parametriocnemus lundbecki	116
Cheumatopsyche sp.	152	Rheocricotopus robacki	88
Isoperla orata/dicala	147	Polypedilum convictum	79
Rheotanytarsus exiguus	131	Tvetenia discoloripes	78
Paraleptophlebia guttata	126	Isoperta nr. nana	77
Brachycentrus numerosus	107	Gillia altilis	58
Stenonema modestum/smithae	107	Stenonema modestum/smithae	56
Phylocentropus sp.	106	Simulium jonesi/dixiense	56
Orthocladics dentifer	106		

The patchy nature of habitat distribution makes it more difficult to generalize about community structural changes among sites samples qualitatively. The dominant species collected qualitatively were dissimilar when comparing pre and post-operational samples, it is not possible to determine the significance of the differences.

Table III Hi

Dominant Species Collected by Multiplate Artificial Substrate Samplers At Five Sites on Upper Three Runs Creek, Savannah River Plant, Aiken County, South Carolina. June 1987 - January 1990.

Ephemeroptera
- Ephemerella dorothea
- Ephemerella invaria/rotunda
- Heptagenia flavescens
- Stenonema modestum/smithae

Plecoptera
- Acroneura abnormis
- Acroneuria mela
- Helopicus subvarians
- Isoperla bilineata
- Isoperla nr. nana
- Isoperla orata/dicala
- Paragnetina kansensis
- Leuctra sp.
- Perlesta placida
- Pteronarcys dorsata
- Taeniopteryx nr. lita

Trichoptera
- Brachycentrus numerosus
- Cheumatopsyche spp
- Chimarra sp.
- Hydropsyche elissoma
- Micrasema rusticum

Megaloptera
- Corydalus cornutus

Coleoptera
- Ancyronyx variegatus
- Macronychus glabratus
- Stenelmis markeli
- Stenelmis sinuata

Diptera (non-Chironomidae)
- Atherix lantha
- Ectemnia invenusta
- Empididae
- Simulium jonesi
- Simulium tuberosum

Diptera (Chironomidae)
- Brillia flavifrons
- Conchapelopia sp
- Corynoneura sp
- Corynoneura sp 3
- Orthocladius dentifer
- Orthocladius curtiseta
- Parakiefferiella sp A, B
- Parametriocnemus lundbecki
- Polypedilum convictum gp
- Rheocricotopus robacki
- Rheotanytarsus distinctissimus
- Rheotanytarsus exiguus
- Symposiocladius lignicola
- Tanytarsus glabrescens gp
- Tanytarsus sp. XVI
- Thienemanniella fusca gp
- Thienemanniella xena gp
- Tvetenia discoloripes
- Tvetenia paucunca/vitracies

I. Water Chemistry

(Table III Ii; Appendix F)

Thirty-one parameters were analyzed monthly on water samples collected from five sites on Upper Three Runs Creek. Six parameters were analyzed monthly on water samples from the mouth of Tim's Branch. A summary of that data is presented in Table III Ii. The complete set of data is included in Appendix F. Three parameters were measured as field values: dissolved oxygen, pH and temperature.

Dissolved Oxygen, pH, Specific Conductance, Temperature and Total Suspended Solids.

The dissolved oxygen concentrations (field measurement; Appendix Di) ranged from 6.9 ppm to 13.8 ppm with an overall mean of 9.3 ppm. The overall mean for pH (Field measurement; Appendix Di) was highest at Tim's Branch (6.4) and lowest at site #1 (5.9). The range for the mean pH at the five sites on Upper Three Runs Creek was 5.9 - 6.1. No significant differences among sites were noted.

Specific conductance varied from a mean high of 23.4 micromhos/cm at site 3 pre-operationally to a low of 20.6 micromhos/cm, at site 5 pre-operationally. No significant differences were noted either among sites or over time.

The overall mean for temperature was 15.1 ^{o}C with a high mean of 14.9 ^{o}C at site 5. The temperature followed normal seasonal fluctuations.

Total suspended solids ranged from a mean high of 9.9 at site 5 (pre-operationally) to a mean low of 4.5 ppm at site 1 (pre-operationally). The suspended solids appear to be similar at all sites, and when comparing pre-operational and post-operational data. Values were consistently low in the stream.

Nitrogen and Phosphorus (Figure Ii)

Through the reporting period the Nitrate Nitrogen was consistently higher at Tim's Branch (post-operational mean: 0.67 mg/l). The annual means at the other sites were between 0.083 and 0.15 mg/l. The increase in the post-operational mean nitrate nitrogen level at downstream sites (0.214 - 0.238 mg/l) as compared to site 1 (0.138 mg/l), suggest that Tim's Branch contributes significantly to nitrate levels in Upper Three Runs Creek. The mean Nitrite Nitrogen at all sites was below the detection limits for that parameter. Mean ammonia nitrogen levels ranged from below detectable limits at all sites pre-operationally to 0.025 mg/l at site 5 post-operationally. In general ammonia nitrogen levels were lower downstream than at the control site.

The annual site means for all Upper Three Runs Creek sites post-operationally for total phosphorus were between 0.029 and 0.048 mg/l. No significant differences among sites were observed. Orthophosphate phosphorus post-operational site means ranged from 0.024 to 0.052 mg/l. In November 1988, high total phosphorus concentrations in Tim's Branch affected total phosphorus readings in Upper Three Runs Creek, resulting in a high level at the first downstream site (2) - 0.2 mg/l, as compared to 0.01 mg/l at station 1. Significant differences were not observed among sites during other post-operational sampling periods.

Sodium, Manganese and Zinc

Mean Sodium concentrations ranged from 1.3 to 2.3 mg/l. The site means for manganese ranged from 0.025 to 0.040 mg/l. Mean zinc concentrations ranged from <0.005 to 0.054 mg/l. Dissolved zinc values ran slightly higher than total zinc values, due to low levels of zinc contamination from the filter paper. Concentrations of sodium, manganese and zinc were not significantly higher at downstream sites than at site 1.

Sediment Mercury

Mercury was not detected in the sediments of Upper Three Runs Creek during pre-operational sampling. During post-operational collection periods, detectable mercury levels have been encountered several times at sites 1,2 and 5, but not at sites 3 and 4. Values at the control site have been detectable on 3 occasions; March 1989 (21 ug/kg), April 1989 (24 ug/kg) and December 1989 (30 ug/kg). None of these values were much above the detection limit (20 ug/kg). At the first downstream site (2), mercury was detected in the sediment during five months of 1989. In general the values exceeded detectable limits by only small amounts (21 - 30 ug/kg). However, a value of 144 ug/kg was found in the site 2 sediment in January 1989. Although the January 1989 site 2 value seems to be an outlier, there is an increasing frequency of higher than detection limit (and higher than the control) sediment mercury levels post-operationally at site 2. Four samples exhibited detectable levels of sediment mercury at site 5; January 1989 (63 ug/kg), July 1989 (27 ug/kg), November 1989 (50 ug/kg), and December 1989 (40 ug/kg). As with site 2, the mercury levels appeared higher than at site 1 and were more frequently detectable post-operationally.

Uranium

Prior to the start-up of the F/H area ETF effluent releases the mean values for Uranium were below detectable limits at all sites. Post-operationally, detectable mean levels of uranium have been measured at all sites. The mean uranium level at site 1 was 0.0009 mg/l. Levels at downstream sites were significantly higher (0.0014 - 0.0030 mg/l).

Chromium, Copper, Lead, Mercury and Uranium

Chromium, copper, lead and mercury (excluding sediment mercury) were right at or below detectable levels at all sites throughout the reporting period.

Residual Chloride

Residual chloride at mean levels above the detection limit was not detected during the reporting period, (detection limit = 0.05 mg/l).

Hardness and Alkalinity

Hardness and alkalinity values were quite low at all sites throughout the period, indicating a very soft water with little available buffering capacity. Post-operational hardness values ranged from 7.0 - 7.9 mg/l and alkalinity ranged from 4.3 - 5.1 mg/l. No significant differences were noted between pre-operational and post-operational data nor among sites.

Tributyl Phosphate and Kerosene

Neither tributyl phosphate nor kerosene were detected above the method detection limits during this part of the study.

Table III Ii:

Statistical Description of the Water Chemistry Parameters Measured at Five Sites Along Upper Three Runs Creek, Savannah River Plant, Aiken County, South Carolina. August 1987 - October 1988.

SITE #1

Parameter	Mean [a]	Standard Deviation	Range
pH	5.93	0.41	5.2 - 6.9
Dissolved Oxygen	8.95	1.2	7.0 - 11.3
Temperature	15.6	5.0	6.0 - 23.0
Conductivity	23.13	5.03	11 - 31
Chromium	<0.005	----	<0.005 - 0.005
Copper	BDL *	----	<0.05 - <0.005
Lead	BDL *	----	<0.001 - <0.01
Manganese	0.022	0.017	<0.005 - 0.071
Mercury	BDL *	----	<0.5 - <0.8
Sodium	1.34	0.15	1.1 - 1.6
Uranium	BDL *	----	<0.001
Zinc	0.0204	0.056	<0.005 - 0.220
Dissolved Chromium	<0.005	----	<0.005 - 0.005
Dissolved Copper	<0.005	----	<0.005 - 0.010
Dissolved Lead	BDL *	----	<0.001 - <0.01
Dissolved Manganese	0.017	0.017	0.006 - 0.074
Dissolved Mercury	BDL *	----	<0.5
Dissolved Sodium	1.41	0.20	1.1 - 1.6
Dissolved Uranium	BDL *	----	<0.001
Dissolved Zinc	0.0318	0.059	<0.005 - 0.234
Nitrate Nitrogen	0.22	0.69	<0.2 - 2.7
Nitrite Nitrogen	BDL *	----	<0.01
Ortho Phosphate as Phosphorus	0.0186	0.0083	<0.01 - 0.03
Total Phosphate as Phosphorus	0.0587	0.122	0.01 - 0.05
Ammonia Nitrogen	BDL *	----	<0.1 - <1
Hardness	7.857	3.348	4 - 16
Alkalinity	4.18	1.207	3 - 8
Residual Chlorine	BDL *	----	<0.05 - <0.1
Tot. Suspended Solids	4.667	3.457	<4 - 11
Kerosene	BDL *	----	<100
Tri-Phosphate	BDL *	----	<50 - <100
Mercury Sediment	BDL *	----	<50

[a] In calculating the Mean and Standard Deviation, results below the detection limit were treated as 0.0.

* BDL = All values were below the detection limits listed in the Range.

Table III Ii: cont.

Statistical Description of the Water Chemistry Parameters Measured at Five Sites Along Upper Three Runs Creek, Savannah River Plant, Aiken County, South Carolina. August 1987 - October 1988.

SITE #2

Parameter	Mean [a]	Standard Deviation	Range
pH	6.05	0.62	5.0 - 7.5
Dissolved Oxygen	9.03	1.5	7.0 - 12.6
Temperature	15.7	5.0	6.0 - 23.0
Conductivity	22.73	4.73	11 - 32
Chromium	<0.005	----	<0.005 - 0.005
Copper	BDL *	----	<0.005 - <0.05
Lead	BDL *	----	<0.001 - <0.01
Manganese	0.0264	0.0355	<0.001 - 0.074
Mercury	BDL *	----	<0.5
Sodium	1.34	0.184	1.1 - 1.8
Uranium	<0.001	----	<0.001 - 0.002
Zinc	0.0233	0.061	<0.005 - 0.299
Dissolved Chromium	<0.005	----	<0.005 - 0.007
Dissolved Copper	<0.005	----	<0.005 - 0.005
Dissolved Lead	<0.005	----	<0.005 - 0.003
Dissolved Manganese	0.0123	0.0137	<0.005 - 0.056
Dissolved Mercury	BDL *	----	<0.5
Dissolved Sodium	1.493	0.258	1.2 - 2.1
Dissolved Uranium	0.067	0.258	<0.001 - 1
Dissolved Zinc	0.036	0.068	<0.005 - 0.277
Nitrate Nitrogen	0.227	0.743	<0.1 - 2.9
Nitrite Nitrogen	BDL *	----	<0.01
Ortho Phosphate as Phosphorus	0.034	0.049	<0.01 - 0.2
Total Phosphate as Phosphorus	0.038	0.025	0.02 - 0.11
Ammonia Nitrogen	BDL *	----	<0.1 - <1
Hardness	7.286	2.4	4 - 14
Alkalinity	5.147	5.33	2 - 24
Residual Chlorine	BDL *	----	<0.5
Tot. Suspended Solids	6.143	7.305	<4 - 28
Kerosene	BDL *	----	<100
Tri-Phosphate	BDL *	----	<50 - <100
Mercury Sediment	BDL *	----	<50

[a] In calculating the Mean and Standard Deviation, results below the detection limit were treated as 0.0.

* BDL = All values were below the detection limits listed in the Range.

Table III Ii: cont.

Statistical Description of the Water Chemistry Parameters Measured at Five Sites Along Upper Three Runs Creek, Savannah River Plant, Aiken County, South Carolina. August 1987 - October 1988.

SITE #3

Parameter	Mean [a]	Standard Deviation	Range
pH	6.23	0.51	5.2 - 7.2
Dissolved Oxygen	9.12	1.5	6.9 - 12.0
Temperature	15.8	5.1	6.0 - 22.5
Conductivity	23.4	5.49	12 - 32
Chromium	<0.005	----	<0.005 - 0.005
Copper	BDL *	----	<0.005 - <0.05
Lead	BDL *	----	<0.001 - 0.01
Manganese	0.0249	0.0180	<0.005 - 0.069
Mercury	BDL *	----	<0.5
Sodium	1.613	0.2899	1.1 - 2.4
Uranium	<0.001	----	<0.001 - 0.003
Zinc	0.0219	0.0517	<0.005 - 0.207
Dissolved Chromium	BDL *	----	<0.005 - <0.05
Dissolved Copper	<0.005	----	<0.005 - 0.005
Dissolved Lead	<0.005	----	<0.005 - 0.002
Dissolved Manganese	0.014	0.0165	<0.005 - 0.066
Dissolved Mercury	BDL *	----	<0.5
Dissolved Sodium	1.66	0.259	1.1 - 2.2
Dissolved Uranium	BDL *	----	<0.001 - <1
Dissolved Zinc	0.0364	0.0649	<0.05 - 0.265
Nitrate Nitrogen	0.32	0.947	<0.2 - 0.5
Nitrite Nitrogen	BDL *	----	<0.01
Ortho Phosphate as Phosphorus	0.0177	0.0094	<0.01 - 0.03
Total Phosphate as Phosphorus	0.0323	0.0132	0.02 - 0.06
Ammonia Nitrogen	BDL *	----	<0.1 - <1
Hardness	6.957	1.968	4 - 12
Alkalinity	4.773	1.58	2 - 8
Residual Chlorine	BDL *	----	<0.05 - <0.1
Tot. Suspended Solids	4.93	3.73	<4 - 11
Kerosene	BDL *	----	<100
Tri-Phosphate	BDL *	----	<50 - <100
Mercury Sediment	BDL *	----	<50

[a] In calculating the Mean and Standard Deviation, results below the detection limit were treated as 0.0.

* BDL = All values were below the detection limits listed in the Range.

Table III Ii: cont.

Statistical Description of the Water Chemistry Parameters Measured at Five Sites Along Upper Three Runs Creek, Savannah River Plant, Aiken County, South Carolina. August 1987 - October 1988.

SITE #4

Parameter	Mean [a]	Standard Deviation	Range
pH	6.14	0.57	5.0 - 7.3
Dissolved Oxygen	9.45	1.6	7.8 - 11.4
Temperature	15.6	5.1	6.0 - 22.5
Conductivity	23.067	4.73	12 - 30
Chromium	0.0004	0.0126	<0.005 - 0.049
Copper	0.001	0.0026	<0.005 - 0.008
Lead	BDL *	----	<0.001 - <0.01
Manganese	0.0271	0.019	<0.005 - 0.077
Mercury	BDL *	----	<0.5
Sodium	1.64	0.206	1.2 - 2.0
Uranium	<0.001	----	<0.001 - 0.001
Zinc	0.0321	0.0705	<0.005 - 0.261
Dissolved Chromium	<0.005	----	<0.005 - 0.009
Dissolved Copper	<0.005	----	<0.005 - 0.010
Dissolved Lead	<0.005	----	<0.005 - 0.001
Dissolved Manganese	0.0156	0.025	<0.005 - 0.104
Dissolved Mercury	BDL *	----	<0.5
Dissolved Sodium	1.647	0.2386	1.3 - 2.1
Dissolved Uranium	BDL *	----	<0.001 - <1
Dissolved Zinc	0.0574	0.0834	<0.005 - 0.280
Nitrate Nitrogen	0.2067	0.534	<0.2 - 0.3
Nitrite Nitrogen	BDL *	----	<0.01
Ortho Phosphate as Phosphorus	0.020	0.0113	<0.01 - 0.04
Total Phosphate as Phosphorus	0.0356	0.0184	<0.25 - 0.07
Ammonia Nitrogen	BDL *	----	<0.1 - <1
Hardness	7.214	1.968	5 - 11
Alkalinity	4.24	1.097	1 - 5.4
Residual Chlorine	BDL *	----	<0.05 - <0.1
Tot. Suspended Solids	6.73	4.183	<5 - 14
Kerosene	BDL *	----	<100
Tri-Phosphate	BDL *	----	<50 - <100
Mercury Sediment	BDL *	----	<50

[a] In calculating the Mean and Standard Deviation, results below the detection limit were treated as 0.0.

* BDL = All values were below the detection limits listed in the Range.

Table III 1: cont.

Statistical Description of the Water Chemistry Parameters Measured at Five Sites Along Upper Three Runs Creek, Savannah River Plant, Aiken County, South Carolina. August 1987 - October 1988.

SITE #5

Parameter	Mean [a]	Standard Deviation	Range
pH	6.20	0.64	5.2 - 7.6
Dissolved Oxygen	9.4	1.7	7.5 - 13.8
Temperature	15.4	5.0	6.0 - 22.0
Conductivity	20.6	8.781	19 - 30
Chromium	<0.005	----	<0.005 - 0.017
Copper	<0.005	----	<0.005 - 0.005
Lead	BDL *	----	<0.001 - <0.01
Manganese	0.0295	0.0187	<0.005 - 0.079
Mercury	BDL *	----	<0.5 - <1
Sodium	1.547	0.2445	1.1 - 2.1
Uranium	<0.001	----	<0.001 - 0.001
Zinc	0.0404	0.097	<0.005 - 0.380
Dissolved Chromium	<0.005	----	<0.005 - 0.008
Dissolved Copper	<0.005	----	<0.005 - 0.007
Dissolved Lead	BDL *	----	<0.001 - <0.01
Dissolved Manganese	0.0129	0.016	<0.005 - 0.067
Dissolved Mercury	BDL *	----	<0.5 - <1
Dissolved Sodium	1.687	0.256	1.4 - 2.3
Dissolved Uranium	0.004	0.015	<0.001 - <1
Dissolved Zinc	0.0518	0.097	<0.05 - 0.38
Nitrate Nitrogen	0.24	0.689	<0.2 - 2.7
Nitrite Nitrogen	BDL *	----	<0.01
Ortho Phosphate as Phosphorus	0.023	0.016	<0.01 - 0.06
Total Phosphate as Phosphorus	0.042	0.0156	0.02 - 0.07
Ammonia Nitrogen	BDL *	----	<0.01 - <1
Hardness	7	1.797	5 - 12
Alkalinity	4.447	0.716	3 - 6
Residual Chlorine	BDL *	----	<0.05 - <0.1
Tot. Suspended Solids	9.933	5.99	<5 - 22
Kerosene	BDL *	----	<100
Tri-Phosphate	BDL *	----	<50 - <100
Mercury Sediment	BDL *	----	<50

[a] In calculating the Mean and Standard Deviation, results below the detection limit were treated as 0.0.

* BDL = All values were below the detection limits listed in the Range.

Table III 11: cont.

Statistical Description of the Water Chemistry Parameters Measured at Five Sites Along Upper Three Runs Creek, Savannah River Plant, Aiken County, South Carolina, August 1987 - October 1988.

TIM'S BRANCH

Parameter	Mean [a]	Standard Deviation	Range
pH	6.42	0.46	5.6 - 7.5
Dissolved Oxygen	9.4	1.3	7.5 - 12.1
Temperature	15.6	5.5	5.0 - 24
Chromium	<0.005	----	<0.005 - 0.015
Copper	<0.005	----	<0.005 - 0.006
Mercury	BDL *	----	<0.5
Zinc	0.0263		<0.005 - 0.245
Nitrate Nitrogen	1.0143	1.488	0.3 - 6.1
Total Phosphate as Phosphorus	0.066	0.0422	0.03 - 0.18
Mercury Sediment	BDL *	----	<50

[a] In calculating the Mean and Standard Deviation, results below the detection limit were treated as 0.0.

* BDL = All values were below the detection limits listed in the Range.

TABLE III iii

Water Chemistry Parameters
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Post-Operational Data
Site 1

Parameter (mg/L)	Mean[a]	Standard Deviation
Conductivity	21.813	3.885
Chromium	BDL*	
Copper	BDL*	
Lead	BDL*	
Manganese	0.026	0.014
Mercury	BDL*	
Sodium	1.423	0.135
Uranium	0.0009	0.0023
Zinc	0.027	0.061
Dissolved Chromium	BDL*	
Dissolved Copper	BDL*	
Dissolved Lead	BDL*	
Dissolved Manganese	0.010	0.015
Dissolved Mercury	BDL*	
Dissolved Sodium	1.471	0.134
Dissolved Uranium	0.0011	0.0030
Dissolved Zinc	0.036	0.066
Nitrate Nitrogen	0.138	0.080
Nitrite Nitrogen	BDL*	
Ortho Phosphate as Phosphorus	0.029	0.073
Total Phosphate as Phosphorus	0.029	0.022
Ammonia Nitrogen	0.014	0.036
Hardness	6.976	1.230
Alkalinity	5.076	2.796
Total Suspended Solids	4.500	5.007
Kerosene	BDL*	
Tributyl Phosphate	BDL*	
Residual Chlorine	BDL*	
Sediment Mercury	0.0047	0.0102

a. In calculating the mean and standard deviation, results below the detection limit were treated as 0.

* BDL = below detection limits.

TABLE III Iii

Water Chemistry Parameters
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Post-Operational Data
Site 2

Parameter (mg/L)	Mean[a]	Standard Deviation
Conductivity	21.813	3.799
Chromium	BDL*	
Copper	0.001	0.003
Lead	0.001	0.002
Manganese	0.027	0.014
Mercury	BDL*	
Sodium	1.602	0.336
Uranium	0.0014	0.003
Zinc	0.035	0.058
Dissolved Chromium	BDL*	
Dissolved Copper	0.001	0.002
Dissolved Lead	BDL*	
Dissolved Manganese	0.012	0.018
Dissolved Mercury	BDL*	
Dissolved Sodium	1.615	0.248
Dissolved Uranium	0.0008	0.002
Dissolved Zinc	0.053	0.110
Nitrate Nitrogen	0.219	0.187
Nitrite Nitrogen	BDL*	
Ortho Phosphate as Phosphorus	0.028	0.073
Total Phosphate as Phosphorus	0.043	0.053
Ammonia Nitrogen	0.001	0.003
Hardness	7.734	1.681
Alkalinity	4.286	2.236
Total Suspended Solids	4.750	7.335
Kerosene	BDL*	
Tributyl Phosphate	BDL*	
Residual Chlorine	BDL*	
Sediment Mercury	0.016	0.036

a. In calculating the mean and standard deviation, results below the detection limit were treated as 0.

* BDL = below detection limits.

TABLE III Iii

Water Chemistry Parameters
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Post-Operational Data
Site 3

Parameter (mg/L)	Mean[a]	Standard Deviation
Conductivity	22.313	3.894
Chromium	BDL*	
Copper	BDL*	
Lead	BDL*	
Manganese	0.025	0.015
Mercury	BDL*	
Sodium	1.718	0.278
Uranium	0.003	0.007
Zinc	0.046	0.099
Dissolved Chromium	0.001	0.003
Dissolved Copper	0.001	0.003
Dissolved Lead	BDL*	
Dissolved Manganese	0.008	0.009
Dissolved Mercury	BDL*	
Dissolved Sodium	1.708	0.257
Dissolved Uranium	0.0011	0.0032
Dissolved Zinc	0.046	0.112
Nitrate Nitrogen	0.214	0.184
Nitrite Nitrogen	BDL*	
Ortho Phosphate as Phosphorus	0.028	0.066
Total Phosphate as Phosphorus	0.030	0.032
Ammonia Nitrogen	0.001	0.003
Hardness	7.166	1.454
Alkalinity	4.881	1.761
Total Suspended Solids	4.375	4.911
Kerosene	BDL*	
Tributyl Phosphate	BDL*	
Residual Chlorine	BDL*	
Sediment Mercury	0.0019	0.0075

a. In calculating the mean and standard deviation, results below the detection limit were treated as 0.

* BDL = below detection limits.

TABLE III iii

Water Chemistry Parameters
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Post-Operational Data
Site 4

Parameter (mg/L)	Mean[a]	Standard Deviation
Conductivity	22.313	4.254
Chromium	BDL*	
Copper	BDL*	
Lead	0.001	0.003
Manganese	0.028	0.016
Mercury	BDL*	
Sodium	1.713	0.275
Uranium	0.0025	0.0053
Zinc	0.026	0.039
Dissolved Chromium	0.001	0.005
Dissolved Copper	0.001	0.003
Dissolved Lead	BDL*	
Dissolved Manganese	0.013	0.013
Dissolved Mercury	BDL*	
Dissolved Sodium	1.747	0.281
Dissolved Uranium	0.0011	0.0027
Dissolved Zinc	0.058	0.108
Nitrate Nitrogen	0.219	0.197
Nitrite Nitrogen	BDL*	
Ortho Phosphate as Phosphorus	0.024	0.056
Total Phosphate as Phosphorus	0.048	0.048
Ammonia Nitrogen	BDL*	
Hardness	7.295	1.277
Alkalinity	4.688	1.689
Total Suspended Solids	5.750	4.420
Kerosene	BDL*	
Tributyl Phosphate	BDL*	
Residual Chlorine	BDL*	
Sediment Mercury	0.0039	0.0158

a. In calculating the mean and standard deviation, results below the detection limit were treated as 0.

* BDL = below detection limits.

TABLE III Iii

Water Chemistry Parameters
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Post-Operational Data
Site 5

Parameter (mg/L)	Mean[a]	Standard Deviation
Conductivity	22.188	4.086
Chromium	BDL*	
Copper	BDL*	
Lead	BDL*	
Manganese **	0.027	0.012
Mercury	BDL*	
Sodium	1.714	0.269
Uranium	0.0028	0.0066
Zinc	0.054	0.091
Dissolved Chromium	0.000	0.000
Dissolved Copper	0.001	0.003
Dissolved Lead	BDL*	
Dissolved Manganese	0.008	0.010
Dissolved Mercury	0.0156	0.0625
Dissolved Sodium	1.789	0.293
Dissolved Uranium	0.0024	0.0062
Dissolved Zinc	0.036	0.094
Nitrate Nitrogen	0.238	0.213
Nitrite Nitrogen	BDL*	
Ortho Phosphate as Phosphorus	0.052	0.171
Total Phosphate as Phosphorus	0.032	0.026
Ammonia Nitrogen	0.025	0.100
Hardness	7.043	1.334
Alkalinity	5.013	1.899
Total Suspended Solids	6.250	3.512
Kerosene	BDL*	
Tributyl Phosphate	BDL*	
Residual Chlorine	BDL*	
Sediment Mercury	0.004	0.016

a. In calculating the mean and standard deviation, results below the detection limit were treated as 0.

* BDL = below detection limits.

TABLE III III

Water Chemistry Parameters
Upper Three Runs Creek
Savannah River Site, Aiken County, South Carolina
Post-Operational Data
Tims Branch

Parameter (mg/L)	Mean [a]	Standard Deviation
Chromium	BDL*	
Copper	BDL*	
Mercury	BDL*	
Zinc	0.040	0.059
Nitrate Nitrogen	0.675	0.478
Total Phosphate as Phosphorus	0.059	0.044

a. In calculating the mean and standard deviation, results below the detection limit were treated as 0.

* BDL = below detection limits.

IV. SUMMARY

The biological and chemical assessment conducted subsequent to the start-up of effluent release by the F/H Area Effluent Treatment Facility of the Savannah River Site indicated the entire stream reach under investigation continues to support a diverse, species rich, well balanced macroinvertebrate community indicative of excellent water quality. However, there were significant changes at all sites in the macroinvertebrate community of Upper Three Runs Creek during 1988 and 1989. The most outstanding shifts were in species richness and numbers of organisms collected, which declined substantially in the summer of 1988 and remained suppressed throughout 1989. Most of this observed decline involved midges. Species richness among the pollution intolerant EPT taxa (Ephemeroptera, Plecoptera and Trichoptera) did not decrease significantly, and the biotic index indicated a greater proportion of pollution intolerant organisms. Post-operational proportions of stoneflies and caddisflies actually increased. It is important to note that the biomass of macroinvertebrates collected in the stream did not decrease over time. The decreased species richness and populations of midges was reflected in other indices compared pre- and post-operationally. Specifically, there were declines in density of macroinvertebrates, the Shannon-Weaver diversity, the proportions of collector-gatherers and increases in the proportions of collector-filterers.

The observed changes in the macroinvertebrate community of the stream during post-operational collection periods indicate there has been an adverse impact. As the stream community remains fundamentally intact, in the sense of remaining rich in species, balanced and pollution intolerant, the impact should probably be classified as slight. In as much as the impact was noted at all sites, including the control, and appeared to begin several months prior to the start-up of the F/H Area ETF effluent releases, the impact should not be attributed to the F/H Area ETF.

Comparisons between the control and downstream sites during post-operational sampling indicated several minor shifts in the macroinvertebrate community. No significant differences were noted for any biological parameter when comparing site 1 (the control) to site 2, site 3 or site 5. Site 4 was found to have more midges, lower macroinvertebrate biomass, an improved biotic index and more collector-filterers. These differences are likely related to habitat and are unlikely to be correlated with effluent releases by the F/H/ area ETF facility. Three water chemistry parameters were measured at higher levels at downstream sites than at the control site; nitrate nitrogen, uranium and sediment mercury. Nitrate nitrogen levels were also found to be elevated in Tim's Branch, which suggests that tributary may be the source of elevated nitrate at downstream Upper Three Runs Creek sites. Sediment mercury and uranium were not sampled in Tim's Branch.

Considering both temporal and spatial comparisons of the data, there appears to be no impact upon the biological community of the stream attributable to the F/H ETF operations.

Species Richness:

The mean species richness per site for quantitative sampling declined from 44.7 pre-operationally to 33.9 post-operationally. The decrease was significant. No significant differences among sites in the number of species collected quantitatively per site were found. The two post-operational qualitative collections yielded 167 species, a high species richness value indicative of excellent water quality. The number of species collected per replicate also declined post-operationally, from 20.5 pre-operationally to 15.4. Post-operational sampling also showed no significant differences among sites for the number of species per replicate.

Total # of Organisms/Mean Density:

5,330 aquatic macroinvertebrates were collected during the post-operational sampling periods. This represented 213.2 organisms per site (348.5/m2) retrieved in quantitative sampling. This was a significant decrease from the mean of 417.2 organisms/site (591.2/m2) collected pre-operationally. Statistical analysis by non-parametric procedures indicated that the mean number of organisms per site (and the mean density of organisms) showed no significant differences among sites. Post-operationally, the highest numbers of organisms were collected during January 1989.

Shannon-Weaver Diversity:

At an average level of 4.27, the measured post-operational diversity of the macroinvertebrate community was high, although significantly reduced from the pre-operational mean of 4.46. There was relatively little variation by site, with no site having a community with a mean diversity significantly different than that at other sites. Diversity did vary on a seasonal basis, and was generally lower during fall sampling and highest during spring sampling. Even the low values, however, were indicative of excellent diversity. The stream community at all sites appears to be well balanced.

Equitability:

Post-operational equitability of the macroinvertebrate community was good at all sites, averaging 0.85. All values equaled or exceeded a value of 0.5 in equitability. No significant differences in the mean equitability among sites were found. Post-operational equitability values did not differ significantly from pre-operational values.

Biomass:

The average biomass collected post-operationally per site per sampling period was 0.4615 g per m2. Among sites, the mean biomass did not vary significantly except at site 4, which had significantly lower biomass values both pre-operationally and post-operationally. Biomass did increase during the winter and spring as many stoneflies, mayflies and caddisflies approached and reached emergence and maturity. Biomass did not change significantly when comparing pre-operational and post-operational data.

Biotic Index:

Overall, the biotic index values obtained were suggestive of good water quality. but not low enough to suggest excellent water quality. This is likely a function of the Biotic Index, designed upon data from northern streams less dominated by midges. It seems likely this index under estimates the presence of pollution intolerant species in this system. This is especially true of the orthoclad midges, which are generally given a poor biotic index rating. Analysis of the data indicated significant differences among site means and between pre-operational and post-operational site means. The biotic index was improved during post-operational sampling (due to fewer midges), especially at site 4.

EPT Index:

The average number of mayfly, stonefly and caddisfly species collected quantitatively per site in post-operational sampling was 14.7, and ranged from 10 to 20. Site 3 exhibited the lowest EPT average. However, the EPT index did not change significantly either among sites or between pre-operational and post-operational sample collections.

Functional Group Analysis:

The macroinvertebrate community of Upper Three Runs Creek in terms of population numbers, is dominated by collectors (65% pre-operationally and 61.8% post-operationally). Predators are dominant in analysis by biomass (70.6% pre-operationally and 60.6% post-operationally). Over time, the percentage of collector-gatherers decreased significantly, while the percentage of collector-filterers increased. This same trend was noted at downstream sites as compared to the control site. Proportions of predators decreased in terms of biomass but increased in terms of population numbers. Shredder-herbivores increased slightly post-operationally, at all sites.

Dominant Species:

Orthoclad midges were the dominant organisms collected by multiplate artificial substrate samplers, particularly the midge *Rheocricotopus robacki*. Common non-midge species included *Hydropsyche elissoma* (Caddisfly) and *Simulium jonesi/dixiense* (blackfly). All these rheophilic species were collected in large numbers. Qualitative sampling showed different species dominant in non-snag habitats. In mud/detritus and leaf pack habitats dominant species included orthoclad and chironomini midges, leptophlebiid mayflies and *Phylocentropus* caddisflies. Sand habitats were dominated by midges characteristic of such an environment, e.g., *Genus* nr. *kloosia*, *Cladotanytarsus* and *Rheosmittia*, as well as numerous other orthoclad midges. Due to the patchy nature of habitat distribution at individual sites, there were some differences in dominant species among sites, but no marked shifts were noted.

Water Quality:

Thirty-one parameters were analyzed monthly on water samples collected from the five sites on Upper Three Runs Creek. Only sediment mercury, uranium and nitrate nitrogen were measured at elevated levels downstream. The difference in nitrate nitrogen may be attributed to nutrient addition from Tim's Branch, rather than the F/H ETF effluent. Detectable sediment mercury was encountered with increasing frequency in 1989, although mercury was not detected in water samples.

All other measured parameters exhibited similar concentrations upstream and downstream, with no observed impact by the F/H area ETF.

REFERENCES

1. Berner L. and M. Pescador, 1988. The Mayflies of Florida. University Presses of Florida, Gainesville, Florida, 415 pp.

2. Bode, R.W. 1983. Larvae of North American Eukiefferiella and Tvetenia (Diptera:Chiromomidae). NYS Mus. Bull. 452:1 - 40.

3. Brigham, A.R., W.U. Brigham, and A. Gnilka (eds.) 1982. The Aquatic Insects and Oligochaetes of North and South Carolina. Midwest Aquatic Enterprises, Mahomet, IL. 837 pp.

4. Caldwell, B.A. 1986. Description of the Immature Stages and Adult Female of Unniella multivirga Saether (Diptera:Chiromonidae) with Comments on Phylogeny. Aquatic Insects.

5. Claasen, P.W. 1931. Plecoptera Nymphs of America (North of Mexico). Thomas Say Found. Ent. Soc. Am. 3:1 - 199.

6. Epler, J.H. 1987. Biosystematics of the Genus Dicrotendipes Kieffer, 1913, (Diptera:Chironomidae:Chironominae) of the World. Mem. Amer. Entom. Soc. 36:1 - 214.

7. Fitzpatrick, J.F. 1983. How to Know the Freshwater Crustacea. Wm. C. Brown Co. Publishers, Dubuque, Iowa. 227 pp.

8. Gelhaus, John. 1986. Larvae of the Crane Fly Genus Tipula. Univ. Kansas. Science Bull.

9. Gilbert, R.O. 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold Company, New York. 320 pp.

10. Grodhaus, G. 1987. Endochironomus Kieffer, Tribelos Townes, Synendotendipes n. gen., and Endotribelos, n. gen. (Diptera:Chironomidae) of the Nearctic region. J. Kansas Ent. Soc. 60:167 - 247.

11. Hilsenhoff, William L., 1987. An Improved Biotic Index of Organic Stream Polution. Great Lakes Entomologist. 20(1):31 - 39.

12. Hirvenoja, M. 1973. Revision der Gattung Cricotopus van der wulp und ihrer Verwandtem (Diptera, Chironomidae). Ann, Zool. Fenn. 10:1 - 363.

REFERENCES

13. Hudson, P.L., D.R. Lenat, B.A. Caldwell and D. Smith. In Press. Chironomidae of the Southeastern United States: A Checklist of Species with Notes on Biology, Distribution and Habitat. Fish and Wildlife Research Series - U.S. Dept. of Interior.

14. Holsinger, J.R. 1972. The Freshwater Amphipod Crustaceans (Gammaridae) of North America. EPA Identification Manual #5.

15. Johannsen, O.A. 1937 - 1939. Aquatic Diptera I-IV. Cornell University. Agric. Exp. Stn.

16. Klemm, D.J. 1985. A Guide to the Freshwater Annelida (Polychaeta, Naidid and Tubificid Oligochaeta, and Hirudinea) of North America. Kendall/Hunt Publishing Co., Dubuque Iowa. 198 pp.

17. Lewis, P.A. 1974. Taxonomy and Ecology of Stenonema Mayflies (Heptageniidae:Ephemeroptera). U.S. EPA, Environmental Monitoring Ser. Rept. EPA-670/4-74-006. 81 pp.

18. McAlpine et al. 1981. Manual of Neartic Diptera, Vol. 1. Res. Branch, Agric. Can. Monogr. 27. 674 pp.

19. Merritt, R.W. and K.W. Cummins (eds.). 1984. An Introduction to Aquatic Insects of North America. Kendall/Hunt Publishing Co., Dubuque, Iowa. 722 pp.

20. Morihara, D.K. and W.P. McCafferty. 1979. The Baetis Larvae of North America (Emphemeropter:Baetidae). Trans. Am. Ent. Soc. 105:139 - 221.

21. Morse, J.C., J.W. Chapin, D.D. Herlong and R.S. Harvey. 1980. Aquatic Insects of Upper Three Runs Creek, Savannah River Plant, South Carolina. Part I: Orders Other than Diptera. J. Georgia Entomol. Soc. 15(1):73 - 101.

22. Morse et al. 1985. Aquatic Insects of Upper Three Runs Creek, Savannah River Plant, South Carolina. Part II: Diptera. J. Georgia Entomol. Soc.

23. Needham, J.G., J.R. Traver, and Y.C. HSU. 1935. The Biology of Mayflies with a Systematic Account of North American Species. Comstock, Ithaca. 759 pp.

REFERENCES

24. Needham, J.G. and M.J. Westfall, Jr. 1955. A Manual of the Dragonflies on North America (Anisoptera) Including the Greater Antillies and the Provinces of the Mexican Border. Univ. Calif. Press, Berkley. 615 pp.

25. Oliver, D.R. and Roussel, M.E. 1983. Redescription of Brillia Kieffer (Diptera:Chironomidae) with Descriptions of Neartic Species. Can. Ent. 115:257 - 279.

26. Pennak, R.W. 1978. Freshwater Invertebrates of the United States (2nd Ed.). J. Wiley and Sons, NY. 803 pp.

27. Roback, S.S. 1981. The Immature Chironomids of the Eastern United States. V. Pentaneurini - Thienemannimyia group. Proc, Acad, Nat. Sci. Philad. 133:73 - 128.

28. Roback, S.S. 1985. The Immature Chironomids of the Eastern United States. VI. Pentaneurini - Genus Ablabesmyia.Proc. Acad. Nat. Sci. Philad. 137:153 - 213.

29. Ross, H.H. 1944. The Caddisflies, or Trichoptera, of Illinois. Bull. Ill. Nat. Hist. Surv. 23:1 - 326.

30. Saether, O.A. 1977. Taxonomic Studies on Chironomidae:Nanocladius, Pseudochironomus and the Harnischia complex. Bull. Fish. Res. Bd. Can. 196:1 - 143.

31. Saether, O.A. and J.E. Sublette 1983. A Review of the Genera Doithrix n. gen., Georthocladius Strenzke, Parachaetocladius Wulker, and Pseudorthocladiuss Goethebuer. (Diptera:Chironomidae, Orthocladinae). Ent. Scand. Suppl. 20:1 - 100.

32. Saether, O.A. 1985. A Review of Rheocricotopus Thienemann and Harnisch, 1932, with the Description of Three New Species (Diptera, Chironomidae). Spixiana Suppl. 11:59 - 108.

REFERENCES

33. Snoddy, E.L. and R. Noblet. 1976. Identification of the Immature Black Flies (Dipter:Simuliidae) of the Southeastern U.S. with Some Aspects of the Adult Role in Transmission of Leucocyytozoon smithi to Turkeys. S.C. Agric. Exp. Sta., Clemson, S.C. Techn. Bull. 1057. 58pp.

34. Soponis, A.R. 1977. A Review of the Neartic Species of Orthocladius (Orthocladius) Van Der Wulp (Diptera:Chironomidae). Mem. Ent. Soc. Can. 102:1 - 187.

35. Schefter, P.W. and G.B. Wiggins. 1986. A Systematic Study of the Neartic Larvae of the Hydropsyche Morosa Group (Trichoptera:Hydropsychidae). Alger Press, Toronto, Canada. 94 pp.

36. Stewart, K. W. and B.P. Stark. 1988. Nymphs of the North American Stonefly Genera (Plecoptera). Entomol. Society of America.

37. Thompson, F.G. 1984. The Freshwater Snails of Florida. A manual for identification. University Presses of Florida, Gainesville, Florida. 94 pp.

38. Usinger, R.L., Ed. 1956. Aquatic Insects of California. University of California Press, Los Angeles, California. 508 pp.

39. Weber, C.I. (Ed.). 1973. Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents. Cincinnati: Nat. Envir. Res. Center. U.S. Environmental Protection Agency. 176 pp.

40. Wiederholm, T. (Ed.) 1983. Chironomidae of the Holarctic Region. Keys and diagnoses. Part 1 - Larvae. Ent. Scand. Suppl. 19:1 - 457.

41. Wiederholm, T. (Ed.) 1986. Chironomidae of the Holarctic Region. Keys and diagnoses. Part 2 - Pupae. Ent. Scand. Suppl. 28:1 - 482.

42. Wiggins, G.B. 1977. Larvae of the North American Caddisfly Genera. Univ. Toronto Press, Toronto. 401 pp.

43. Williams, W.D. 1972. Freshwater Isopods (Asellidae) of North America. U.S. EPA Indentification Manual #7.

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