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MEIOFAUNA AND MACROFAUNA IN SIX HEADWATER STREAMS OF THE ALAFIA RIVER, FLORIDA

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MEIOFAUNA AND MACROFAUNA IN SIX HEADWATER STREAMS OF THE ALAFIA RIVER, FLORIDA, 1993-1994

FINAL REPORT

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DISCLAIMER

PERSPECTIVE

The potential impact of mining and reclamation activities on the environmental health of rivers and streams is of considerable public interest. Surface mining for phosphate can directly affect watersheds and small headwater streams. There may also be indirect effects on larger streams. Agriculture and residential use of lands can also impact streams. The purpose of this project was to compare benthic invertebrates in reclaimed headwater streams and unmined "natural" headwater streams of the Alafia River Basin in relation to the physical, chemical, and biological characteristics of the headwaters. The ultimate goal of this and related research is to develop information that will better enable the phosphate mining industry to reclaim and restore streams following mining activities.

Other related FIPR projects include:

"Sink Branch: Stream Relocation and Reclamation by the Florida Phosphate Industry," FIPR Publication No. 03-033-060 (1987).

"Techniques and Guidelines for Reclamation of Phosphate Mined Lands," FIPR Publication No. 03-044-095 (1991). Especially note: Chap. 1, "Stream and Drainage Basin Characteristics;" Chap. 2, "Drainage Basins and Regional Landscape Associations;" and Chap. 3, "Floodplain Vegetation of Small Stream Watersheds."

"An Evaluation of Benthic Meiofauna and Macrofauna as Success Criteria for Reclaimed Wetlands," FIPR Project No. 88-03-086R (Final Report submitted Sept. 1997).

"Hydrologic Investigation of the Phosphate Mined Upper Saddle Creek Watershed," FIPR Project No. 95-03-118 (Three year project scheduled for completion in March 1999).

Steven G. Richardson
FIPR Reclamation Research Director

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EXECUTIVE SUMMARY

It is often assumed that changes in the biota of a stream, over time and location, are reflections of changes in the physical environment. But recent studies have shown that land use in the surrounding drainage basin may be equally or more important in influencing invertebrate assemblages. Information on the temporal and spatial distributions and abundances of stream invertebrates in Florida is lacking, especially in the peninsular portion of the state where low topographic relief and variable discharge rates prevail. The principle objective of this study was to compare the distributions and abundances of macrofauna and meiofauna (organisms smaller than 500 µm in size) in headwater streams of the Alafia River with different land uses in the drainage basins, i.e., reclaimed basins, basins receiving runoff from phosphate mining, and basins receiving runoff from agriculture and/or residential communities. Meiofaunal organisms have not been studied at all in Florida, and they may have profound influence upon the trophic dynamics of stream patches. Thus, we decided to look at the seasonal and spatial variability of species assemblages in different types of headwater streams. A secondary goal, assuming that we would find differences between streams, was to investigate possible causes of the variability.

We sampled two sites, upstream and downstream, on each of six headwater streams at quarterly intervals; two streams were reclaimed following mining, two were not mined but were influenced by runoff from phosphate mined lands, and two were disturbed either by agriculture or residential developments. Meiofauna and smaller members of the macrofauna were sampled with a core sampler ($n = 16$ for each stream site on each sampling date), and larger macroinvertebrates from all habitat patches were collected with dip nets. Hester-Dendy samplers, recommended by U.S. EPA, also were suspended for four week intervals. Physical-Chemical parameters were measured concurrently with benthic sampling.

Annual mean densities of invertebrates at the twelve stream sites ranged from 20,896 to 175,212 m^{-2}, and the mean for all twelve stream sites was 56,492 m^{-2}. There was considerable variation among seasons, fall and winter densities were 2.4-fold greater than those of spring and summer. The reclaimed streams and one agriculture influenced stream had low annual mean densities (20,896-39,621 m^{-2}). On a numerical basis, meiofauna comprised 62% of the fauna of the six streams. The reclaimed streams had higher percentages (68-91%) than mine-influenced (55-60%) or human disturbed streams (43-62%). The taxonomic composition of samples from the reclaimed streams was dominated by Crustacea (up to 75-85% of total densities). The other two types of streams were dominated by species of Chironomidae (Diptera) and Annelida which comprised 71-92% of the total densities. Numbers of taxa per season for core samples ranged from 90-127 and the total for the year was 187 taxa. The Czekanowski-Dice-Sorensen similarity index showed that the reclaimed streams were quite similar to each other, but markedly dissimilar from the other stream types. Diversity, species richness and Florida Metric indices also showed marked differences between streams with different land uses; reclaimed streams had low values.

The Hester Dendy samplers, utilized to collect drifting organisms, showed no differences in densities between stream types ($p = 0.221$). The drift fauna (both macro- and microinvertebrates) was comprised predominately of Chironomidae, Crustacea and Annelida; reclaimed streams had significantly higher numbers of Crustacea than the other streams. Similarity and diversity indices were lower for Hester Dendy samples than for core samples, and there were no clear groupings based upon land use. The shallow nature of the Alafia River headwater streams and associated water level fluctuations (within and between seasonal samples) caused much of the variability in Hester Dendy data. We feel that these samplers should not be used in lower reaches, 1st and 2nd order streams, of streams in peninsular Florida. In contrast, the dip net sampling collected many of the larger insect taxa (Odonata, Hemiptera and Coleoptera) that were not found in core or Hester Dendy samples; this added another 24 taxa to our list (187 + 24 = 211 taxa).

Our study of the physical-chemical characteristics of the Alafia River headwater streams showed marked variation between seasons which adversely affected invertebrate distributions and abundances. Ranges of seasonal means for stream flow parameters were: depth = 0 to 3 1.6 cm, current velocity = 0 to 0.27 m sec^{-1}, and discharge = 0 to 0.155 m^3 sec^{-1}; three sampling sites were dry during the spring . Percent organic matter in the substratum where benthic samples were collected, showed only minor variation within stream sites, but the reclaimed streams had significantly higher concentrations than other streams. Annual means for percent organic matter ranged from 20-50% at reclaimed sites whereas other stream sites had means of <10%. Conductivity, turbidity, alkalinity and dissolved oxygen showed large variations between streams while pH and temperature were quite uniform. Nitrogen compounds, showed few significant differences between streams within seasons, but there were marked differences in annual means; spring had the lowest values. Phosphorus compound means were similar between seasons. Iron and manganese concentrations were much higher in the reclaimed streams with peaks of 4,699 µg l^{-1} and 853 µg l^{-1} respectively.

Best subset regression was used seasonally at each of the twelve sampling sites to determine whether the three independent variables (percent organic matter, current velocity and depth) measured concurrently with the collection of benthic samples had significant influence upon total densities of invertebrates. A total of 14 of 45 models (31.1%) was significant ($p < 0.05$) but all R^2 values were less than 0.45, i.e., only 45% of the variability in total density was explained by the independent variables. Organic matter occurred in 8 models, current velocity in 4 and depth in 3. In another multiple regression, we incorporated all seasonal data (14 physical-chemical variables and total densities of invertebrates) into a single data set, the only significant variable was dissolved oxygen ($p = 0.0002$, $R^2 = 0.272$). However, because of the small sample sizes in this regression model, the results were not expected to account for large percentages of the variability, unless there were profound and consistent differences between stream sites. Our data indicated that this was not true, so the models can only be used to get insight into which variables warrant further consideration.

The correlation matrix comparing seasonal mean densities of invertebrates with the 14 physical-chemical variables showed four variables with significant ($p < 0.05$) relationships. Dissolved oxygen correlated positively ($r = 0.52$, $p = 0.0002$) with total density, and iron ($r = -0.40$, $p = 0.007$), total nitrogen ($r = -0.39$, $p = 0.008$), and percent organic matter ($r = -0.29$, $p = 0.05$) correlated negatively.

Influences of other factors that could cause the differences between the reclaimed and non-reclaimed streams are discussed; these include: 1) physical-chemical factors, 2) substrate type and refugia, and 3) spates and droughts. We believe that the high percentages of crustaceans in the reclaimed streams were caused by low predator abundances and utilization of the bacteria associated with organic matter as food. Low dissolved oxygen during the summer appeared to cause the small densities and different taxa of Chironomidae in Hall's Branch (reclaimed stream). Low flow rates and the absence of spates in the reclaimed streams, failed to remove the large quantities of particulate organic matter (POM) which causes the low dissolved oxygen. Drought in the spring at both Hall's Branch sites and Poley Creek-East eliminated the fauna but recolonization at the latter was much more rapid because of higher discharge rates. Recommendations are made for possible procedures to increase invertebrate densities in reclaimed streams through modifications of flow patterns, geomorphology and habitat patch dynamics.

CHAPTER 1, DISTRIBUTION AND ABUNDANCE

Introduction

A stream may be viewed as a system of mosaic patches characterized by different environmental conditions (Pringle et al., 1988). Patches with similar hydraulic patterns, substrata, and vegetation (both terrestrial and aquatic) are termed habitats or biotopes. It often is assumed that different biotopes are inhabited by distinct macro- and meiofaunal assemblages (Palmer et al. 1991; Shiozawa 1991), and that changes in the biota are reflections of changes in the physical environment (Faith and Norris 1989). The dominant environmental changes are usually those associated with time and location. The benthic community varies with season of the year and with its spatial position within the stream, upstream vs. downstream (Matthews et al. 1991). Until recently, the use of land throughout a drainage basin, and its influence on the biota, received little attention. However, Corkum (1990, 1991) showed that land use adjacent to a river exerted a stronger influence on macroinvertebrate assemblages than factors associated with longitudinal gradients.

Information on the temporal and spatial distributions and abundances of stream invertebrates in Florida is lacking, especially in the peninsular portion of the state where low topographic relief and variable discharge rates prevail. Meiofaunal organisms and their functional relationships have not been studied at all. The principle objective of this study is to compare the distribution and abundance of macrofauna and meiofauna (organisms smaller than 500 **μm** in size) in headwater streams with different land uses in the drainage basins, i.e., reclaimed basins, basins receiving runoff from phosphate mining, and basins receiving runoff from agriculture and/or residential communities. Other goals are to determine: 1) whether specific assemblages of invertebrates are associated with subjectively defined habitats; 2) the seasonal and/or spatial constancy of these assemblages; and 3) whether the species assemblages are similar in different types of headwater streams.

Stream Locations

We sampled two sites on each of six headwater streams (see Figure 1) of the Alafia River, Florida (82 ° N, 28° W). Two of the streams, located in Polk County southeast of Lakeland, were tributaries of the North

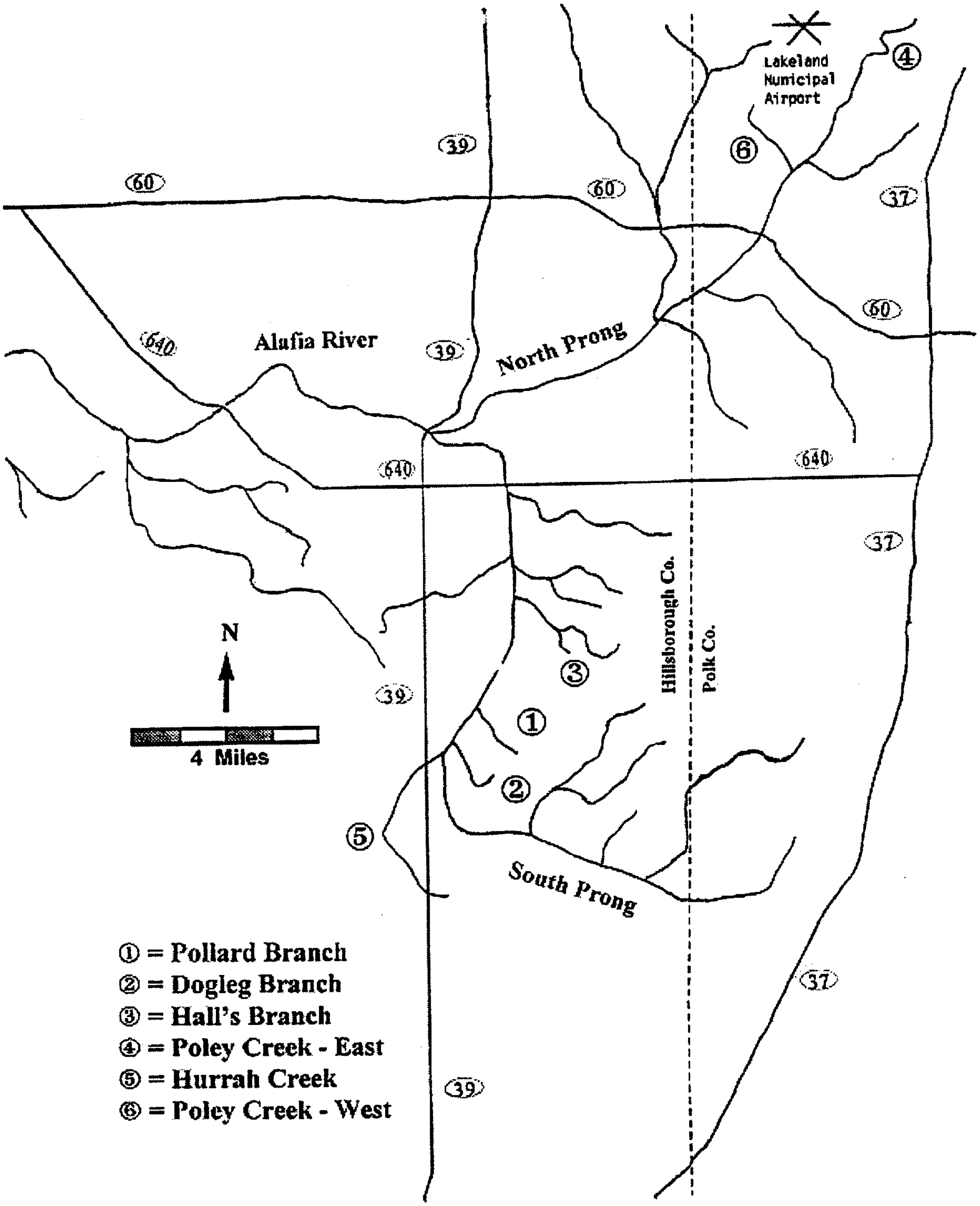

Figure 1. Map showing the north and south prongs of the Alafia River, Florida, and locations of the six headwater streams sampled for meiofauna and macrofauna in 1993 - 1994.

Prong of the river. Four streams were located in southeast Hillsborough County and flowed into the South Prong. In the locations listed below, streams are identified using an arbitrary numbering system, with “A” representing the upstream site and “B” the downstream site. Distances between sites ranged from 300 m to 3 km and were determined by available access and changes in flow dynamics:

1. Pollard Branch (mine-influenced), is located at T31S, R22E in Hillsborough County on Brewster Phosphates property, on S.R. 39.

2. Dogleg Branch (reclaimed), is located at T31S, R22E in Hillsborough County, due east of the junction of S.R. 640 and S.R. 39 at Picnic, FL. Initiation of restoration at Site 2B was in 1988; site 2A is upstream in a riverine hardwood forest.

3. Hall’s Branch (reclaimed), is located at T30S, R22E in Hillsborough County on Brewster Phosphates property. A total of 17.2 acres were mined and restoration was initiated in 1988.

4. Poley Creek-East (mine-influenced), is located at T29S, R23E in Polk County. Site 4A is on Harden Blvd. just south of Drane Field Rd.; 4B is close to the junction of Pipkin Rd. and Lunn Rd.

5. Hurrah Creek (agriculture-influenced) is located at T32S, R22E in Hillsborough County, on S.R. 39 north of Ft. Lonesome.

6. Poley Creek-West (agriculture- and residential-influenced) is located at T29S, R22E in Polk County. Site 6A is on Eastbrook Drive, east of Yates Rd; 6B is on Ewe11 Rd., east of Yates Rd.

More detailed descriptions of these study sites will be presented in Chapter 2.

Methods

a) Core Samples

Samples of meiofauna and smaller members of the macrofauna were collected seasonally at twelve stream sites; two sites within each of six streams. At each site 16 samples were randomly collected, from a 15 m length of stream, with a 47 mm core sampler; a preliminary study using the Bros and Cowell(1987) technique for optimizing sample size showed that 16 replicates provided a resolving power that would not change appreciably with additional samples. With this procedure, we collected 192 samples each season and 720 for the year.

Sampling was always initiated at the downstream end and then progressed upstream; care was taken to avoid disturbance of the stream bed whenever possible. Each sample, consisting of approximately 10 cm of substratum, with the associated twigs, leaf mats, macrophytes and detritus, and 10-20 cm of water above, was placed in a jar and preserved with 10% formalin-Rose Bengal solution (Mason and Yevich 1967). Concurrent with the collection of benthic samples, we measured depth of the water, current velocity, using a Marsh-McBirney (Model 2000) portable flowmeter, and took a 25 mm core sample for determining percent organic matter. Other physical-chemical samples (dissolved oxygen, N and P compounds, Fe, Mn, pH, alkalinity and turbidity) were collected prior to benthic sampling (see Chapter 2).

In the laboratory the formalin-rose bengal mixture was decanted through a 73 µm stainless steel sieve which was small enough to retain all organisms except the smaller stages of copepod nauplii. Organisms were separated from sand and debris using sugar flotation (Anderson 1959) under 7x magnification. Specimens which did not float (annelids and molluscs) were retrieved by decanting most of the sugar solution and then scanning the sediment microscopically. Organisms were preserved in 70% ethanol and were counted in a Ward plankton wheel under 16x magnification. For identification, some animals were mounted on slides using polyvinyl lactophenol as a mounting medium. Taxonomic references are listed in Appendix A.

b) Hester-Dendy and Dip Net Samples

Samples were collected at seasonal intervals from twelve stream sites (two sites within each of six streams) using Hester-Dendy samplers and dip nets. Two Hester-Dendy samplers, comprised of 9 boards (76 mm x 76 mm) were suspended at each site for a four week duration. Because of the fluctuating discharge volumes, samplers were placed at a mid-depth in deeper locations within the stream; this was less than 50 cm in deeper streams while in shallower streams it was approximately 20 cm. When collected, the Hester-Dendy samplers were taken apart, boards were scraped in an enamel pan with a glass slide, and the organisms and debris were placed in a jar and preserved with a 10% rose bengal - formalin mixture (Mason and Yevich 1967). Organisms were separated from debris with sugar floatation (Anderson, 1959), and were counted in a Ward plankton wheel on a dissecting microscope. Final preservation was in 70% ethanol.

Dip net samples for larger macroinvertebrates were collected, downstream from core sample sites, by dipping in all microhabitats with a D-frame net (595 mμ mesh) for 6 minutes. Net contents were placed in a large pail and returned to the laboratory in a "live" state. Live samples then were picked, from enamel pans, for 30 minutes and organisms were preserved in 70% ethanol. This was a qualitative analysis designed to show the presence/absence and relative abundance of large macroinvertebrates not collected by core samples and/or Hester-Dendy samples. Thus the picking of more abundant organisms was stopped when more than 20 organisms of a given taxon had been preserved; this insures that small, less abundant taxa will not be overlooked (see Johnson et al. 1996). Organisms were identified using a dissecting microscope and taxonomic references in Appendix A.

c) Metrics

The biota of streams are natural monitors of changes in environmental quality (Barbour et al. 1996). "Metrics" are indicators that measure biotic changes in structure and function that are attributable to human influence and adhere to sound ecological principles (Karr et al. 1986; Lyons, 1992; Barbour et al. 1995). Multimetric approaches, incorporating several aspects of structure and function, are regarded as more powerful methods for evaluation, and protocols for benthic invertebrates currently are being developed (see Barbour et al. 1996).

In this study, we have not used all of the metrics or an aggregated biological index because of our incorporation of meiofauna, and the differences in modes of collecting dip net samples. Some of our metrics will be just for core samples (percentages of Diptera, Chironomidae, and the dominant taxon) while others will be for both cores and dip nets (taxa of Ephemeroptera, Trichoptera, and EPT organisms); the two groups of metrics will be presented in different sections of the Results.

d) Statistical Procedures

When statistical procedures were used to compare within and between stream differences, densities of organisms (Y) were transformed using Log (Y+l). Normality and homogeneity of variances were respectively tested with the Kohnogorov-Smirnov test and the Levene median test. One-way Anova's and the Student-Newman-Keuls test (SNK) were used to test parametric data; the Kruskal-Wallis Anova on ranks, the SNK multiple comparison on ranks, and the Friedman Repeated Measures Anova were used for non-parametric data (Siegel 1956; SigmaStat 1994). We followed the recommendations of Pielou (1975) and Magurran (1988) for similarity and diversity measures. The Czekanowski-Dice-Sorensen index (ics) was used for similarity. A total of four diversity, richness, and evenness measures were used: 1) Shannon's index (H'), 2) the reciprocal of Simpson's index ($1/C = N_2$), 3) the number of species (S), and 4) the Molinari (1989) modification of the Alatalo (1980) evenness index.

Results

a) Core Samples

1) Total Densities

There were marked variations in benthic invertebrate densities between streams, sample sites within streams, and different seasons of the year. (Table 1). Mean densities were approximately 2.4-fold greater in the fall and winter than in the spring or summer. Ranges in site mean densities for different seasons were: fall - 11,607 to 343,611 m^{-2} ; winter - 43,842 to 184,070 m^{-2}; spring - 0 to 55,589 m^{-2}; and summer - 3,066 to 69,781 m^{-2}. Annual mean densities for the twelve sites ranged from 20,896 to 175,212 organisms per m^{-2}; they were low (< 40,000 m^{-2}) in reclaimed streams (2,3) and one agriculturally disturbed stream (5), intermediate (40,000-66,000 m^{-2}) in stream 4 and stream sites 1B and 6A, and high (>90,000 m^{-2}) at sites 1A and 6B. The annual mean for all twelve sites was 56,492 m^{-2}.

Statistical comparisons of benthic invertebrate densities in the core samples from the twelve stream sites were conducted using non-parametric statistics (log transformed data lacked normality in all seasons). The Kruskal-Wallis one-way Anova's showed significant differences between stream sites in all seasons (p<0.000l), but the SNK multiple comparison test on ranks showed considerable seasonal variation (Table 2). In the fall, all within stream differences between upstream (A) and downstream (B) were significant

Table 1. Densities of benthic invertebrates in core samples from six Alafia River headwater streams during 1993-1994. Seasonal mean for each stream site are based on 16 random samples; upstream and downstream sites are indicated by the letters “A” and “B” respectively. Streams 1 and 4 receive runoff from mined lands, 2 and 3 were mined and reclaimed in 1988, and 5 and 6 are disturbed by agriculture and/or residential development.

	Number m^{-2}				
Stream and Site	Fall	Winter	Spring	Summer	Annual Mean ± 1 S.E.
1A	99,265	184,070	55,589	32,850	92,943 ± 33,355
1B	63,145	84,060	50,918	20,988	54,777 ± 13,179
2A	27,706	49,017	46,173	35,588	39,621 ± 4,911
2B	35,040	64,726	19,783	10,877	32,607 ± 11,821
3A	38,471	42,048	0*	3,066	20,896 ± 11,221
3B	32,272	43,842	0*	20,477	24,148 ± 9,356
4A	89,900	116,894	0*	55,590	65,596 ± 25,208
4B	68,949	53,984	45,669	44,457	53,264 ± 5,640
5A	26,297	67,454	49,312	6,753	37,454 ± 13,253
5B	11,607	93,039	29,857	5,621	35,031 ± 20,011
6A	67,744	59,915	44,274	13,469	46,350 ± 11,997
6B	343,611	138,128	49,238	169,871	175,212 ± 61,665
Seasonal Mean	77,334	83,098	32,568	34,967	56,492

* = Stream was dry.

Table 2. Statistical comparison of benthic invertebrate densities in core samples from twelve Alafia River stream sites during 1993-1994. A Kruskal-Wallis Anova and the SNK multiple comparison on ranks were used because log transformed data were not normally distributed. Kruskal-Wallis probabilities are indicated adjacent to the season; for SNK tests, sites underlined by the same line are not significantly different from each other ($p > 0.05$).

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1. Fall ($p < 0.0001$)

Median	4.00	4.24	4.30	4.37	4.51	4.55	4.67	4.77	4.79	4.85	4.89	5.25
Site	5B	2A	5A	3B	2B	3A	6A	1B	4B	1A	4A	6B

2. Winter ($p < 0.0001$)

Median	4.53	4.59	4.60	4.62	4.71	4.76	4.83	4.83	4.83	4.92	5.03	5.21
Site	5A	3A	2A	3B	4B	6A	1B	2B	4A	5B	6B	1A

3. Spring ($p < 0.0001$)

Median	0.00	0.00	0.00	4.24	4.42	4.48	4.49	4.53	4.54	4.63	4.67	4.74
Site	3A	3B	4A	2B	5B	1B	2A	6A	6B	4B	5A	1A

4. Summer ($p < 0.0001$)

Median	3.16	3.54	3.54	3.85	4.08	4.19	4.28	4.42	4.47	4.52	4.60	4.80
Site	3A	5B	5A	2B	6A	3B	1B	1A	2A	4A	4B	6B

($p < 0.05$), and only four of sixty-six pairwise comparisons were non-significant ($p>O.05$). Winter median values were similar ($p > 0.05$) at nine of the twelve sites and upstream (A) differed from downstream (B) in streams 1, 5 and 6. The lack of rainfall during the spring caused three stream sites to be dry (3A, 3B and 4B) and statistically different from all other sites ($p < 0.05$). Site 2B also was different, but most of the remaining sites had statistically similar median ranks ($p > 0.05$). Upstream differed from downstream in three streams (2, 4 and 5) during the spring. Significant differences between upstream and downstream also were found in streams 1, 2, 3 and 6 during the summer, and only seven of the sixty-six pairwise comparisons were non-significant. Overall trends showed a larger number of non-significant differences between sites in the winter (36) and spring (29), and smaller numbers in the summer (7) and fall (4).

2) Percent Meiofauna

To determine the percentage of meiofauna in core samples, we examined the size distributions of all taxonomic families and the probabilities of passing through a 500 µm mesh sieve. Most of the families separated clearly into meiofauna (less than 500 µm) or macrofauna. In a few cases immature and mature larvae were put in different groups. However, because the Chironomidae (Insecta:Diptera) show such wide variation in size, we had to separate taxa at the generic level. We used Wiederholm's (1983) text and if he classified the mature larva as "small, less than 5 mm", we entered the genus as a member of the meiofauna. If he classified the larva as "medium to large", i.e., > 6.5 mm, it was entered as a macrofaunal component. Using this procedure, 15 genera (4 Orthocladinae, 4 Tanypodinae, 5 Tanytarsini, and 2 Chironominae) were meiofauna, and 22 genera (2 Orthocladinae, 8 Tanypodinae, 1 Tanytarsini, and 11 Chironominae) were macrofauna.

On a numerical basis, the annual mean percentage of meiofauna for the twelve stream sites was 62% (Table 3). Reclaimed streams had higher percentages (68% to 91%) than the other streams (43% to 62%) . However, when seasonal aspects were considered for streams 4, 5 and 6, there was marked variation in one or two seasons (spring and/or summer) with unusually high macrofaunal percentages which lowered the annual

Table 3. Percent meiofauna in core samples from six Alafia River streams. Upstream and downstream sites are indicated with the letters ‘A’ and ‘B’ respectively. Three stream sites were dry during the spring sampling.

	Percent Meiofauna in Core Samples from Stream Site												
Season	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	Mean
Fall	69	56	86	84	89	94	59	77	60	52	61	94	73
Winter	69	69	78	90	75	91	48	66	47	56	46	77	68
Spring	46	52	42	73	---	---	---	74	54	46	29	69	54
Summer	49	45	66	92	69	88	72	15	39	60	36	11	53
Annual Mean	58	55	68	85	78	91	60	58	50	53	43	62	62

means, e.g., stream sites 4B, 5A, 6A and 6B in the summer and 6A in the spring; these may be related to reproduction of specific macrofaunal components, i.e., tubificid worms, amphipods and molluscs. In the summer, site 4B was numerically dominated by the non-indigenous Asiatic clam, *Corbicula fluminea (62%);* site 5A by large Chironomidae (25%) and tubificid worms (22%); site 6A by the tubificid, *Limnodrilus hoffmeisteri* (31%) and *Corbicula fluminea* (10%); and site 6B by a massive percentage of *Limnodrilus (86%).* Likewise, at site 6A in the spring, percentages of the amphipod, *Gammarus tigrinus* (3 8%) and the tubificid, *Limnodrilus hofieisteri* (16%) were quite high.

3) Taxonomic Composition

Percent composition of the predominant groups of taxa (Phyla and Classes) at individual stream sites showed only slight variation between seasons, but there were large differences between stream sites during the same season (Figure 2); Tables of percent composition for all four seasons are in Appendix B. Communities at both of the reclaimed streams (2 and 3) were numerically dominated by Crustacea (Ostracoda, Amphipoda, Copepoda, and Cladocera) which on an annual basis, comprised 45-77% of the total density. However, the lower values (45% and 53%), at Hall's Branch (Stream 3), were depressed markedly by the stream being dry during the spring; excluding these values yields 60% and 71% respectively at 3A and 3B. Thus, the spring values will be excluded from subsequent ranges. Percent composition of Annelida in the reclaimed streams ranged from l-30% while the other taxonomic groups (Nematoda and Minor Orders, Chironomidae, Ceratopogonidae, other Phyla of Insecta, Acari, and Mollusca) all had percentages of 10% or less.

At the mine-influenced streams (1 and 4), percent composition was more evenly distributed among taxonomic groups with the following ranges: Chironomidae, 43-56% except at 4B (8-13%); Annelida, 18-65% except at 4A (7-18%); and Crustacea, 17-29% except at 1B (3-4%). Poley Creek-East, Site 4A, had high percentages (4-15%) of other insects (principally Trichoptera) and Nematoda (4-25%). Site 1A also had large numbers of Nematoda (5-6%).

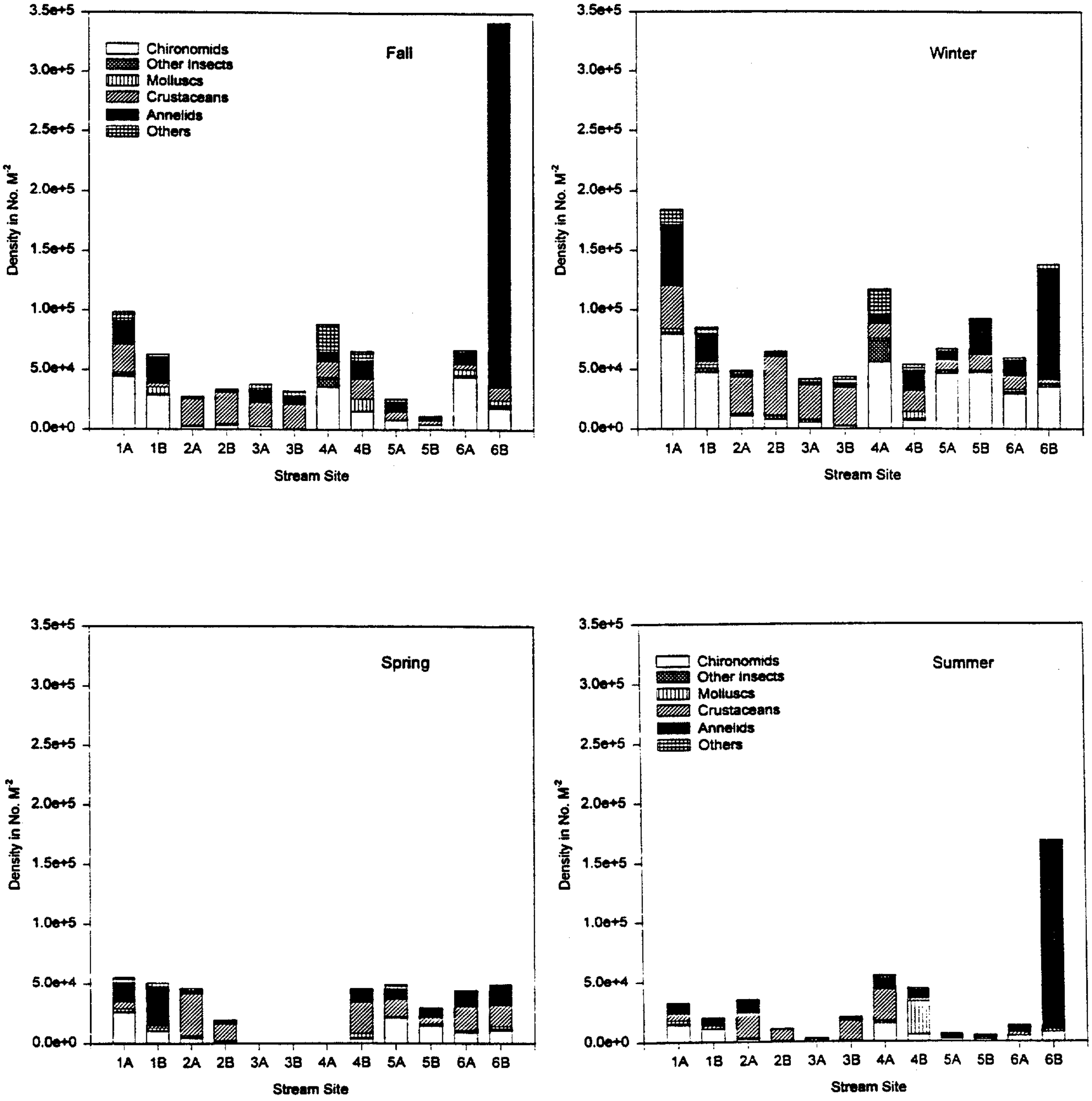


Figure 2. Densities of the predominant groups of benthic invertebrates at twelve headwater stream sites in the Alafia River, Florida, 1993-1994; upstream and downstream are indicated by the letters ‘A’ and ‘B’ respectively. Streams 1 and 4 receive runoff from mined lands, 2 and 3 were mined and reclaimed in 1988, 5 and 6 are disturbed by agriculture and/or residential development.

Benthic communities at the agricultural- and residential-influenced streams (5 and 6) were composed predominantly of Chironomidae and Annelida, percentages ranged from 50-98%. Worms were always more abundant at downstream sites which were deeper with larger percentages of organic matter (see Chapter 2). In general, abundance and percent composition of the principle taxonomic groups were highest in the fall and/or winter, and lowest in the spring and/or summer (Figure 2). The total number of taxa per season ranged from 90-127: 121 in fall, 127 in winter, 100 in spring and 90 in summer, and the total number for the year was of 187 taxa. But, the taxonomy of all groups has not been completed (Nematoda, Ostracoda, and Harpacticoida) so the lists are complete to the current level of identification (listings of taxa and mean densities for the twelve stream sites during the winter and summer seasons are found in Appendix C).

4) Similarity

The Czekanowski-Dice-Sorensen index (ics) showed large variation between stream sites, both within and between seasons (Figure 3). The reclaimed streams (2 and 3) comprised a separate grouping which had low similarity compared to the other streams (1,4,5, and 6). The linkage between the two groups showed a steady temporal decrease from fall (20% similarity) to summer (3% similarity). Streams in the second group (mine-influenced and agricultural- and/or residential-disturbed) varied markedly with season. Clustering was more pronounced during the fall and spring (most linkages were in the range of 30%-40% similarity), while in the winter and summer several stream sites clustered at low similarity levels (< 30%). Percent similarity between upstream and downstream sites varied seasonally and between streams (Table 4). Streams 2 and 5 showed little seasonal variation, ranging from 42 to 51%, but streams 3, 4 and 6 showed 2- to 4-fold decreases between fall or winter and spring or summer (dry streams not included). Stream 1 increased from 33% in fall to 55% in summer. The highest similarities were between 3A and 3B in the fall (66%) and winter (72%).

5) Diversity, Richness and Evenness

The two diversity indices (H' and N_2) yielded similar results in the comparison of annual and seasonal indices for different stream sites (Figure 4). Stream sites 2A, 2B, 3A and 3B had low annual mean diversity

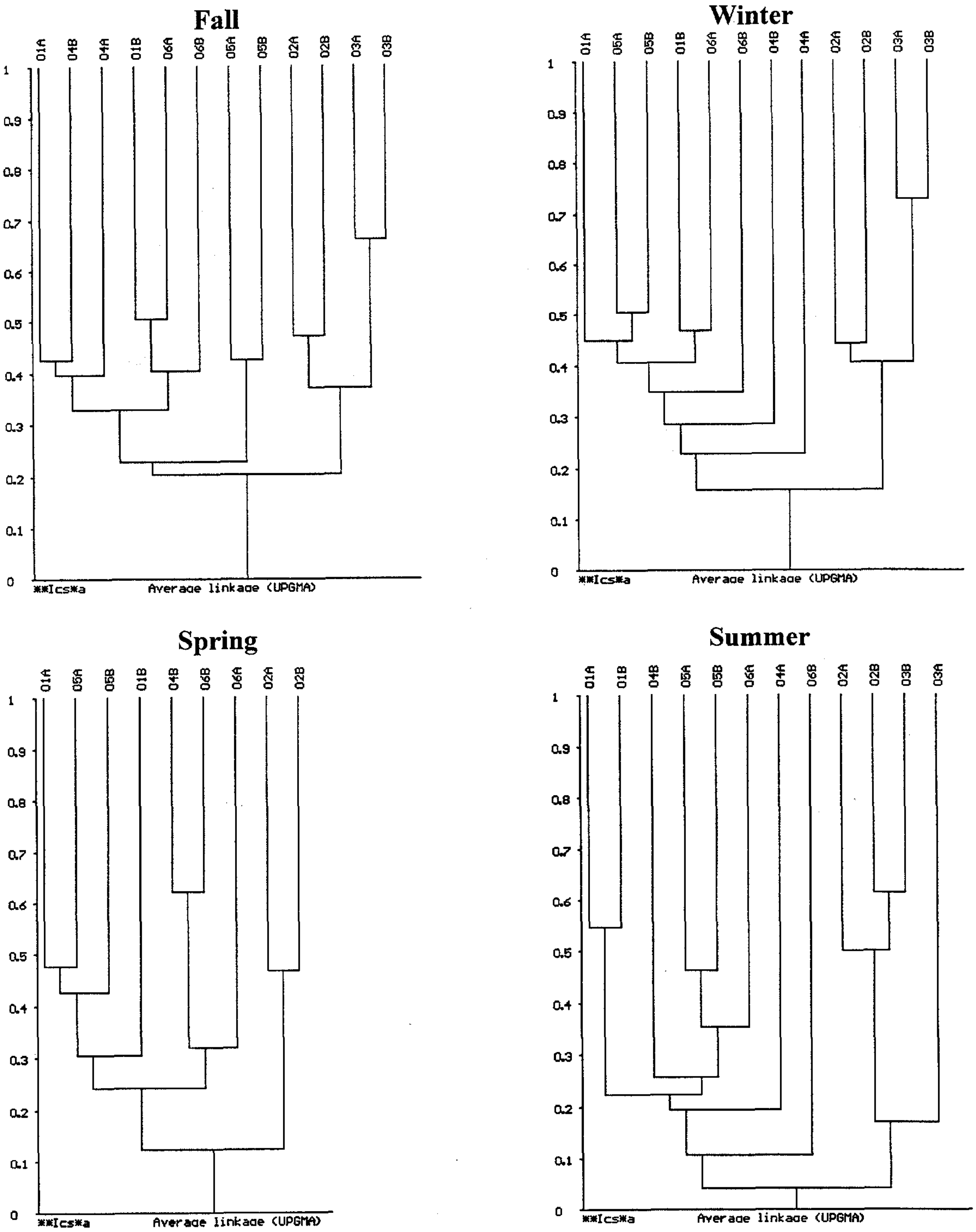


Figure 3. Percent similarity by season for twelve headwater stream sites in the Alafia River, Florida, 1993-94. Average linkage (UPGMA) was used with the Czekanowski-Dice-Sarrensen index for core sample data.

Table 4. Seasonal and annual comparisons of core sample percent similarity (expressed as decimals) between upstream and downstream sites on six Alafia River headwater streams, 1993-94. Streams 2 and 3 are reclaimed, 1 and 4 are mine-influenced, and 5 and 6 are agriculture- or residentially-influenced.

	Season				
Stream Number	Fall	Winter	Spring	Summer	Annual Mean ± 1 S.E
1	0.33	0.47	0.30	0.55	0.41 ± 0.06
2	0.45	0.44	0.47	0.50	0.46 ± 0.01
3	0.66	0.72	0.00[1]	0.17	0.52 ± 0.17
4	0.40	0.22	0.00[2]	0.22	0.21 ± 0.08
5	0.42	0.51	0.44	0.46	0.46 ± 0.02
6	0.40	0.35	0.32	0.11	0.30 ± 0.06
Mean ± 1 S.E.	0.44 0.05	0.45 0.07	0.26 0.08	0.34 0.08	

[1] = Stream sites 3A and 3B were dry.
[2] = Stream site 4A was dry.

($H' < 2.2$ and $N_2 < 7$) while 1A, 5A, and 5B had high values ($H' > 3.0$ and $N_2 > 12$); for stream site 4B the N_2 value of 12.4 also was high, but H' was only 2.69. The other stream sites (1B, 4A, 6A and 6B) had intermediate values, ranging from 5.8 to 9.3 for N_2 and 2.49 to 2.69 for H'. Fall and winter means for the N_2 index were 50% - 60% higher than spring and summer means; for H' the differences ranged from 25% to 45%. However, the three dry stream sites in spring markedly depressed the mean value. A spring mean based upon the 9 flowing streams would have been more similar to the fall and winter values, and summer would be the only season showing a marked difference.

Figure 5 shows that species richness was low in the reclaimed streams (2 and 3), annual mean numbers of species at upstream and downstream sites were: 40 and 37 (Stream 2), 20 and 26 (Stream 3). Stream site 1A had the highest annual mean, S = 58, while the other sites ranged between 42 and 48. Fall and winter means (48 and 53 respectively) were approximately 25% higher than spring and summer (33 and 35), but the three dry sites in spring had a marked effect upon the mean.

Molinari’s evenness index also showed large variations between stream sites and between seasons within the same site (Figure 5). However, when annual mean values were calculated, the sites separated into three distinct groups. Mean evenness was low (< 0.10) at 2B and 4A, intermediate (0.11 - 0.20) at 2A, 3A, 3B, 6B and 6A, and high (0.21- 0.30) at 1B, 4B, 5A, 1A and 5B. Seasonal means of the evenness index were similar in the winter, spring and summer (respective values were 0.169, 0.140 and 0.166, but the fall index (0.209) was higher.

6) Metrics

The Florida metrics for core samples from the Alafia headwater streams show marked differences between the reclaimed, mine- influenced and agriculture- or residential-influenced streams (Table 5). On an annual basis, the mean percentage of the dominant taxon was 45% for the reclaimed streams (2A, 2B, 3A and 3B) while the mean for the other eight sites was 25% [even with the inclusion of site 6B which had high percentages of the naidid oligochaete, *Pristineila jenkinae* in the fall (83%) and the tubificid, *Limnodrilus*

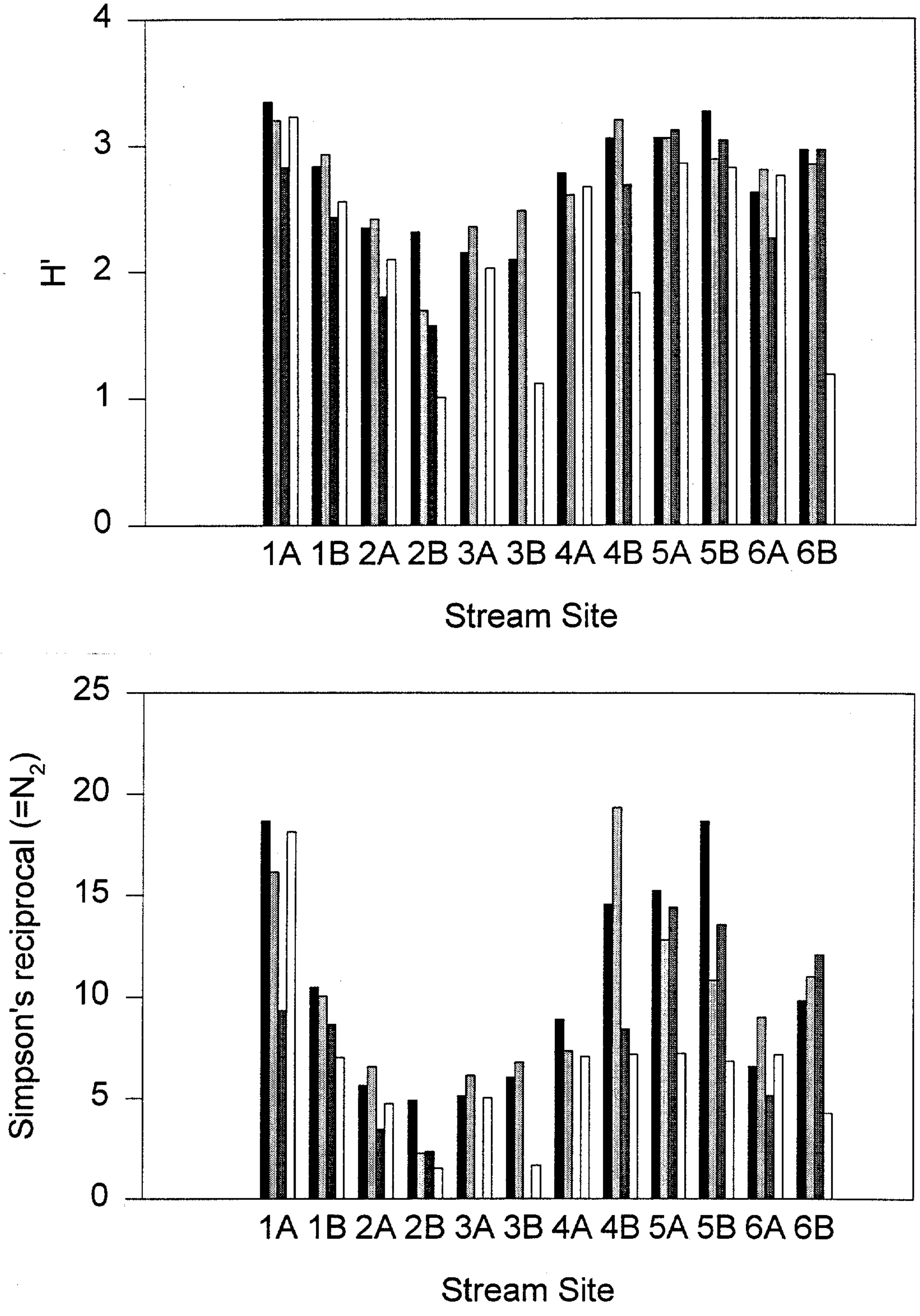
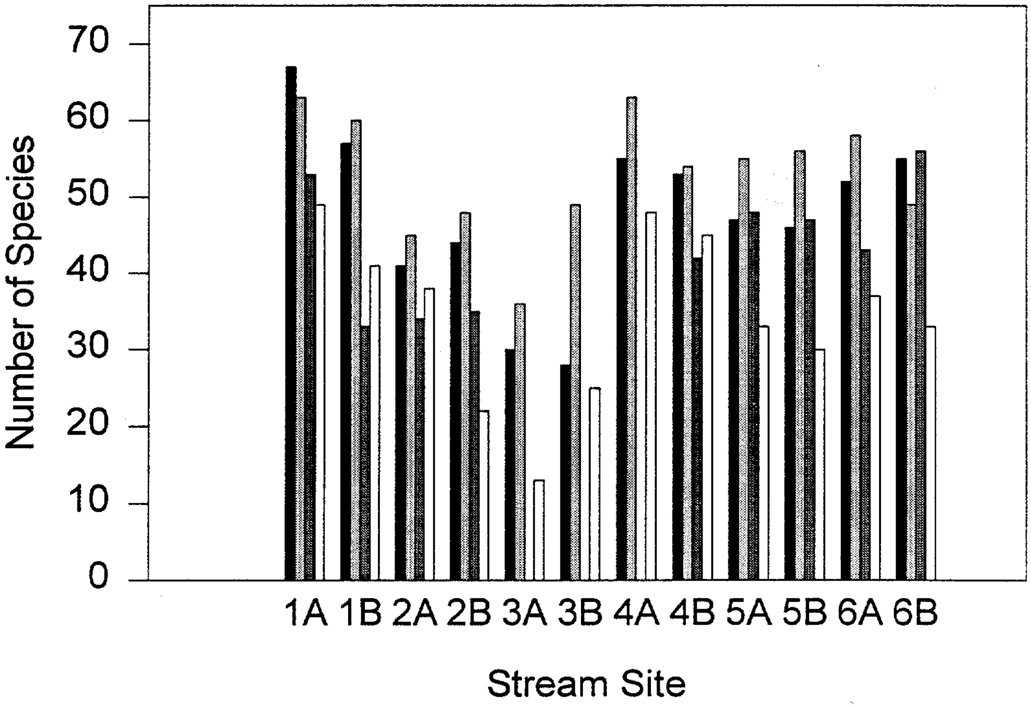


Figure 4. Shannon’s diversity index (H') and Simpson’s Reciprocal (N_2) for twelve headwater stream sites in the Alafia River, Florida, 1993-94. Bar shades for seasonsa are: black is fall 1993, light gray is winter, dark gray is spring and clear is summer, 1994.



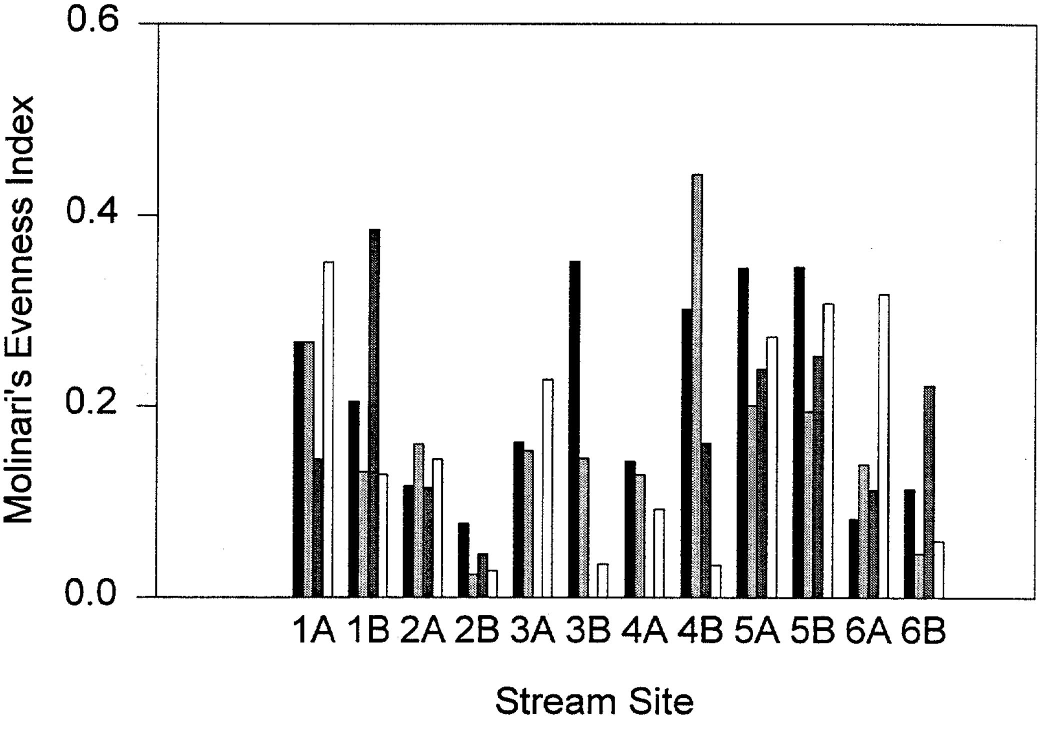


Figure 5. Species richness (number of species) and Molinari's evenness index for twelve headwater stream sites in the Alafia River, Florida, 1993-94. Bar shades for seasons are: black is fall 1993, light gray is winter, dark gray is spring, and clear is summer, 1994.

hoffmeisteri in the summer (77%)]. Moreover for seasonal comparisons, the dominant taxon at the reclaimed sites was a meiofaunal crustacean in 13 of 14 cases whereas at other stream sites they represented only 3 of 31 cases. Macrofaunal dominants at sites 1 A, 1B, 4A, 4B, 5A, 5B, 6A and 6B (31 cases) were Chironomidae - 11, Oligochaeta - 3, Amphipoda - 1, Trichoptera - 1, and Mollusca - 1.

The mean percentages of Diptera were low in the core samples from the reclaimed streams, < 14% (Table 5). The downstream sites on the north prong also had low percentages, 16% at site 4B and 15% at 6B, but at the other non-reclaimed sites (1A, 1B, 4A, 5A, 5B and 6A), Diptera comprised 30-46% with a mean of 42%. Percentages of the dipteran family Chironomidae closely reflect the variation for the Order (Table 5). For the year, Chironomidae comprised 95% of the Diptera. The mean number of chironomid taxa was low in stream 3 (3A = 3 and 3B = 6 taxa), but mean numbers at other stream sites ranged from 13-20 (Table 5). Species differences will be discussed in Chapter 2.

b) Hester-Dendy and Dip Net Samples

1) Hester-Dendy Densities

A Friedman Repeated Measures Anova on the yearly data set, showed no differences among the twelve stream sites ($p = 0.221$), but there were significant differences among sampling dates ($p < 0.01$). Spring densities were lower than those for other seasons; all stream sites had densities of less than 7000 organisms per m^{-2} of board surface (Figure 6). During the other three seasons, densities ranged from near zero to > 25,000 m^{-2}, and seasonal mean densities were 2.5- to 3-fold higher (8,100 - 9,500 m^{-2}) than for spring (2,900 m^{-2}).

2) Taxonomic Composition

The Hester-Dendy samples were comprised predominately of Chironomidae, Crustacea, and Annelida (Figure 6), with percent composition of these organisms ranging from 91- 96%. Chironomids were abundant in all seasons except the spring; crustaceans were most abundant in the spring, but densities also were high

Table 5. Florida metrics for core samples from six headwater streams of the Alafia River, Florida during 1993-94. Streams are: 1 = Pollard Branch, 2 = Dogleg Branch, 3 = Hall's Branch, 4 = Poley Creek-East, 5 = Hurrah Creek, 6 = Poley Creek-West; 'A' is upstream and 'B' is downstream. The asterisks represent dry streambeds. Means are subject to rounding errors.

	Stream and Site												
	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	Mean
Percent Dominant Taxon													
Fall	14	21	34	39	36	26	25	13	13	10	32	83	29
Winter	14	23	29	65	38	29	11	9	16	18	24	53	27
Spring	27	12	42	63	***	***	***	27	15	13	38	20	28
Summer	14	32	38	80	39	77	37	62	15	10	17	77	42
Mean	17	22	36	62	38	44	24	27	15	13	28	58	32
Percent Diptera													
Fall	46	46	8	12	7	3	42	27	32	37	67	6	28
Winter	44	58	25	17	16	5	50	15	70	51	51	27	36
Spring	48	21	12	9	***	***	***	10	44	50	22	23	20
Summer	46	53	8	8	5	5	27	13	33	29	37	5	22
Mean	46	45	13	12	9	4	40	16	45	42	44	15	26
Percent Chironomidae													
Fall	45	45	8	10	6	3	40	22	31	35	66	5	26
Winter	43	57	22	12	12	4	48	13	69	51	49	26	34
Spring	47	20	10	7	***	***	***	8	43	49	20	22	25
Summer	44	52	6	6	5	4	27	13	30	28	36	5	21
Mean	45	44	11	9	8	4	38	14	43	41	43	14	27
Taxa of Chironomidae													
Fall	22	18	17	14	5	3	20	17	15	15	12	17	15
Winter	20	22	14	19	7	13	23	19	22	21	16	15	18
Spring	18	9	13	11	***	***	***	11	18	16	12	13	10
Summer	18	9	12	8	1	6	15	13	8	9	11	10	10
Mean	20	15	14	13	4	7	19	15	16	15	13	14	13

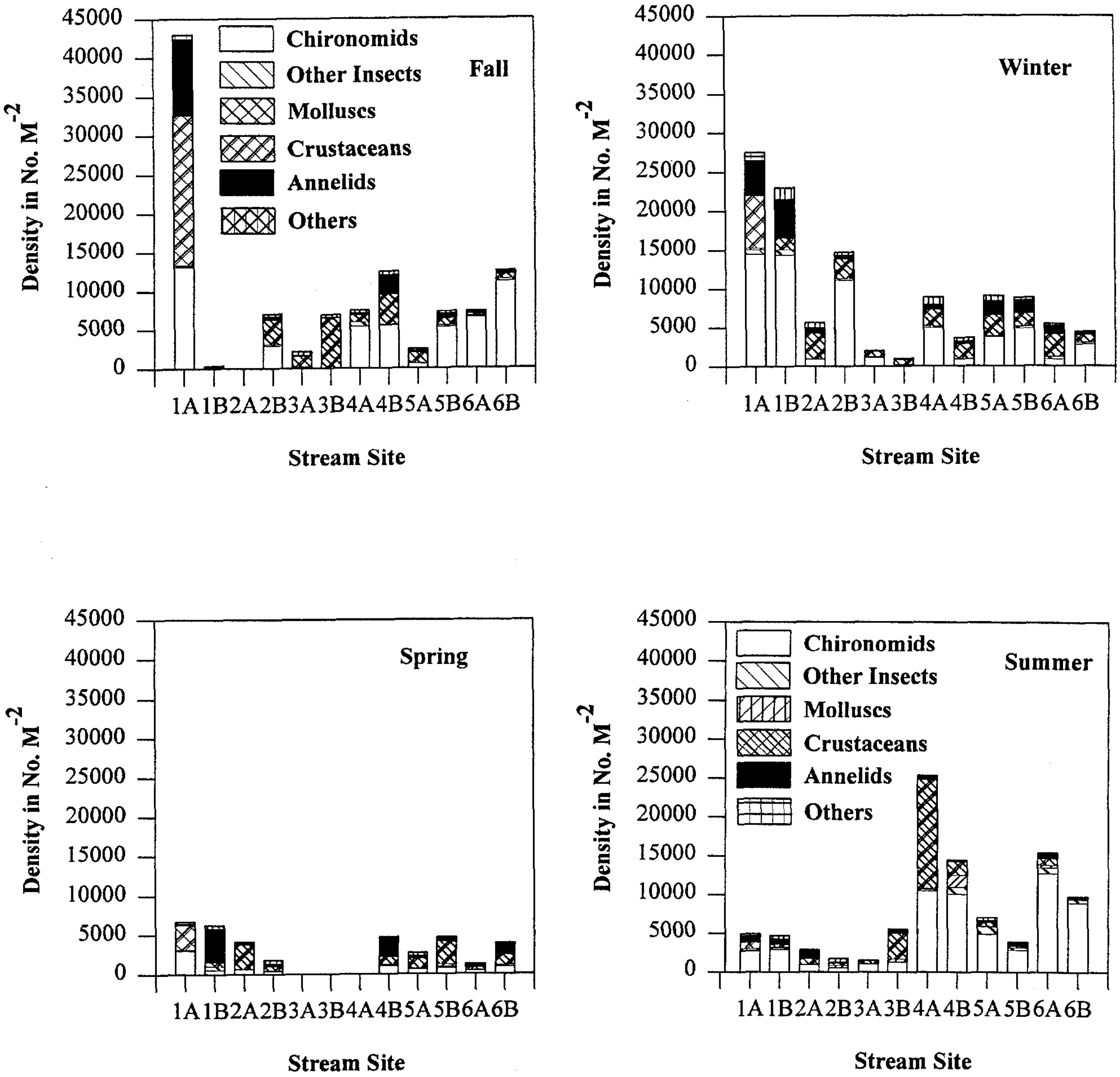


Figure 6. Seasonal abundances of major groups of invertebrates collected on Hester-Dendy samplers at twelve sites in six headwater streams of the Alafia River, Florida, 1993-94. The spring season was exceptionally dry; three sites were dry during the sample period.

in other seasons; and annelids were more abundant in the fall and winter seasons. Taxa of reclaimed streams(2 and 3) were principally Crustacea, except for 2B in winter, while chironomids and annelids were more abundant in the other streams.

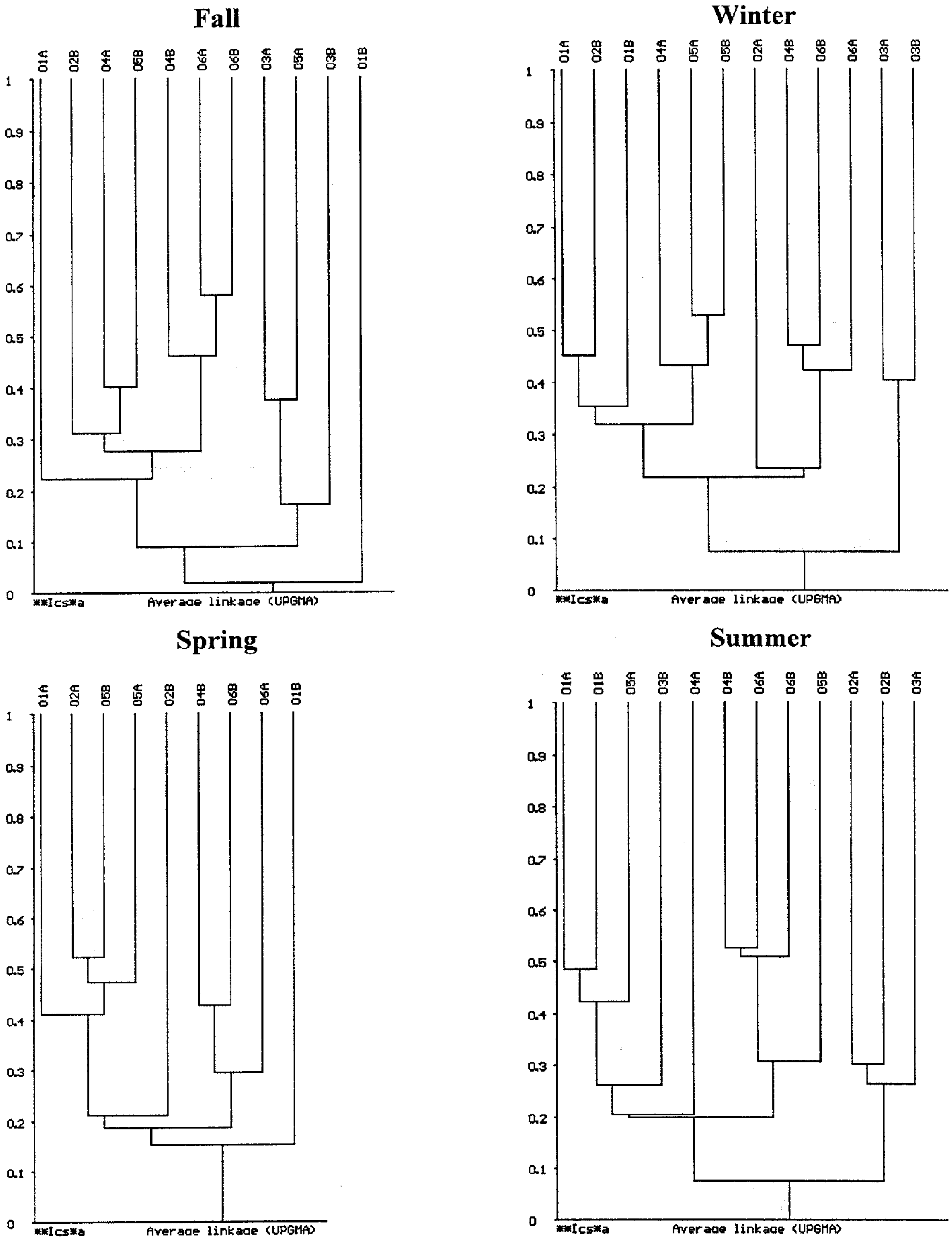
3) Similarity

Similarity values for Hester-Dendy samples usually were lower than those for core samples, and seasonal variability was marked (Figure 7). The streams tended to cluster in distinct groups, usually 2 or 3, but there was no clear grouping based on stream land use; linkage of the major groups occurred at low levels,< 16%, throughout the year. Variability between upstream and downstream sites was high, with similarity ranging from 1% to 58% (Table 6). The winter and spring showed less variability among sites, ranges were 21-53% and 16-48% respectively (excluding the dry streams); fall and summer ranges were 1-58% and 9-51%.

4) Diversity, Richness and Evenness

Seasonal variability in Hester-Dendy diversity was marked with N_2 values ranging from 0 to 14.1 (Figure 8), and differences between seasons from 7-12 units. Mean diversity for the 12 sites was high in the winter and summer (7.75 and 8.08 respectively) and low in the fall and spring (3.82 and 4.94 respectively). Annual means for the different stream sites ranged from 4.32 to 8.80; lower means (<5.20) were associated with the three sites that were dry in the spring (3A,3B and 4A).

Species richness and evenness indices were less variable than diversity (see Figure 9). For richness there were few differences except those caused by dryness; site means ranged from 32-42 taxa and seasonal means ranged from 32-37 when dry sites were deleted. The Molinari evenness index showed large seasonal fluctuations for any given site, except for site 2B (Figure 9). Maximum values for 5 of the 12 sites (41.6%) occurred in the winter, summer had 3 of 12 (25%), and fall and spring each had 2 of 12 (16.7%). In contrast, minimal values for 9 of the 12 sites (75%) were in spring, 1 was in fall (8.3%) and 2 were in the winter (16.7%). Yet, there was little variation in the seasonal means for all sites when dry streams were omitted; values were: 0.200, 0.237, 0.175 and 0.211 respectively for the fall, winter, spring and summer seasons.



Fall

Winter

Spring

Summer

Figure 7. Percent similarity by season for twelve headwater stream sites in the Alafia River, Florida, 1993-94. Average linkage (UPGMA) was used with the Czekanowski-Dice-Sorensen index on Hester-Dendy data.

Table 6. Seasonal and annual comparisons of Hester-Dendy percent similarity (expressed as decimals) between upstream and downstream sites on six Alafia River headwater streams, 1993-94. Streams 2 and 3 are reclaimed, 1 and 4 are mine-influenced, and 5 and 6 are agriculture- or residentially-influenced.

	Season				
Stream Number	Fall	Winter	Spring	Summer	Annual Mean ± 1 S.E
1	0.01	0.35	0.16	0.48	0.25 ± 0.10
2	----[1]	0.21	0.21	0.30	0.24 ± 0.03
3	0.18	0.40	0.00[2]	0.09	0.17 ± 0.09
4	0.28	0.21	0.00[3]	0.20	0.17 ± 0.06
5	0.09	0.53	0.48	0.20	0.32 ± 0.11
6	0.58	0.42	0.29	0.51	0.45 ± 0.06
Mean	0.23	0.35	0.19	0.30	
± 1 S.E.	0.10	0.05	0.07	0.07	

[1] = Hester-Dendy samplers were missing at site 2A; thus fall was excluded from all means and standard errors.
[2] = Stream sites 3A and 3B were dry.
[3] = Stream site 4A was dry.

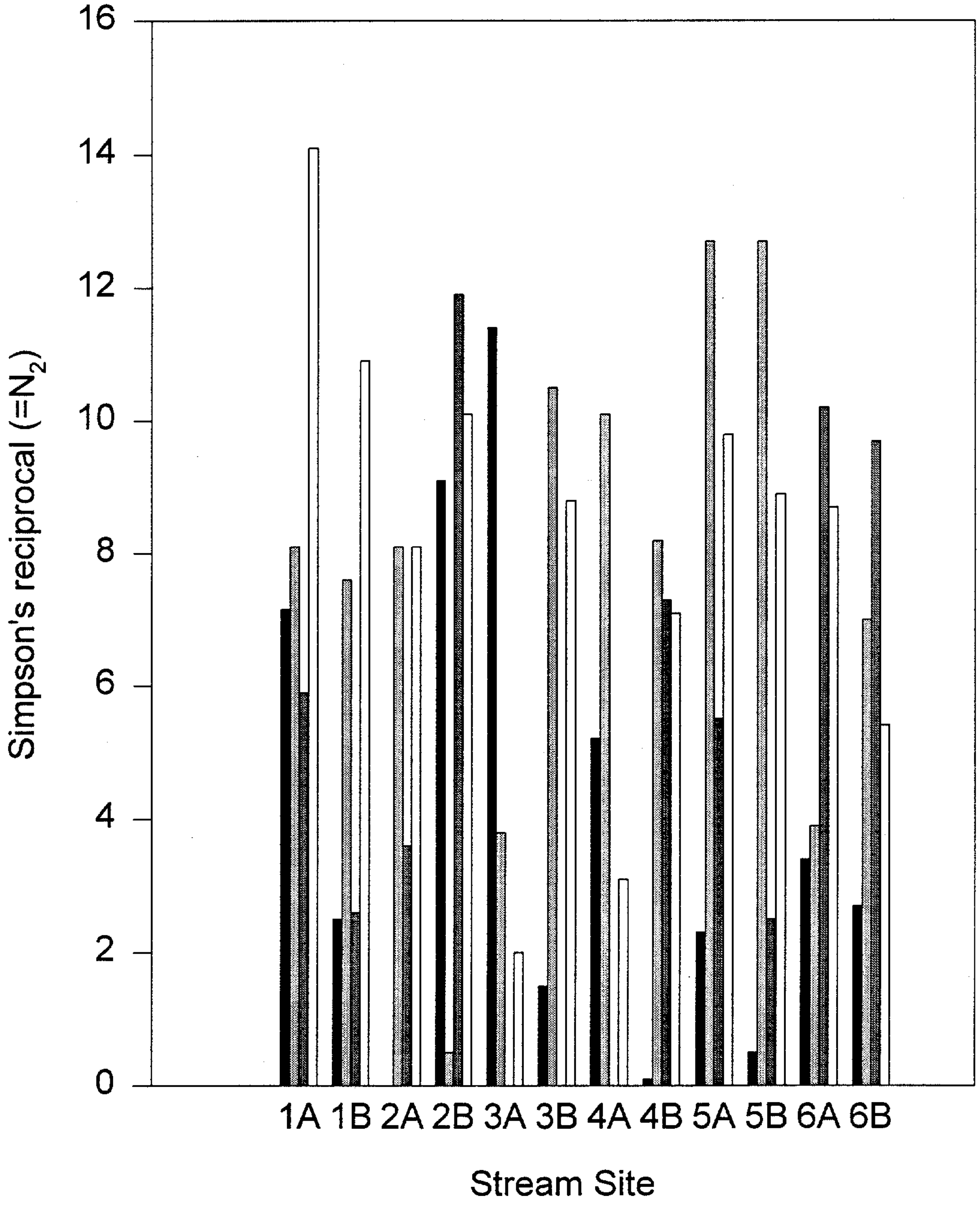


Figure 8. Simpson's reciprocal diversity index (N_2) for Hester-Dendy samples from twelve headwater stream sites in the Alafia River, Florida, 1993-94. Bar shades for seasons are: black is fall 1993, light gray is winter, dark gray is spring, and clear is summer, 1994.

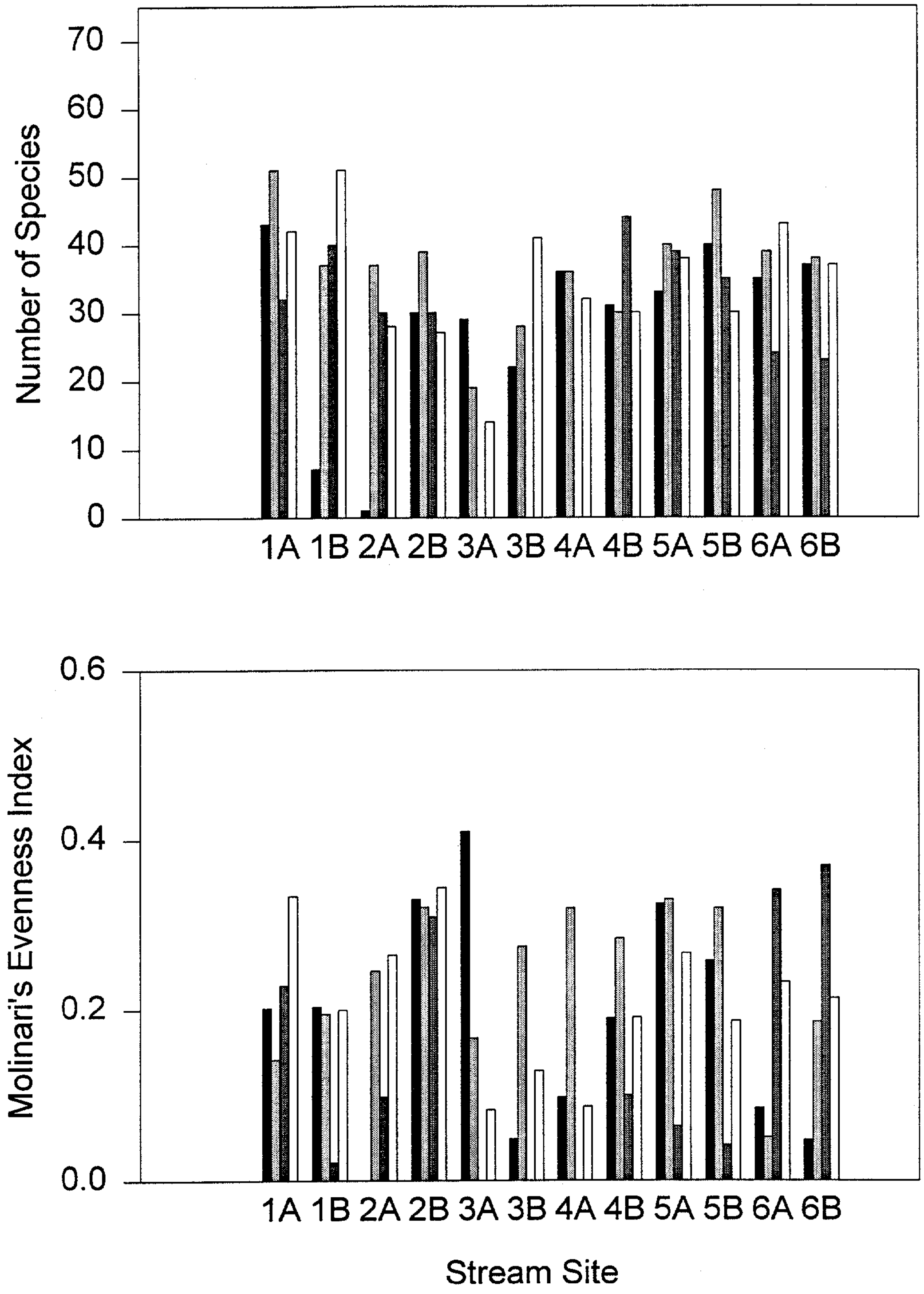


Figure 9. Species richness (number of species) and Molinari's evenness index for Hester-Dendy samples from twelve headwater stream sites in the Alafia River, Florida, 1993-94. Bar shades for seasons are: black is fall 1993, light gray is winter, dark gray is spring, and clear is summer, 1994.

Dip net samples were collected to insure that all taxa were represented in the data. There were no marked differences between seasons, but a number of larger taxa (Odonata, Hemiptera and Coleoptera) that were not collected in the core or Hester-Dendy samples, were found (Table 7). In addition, larger instars or growth stages of some of the smaller, meiofauna taxa [e.g. Copepoda, Cladocera and Orthocladinae (Chironomidae)] were collected in small numbers.

5) EPT Metrics

The numbers of taxa of Ephemeroptera, Plecoptera and Trichoptera (organisms particularly sensitive to pollution) are expected to decrease as disturbance increases, and the combined number (EPT taxa) is a useful metric for evaluating streams (Barbour et al 1996). Table 8 shows the numbers of taxa for Ephemeroptera and Trichoptera collected seasonally in core and dip net samples for each of the 12 stream sites in the Alafia River; a single plecopteran, *Neoperla clyme,* occurred at Site 1B in a Hester-Dendy sample. Numbers of mayfly taxa showed small seasonal or annual variation between stream sites, ranging from 0 to 4 taxa . Reclaimed streams (2 and 3) and mine-influenced streams (1 and 4) had 2 or less taxa (usually *Caenis sp.* and *Baetis so.)* on an annual basis, while the agricultural- and/or residentially disturbed streams (5 and 6) had 3 to 4 taxa. The number of taxa of Trichoptera was low in the reclaimed streams (0-2 species) while the other streams had 4-6 species (Table 8). For Ephemeroptera + Trichoptera, reclaimed streams had 2-3 species and the other streams had 6-9 species.

Discussion

a) Comparison of Total Densities of Invertebrates

Our data can be compared with those from a few other lotic studies where all meiofaunal groups were counted. The mean abundance for the Alafia streams (56,492 m”) was 5- to 38-fold lower than for the following natural streams: 1) White Clay Creek, Pennsylvania, 536,000 m^{-2} (Borchardt and Bott 1995); 2) Goose Creek, Virginia 2,144,000 m^{2}(Palmer 1990); and 3) “clean” Ohio streams, 279,000 m^{-2} (Hummon et al. 1978). Hummon et al. also reported 115,000 m^{-2} for “polluted” streams recovering from acid-mine drainage.

Table 7. Number of invertebrate taxa collected in dip net samples from twelve sites in six headwater streams of the Alafia River, Florida, 1993-94. Numbers of taxa not found in core or Hester-Dendy samples are indicated in parentheses.

Taxonomic Group	Fall	Winter	Spring	Summer
Minor Orders	0	2	3 (1)	1
Crustacea	4	5 (1)	5 (1)	4 (2)
Ephemeroptera	1	3	1	3 (1)
Odonata	7 (4)	10 (6)	6 (4)	8 (5)
Hemiptera	4 (4)	4 (4)	3 (2)	3 (3)
Megaloptera	1	1	0	1 (1)
Trichoptera	1	1	2	1
Lepidoptera	0	0	1 (1)	0
Coleoptera	3 (3)	5 (2)	3 (1)	4 (2)
Chironomidae	5	11	0	10
Other Diptera	3 (1)	1	2 (2)	0
Mollusca	4 (1)	4 (1)	4 (2)	4 (3)
Total	33 (13)	47 (14)	30 (14)	39 (17)

Table 8. Taxa of Ephemeroptera and Trichoptera in six headwater streams of the Alafia River, Florida during 1993-1994. Streams are identified in the Stream Location section; A is upstream and B is downstream. The symbol *** notes that the stream was dry.

	Stream and Site											
	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B
A. Taxa of Ephemeroptera												
Fall	1	1	0	2	1	0	1	1	0	1	3	2
Winter	1	1	0	2	0	1	1	0	0	2	2	1
Spring	0	1	0	1	***	***	***	0	0	2	1	2
Summer	0	0	0	0	0	0	2	1	2	1	3	3
Yearly Total	1	1	0	2	1	1	2	2	2	3	4	4
Stream Total		1		2		1		2		3		4
B. Taxa of Trichoptera												
Fall	3	1	0	0	1	0	1	1	1	1	2	0
Winter	1	2	0	0	0	1	3	0	2	1	1	3
Spring	2	1	0	0	***	***	***	1	3	1	1	1
Summer	1	1	0	0	0	0	2	1	1	1	1	0
Yearly Total	5	3	0	0	1	1	4	2	4	3	4	4
Stream Total		6		0		2		4		4		5
C. Taxa of Ephemeroptera and Trichoptera												
Fall	4	2	0	2	2	0	2	2	1	2	5	2
Winter	2	3	0	2	0	2	4	0	2	3	3	4
Spring	2	2	0	1	***	***	***	1	3	3	2	3
Summer	1	1	0	0	0	0	4	2	3	2	4	3
Yearly Total	6	4	0	2	2	2	6	4	6	6	8	8
Stream Total		7		2		3		6		7		9

However, these higher densities in temperate streams probably do not represent increased productivity over the Florida streams. Temperate streams are appreciably cooler, and this leads to cohort reproduction at defined intervals. In subtropical Florida streams (16-33°C), reproduction is continual over most of the year; e.g., the life cycle of many of the chironomids in the Tampa vicinity is 14-17 days at 31° C (Cowell and Vodopich 1981). Copepods also show rapid development times (< 10 days) at 31° C (Elmore 1983). Thus rapid reproduction should lead to higher productivity rates and greater turnover rates for subtropical communities.

Seasonal mean densities in headwater streams of the Alafia River showed 2-fold differences between Fall-Winter and Spring-Summer (Table 1). This comparison was confounded by three streams being dry in the Spring, and by reflooding and invertebrate recolonization during summer. Resh et al. (1988) discussed the roles of disturbance in streams and noted that because organisms are adapted to predictable seasonal fluctuations, it is likely that the unpredictable disturbance will have marked impact on the community. Blinn et al. (1995) found a ≥85% reduction in benthic macroinvertebrate biomass after only one 12-h summer exposure to dry conditions. Drought is predictable on a global basis, but not for an annual study; studies of much longer duration are necessary before seasonal variation becomes meaningful to the ecologist. We found that: 1) the reclaimed streams (2 and 3) had low mean densities, but an agriculturally-disturbed stream (5) had comparable densities (see Table 1); 2) upstream and downstream locations on the same stream varied seasonally (Table 2); and meiofauna comprised a majority of the benthos, especially in the reclaimed streams (Table 3).

b) Taxonomic Composition

The invertebrate communities at the reclaimed streams (2 and 3) were not as well developed as in the mine-influenced and agriculturally or residentially disturbed streams. Crustacea (principally Copepoda and Ostracoda) predominated the fauna of the reclaimed streams (Figure 2), and there were extremely low densities of Chironomidae, a major component of the other streams. Moreover, all of the Alafia headwater streams lacked Rotifera, a phylum that contributed significantly to the total density of organisms in White Clay Creek, (Borchardt and Bott 1995), Goose Creek (Palmer 1990) and the southern Ohio streams (Hummon et al. 1978).

Abundances of individuals or the presence of specific taxa in a habitat often increase when heterogeneity in a habitat increases (see Bell et al. 1991 and references therein). In aquatic habitats, structure may increase densities directly by providing increased habitable surfaces (e.g., Bros 1987, Pringle 1988, Kershner and Lodge 1990 and Matsumasa 1994), or indirectly by providing refugia from predation (e.g., Heck and Crowder 1991). In addition, the presence of structure often entrains leaves and other organic matter that otherwise would be swept away by currents (Carpenter and Lodge, 1986), and this increases the functional responses of the community.

Some of the following habitat and structure characteristics, observed during our sampling, probably had considerable influence upon the taxonomic compositions and densities of the reclaimed headwater streams studied in this project: 1) shallow streams with few pools or backwaters; 2) absence of tree roots and underhang refugia; and 3) the lack of a tree canopy and associated snag-producing branches and leaves. Increases in all of these factors would produce structure that would enhance food-webs and also would create new refugia from predators. Hall's Branch (stream 3) also had large blooms of an iron-depositing bacterium, *Leptrothrix ochracea*, in the fall and winter. Wellnitz et al. (1991) noted that large blooms of this bacterium, caused by high concentrations of iron and magnesium, were toxic to some invertebrates or produced reduced growth rates when fed upon; this probably is another limiting factor for this stream.

Because rotifers are so easily transported, their distribution is usually regarded as potentially cosmopolitan (Edmondson 1959). However, Irvine et al. (1990) showed that increased abundances of macrophytes in wetlands produced increases in numbers of sessile rotifers, and thus the absence of appreciable amounts of macrophytes and filamentous algae in the Alafia River headwater streams may have had a negative influence upon both taxonomic composition and invertebrate densities.

c) Similarity, Diversity, Species Richness and Evenness Indices

Our findings for percent similarity, diversity, species richness and evenness indices basically corroborated the differences between the reclaimed streams (2 and 3) and the other streams. The Czekanowski-Dice-Sorensen similarity index (Figure 3) and Simpson's reciprocal $(=N_2)$ (Figure 4) both showed profound differences which became larger during the dry season. Species richness (number of taxa) was low in streams 2 and 3, and annual means were only 48-54% of the means for other sites (Figure 5); yet our numbers of taxa, based on core samples, were appreciably higher (about 2-fold) than those recorded for Florida streams using dip nets (Barbour et al. 1996). Molinari's evenness index showed high variation between stream sites and seasons (Figure 5), but it did not clearly separate the reclaimed streams; they were at the lower end, however.

These metrics are often used to describe ecological communities, but there has been a wealth of criticism for some of the indices. For example, the Shannon-Wiener index which is currently the biocriterion for Florida streams (Barbour et al.1996) is rather sensitive to the few commonest species (Kempton and Taylor 1976). Because of this, Baev and Penev (1993) recommend the N_2 diversity index (showing how many species will be present in a hypothetical collection composed of equally abundant species if it would have the same diversity as the collection under question), but the index has not been used for any meiofaunal studies or for stream comparisons in North America. For macrofauna, the number of taxa (species richness) is one of the most useful metrics (Barbour et al. 1996); we also found it useful for core samples containing both meiofauna and macrofauna. Evenness or the second aspect of the diversity index was not as useful for our streams because of the marked seasonal variation.

d) Other Core Metrics

The percentages of the dominant taxon, Diptera and Chironomidae are meaningful metrics for macrofauna in the Florida peninsula (Barbour et al. 1996). For core samples containing both meiofauna and macrofauna, we found that percent of the dominant taxon and percent Chironomidae were useful metrics; percent Diptera was dominated by Chironomidae (95%) and therefore redundant (Table 5). Reclaimed streams in this study had 1.8-fold higher percentages of the dominant taxon (45% vs 25%) that were predominated by meiofauna, whereas macrofauna usually were the dominant taxon in the other stream types. The percent Chironomidae in our reclaimed streams was ≤ 11% , but 6 of 8 sites in the mine-influenced and agriculture- or residential-disturbed streams had ≥38%.

e) Hester-Dendy Samples

On an annual basis, there were no significant differences in Hester-Dendy densities between the 12 stream sites ($p = 0.221$), but there were marked differences between seasons ($p<0.01$). With one-month suspension times, the available space on a Hester-Dendy should be occupied by invertebrates unless large disturbances (oxygen depletion, desiccation or loss of samplers) have occurred. The seasonal differences in densities correlated with the lack of rainfall in the spring; densities were 2.5- to 3-fold greater during other seasons.

The taxonomic composition of the Hester-Dendy samplers was predominated by Chironomidae, Crustacea and Annelida, similar to the core samples. Taxa of the reclaimed streams were principally Crustacea but in winter chironomids were more abundant; chironomids and annelids predominated at the other streams. Similarity (Figure 6) and diversity (Figure 7) showed no clear groupings based on land use in the stream basins. However, the N_2 index showed marked seasonal differences with peak densities of insects in the winter, peaks of Crustacea in the spring; and peaks of annelids in the fall and winter. Numbers of taxa on the Hester-Dendy samplers were higher in this study than for the streams studied by Barbour et al. (1996) because of the larger numbers of meiofaunal crustaceans and chironomids. Species richness and evenness indices were less variable than the diversity index, and it was principally the spring dry season that accounted for differences.

We encountered several problems with the use of Hester-Dendy samplers. First, there is need for more H-D samplers per stream site, and careful placement of samplers, predicated when possible by previous information on flow dynamics. We used two samplers per site and found that fluctuating discharge (leaving the samplers dry or at much deeper depths), shifting sand and debris (burial of samplers) and loss of samplers (due to spates and associated turbidity) often reduced the number of replicates to 1 or in one case 0. These problems prevailed even though we had reduced the number of boards per sampler to 9 to prevent the sampler from sitting on the bottom in shallow segments of the stream. We recommend 3 or 4 samplers placed in locations that are based on anticipated rainfall. Shorter suspension time also may be appropriate when organisms show rapid development rates, such as chironomids and crustacea (at 31° C) in subtropical environments.

Dip net sampling was valuable in that a number of large taxa (crayfish, dragonflies, damselflies, and beetles) were obtained. The probability of collecting these with the core sampler or Hester-Dendy samplers is exceptionally low. Dip net and other semi-quantitative collections are being developed to provide rapid criteria for assigning water quality ratings and bioassesment (see Eaton and Lenat 1991; and Lenat 1993).

f) EPT Metrics

EPT taxa (Ephemeroptera, Plecoptera and Trichoptera) were collected using all of our sampling methods. More mayflies were collected with dip nets, probably because of their patchy distributions, more caddisfly larvae, especially the small members of the Hydroptilidae, were collected in core samples, and the only stonefly collected was found on a Hester-Dendy sampler. Barbour et al. (1996) found in a statewide survey that the interquartile range (25-75%) of numbers of EPT taxa was 4 to 11 species, but they noted that stoneflies and caddisflies were less common in the middle portion of the Florida peninsula. Using a normalization into unitless scores and interquartile ranges, Barbour et al (1996) developed a stream condition index (similar to those of Karr et al 1986 and Karr 1991) to discriminate between streams. For 89 collections of EPT taxa in the Florida peninsula, the EPT scores were: ≥4 taxa = good, 3-2 taxa = fair and < 2 = poor. Our annual values for the Alafia headwater streams ranged from 2 to 3 in the reclaimed streams, 6 to 7 in the mine-influenced streams, and 7 to 9 in the agriculture and/or residentially disturbed streams (Table 6).

g) Sampling Methods

The rapid bioassessment protocols (e.g. Barbour et al. 1996; Barbour et al. 1992; Lenat and Barbour 1994; Platkin et al. 1989; Resh and Jackson 1993) primarily seek quick, cost-effective assessments of stream condition. Hester-Dendy samplers and the semi-quantitative dip net methodology appear to work well for macroinvertebrates (Barbour et al. 1996), but there has been criticism of the bias [e.g. small sample size, consistent unit effort (100 organisms randomly picked), negative contagion and the need for meaningful numbers per unit area] associated with these methods (see Courtemanch 1996). Barbour and Gerristsen (1996) responded to the above criticisms by justifying the use of subsamples and recommending the use of appropriate subsample strategy for fixed-count procedures. The debate on these issues undoubtably will continue for some time.

Our technique ofoptimizing sample size for core samples should satisfy Courtemanch's "small sample size" objection, but Barbour and Gerristsen would argue that an extensive inventory of this type would require inordinately large numbers of identifications and time. The dip net technique we used appears sound for determining presence/absence of macroinvertebrate taxa, but it is inappropriate for calculating a stream condition index (SCI) (see Courtemanch's recommendations). We think justification of sampling methods should be based on the objectives of the study. Barbour's methodology may be appropriate for screening sites for possible disturbance, but it would not satisfy the needs of a study on the structure and function of the entire community. Meiofauna have not been studied in detail (Borchardt and Bott 1995) and food webs and energy flow through individual components (organic detritus, algae, bacteria, protozoa. meiofauna, macrofauna and fish) will be needed to adequately develop predictive models and better understanding of the ecosystem.

CHAPTER 2, FACTORS INFLUENCING THE DISTRIBUTION AND ABUNDANCE

Introduction

One of the fundamental principles of benthic ecology is that changes in the biota are reflections of changes in the physical environment (Matthews et al. 1991). Ecologists typically have used multivariate analyses and other classification and ordination techniques to investigate the structure of lotic invertebrate communities and their relationships with environmental parameters (e.g., Rabeni and Gibbs 1980; Ormerod and Edwards 1987; Rundle and Hildrew 1990; Storey et al. 1990). However, the complex distributions and patterns, both spatial and temporal, exhibited by invertebrates make statistical confirmation of such relationships difficult. Often there is need for additional refinement of variables and repetition of the multivariate analyses.

Although this study is preliminary in nature, it represents the first statistical study in peninsular Florida of inter-relationships between invertebrate densities and environmental parameters such as current velocity, water depth, percent organic matter, water chemistry (NH_4-N, NO_2 + NO_3 , Total N, ortho-P, Total P, Fe, Mn, dissolved oxygen, pH, alkalinity and turbidity) and terrestrial vegetation or canopy cover. The study employs six headwater streams of the Alafia River, Florida with different patterns of land-use in the catchments or drainage basins. These include: mined streams under reclamation (2), streams receiving runoff from mined lands (2), and streams receiving agricultural and/or residential runoff (2). The goal is to suggest better management strategies for these streams, and to determine meaningful variables for future studies.

Stream Descriptions

Information for the following descriptions comes from our seasonal (4) samplings of the sites (see Appendix D for a complete listing of physical characteristics) and from the Bartsch and Mushinsky vegetation report (Appendix E); the latter includes both species lists and observational comments. Stream site locations are listed in Chapter 1.

Stream Site 1A Pollard Branch is a shallow stream (< 6 cm mean depth) with moderate current velocity (annual mean = 6 cm sec^{-1}) and low discharge (annual mean = 0.0048 m^3 sec^{-1}). The forest surrounding this mine-influenced stream is a mixture of deciduous and persistent leaved species; cover is approximately 75%. The ground cover is principally ferns and tree litter (leaves and branches). The stream substrate is sandy with small pockets of organic debris.

Stream Site 1B - This site located about 1 km downstream from 1A has intermediate depth (12.6 cm mean depth), current velocity (annual mean = 9.3 cm sec^{-1}) and discharge (0.015 m^3 sec^{-1}). The forest is a mixture of deciduous and persistent leaved trees, comprising about 50% cover. The ground cover is principally grasses, ferns and tree litter. The stream substrate is sandy and there is more organic debris than at 1A.

Stream 2 - Dogleg Branch is a newly reclaimed stream (5-6 years) at Site 2B and a mine-influenced stream at Site 2A. The forest at 2A (5.71 acres) was preserved by the Florida Department of Environmental Regulation mining permit and was not mined like at 2B. However, alterations of runoff into 2A during mining and the restructuring of the drainage basin during reclamation appear to have created large areas of organic deposits and low current velocity (absence of spates to remove the organic matter). Thus, we designated both sites as “reclaimed”.

Stream Site 2A - This site is of intermediate depth (annual mean = 8 cm), but current velocity (annual mean = 1.4 cm sec^{-1}) and discharge (annual mean = 0.0013 m^3 sec^{-1}) are low compared to other stream sites. The forest is a mixture of deciduous and persistent leaved species; cover is approximately 80%. The ground cover is ferns and herbs with large numbers in contact with the stream. The substrate contains large concentrations of organic matter (5% to 65%) which coupled with exposed tree roots often cause the stream to flow in a braided pattern.

Stream Site 2B - Site 2B is of intermediate depth (annual mean = 12.2 cm), but current velocity (annual mean = 3.5 cm sec^{-1}) and discharge (annual mean = 0.0060 m^3 sec^{-1}) are low. The site lacks the oaks found at other stream sites. Red Maple *(Acer rubrum)*, Wax Myrtle *(Myrica cerifera)* and Carolina-willow *(Salix caroliniana)* predominate (0 to 50% cover), and there are large numbers of nuisance species in the area (cogon grass, *Imperata cylindrica;* cattail, *Typha domingensis;* and primrose willow, *Ludwigia peruviana).* A lot of this vegetation occurs within the stream and the sand substrate is covered to a large extent by plants and debris. Concentrations of organic matter are lower than at 2A, but higher than in non-reclaimed streams.

Site 3A - This 5-6 year old, reclaimed site on the upstream end of Hall's Branch, is of intermediate depth (annual mean = 11.6 cm), but current velocity (annual mean = 0.5 cm sec^{-1}) and discharge (annual mean = 0.0012 m^3 sec^{-1}) rates were the lowest of the 12 study sites; these low figures are attributable to the spring season when the stream was dry. The forest is deciduous trees covered by *Vitis sp.;* canopy cover is about 50% while ferns and herbs prevail at ground level. This site is a series of fairly deep pools connected by shallow runs. The substrate is sand mixed with high percentages of organic matter. During the fall and winter dense populations of the iron bacterium, *Leptothrix ochracea* covered most of the substrata.

Site 3B - This reclaimed site is shallower (mean depth = 4.6 cm) than 3A, with an absence of pools. Current velocity (annual mean = 1.2 cm sec^{-1}) and discharge (annual mean = 0.0013 m^3 sec^{-1}) are both low compared to other sites; this location was dry in the spring season. The forest canopy, principally Carolina-willow, covers 20-50% of the area. Cattail *(Typha domingensis)* and dog fennel *(Eupatorium capillifolium)* are common at this site, and grass often occurs in the stream covering the sand and clay substrata. *Leptothrix* is present at this site but not as abundantly as at Site 3A.

Site 4A - This branch of Poley Creek is mine influenced. The stream is intermediate in depth (annual mean = 9.9 cm) with high current velocity (annual mean = 10.7 cm sec^{-1}) and moderate discharge (0.0228 m^3 sec^{-1}). The forest is mixed with both deciduous and persistent leaved species, percent canopy cover is approximately 60%. The ground cover is predominately grasses, ferns and herbs; near the road (Harden Blvd) several exotic species are found. The substrate is a mixture of sand and limestone with underlying clay deposits. Considerable amounts of fallen tree branches and snags overlay the stream surface. This site is the only one where water flows across riffles and pools.

Site 4B - Physical characteristics of this site are all at moderate levels compared to other Alafia, headwater-stream sites. Annual means for depth, current velocity and discharge during the study were: 1) mean depth

= 12.3 cm, 2) mean current velocity = 6.9 cm sec^{-1}, and mean discharge = 0.0277 m ^{3}sec $^{-1}$. The forest is mixed with a heavy canopy (85%). The ground cover is comprised of a diverse fern population, but a large number of exotic species occur on the north side of the stream near a residential development. The substrate is sand and clay with small pockets of organic matter; it also contains large numbers of shells of the Asiatic clam *Corbicula fluminea)* .

Site 5A - Annual mean depth at this site is moderate (9.9 cm), current velocity is comparatively high (annual mean = 10.9 cm sec^{-1}) and mean discharge is low to moderate (0.0247 m^{3} sec^{-1}). The mixed forest has *Vitis sp.* in the canopy and cover is approximately 90%. The ground cover is lush with ferns. In the more rapid flow areas, the substrate is sandy, but along the margins of the streams, large deposits of organic matter (decomposing leaves) accumulate. Branches of trees are commonly found in the stream.

Stream 5B - This site contains a large number of deep pools and a few, shallow sandy runs. Annual means for depth, current velocity and discharge during the study were: 27.7 cm, 4.7 cm sec^{-1}, and 0.0252 m^{3} sec^{-1} respectively. The mixed forest canopy covers about 80% of the stream. Ground cover is sparse because cattle use this area for shade and water. The substrate is sand with moderate amounts of organic matter.

Site 6A - This site is deep and wide with moderate current velocity and high discharge rates. The annual mean depth is 17.1 cm, mean width (269 cm) is greater than for the other stream sites, the annual mean current velocity is 9.5 cm sec^{-1}, and mean discharge is 0.0575 m^{3} sec^{-1}. The mixed forest, deciduous and persistent leaved trees, has a canopy cover of approximately 80%. Ferns and grasses comprise the ground cover but there are three exotic species (Carolina-willow, *Salix caroliniana;* Primrose willow, *Ludwigia peruviana* and bamboo, *Bambusa* spp.) along the road. In shallow areas the substrate is sand and tree litter; deeper areas contain increased amounts of organic matter.

Site 6B - Values for depth, current velocity and discharge are high at this site. Annual means were: 25.6 cm, 11.2 cm sec^{-1}, and 0.0808 m^{3} sec^{-1} respectively. This stream flows through deeply cut banks such that water only moves into the forest during periods of excessive rainfall. The canopy is deciduous and covers 75%

during the summer. About 80% of the ground is covered by tree leaves, ground cover other than a few palmettos (Serenoa repens), is sparse. The substrate is sand and clay with moderate amounts of organic matter.

Methods

a) Physical-Chemical Parameters

At each seasonal sampling (n =4), 6 physical and 11 chemical measurements were made. Physical parameters included current velocity, depth, discharge, temperature, turbidity, and percentage of organic matter in the substrate. Chemical parameters were pH, alkalinity, conductivity, dissolved oxygen, Total Kjeldahl Nitrogen (TKN), Ammonia-N, Nitrite + Nitrate-N, Total Phosphorus, Ortho-Phosphorus, Iron, and Manganese. All samplings were made during the morning hours, before benthic sampling was initiated, at locations downstream from the benthic sampling plots. Samples were transported on ice to the laboratory; nutrients and metals were preserved in the field using U.S. EPA approved methods. Nutrient and metal samples were stored in a cold room for periods not exceeding EPA recommended holding times (U.S. EPA 1982).

A Marsh-McBirney (model 2000) portable flowmeter was used to measure current velocity, depth and width were measured with a meter stick, and discharge (a minimal estimate) was calculated using mean depth and mean current velocity just above the substrate (n = 16 for each core sampling plot). Samples for percent organic matter were collected adjacent to benthic cores with a 25 cm syringe corer; samples were then dried at temperatures < 100° C, and subsamples were ignited for 4 hrs at 550° C. Water temperature and conductivity were measured using a Tri-R electric thermistor and a Beckman RB3-338 conductivity bridge. Turbidity was determined with a Hach turbidimeter using nephelometric calibration (U.S. EPA 1979).

Hydrogen-ion concentrations were determined with a Coming 250 ion analyzer. Alkalinity was determined by titrating with 0.02 N H_2SO_4 using phenolphthalein and bromocresol green indicators (American Public

Health Association, et al. 1989). Dissolved oxygen was measured using the azide modification of the Winkler method (American Public Health Association, et al. 1989).

Nutrient determinations were made using an AutoAnalyzer and methods described in Standard Methods, 16th Edition (A.P.H.A. 1985). Total Kjeldahl Nitrogen (Std. Method 420) was measured, after digestion with a block digester. Nitrite + Nitrate-N was analyzed using Std. Method 419 and Ammonia-N was done with the automated phenate method (Std. Method 417 G). Phosphorus concentrations were determined for Ortho-Phosphorus (automated Ascorbic Acid Reduction Method - Std. Method 424 G) and Total Phosphorus (Ascorbic Acid Method - Std. Method 424 F). Iron and Manganese concentrations were determined using an Atomic Absorption Spectrophotometer/Flame (Std. Method - 303 A, Standard Methods, 1985)

b) Multiple Regression Analyses

Two models, Best Subset Regression and Stepwise Forward Regression, were used for making seasonal comparisons of the relationships between the total densities of invertebrates (dependent variable) and three independent variables [percent organic matter (POM), depth and current velocity (CV)] measured concurrently at each stream site (n=16 for all variables); other physical-chemical variables were not included because of the small numbers of samples in a season (maximum n=4). Total density and percent organic matter were transformed, to meet normality assumptions, using Log (Y+1) and arcsin $\sqrt{Y}$ respectively.

For comparisons of the entire data set (4 seasons), seasonal means were used for total density (dependent variable) and for each of the 14 physical-chemical factors (independent variables). Density and percent organic matter were transformed as in the previous analyses, and stepwise forward regression or best subset regression were calculated using SigmaStat statistical programs. Because of the small sample sizes, this analysis was not expected to account for large percentages of the variation, unless there were profound and consistent differences between stream sites. However, it can be used to get insight into which independent variables warrant further consideration.

Results

a) Physical and Chemical Parameters

Seasonal graphs of means for current velocity (m sec^{-1}), water depth (cm), and discharge (m^3 sec.’) for each stream site are presented in Figures 10 and 11. Because current velocity was measured at the surface of the substratum, in close proximity to the benthic invertebrates, these estimates and the discharge rates calculated using them are minimal values.

Current velocity was greatest in the summer when stream site means ranged from 0.02 to 0.27 m sec^{-1} (Figure 11). Six of the twelve stream sites (ranks in order of magnitude were: 5A, 4A, 6B, 6A, 1B and 4B) had means >0. 10 m sec^{-1}. Spring was the season with lowest current velocity; means for all stream sites were <0.10 m sec^{-1}, and three sites, 3A, 3B, and 4A were dry (Figure 11). The winter season ranked second in current velocity with 3 of 12 sites >0.10 m sec^{-1} (Figure 10), and fall was close behind with 1 of 12 sites >0. 10 m sec^{-1} (Figure 10). Summer and fall generally had greater current velocities at upstream sites (four of six and three of six respectively), whereas winter and spring had maximum velocities at downstream sites (five of six, and four of five streams respectively).

Mean depth at individual stream sites closely tracked the current velocity. Peak values occurred in the summer, minima were in the spring, and the fall and winter values were intermediate (Figures 10 and 11). Seasonal mean depths, for flowing streams, ranged from <.01 to 0.42 cm.

Discharge rates varied from <.002 to 0.15 m^3 sec^{-1} (Figures 10 and 11). Streams 4, 5 and 6 had markedly higher rates than streams 1, 2 and 3. Some of this was attributable to the higher summer rainfall amounts in the north prong (near Lakeland, Fla., the site of streams 4 and 6), but smaller drainage basins for streams 1, 2 and 3 also influenced discharge rates.

Seasonal means for the percent organic matter in the substratum are given for each of the twelve stream sites in Figure 12 (each mean represents 16 samples collected adjacent to benthic invertebrate samples, there were 192 samples per season and 720 samples for the yearly period). Organic matter concentrations were

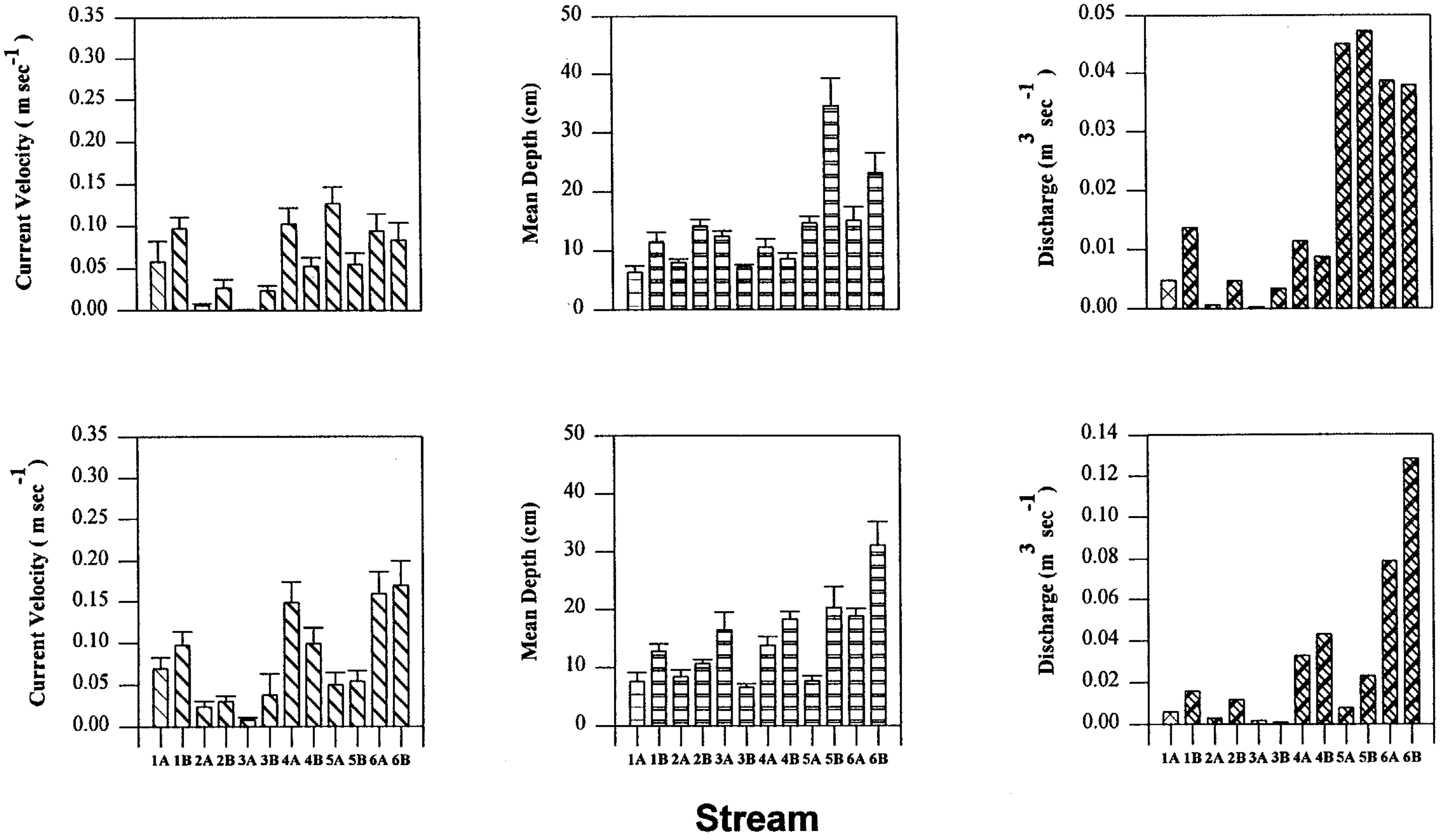


Figure 10. Mean values for current velocity, depth and discharge at twelve headwater stream sites in the Alafia River during the fall of 1993 (upper graphs) and winter of 1994 (lower graphs). Scales are similar in all seasons (including Figure 11) for comparative purposes.

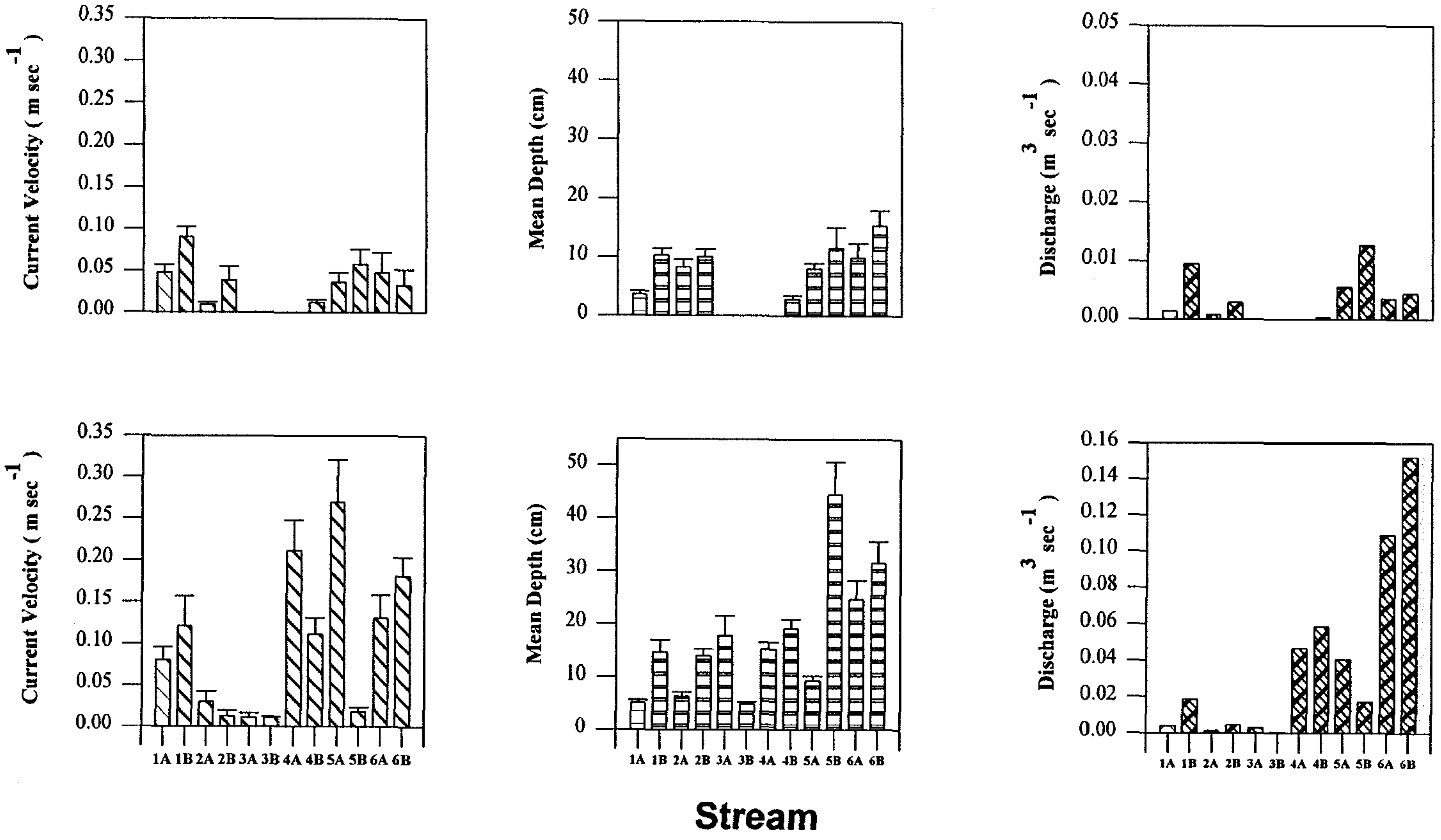


Figure 11. Mean values for current velocity, depth and discharge at twelve headwater stream sites in the Alafia River during the spring (upper graphs) and summer of 1994 (lower graphs). Scales are similar in all seasons (including Figure 10) for comparative purposes.

exceptionally high in the reclaimed streams (2 and 3) where annual means ranged from 21.76-35.91%; these reflected the low current velocities and discharge rates noted above. Both the mine-influenced streams (1 and 4) and the agricultural- and/or residential-disturbed streams (5 and 6) were an order of magnitude lower in organic matter than the reclaimed streams; annual mean concentrations for these sites ranged from 2.04% to 5.46%. Seasonal variation was slight at most of the stream sites; site 2A and the spring dry sites (3A, 3B, and 4A) were the only exceptions.

Annual means (n = 4) for seasonal measurements of selected water quality parameters (temperature, conductivity, pH, turbidity, alkalinity and dissolved oxygen concentration) at the twelve stream sites are given in Table 9. Measurements of water temperature ranged from 16-30° C, and the annual means ranged from 22.9-25.6° C. Mean conductivity values showed large differences among the six streams, ranging from a low of 130 $\mu S\ cm^{-1}$ in stream 5 to a high of 497 $\mu S\ cm^{-1}$ in stream 3; concentrations in reclaimed streams (2 and 3) were 1.5- to 3.8-fold greater than in mine-influenced or agricultural/residential disturbed streams.

Water pH showed little variation between streams (Table 9), with annual means ranging from 6.33 to 7.54. Turbidity was more variable with means ranging from 1.3 - 7.8 NTU. Three of the streams (3, 4 and 6) showed large variation (> 2 NTU) between upstream and downstream; the largest difference (5.7 NTU), found in stream 3, probably reflects the differences in population densities of the iron bacterium, *Leptothrix ochracea.*

Alkalinity concentrations were highly correlated with conductivity readings (see Table 9). Alkalinity concentrations were high (230-246 mg l^{-1} $CaCO_3$) in the reclaimed streams; the mine-influenced and agricultural/residential disturbed stream sites had annual means ranging from 16 to 112 mg l^{-1} $CaCO_3$. Annual mean dissolved oxygen concentrations were low (<4.0 mg l^{-1}) at stream sites with high percentages of organic matter and low current velocities, especially sites 2A and 3A (Table 9).

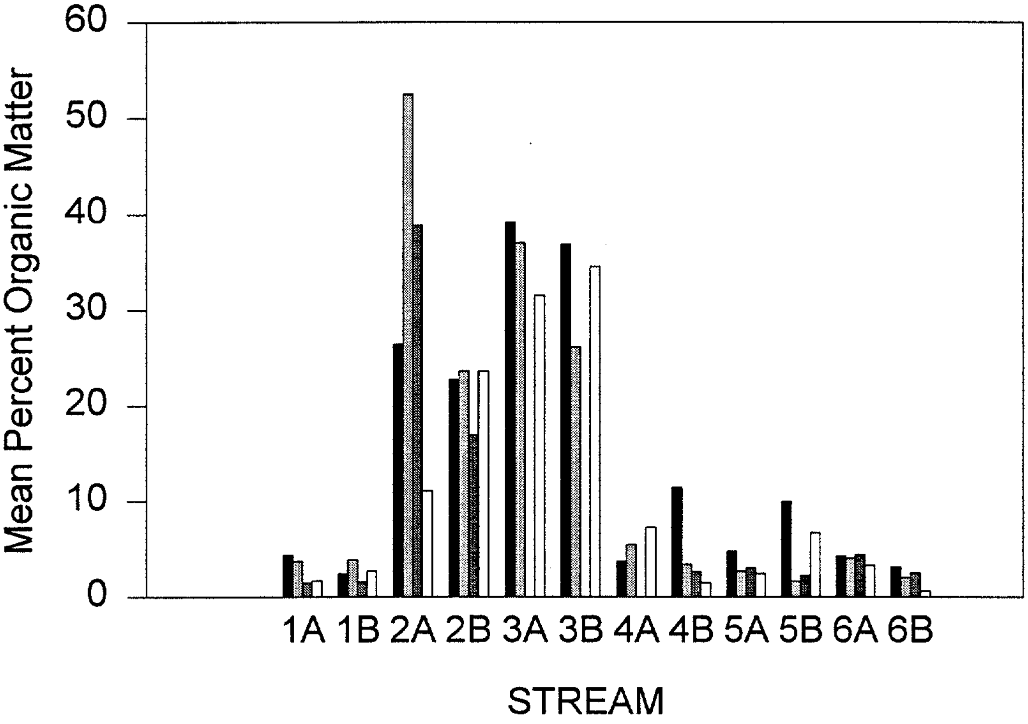


Figure 12. Percent organic matter (POM) concentrations by season at twelve headwater stream sites in the Alafia River, Florida, 1993-94. Black bars represent the fall season, lightly shaded is winter, heavily shaded is spring, and clear is summer.

Table 9. Annual means for seasonal measurements (n=4) of selected physical-chemical parameters for twelve stream sites on six headwater streams of the Alafia River, Florida, November 1993 through August 1994.

Stream Site	Temperature (°C)	Conductivity (μS cm^{-1})	pH	Turbidity (NTU)**	Alkalinity (mg l^{-1} $CaCO_3$)	Dissolved Oxygen (mg l^{-1})
1A	24.8	240	6.95	2.2	66	6.53
1B	24.4	248	7.30	1.3	88	7.48
2A	25.1	438	7.27	1.8	238	3.59
2B	23.9	438	7.54	2.4	230	5.46
3A*	22.9	497	7.08	7.8	246	2.11
3B*	25.6	487	7.51	2.1	241	5.08
4A*	23.0	213	7.22	4.9	66	5.51
4B	23.6	284	7.38	7.1	92	6.20
5A	25.6	150	6.60	1.7	19	4.32
5B	25.3	130	6.33	2.2	16	6.09
6A	24.6	325	7.05	6.6	112	6.02
6B	25.5	305	7.33	4.5	108	6.20

* Stream sites 3A, 3B and 4A were dry during the spring of 1994; means are based on n = 3.

** During the fall, turbidity was not measured in NTU units. Thus, n = 3 except for the streams that were dry in the spring.

Seasonal means for ammonia-N, nitrite-nitrate-N and TKN, averaged over all 12 stream sites, are shown in Figure 13. Ammonia-N was high in the spring (0.27 mg l^{-1}) and low in the fall (0.06 mg l^{-1}) , Nitrite-nitrate-N also was high in the spring (0.75 mg l^{-1}), but Total Nitrogen was highest in the summer (1.25 mg l^{-1}) and lowest in the spring (0.5 mg l^{-1}).

Phosphorus compounds only showed slight variation between seasons. Ortho-Phosphorus (Soluble Inorganic Phosphorus) ranged from 0.48 mg l^{-1} in the winter to 0.60 mg l^{-1} in the fall; spring and summer values were intermediate, between these values (Figure 14). Total Phosphorus peaked during the fall, at 0.85 mg l^{-1}, but the seasonal means were fairly constant, around 0.60 mg l^{-1}, in other seasons.

Seasonal means for iron and manganese are shown in Figure 15 . The mean iron concentration was 800 mg l^{-1} in the summer, but this was attributable to a high concentration at stream site 3A, where the summer concentration was 4,699 mg l^{-1}; all other sites had concentrations $< 1,000$ mg l^{-1} . The spring low, with a mean of 107 mg l^{-1}, occurred when stream 3 was dry. Manganese concentrations were fairly similar on a seasonal basis, seasonal means ranged from 40-120 mg l^{-1} (Figure 15). Again, stream site 3A had maximum concentrations, the peak of 853 mg l^{-1} occurred in the fall. A table of all the water quality and the chemical data is presented in Appendix F.

b) Multiple Regression Analyses

Table 10 shows a summary of the seasonal models, obtained from Best Subset Regressions at each of the 12 stream sites, for the relationships between total density of invertebrates (meiofauna + macrofauna) and the three independent variables (percent organic matter, depth and current velocity) measured concurrently. A total of 14 of the 45 models (31.1%) showed significant relationships ($p<0.05$); 13 of these were single variable models for which Best Subset and Stepwise Forward Regressions yielded similar results. Only 1 of the two-variable models was significant, this was at site 2A in the winter season and the predictive model was: Log_{10} Density = 3.574 + 0.919 POM + 9.474 CV . The R^2 values for all 45 models were less than 0.45, indicating that the best models explained less than 45% of the variability in total density. Streams 2 and 4 (2

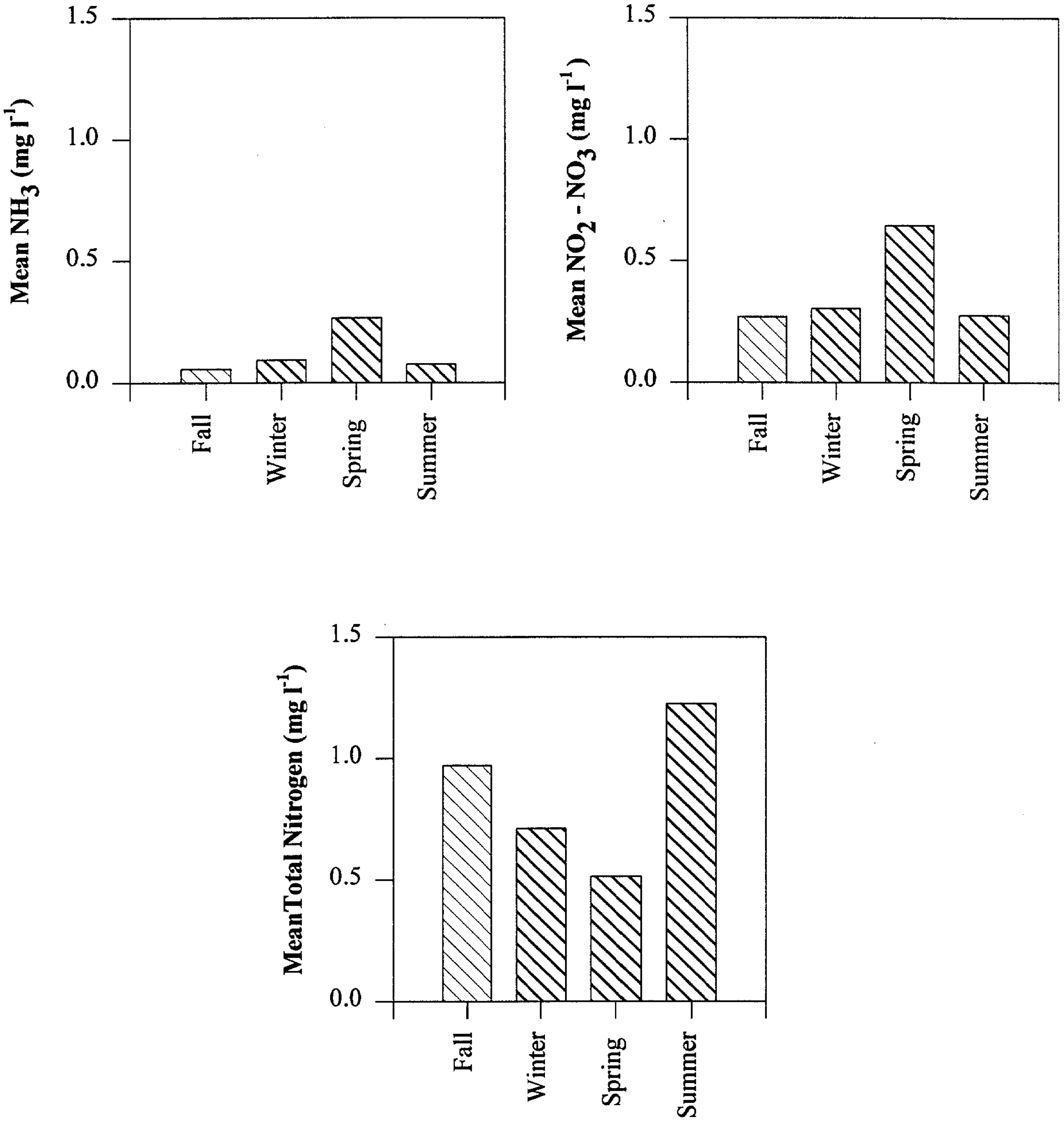


Figure 13. Seasonal means for nitrogen compounds in headwater streams of the Alafia River, Florida. 1993-94; means represent all twelve stream sites.

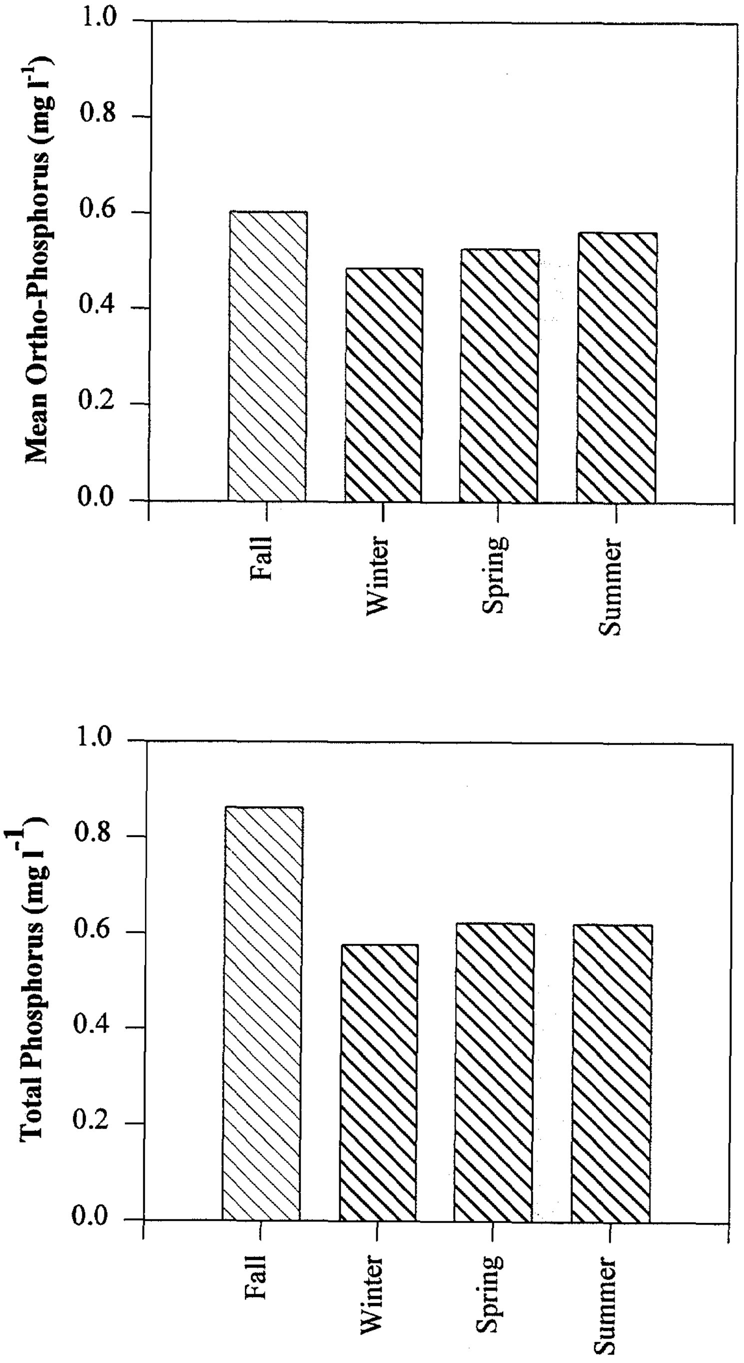
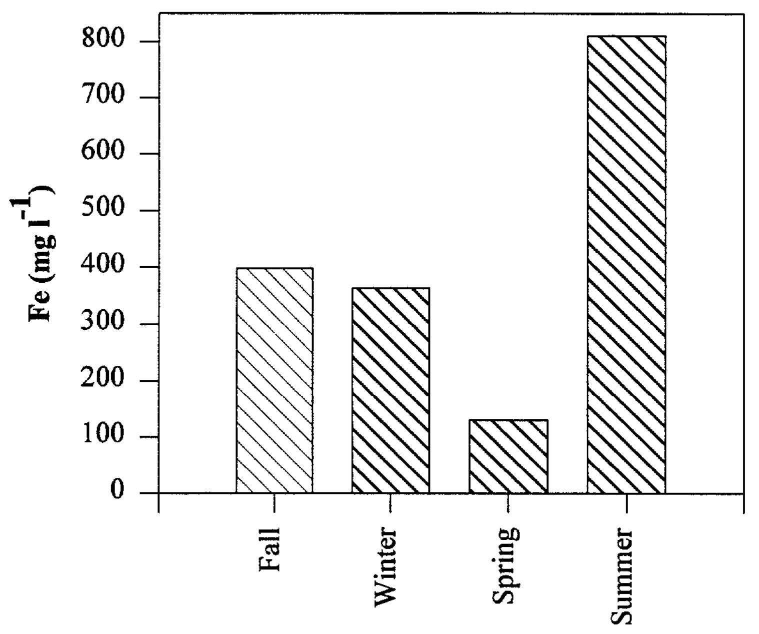


Figure 14. Seasonal means for phosphorus compounds in headwater streams of the Alafia River, Florida. 1993-94; means represent all twelve stream sites.



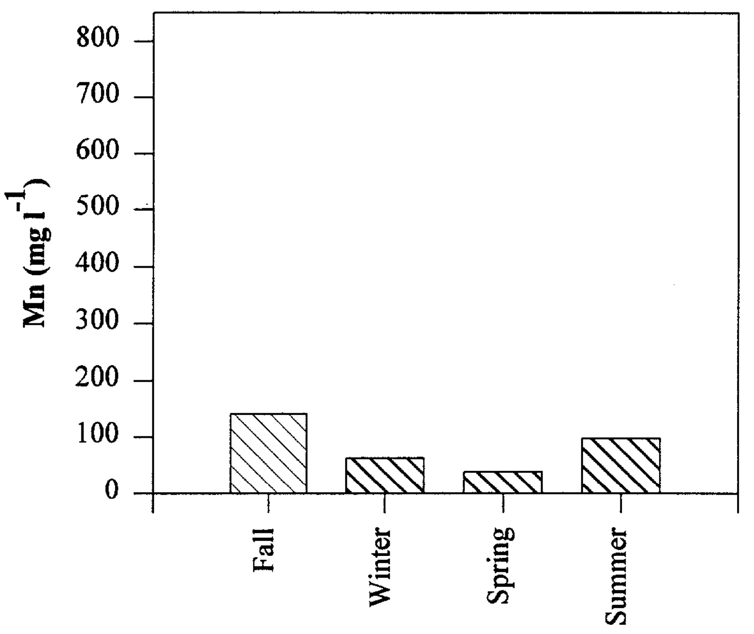


Figure 15. Seasonal means for iron and manganese compounds in headwater streams of the Alafia River, Florida. 1993-94; means represent all twelve stream sites.

Table 10. Multivariate analyses (Best Subset Regressions) for the relationships between total density of benthic invertebrates (dependent variable) and percent organic matter (POM), depth and current velocity (CV) at twelve headwater streams on the Alafia River, 1993-94. Transformations used included: Log $(Y+1)$ for total density and arcsin $\sqrt{Y}$ for percent organic matter. Equations are given for significant models ($p<0.05$). For each regression, $n = 16$.

Stream Site	Season of Year	R	R^2	P	Equation
1A	Fall	0.669	0.447	0.0046	$\text{Log } Y = 4.649 + 1.409 \text{ POM}$
	Winter	0.295	0.087	0.2674	
	Spring	0.456	0.208	0.0757	
	Summer	0.189	0.036	0.4837	
1B	Fall	0.436	0.190	0.0911	
	Winter	0.429	0.184	0.0974	
	Spring	0.318	0.101	0.2294	
	Summer	0.136	0.018	0.6168	
2A	Fall	0.545	0.297	0.029	$\text{Log } Y = 3.205 + 1.997 \text{ POM}$
	Winter	0.623	0.388	<0.036	$\text{Log } Y = 3.574 + 0.919 \text{ POM} + 9.474 \text{ CV}$
	Spring	0.564	0.318	0.023	$\text{Log } Y = 4.878 - 0.048 \text{ Depth}$
	Summer	0.370	0.137	0.159	
2B	Fall	0.252	0.064	0.346	
	Winter	0.541	0.293	0.031	$\text{Log } Y = 5.333 - 1.278 \text{ POM}$
	Spring	0.524	0.274	0.037	$\text{Log } Y = 4.678 - 1.347 \text{ POM}$
	Summer	0.127	0.016	0.640	
3A	Fall	0.526	0.277	0.036	$\text{Log } Y = 3.968 + 0.044 \text{ Depth}$
	Winter	0.046	0.002	0.867	
	Spring	Dry	Dry	Dry	
	Summer	0.312	0.097	0.240	
3B	Fall	0.337	0.113	0.202	
	Winter	0.276	0.076	0.301	
	Spring	Dry	Dry	Dry	
	Summer	0.290	0.084	0.277	
4A	Fall	0.486	0.236	0.057	
	Winter	0.598	0.358	0.014	$\text{Log } Y = 4.283 + 2.508 \text{ POM}$
	Spring	Dry	Dry	Dry	
	Summer	0.436	0.190	0.092	
4B	Fall	0.531	0.282	0.034	$\text{Log } Y = 4.643 + 0.020 \text{ Depth}$
	Winter	0.583	0.340	0.018	$\text{Log } Y = 4.472 + 1.929 \text{ CV}$
	Spring	0.292	0.085	0.290	
	Summer	0.559	0.312	0.024	$\text{Log } Y = 4.942 - 4.029 \text{ POM}$

5A	Fall Winter Spring Summer	0.207 0.364 0.612 0.055	0.043 0.132 0.375 0.003	0.442 0.166 0.012 0.839	Log Y = 4.748 - 2.639 CV
5B	Fall Winter Spring Summer	0.444 0.167 0.653 0.192	0.198 0.028 0.427 0.037	0.085 0.537 0.008 0.477	Log Y = 4.525 - 2.512 CV
6A	Fall Winter Spring Summer	0.553 0.343 0.311 0.405	0.306 0.118 0.097 0.164	0.026 0.193 0.240 0.119	Log Y = 4.890 - 1.066 POM
6B	Fall Winter Spring Summer	0.250 0.336 0.231 0.285	0.062 0.113 0.054 0.081	0.350 0.204 0.389 0.285	

= Dogleg Branch, a reclaimed stream and 4 = Poley Creek, a mine-influenced stream) had more significant models, 5 and 4 respectively, than the other streams which had only 1 significant model each.

Percent organic matter (POM) appeared in 8 of the significant models, current velocity (CV) in 4 and depth in 3. Organic matter had both positive and negative influences on density. Positive POM values were recorded at three upstream sites (1A, 2A and 4A) while negatives occurred at two downstream and one upstream sites (2B, 4B and 6A). Current velocity showed a positive influence at one reclaimed (2A) and one mine-influenced (4B) site; negative values were recorded at 5A and 5B (agriculturally disturbed) during the spring dry season. Depth was significant at site 2A during the spring and at sites 3A and 4B during the fall (Table 10).

The chemical variables (ammonia, nitrite-nitrate, total nitrogen, ortho-phosphorus, total phosphorus, iron, manganese, conductivity, pH, alkalinity and dissolved oxygen) were measured from single samples collected from each stream site (n=l). Thus, seasonal multivariate analyses on these variables were not possible. By incorporating the data for all four seasons and all twelve stream sites into a single data set, the sample size increased to n=45 and further analyses of possible indicators were attempted. However, a correlation

Table 11. Correlation matrix for total density of invertebrates and fourteen physical-chemical variables and associated probability values (p); n = 45. Abbreviations are: CV = current velocity, POM = percent organic matter, NH, = ammonia, NO_2 = nitrate + nitrite, TN = total nitrogen, SRP = ortho-phosphorus, TP = total phosphorus, FE = iron, MN = manganese, COND = conductivity, ALK = alkalinity and DO = dissolved oxygen.

VARIABLES	CV	DEPTH	POM	NH3	NO2	TN	SRP	TP	FE	MN	COND	pH	ALK	DO
LOG DENSITY	0.19	-0.121	-0.29	-0.06	-0.12	-0.39	0.15	0.1	-0.4	-0.28	0.08	0.17	-0.2	0.52
p	0.21	0.43	0.05	0.69	0.45	0.008	0.34	0.51	0.007	0.06	0.59	0.25	0.19	0.0002
CV		0.27	-0.58	-0.26	0.02	-0.11	0.07	-0.06	-0.11	-0.4	-0.47	-0.18	-0.56	0.3
p		0.07	0.00004	0.09	0.91	0.46	0.65	0.71	0.49	0.007	0.001	0.24	0.00006	0.05
DEPTH			-0.31	-0.21	0.06	0.29	-0.12	-0.14	0.2	-0.1	-0.38	-0.35	-0.32	0.11
p			0.04	0.18	0.69	0.05	0.42	0.35	0.18	0.52	0.009	0.02	0.03	0.48
POM				0.11	-0.27	0.27	-0.02	0.11	0.3	0.6	0.64	0.27	0.86	-0.59
p				0.46	0.08	0.08	0.89	0.46	0.04	0.00002	2E-06	0.07	3E-14	0.00002
NH3					-0.03	0.38	0.47	0.45	0.09	0.11	0.12	0.17	0.13	-0.37
p					0.85	0.01	0.001	0.002	0.57	0.47	0.43	0.26	0.4	0.01
NO3						-0.08	-0.32	-0.27	-0.14	-0.17	-0.43	-0.47	-0.46	-0.06
p						0.6	0.03	0.07	0.35	0.26	0.003	0.001	0.002	0.69
TN							0.32	0.44	0.29	0.36	0.1	0.08	0.17	-0.48
p							0.03	0.003	0.05	0.01	0.53	0.62	0.26	0.0009
SRP								0.92	-0.14	0.09	0.25	0.18	0.04	0.01
p								4E-19	0.35	0.56	0.1	0.23	0.82	0.95
TP									-0.13	0.2	0.31	0.12	0.11	-0.02
p									0.4	0.19	0.04	0.44	0.46	0.9
FE										0.72	-0.17	-0.04	0.28	-0.51
p										2E-08	0.26	0.81	0.06	0.0003
MN											0.28	0.04	0.52	-0.56
p											0.06	0.81	0.0003	0.00007
COND												0.53	0.81	-0.23
p												0.0002	1E-11	0.13
pH													0.5	-0.02
p													0.0004	0.92
ALK														-0.47
p														0.001

matrix of the chemical variables indicated that 9 of the 11 variables were autocorrelated significantly ($p \leq 0.03$), and when the physical variables (current velocity, depth and percent organic matter) were added, almost all variables were autocorrelated (Table 11). In another model, seasonal mean densities (Log,, transformed) at the 12 stream sites were correlated with the 14 physical-chemical variables to determine which had the greater mathematical relationships. Four variables had significant correlations with total density: dissolved oxygen correlated positively ($r = 0.52$, $p = 0.0002$) and iron ($r = -0.40$, $p = 0.007$), total nitrogen ($r = -0.39$, $p = 0.008$) and percent organic matter ($r = -0.29$, $p = 0.05$) correlated negatively (Table 11). When all independent variables were forced, regardless of autocorrelations, using either stepwise forward or best subset regression, the only significant variable was dissolved oxygen ($p = 0.0002$, $r^2 = 0.272$). Another forced regression using only the four independent variables with significant r values (dissolved oxygen, iron, total nitrogen and organic matter) yielded similar results.

c) Terrestrial Vegetation

The Bartsch and Mushinsky vegetation report (Appendix E) showed that there were significant differences between the dominant canopy trees at natural vs. reclaimed stream sites. The 1988 reclaimed sites (2B, 3A and 3B) were comprised principally of deciduous trees and percent cover was less than 50%, while the more natural sites usually were mixed (deciduous and evergreen species) with 60-90% cover. The principal species at the reclaimed sites were: *Salk caroliniana, Acer rubrum* and *Myrica cerifera.*

The reclaimed sites also had abundances of exotic species in the ground cover, including: *T. domingensis, Ludwigia peruviana,* and *Eupatorium capillifolium.* The nuisance species, *Imperata cylindrica* (cogon grass) occurred at site 2B. Ferns and herbs were the predominant ground cover at most natural sites.

Deciduous leaves and leaves from much of the ground cover decay more quickly than the scelerophyllous, evergreen leaves. This increases the FPOM (fine particulate organic matter) in the reclaimed streams, whereas persistent leaves or CPOM (course particulate organic matter) prevail in more mature forests. These differences can have marked influences on the meiofauna and macrofauna abundances (see Discussion).

Discussion

Lotic ecology is increasingly becoming an ecosystem-oriented or holistic science which links biotic dynamics and interactions with fluctuations in abiotic factors (Power et al. 1988). Species distributions, abundances and interactions (community dynamics) are increasingly being related to temporal and spatial changes in abiotic factors such that predictive models can be established to deal with natural variability and/or anthropogenic disturbances. Here we examine the influences of physical-chemical factors, substrate types and refugia, and spates and droughts upon benthic invertebrate densities.

a) Physical and Chemical Factors

In temperate streams, current velocity and discharge rates have been shown to have profound influences on stream bed complexity and invertebrate presence/absence or abundances. In peninsular Florida, where topographic relief and discharge rates are low, lesser impacts might be expected. But the pronounced seasonal variability in rainfall may also have influence; 55% of the annual rainfall in Central Florida occurs in the summer rainy season (June through September), and the winter and spring months usually have low rainfall (N.O.A.A. 1983). Our measurements of current velocity, depth and discharge (1993-1994), corroborated the seasonal variation in these patterns (Figures 10-11), but were responsible for only a few significant Multivariate models (~ 15%) between current velocity, depth and invertebrate densities. Current velocity had positive relationships with density in two streams during the winter (2A and 4B), and negative relationships at both sites on Hurrah Creek (5A and 5B) during the spring, but the r^2 values were low, < 0.45, and accounted for small percentages of the variability (Table 10). Depth appeared in two fall models (3A and 4B) and one spring model (2A), but all r^2 values were < 0.32 (Table 10).

The high organic matter concentrations (22-36%) in the reclaimed streams (streams 2 and 3) appear to be related to reclamation procedures, low discharge rates and the absence of scouring spates (see below). Allochthonous input from the organic mulch (spread during reclamation to hold moisture) and the deciduous trees planted adjacent to the reclaimed streams usually is rapidly decomposed, and falls to the bottom as

CPOM or FPOM (course or tine particulate organic matter) and becomes trapped in pools (e.g., 3A) or against aquatic vegetation (in 2B, 3A and 3B). With low discharge rates in these locations, the organic matter creates a reducing environment which has profound effects on dissolved oxygen and water chemistry (see Wetzel, 1983). However, in some of the mine-influenced or human-disturbed streams where evergreen tree species (oak) with sclerophyllous leaves (very slow decomposition) predominate, the smaller quantities of FPOM can be important sources of nutrition for benthic invertebrates (see Snaddon et al. 1992). These differences could be the reason that POM had positive influences on some models and negative influences on others.

When we forced the autocorrelated independent variables in annual multivariate analyses, four variables (dissolved oxygen, iron, total nitrogen and POM) showed significant correlations with total densities of macrofauna and meiofauna. But these correlations were anticipated based on water chemistry relationships. High POM and total nitrogen concentrations, especially in the summer months, create reducing environments which decrease dissolved oxygen concentrations, and under anoxic conditions, ferrous iron is released from the bottom sediments into the water (Wetzel 1983).

The impacts of low dissolved oxygen and/or high iron concentration appear to have had profound effects on the occurrence of chironomid (Diptera: Chironomidae) species in Hall's Branch (Table 12). Six taxa of chironomids occurred at all sampling sites except the two in Hall's Branch (10 of 12) . Moreover, the percent occurrence shows that these taxa occurred frequently (40-71%) in the other streams. One more taxon, *Paracladopelma sp.*, occurred at all sites except the reclaimed streams, Hall's Branch and Dogleg Branch, and five taxa were ubiquitous, occurring at all sites (Table 12).

b) Substrate Types and Refugia

Community ecologists working in streams have been trying to determine whether community structure is controlled by deterministic interactions between species (competition and predation) or by stochastic factors like disturbance (Townsend 1989). Many believe that streams conform well with the concept of patch

Table 12. Percent occurrence of the predominant taxa of Chironomidae at twelve sites in six headwater streams of the Alafia River, Florida during quarterly sampling 1993-94. The total number of sites sampled was n = 45; three sites (3A, 3B and 4A) were dry during the spring quarter. Hall's Branch (Stream 3) and Dogleg Branch (Stream 2) are reclaimed streams.

Percent Occurrence					
Ubiquitous Taxa, Present at all Sites		**Present at all Sites Except Hall's Branch**		**Present at all Sites except Hall's Branch and Dogleg Branch**	
Ablabesmyia mallochi	*48%*	*Pentaneura inconspicua*	44%	*Paracladopelma sp.*	35%
Thienemanniella sp.	54%	*Corynoneura sp.*	*71%*		
Rheotanytarsus sp.	52%	*Rheosmittia sp.*	40%		
Tanytarsus spp.	79%	*Polypedilum convictum*	71%		
Cryptochironomus sp.	56%	*Polypedilum halterale*	54%		
		Polypedilum scalaenum	69%		

dynamics (Pickett and White 1985) on a spatial or temporal scale. Pringle et al. (1988) stated that stream patches are determined by a number of interacting factors, such as: substratum conditions, topography, current patterns, organisms and disturbance. They further noted that patch sizes and boundaries perceived by individual organisms vary significantly among taxa and between different points in time. Our objective here is to cite examples of some of these factors studied in temperate streams and to compare them with our observations in the headwater streams of the Alafia River.

The erosive nature of water in meandering streams often creates large-sized habitat mosaics that are important to the distributions of many macrofaunal organisms. These instream habitat patches (macro-refugia) include areas such as: undercut banks, logs, regions in or out of the main current, and substratum composition (boulders, cobbles, stones, pebbles, sand and organic deposits). Streams with large spatial variety in habitat patches have the potential for larger numbers of species in the community. Pickett and White (1985) noted that localized areas of differing geomorphometry also may respond differently to the same disturbance. Townsend (1989) stated that temporal variation in disturbance is probably the factor of overriding significance, and that species with weedy characteristics are particularly prominent features of streams.

The Alafia River headwater streams of our study differed markedly in patch dynamics. Streams 4, 5 and 6 had more deeply cut beds with moderate sized banks (> 40 cm during the winter), and showed meandering drainage patterns. Stream 1 had similar meanders but lower banks (20- 30 cm). In contrast, the reclaimed streams (2 and 3) had shallow beds with little bank development, and moved in fairly straight patterns over sandy runs and deeper pools. Clewell (l994) stated that the comparatively straight pattern in Hall's Branch (3) resulted from excess water overflow from an upland marsh which was allowed to cut its own channel. In Dogleg Branch (2), the replacement stream flows lengthwise down the center of the restored terrain and connects with the original Dogleg Branch via a hydrologically connected canal (Clewell and Kelly 1995). Streams 1, 2 and 3 have low discharge rates that probably are attributable to small drainage basins, but water movement through the sand tailings, used in reconstruction, into the ground water or hyporheic regions is another possibility. In contrast, streams 4, 5 and 6 have substantial amounts of clay mixed with the sand which should slow water movement through the substratum.

In most streams there are large numbers of small, microhabitat patches such as the surfaces of snags, macrophytes, decomposing wood, leaf litter, and other allochthonous riparian vegetation, which serve as structure for epiphytic colonization. Often there are marked differences in the nutrient regimes between these patches which can control both the growth and abundances of algae, microbes, and zoobenthos (Pringle *et al.* 1988). Temporal differences due to the seasonal inputs of leaves and other allochthonous materials (CPOM) also contribute to nutrient variation. Some investigators have attempted to measure the nutrient regimes, but the techniques used were orders of magnitude too large to detect fine-grain temporal and spatial variation in patches (Pringle *et al.* 1988). However, Myers et al. (1988) noted that availability of essential elements is a key factor controlling rates of primary production and decomposition, and they recommended whole system manipulations to understand the interactions between elements and ecological processes. Some of the latter are currently being investigated, e.g. see: 1) measurements of meiofaunal grazing on algae and bacteria (Borchardt and Bott 1995), 2) interactions between stream herbivores and periphyton (Feminella and Hawkins 1995), and 3) new modes of quantifying spatial heterogeneity (Cooper et al. 1997).

In our headwater streams, microhabitat patches and refugia were more available at sites that had not been reclaimed, and these may have produced the high densities of chironomids and other insects during the fall and winter (see Chapter 1). But in the reclaimed streams, crustacean zooplankton were the predominant taxa because they cope more easily with low dissolved oxygen concentrations and can feed on the bacteria and particulate organic matter in suspension rather than utilizing benthic algae and protozoans. Lancaster and Robinson (1995) stated that organic detritus is the primary energy base in many running waters and microcrustacea may play a crucial functional role in energy flow through food webs, by virtue of their assimilation efficiency and high abundances Brussock et al.(1985) found that crustacean zooplankton tended to be more abundant in small-order reaches of Arkansas streams where the channel form is alluvial riffle and pool. In downstream reaches (2nd and 3d order streams), Brown et al. (1989) noted that significant quantities of zooplankton were produced in slow-moving pools and then removed by benthic invertebrate predation as the water flowed through riffles; fewer zooplankton were collected at downstream sites (> 3d order).

c) Spates and Droughts

Seasonal fluctuations in stream discharge have pronounced effects upon meiofaunal and macrofaunal life histories (e.g., see Welcomme 1985). Rising water levels increase the availability of bacterial and detrital food for many species (Goulding 1981; Welcomme 1985). Hauer and Benke (1987) found that blackflies increased in both number and body size following an increase in bacteria and particulate matter as waters spread onto the floodplain of a southeastern stream during a flood. However, the extremes in discharge fluctuations, i.e., scouring spates and droughts probably are more important because they eliminate most of the taxa; recovery rates vary with temperature, geographic location and colonization rates of individual taxa (see Mackay 1992).

Scouring spates have profound effects on both macro- and microhabitat patches, upstream reaches may be denuded of biota. For invertebrate survival in these situations, there must be natural spatial heterogeneity in the stream where spate-related increases in shear stress are not great. These include areas behind boulders, in riffles, near the banks, in backwaters and in deadwater zones associated with meanders (on the inside bend downstream from the meander apex) (Townsend 1989). Other temporary refugia include floodplain pools and hyporheic habitats with lower hydraulic stress. Irvine and Henriques (1984) noted that organisms may move with the water as it spills onto the floodplain and subsequently return when water flows back into the channel as the water level recedes. Stanford and Ward (1988) found that hyporheic regions with suitable pore space, oxygen gradients. substratum stability and organic flux through the habitat were important refugia for some zoobenthos; however streams in peninsular Florida do not appear to have many of these characteristics.

Floodplain pools are common occurrences in the low banked streams of peninsular Florida, like stream site 2A in this study, where lack of topographic variability causes movement of water onto the floodplain and, at the same time, reduces the scouring effects of the spate. Moreover, if the drainage basin is small, as in our reclaimed streams, then scouring spates are not as likely to occur and this could explain why large concentrations of organic matter persist in these streams.

Microhabitat patches are more influenced by increased discharge rates than macrohabitats. Snaddon et al. (1992) found that leaf retention decreased markedly with increasing discharge and that this had adverse effects upon shredder organisms (those feeding on CPOM). Macrophytes are readily uprooted by floods and are swept downstream to larger reaches, i.e., sections with higher stream-order numbers, where decomposition is rapid. Epiphytic algae and invertebrates on the stems of these macrophytes have difficulty surviving the flood, especially when the movement is to waters with different physical and chemical conditions (e.g., lower light levels and currents, coupled with differences in nutrient concentrations).

Drought probably has greater influence upon stream invertebrates than spates because death of the biota occurs quickly. Blinn et al. (1995) observed a ≥ 85% reduction of benthic macroinvertebrate mass after only one 12-hr summer exposure; repetitive periods of daily desiccation coupled with freezing temperatures significantly limited community biomass and energy. When desiccation occurs for long periods of time, most of the invertebrates die. However a few species have extraordinary physico-chemical tolerance. McLachlan and Cantrell (1980) found that the midge (Chironomidae), *Polypedilum vanderplanki,* could survive for years in sun baked sediments, yet grow rapidly following re-watering.

Recolonization of streams following re-watering is a variable dependent upon time of the year, presence or absence of desiccation-resistant eggs, invertebrate life history patterns and proximity to other aquatic habitats. Recolonization under cold temperatures in temperate streams obviously would be slow, yet in warm tropical environments, temperature should be of minor importance. Many crustaceans (copepods, cladocerans, fairy shrimp, etc.) have desiccation-resistant eggs which hatch quickly after reflooding. As long as reproductive adults of insects are available in close proximity to the re-watered stream, colonization will be rapid, but survival will be dependent on the abundance of algae, microbes, protozoans and other microinvertebrates. Blinn et al. (1995) found that snail (Gasteropoda) abundance on cobbles that had been desiccated for 6 mo. equalized control cobbles within 1 wk, whereas recolonization by amphipods and chironomids was much slower, i.e., ≤30% of controls after 4 months. Streams at considerable distance from other aquatic habitats could remain at low abundances of invertebrates for long periods of time (Merritt and Cummins 1984). In this study, low discharge rates and low dissolved oxygen in Hall’s Branch (Stream 3) during the summer appeared to delay the invertebrate recovery following re-watering, but at Poley Creek-East (Site 4A) where these problems did not exist, recovery was rapid (< 3 months).

There is need for continued work on factors influencing the distributions and abundances of meiofauna and macrofauna in streams. Part of the difficulty with our multivariate analyses was incomplete knowledge of temporal and spatial variations in community dynamics. This study resolved some of these problems but the need for additional sampling dates both within and between years (long-term environmental studies) to increase the statistical validity would be financially inequitable. Controlled experiments of short duration, using refined experimental equipment (e.g., continuous monitoring of physical chemical variables) and physical modification of geomorphology and biological structure should be good alternatives for solving design strategies for reclaimed streams.

CHAPTER 3, SUMMARY AND RECOMMENDATIONS

Summary

a) Distribution and Abundance

1. Annual mean densities of invertebrates at the twelve stream sites (2 sites on each stream) ranged from 20,896 to 175,212 organisms per square meter, and there was considerable variation among seasons of the year; densities in the fall and winter were approximately 2-fold greater than in the spring or summer. Kruskal-Wallis ANOVAs showed significant differences among sample sites in all seasons ($p<0.0001$), but multiple comparisons of the twelve sites showed distinct seasonal variability. During the fall and winter there were few significant differences (i.e., total densities at different sites were quite similar), but in the spring and summer, numbers of significant differences were considerably larger (i.e., sites differed from each other). The reclaimed streams had low densities.

2. On a numerical basis, the annual mean percentage of meiofauna, organisms less than 5 mm, for the twelve stream sites was 62%. The reclaimed streams had higher percentages (68-91%) than the mine-influenced (55-60%) or human disturbed (43-62%) streams.

3. The taxonomic composition of samples from the reclaimed streams was dominated by crustaceans (up to 75-85% of total densities). Streams receiving effluents from mined property and streams receiving effluents from agricultural or residential land-use were dominated by chironomids (Diptera) and annelids which comprised 71-92% of the total numbers of organisms. The number of taxa per season ranged from 90-127 and the total for the year was 187 taxa; Nematoda, Ostracoda, Harpacticoida and Hydracarina still need to be identified.

4. The Czekanowski-Dice-Sorensen similarity index showed that the reclaimed streams were similar to each other but markedly dissimilar from the other stream types. Diversity and species richness indices also were lower in the reclaimed streams.

5. Florida metrics for core samples showed marked differences between streams with different land uses. On an annual basis the percentage of the dominant taxon was 45% for reclaimed streams and 25% for the other stream types. Percentages of Diptera were low in the reclaimed streams, < 14%, while in most of the non-reclaimed sites it ranged from 30-46%. Numbers of species of Chironomidae (Diptera) also were low in the reclaimed streams, and the taxonomic composition was markedly different from that of the mine-influenced and agriculture or residentially disturbed streams.

6. We used Hester-Dendy samplers to collect drifting organisms at each stream site. On an annual basis, there were no differences between densities of organisms on the Hester-Dendy samplers at the twelve stream sites ($p = 0.221$). However, spring densities were markedly lower than those for other seasons, probably because of low flow rates (three sites were dry in the spring). The drift fauna was comprised predominately of Chironomidae, Crustacea and Annelida (91-96%); reclaimed streams had higher numbers of Crustacea. Similarity and diversity indices were lower than for the core samples with no clear groupings based upon land use. The shallow nature of the Alafia headwater streams and associated water level fluctuations caused much of the variability in the Hester-Dendy data. These samplers probably should not be used in the lower reaches (1st and 2nd orders) of streams of Florida.

7. Dip net sampling collected many larger taxa (Odonata, Hemiptera and Coleoptera) which were missed by core and Hester-Dendy sampling; this added another 24 taxa to our list (187 + 24 = 211 taxa).

b) Factors Influencing Distribution and Abundance

1. The Alafia River headwater streams can be characterized as quite shallow with low current velocities and discharge rates. Ranges for seasonal means of these parameters were: depth - 0 to 31.6 cm, current velocity - 0 to 0.27 m sec^{-1}, and discharge - 0 to 0.155 m^3 sec^{-1}. Three of our stream sites were dry during the spring season and velocity and discharge rates were very low at other stream sites. Invertebrate distributions and abundances were adversely affected by these changes, especially at the reclaimed sites.

2. Seasonal means of the percent organic matter in the substratum where benthic samples were collected, showed only minor variation within stream sites, but the reclaimed stream sites had significantly higher concentrations than other sites; means for these streams (2 and 3) ranged from 20 to 50% whereas most of the other streams (1, 4, 5 and 6) had means of less than 10%.

3. Water quality also showed variation between streams. Conductivity, turbidity, alkalinity and dissolved oxygen showed large variation while pH and temperature were quite uniform. Surprisingly, pH tended to be near neutral at all sites, annual means ranged from 6.33 to 7.54, and were not in the 4 to 6 range expected for Florida streams.

4. Nutrient analyses (N- and P- compounds) showed few significant differences between streams (within seasons), but there were marked seasonal differences when means of all twelve stream sites were averaged. Total Nitrogen decreased 2-fold from fall to spring, but then increased 2.5-fold between spring and summer. Ammonia-nitrogen showed a reverse pattern from that of Total Nitrogen. Nitrate-Nitrite-N was constant except for a spring high. Mean Phosphorus concentrations (Ortho-phosphorus and Total Phosphorus) were similar between seasons.

5. Iron and Manganese concentrations were much higher in the reclaimed streams; concentrations peaked at 4,699 µg l^{-1} and 853 µg l^{-1} respectively. Large populations of the iron bacterium, *Leptothrix ochracea* were found in Hall's Branch, this organism may have toxic effects on benthic invertebrates.

6. Multiple Regression Analyses (Best Subset Regression) were used seasonally at each of the twelve stream sites to compare total density of invertebrates (meiofauna plus macrofauna) with the three independent variables measured concurrently (percent organic matter, current velocity and depth). A total of 14 of the 45 models (31.1%) was significant ($p< 0.05$), but all R^2 values were less than 45%. Percent organic matter (POM) appeared in 8 of the models, current velocity (CV) in 4 and depth in 3. But when all independent variables were forced, regardless of autocorrelations, using either stepwise forward or best subset regression, the only significant variable was dissolved oxygen ($p = 0.0002$ and $r^2 = 0.272$). Because

of the small sample sizes in these regression models, the results were not expected to account for large percentages of the variability, unless there were profound and consistent differences between stream sites. Our data indicated that the latter was not true and thus the models can only be used to get insight into which variables warrant further consideration.

7. We used a correlation matrix to compare seasonal mean densities of invertebrates (Log_{10} transformed) with the 14 physical-chemical variables and found four variables with significant ($p< 0.05$) relationships. Dissolved oxygen correlated positively ($r = 0.52$, $p = 0.0002$) with total density and iron ($r = -0.40$, $p = 0.007$), total nitrogen ($r = -0.39$, $p = 0.008$), and percent organic matter ($r = -0.29$, $p = 0.05$) correlated negatively.

8. The reclaimed sites (streams 2 and 3) had deciduous tree cover but percent cover was less than 50%, while more natural sites usually had mixed (deciduous plus evergreen, oak species) canopies with 60-95% cover. The reclaimed sites also had abundances of exotic plants in the ground cover.

9. Influences of other factors that could cause the differences between the reclaimed and non-reclaimed streams are discussed; these include: 1) physical-chemical factors, 2) substrate type and refugia, and 3) spates and droughts. We believe that the high percentages of crustaceans in the reclaimed streams were caused by low predator abundances and utilization of the bacteria associated with organic matter as food. Low dissolved oxygen during the summer appeared to cause the small densities and different taxa of Chironomidae in Hall’s Branch (reclaimed stream). Low flow rates and the absence of spates in the reclaimed streams, failed to remove the large quantities of particulate organic matter (POM) which causes the low dissolved oxygen. Drought in the spring at both Hall’s Branch sites and Poley Creek-East eliminated the fauna but recolonization at the latter was much more rapid because of higher discharge rates.

Recommendations for Reclaimed Streams

The following recommendations are based on the results of this study, our observations on Alafia headwaters, and current ecological knowledge. The goal is to list procedures which should increase the total density of invertebrates through alteration of flow patterns, geomorphology and habitat patch dynamics. Not all of these recommendations will work in a given stream, assessment of the recommendations has to be based on the characteristics of each stream.

a) Discharge Rates and Geomorphology

1. Discharge rates need to be of sufficient volume to produce a natural stream meander; this may be a seasonal event. The stream should be allowed to grade to a sufficient level so that high banks prevail (grading and berm placement are alternatives for low water situations), such that the organic matter will remain on the floodplain when de-watering occurs following a flood. Construction of backwaters that retain excess flood waters would be another alternative.

2. Geologists and hydrologists should work to increase the geomorphology of the stream beds. Added structure and deposits of non-permeable soil types will aid in creating stream meanders, but excessive losses of water through movement into the ground water and/or hyporheic environs will be prevented.

3. Concurrent with increased discharge is the need to increase the number of scouring spates so that the large deposits of sclerophyllous leaves and FPOM are routinely flushed downstream, i.e., the potential for anoxic conditions should decrease.

b) Increasing both Macro- and Microhabitat Patches

1. Placement of logs and branches in newly reclaimed streams should entrap leaves (from upstream, unmined areas) and lead to the subsequent development of microbial and protozoan communities which act as food for invertebrates.

2. Planting aquatic vegetation during the early years of reclamation should provide additional micro-patches for the growth of epiphytic foods.

3. Planting a mixed forest, one with both deciduous and evergreen tree species, should provide leaves and branches for food and refugia.

4. Establishing backwater pools, in protected areas, to provide refugia for organisms during droughts would be beneficial.

5. Because the recovery time for droughts appears to be lengthy (> 3 mo. in this study), efforts should be made to prevent drought (increase the drainage basin size or modify land elevations within the basin). If droughts occur with regularity, it may not be possible to restore the stream to sound ecological conditions.

c) Continued Research

There is need for continued work on factors influencing the distributions and abundances of meiofauna and macrofauna in headwater streams. Controlled experiments, using refined experimental equipment (continuous monitoring of physical-chemical variables) and modification of geomorphology and biological structure should be good starting points. These experiments would yield “cause and effect” results rather than “correlations” which are hard to verify.

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APPENDICES FOR: MEIOFAUNA AND MACROFAUNA IN SIX HEADWATER STREAMS OF THE ALAFIA RIVER, FLORIDA, 1993 - 1994.

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Appendix A: Taxonomic References

A) Invertebrate Taxa

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FIPR FALL DATA
PERCENT COMPOSITION OF MAJOR GROUPS

STREAM SITE	01A	01B	02A	02B	03A	03B	04A	04B	05A	05B	06A	06B
GROUP												
Misc. Phyla	7	3	1	2	9	9	25	10	8	5	2	0
Annelida	21	35	6	6	30	22	9	23	33	29	15	89
Ostracoda	5	0	19	39	7	21	4	1	5	9	1	0
Amphipoda	1	0	2	3	0	0	0	1	0	0	1	1
Copepoda	13	1	23	28	43	41	9	20	14	14	4	2
Cladocera	4	3	36	5	2	0	0	2	6	2	0	0
Misc. Insecta	2	2	0	2	0	0	8	1	0	4	2	1
Chironomidae	45	45	8	10	6	3	40	22	31	35	66	5
Ceratopogonidae	1	1	0	2	1	0	1	4	1	2	1	0
Aquatic Mites	0	0	1	0	2	4	0	0	1	1	1	0
Mollusca	1	10	4	2	0	0	2	15	0	0	7	1
Total	100	100	100	100	100	100	100	100	100	100	100	100

Appendix B

FIPR WINTER DATA
PERCENT COMPOSITION OF MAJOR GROUPS

STREAM	01A	01B	02A	02B	03A	03B	04A	04B	05A	05B	06A	06B
GROUP												
Misc. Phyla	6	3	4	2	5	11	18	9	3	1	3	3
Annelida	28	28	7	4	7	9	7	33	11	32	22	67
Ostracoda	2	0	29	65	34	29	3	0	3	6	2	0
Amphipoda	1	0	15	1	0	0	1	7	0	0	14	1
Copepoda	16	2	2	5	34	43	6	24	7	7	2	1
Cladocera	1	1	15	5	0	0	0	0	2	1	0	0
Misc. Insecta	0	4	0	0	2	1	14	0	3	1	1	1
Chironomidae	43	57	22	12	12	4	48	13	69	51	49	26
Ceratopogonidae	1	1	3	5	2	1	1	3	1	0	2	1
Aquatic Mites	0	1	0	0	1	1	0	0	0	0	0	0
Mollusca	1	3	2	0	3	1	1	11	0	1	4	1
Total	100	100	100	100	100	100	100	100	100	100	100	100

Appendix B

FIPR SPRING DATA
PERCENT COMPOSITION OF MAJOR GROUPS

STREAM SITE	01A	01B	02A	02B	03A	03B	04A	04B	05A	05B	06A	06B
GROUP												
Misc. Phyla	7	5	2	1	0	0	0	3	7	2	0	1
Annelida	30	65	7	16	0	0	0	22	19	25	30	34
Ostracoda	2	0	33	63	0	0	0	0	15	14	0	0
Amphipoda	1	0	42	1	0	0	0	4	0	0	38	5
Copepoda	5	1	0	3	0	0	0	48	8	2	5	23
Cladocera	1	2	0	0	0	0	0	5	5	2	0	7
Misc. Insecta	1	1	0	1	0	0	0	1	1	3	2	2
Chironomidae	47	20	10	7	0	0	0	8	43	49	20	22
Ceratopogonidae	1	0	2	2	0	0	0	2	0	1	1	1
Aquatic Mites	0	0	0	1	0	0	0	0	0	0	0	0
Mollusca	4	5	3	4	0	0	0	8	1	2	1	4
Total	100	100	100	100	0	0	0	100	100	100	100	100

Appendix B

FIPR SUMMER DATA
PERCENT COMPOSITION OF MAJOR GROUPS

STREAM SITE	01A	01B	02A	02B	03A	03B	04A	04B	05A	05B	06A	06B
GROUP												
Misc. Phyla	5	2	3	1	14	5	4	2	4	10	1	0
Annelida	22	33	28	1	11	8	18	17	46	34	43	93
Ostracoda	2	1	38	80	39	77	2	0	2	12	1	0
Amphipoda	2	0	18	0	0	0	1	2	1	0	1	0
Copepoda	9	1	2	4	20	2	7	1	1	5	4	0
Cladocera	4	2	1	3	0	0	37	2	1	3	1	0
Misc. Insecta	1	1	0	0	4	1	4	1	8	5	2	1
Chironomidae	44	52	6	6	5	4	27	13	30	28	36	5
Ceratopogonidae	3	1	2	3	0	0	0	0	3	1	1	0
Aquatic Mites	0	1	0	1	0	2	0	0	1	0	1	0
Mollusca	8	6	2	1	7	0	0	62	5	1	10	1
Total	100	100	100	100	100	100	100	100	100	100	100	100

Appendix C. Taxa of Benthic Invertebrates at twelve headwater stream sites during the Winter.

	Density in No. m^{-2}					
Stream Site	**04A**	**04B**	**05A**	**05B**	**06A**	**06B**
Taxon						
Hydra sp. (Cnidaria)	37	146	37	0	0	0
Dugesia sp. (Tubellaria)	37	37	183	0	0	0
Helobdella sp. (Hirudinea)	0	0	0	0	37	0
Nematoda (several species)	21061	4563	1497	621	1488	3615
Nemertea (unidentified)	0	0	0	0	0	0
Total Miscellaneous Phyla	21134	4745	1716	621	1525	3615
Bratislavia bilongata	0	0	0	0	0	0
Chaetogaster diaphanus	0	511	0	0	0	0
Chaetogaster diastrophus	3373	1796	949	2847	1153	1570
Chaetogaster limnaei	131	1862	0	9052	6782	4065
Dero furcata	0	0	0	0	0	0
Dero nivea	0	0	0	0	0	0
Dero sp.	0	0	0	0	0	0
Haber speciosus	0	0	0	0	0	0
Nais bretscheri	0	37	0	0	0	91
Nais communis	0	1302	0	37	110	0
Nais paradalis	0	0	0	0	73	0
Nais pseudobtusa	0	0	0	0	0	0
Nais variablis	0	2285	0	37	117	2008
Ophidonais serpentina	0	0	0	0	0	0
Pristina aequiseta	0	0	73	0	0	0
Pristina breviseta	73	0	1241	1648	467	37
Pristina longiseta bidentata	584	0	475	0	183	475
Pristina longiseta longiseta	100	0	0	0	37	0
Pristina longisoma	0	0	0	122	0	0
Pristina osborni	1597	511	1186	576	37	1230
Pristina sima	110	0	0	0	0	0
Pristina sp.	0	37	0	0	0	0
Pristinella jenkinae	724	2430	438	13031	1578	72808
Slavina appendiculata	0	0	0	2327	37	0
Specaria josinae	0	0	0	0	0	0
Stephensonia tandyi	37	0	0	0	219	986
Stephensonia trivandrana	0	110	73	0	0	0
Stylaria fossularis	0	0	0	0	0	0
Total Naididae	6728	10878	4435	29675	10791	83267
Crustipellis tribranchiata	0	0	110	0	0	0
Eclipidrilus sp.	0	0	0	0	0	0
Enchytraeidae	110	3570	0	0	329	0
Lumbricus varigatus	523	956	694	73	37	329
Aulodrilius pigueti	0	37	0	0	0	0
Spirosperma sp.	268	292	511	73	803	2519
Limnodrilus hoffmeisteri	183	1641	1989	73	1482	6716
Quistadrilus multisetosus	0	0	0	0	0	0

Appendix C. **Taxa of Benthic Invertebrates at twelve headwater stream sites during the Winter.**

	Density in No. m^{-2}					
Stream Site	**04A**	**04B**	**05A**	**05B**	**06A**	**06B**
Taxon						
Hydra sp. (Cnidaria)	37	146	37	0	0	0
Dugesia sp. (Tubellaria)	37	37	183	0	0	0
Helobdella sp. (Hirudinea)	0	0	0	0	37	0
Nematoda (several species)	21061	4563	1497	621	1488	3615
Nemertea (unidentified)	0	0	0	0	0	0
Total Miscellaneous Phyla	21134	4745	1716	621	1525	3615
Bratislavia bilongata	0	0	0	0	0	0
Chaetogaster diaphanus	0	511	0	0	0	0
Chaetogaster diastrophus	3373	1796	949	2847	1153	1570
Chaetogaster limnaei	131	1862	0	9052	6782	4065
Dero furcata	0	0	0	0	0	0
Dero nivea	0	0	0	0	0	0
Dero sp.	0	0	0	0	0	0
Haber speciosus	0	0	0	0	0	0
Nais bretscheri	0	37	0	0	0	91
Nais communis	0	1302	0	37	110	0
Nais paradalis	0	0	0	0	73	0
Nais pseudobtusa	0	0	0	0	0	0
Nais variablis	0	2285	0	37	117	2008
Ophidonais serpentina	0	0	0	0	0	0
Pristina aequiseta	0	0	73	0	0	0
Pristina breviseta	73	0	1241	1648	467	37
Pristina longiseta bidentata	584	0	475	0	183	475
Pristina longiseta longiseta	100	0	0	0	37	0
Pristina longisoma	0	0	0	122	0	0
Pristina osborni	1597	511	1186	576	37	1230
Pristina sima	110	0	0	0	0	0
Pristina sp.	0	37	0	0	0	0
Pristinella jenkinae	724	2430	438	13031	1578	72808
Slavina appendiculata	0	0	0	2327	37	0
Specaria josinae	0	0	0	0	0	0
Stephensonia tandyi	37	0	0	0	219	986
Stephensonia trivandrana	0	110	73	0	0	0
Stylaria fossularis	0	0	0	0	0	0
Total Naididae	6728	10878	4435	29675	10791	83267
Crustipellis tribranchiata	0	0	110	0	0	0
Eclipidrilus sp.	0	0	0	0	0	0
Enchytraeidae	110	3570	0	0	329	0
Lumbricus varigatus	523	956	694	73	37	329
Aulodrilius pigueti	0	37	0	0	0	0
Spirosperma sp.	268	292	511	73	803	2519
Limnodrilus hoffmeisteri	183	1641	1989	73	1482	6716
Quistadrilus multisetosus	0	0	0	0	0	0

unidentifiable Tubificid	37	0	0	0	0	0
Total Tubificidae	2788	726	146	37	73	840
Total Annelida	52049	23944	3285	2701	2993	4015
Malacostraca: Astacidae (imm)	0	0	0	0	0	0
Palaemonetes paludosus	0	0	0	0	0	0
Ostracoda	3650	292	14418	42377	14199	12921
Gammarus sp. (Amphipoda)	0	0	0	0	0	0
Hyalella azteca (Amphipoda)	1935	0	7483	402	0	0
Asellus sp. (Isopoda)	0	0	0	0	0	0
Eucyclops agilis	3754	97	292	1237	5871	7817
Paracyclops fimbriatus poppei	1525	110	73	880	2978	4027
Macrocyclops albidus	473	0	438	37	1604	1982
Cyclopoid copepodids (unid.)	9031	341	256	694	3344	3991
Cyclopoid nauplii	3139	110	0	37	511	438
Harpacticoida	10731	840	37	110	73	438
Total Copepoda	28652	1497	1095	2993	14381	18694
Alona circumfimbriata	1424	548	0	1994	0	0
Alona quadrangularis	0	0	0	0	0	0
Alona rustica	0	0	0	0	0	0
Camptocercus rectirostris	0	0	0	0	0	0
Daphnia ambigua	0	0	0	0	0	0
Ilyocryptus spinifer	0	0	0	0	0	0
Leydigia quadrangularis	256	0	7556	1303	0	0
Macrothrix laticornis	0	0	0	0	0	0
Simocephalus expinosus	0	0	0	0	0	0
Total Cladocera	1679	548	7556	3297	0	0
Total Crustacea	35916	2336	30551	49068	28580	31615
Insecta	0	0	0	0	0	0
Sminthurides sp. (Collembola)	0	0	0	0	0	0
Hypogastrura denticulata(Collemb	0	0	0	0	0	0
Entomobrya assata (Collembola)	0	0	0	0	0	0
unid. Entomobryiidae (Collembola)	0	0	0	0	37	37
Isotomurus palustris (Collembola)	0	0	0	0	0	0
Salina banksii (Collembola)	0	0	0	0	0	0
Stenonema sp.	0	0	0	0	0	0
immature Heptageneidae	0	0	0	0	0	0
Caenis diminuta	0	0	0	183	0	0
immature Baetidae	0	329	0	37	0	73
Baetis sp.	37	256	0	0	0	0
Eurylophella temporalis	0	0	0	0	0	0
Macromia taeniolata	0	0	0	0	0	0
Immature Aeshnidae	0	37	0	0	0	0
Miathyria marcella	0	0	0	0	0	0
Dromogomphus spinosus	0	37	0	0	0	0
Gomphus sp.	0	37	0	0	0	0
Calopteryx maculata	37	0	0	0	0	0
dmgd & imm. Zygoptera	0	0	73	0	37	0
Hemiptera (unid., immature)	0	0	0	0	73	0
Rhagovelia sp.	0	0	0	0	0	0

unidentifiable Tubificid	0	183	0	0	37	0
Total Tubificidae	450	2152	2500	146	2321	9234
Total Annelida	7811	17557	7738	29894	13477	92830
Malacostraca: Astacidae (imm)	0	0	0	0	0	0
Palaemonetes paludosus	0	0	0	0	37	0
Ostracoda	3723	183	2190	5256	949	292
Gammarus sp. (Amphipoda)	0	3906	0	0	8286	1497
Hyalella azteca (Amphipoda)	584	0	0	0	0	0
Asellus sp. (Isopoda)	0	0	0	0	219	37
Eucyclops agilis	340	2557	402	460	73	0
Paracyclops fimbriatus poppei	694	4691	694	1066	438	73
Macrocyclops albidus	0	37	110	37	0	0
Cyclopoid copepodids (unid.)	610	1803	1169	591	146	183
Cyclopoid nauplii	183	840	37	183	37	0
Harpacticoida	5585	3139	2263	4307	511	584
Total Copepoda	7410	13067	4672	6643	1205	840
Alona circumfimbriata	219	0	584	438	256	110
Alona quadrangularis	0	0	73	73	0	37
Alona rustica	0	0	0	0	0	0
Camptocercus rectirostris	0	0	0	0	0	0
Daphnia ambigua	37	0	0	0	0	0
Ilyocryptus spinifer	0	0	0	0	0	0
Leydigia quadrangularis	0	0	840	402	37	0
Macrothrix laticornis	0	0	0	0	0	0
Simocephalus expinosus	0	0	0	0	0	0
Total Cladocera	256	0	1497	913	292	146
Total Crustacea	11972	17155	8359	12812	10987	2811
Insecta	0	0	0	0	0	0
Sminthurides sp. (Collembola)	0	0	0	0	0	37
Hypogastrura denticulata(Collemb	0	0	0	37	0	0
Entomobrya assata (Collembola)	0	0	0	0	0	0
unid. Entomobryiidae (Collembola)	0	0	0	0	0	0
Isotomurus palustris (Collembola)	0	0	0	0	0	0
Salina banksii (Collembola)	0	0	0	0	0	0
Stenonema sp.	0	0	0	0	37	0
immature Heptageneidae	0	0	0	0	0	0
Caenis diminuta	0	0	0	0	0	0
immature Baetidae	402	0	0	511	73	73
Baetis sp.	475	0	0	183	37	183
Eurylophella temporalis	0	0	0	37	0	0
Macromia taeniolata	0	0	0	37	0	0
Immature Aeshnidae	0	0	0	0	0	0
Miathyria marcella	0	37	0	0	0	0
Dromogomphus spinosus	0	0	0	0	0	0
Gomphus sp.	37	0	0	0	0	37
Calopteryx maculata	0	0	0	0	0	0
dmgd & imm. Zygoptera	0	0	0	0	0	0
Hemiptera (unid., immature)	0	0	0	0	0	0
Rhagovelia sp.	0	0	0	0	0	0

Corydalus cornutus (Megaloptera)	0	0	0	0	0	0
imm. Hydropsychidae (Tricoptera)	0	0	0	0	0	0
Cheumatopsyche sp.	0	256	0	0	0	0
immature Hydroptilidae	37	110	0	0	0	0
Orthotrichia	0	0	0	0	0	0
Oecetis sp.	0	0	0	0	0	37
Immature Polycentropodidae	0	0	0	0	0	0
Polycentropus sp.	0	0	0	0	0	0
Triaenodes sp.	0	0	0	0	0	0
Chimarra sp.	0	0	0	0	0	0
Parapoynx sp. (Lepidoptera)	0	0	0	0	0	0
Petrophila confusalis	0	0	0	0	0	0
Hydrophilidae (Coleoptera)	0	0	0	0	0	0
Dubiraphia sp. (larva)	0	73	0	0	0	0
Dubiraphia sp. (adults)	0	0	0	0	0	0
Stenelmis sp. (larva)	146	949	0	0	0	37
Dryopidae larva	0	0	0	0	0	0
Elmidae (Adults)	0	219	0	0	0	0
Dineutus sp. (Gyrinidae)	0	0	0	0	0	0
Bidessus sp. (Dytiscidae)	0	0	0	0	0	0
Immature beetle larva	0	0	0	0	0	0
Wyeomyia sp. (Diptera: Culicidae)	0	0	0	0	0	37
Simulidae (Diptera: larva)	365	986	0	0	0	0
Bittacomorpha sp. (Diptera)	0	0	0	0	621	0
Pseudolimnophila sp. (Diptera)	37	0	0	0	37	37
Empididae (Diptera)	0	0	0	0	0	0
Sciomyzidae (Diptera)	37	37	0	0	0	0
Allognosta sp. (Diptera: Syrphidae)	0	0	0	0	0	0
Chrysops sp. (Diptera:Tabanidae)	0	0	37	0	0	0
Total Miscellaneous Insects	694	3322	110	219	803	256
Chironomidae	0	0	0	0	0	0
Ablabesmyia mallochi	195	175	0	0	0	0
Ablabesmyia rhamphe	170	139	37	0	0	0
Ablabesmyia sp.	0	0	0	0	0	0
Denopelopia sp.	0	0	0	0	0	0
Djalmabatista sp.	0	0	0	0	0	0
Clinotanypus	0	0	37	110	0	0
Coleotanypus sp.	0	0	0	0	0	0
Larsia sp.	0	0	329	146	110	110
Labrundinea sp.	0	51	0	0	0	0
Natarsia sp	0	0	0	0	0	0
Nilotanypus sp.	0	73	0	0	0	0
Pentaneura inconspicua	0	146	0	0	0	0
Tanypus sp.	0	0	0	0	0	0
unidentifiable Tanypodinae	0	68	0	37	0	37
Corynoneura sp	9042	2222	5026	1599	0	329
Cricotopus sp.	0	0	0	110	0	110
Nanocladius sp.	0	0	0	0	0	0
Orthocladinae Sp. F	3961	64	0	0	0	0

Corydalus cornutus (Megaloptera)	0	0	0	0	0	0
imm. Hydropsychidae (Tricoptera)	694	0	1533	0	0	0
Cheumatopsyche sp.	12848	0	329	0	0	73
immature Hydroptilidae	256	0	37	0	0	0
Orthotrichia	0	0	0	37	0	0
Oecetis sp.	219	0	0	0	0	37
Immature Polycentropodidae	0	0	0	73	0	0
Polycentropus sp.	0	0	0	37	37	0
Triaenodes sp.	0	0	0	0	37	0
Chimarra sp.	0	0	0	0	0	0
Parapoynx sp. (Lepidoptera)	0	0	0	0	0	0
Petrophila confusalis	37	0	0	0	0	0
Hydrophilidae (Coleoptera)	73	37	0	0	0	0
Dubiraphia sp. (larva)	0	73	0	256	329	256
Dubiraphia sp. (adults)	0	0	0	0	0	0
Stenelmis sp. (larva)	1058	110	37	0	256	37
Dryopidae larva	0	0	0	0	0	0
Elmidae (Adults)	0	0	0	0	0	0
Dineutus sp. (Gyrinidae)	73	0	0	0	0	0
Bidessus sp. (Dytiscidae)	0	0	0	73	0	0
Immature beetle larva	37	0	0	0	0	0
Wyeomyia sp. (Diptera: Culicidae)	0	0	0	0	0	0
Simulidae (Diptera: larva)	256	0	0	0	37	0
Bittacomorpha sp. (Diptera)	0	0	0	0	0	0
Pseudolimnophila sp. (Diptera)	146	0	37	0	0	0
Empididae (Diptera)	0	0	37	0	0	0
Sciomyzidae (Diptera)	0	0	0	0	0	0
Allognosta sp. (Diptera: Syrphidae)	0	0	0	0	0	0
Chrysops sp. (Diptera:Tabanidae)	0	0	0	0	0	0
Total Miscellaneous Insects	16607	256	2008	1278	840	730
Chironomidae	0	0	0	0	0	0
Ablabesmyia mallochi	0	0	1866	1497	0	0
Ablabesmyia rhamphe	73	0	37	0	0	0
Ablabesmyia sp.	0	0	0	0	0	0
Denopelopia sp.	0	0	0	0	0	0
Djalmabatista sp.	0	0	0	0	0	0
Clinotanypus	0	0	0	0	129	0
Coleotanypus sp.	0	0	0	0	0	0
Larsia sp.	0	0	0	239	0	0
Labrundinea sp.	73	0	0	146	0	0
Natarsia sp	110	0	0	0	0	0
Nilotanypus sp.	0	0	0	0	0	0
Pentaneura inconspicua	411	0	501	966	0	110
Tanypus sp.	0	83	37	0	0	0
unidentifiable Tanypodinae	73	73	0	73	0	0
Corynoneura sp	9379	509	4365	399	954	511
Cricotopus sp.	2327	85	0	998	0	316
Nanocladius sp.	134	37	0	558	0	0
Orthocladinae Sp. F	293	0	182	0	0	0

Rheocricotopus sp.	741	1628	37	73	0	0
Rheosmittia sp.	4722	19017	0	0	0	0
Thienemanniella sp.	1611	3561	1233	226	0	402
unidentifiable Orthocladinae	0	37	110	0	0	37
Cladotanytarsus sp.	4803	1918	0	0	0	0
Tanytarsus sp	11036	776	516	1681	110	329
Paratanytarsus sp. A	0	0	0	0	0	37
Rheotanytarsus sp.	1860	1484	2285	2006	73	256
Stempellina sp.	0	0	0	0	0	0
Stempellinella sp.	4248	1866	37	529	0	37
Chironomus sp.	0	0	0	0	3338	73
Cryptochironomus sp.	3921	285	0	219	0	37
Cryptotendipes sp.	0	0	0	0	0	0
Goeldichironomus sp.	0	0	0	0	1079	0
Paracladopelma sp.	1473	137	0	0	0	0
Paralauterborniella sp.	403	438	0	110	0	0
Phaenosectra sp.	0	0	0	0	0	0
Polypedilum convictum	4710	2380	110	164	277	0
Polypedilum fallax	0	0	51	0	0	0
Polypedilum halterale	1877	292	387	73	0	0
Polypedilum illinoense	0	0	0	0	0	0
Polypedilum scalaenum	22598	10548	0	183	0	0
Polypedilum tritum	0	0	0	110	51	0
Polypedilum sp.	433	0	0	110	0	37
Stenochironomus sp.	0	0	85	37	0	0
Tribelos jucundum	496	0	0	0	0	0
Xestochironomus sp.	37	0	0	37	0	0
unknown chironomid	0	0	0	73	0	73
chironomid pupa	1231	292	329	37	73	0
Total Chironomidae	79570	47596	10605	7665	5110	1898
Bezzia	621	438	0	219	0	37
Dashyelinae Sp. B	0	0	0	0	0	0
Mallochohelia sp.	511	110	1401	3139	986	256
Total Ceratopogonidae	1132	548	1401	3358	986	292
Aquatic Mite	475	803	183	219	292	365
Bivalvia	0	0	0	0	0	0
Elliptio buckleyi	0	0	0	0	0	0
Corbicula fluminea	2081	2409	767	37	621	0
Gastropoda	0	0	0	73	37	0
Ferrissia sp.	475	183	0	37	0	73
Melanoides tuberculata	0	0	0	73	0	0
Physella sp.	110	0	0	0	438	292
immature Planorbidae	0	0	0	0	37	110
Viviparus georgiana	0	0	0	0	0	0
Total Mollusca	2665	2592	767	219	1132	475
GRAND TOTAL	184070	84060	49017	64726	42048	43842

Rheocricotopus sp.	1009	37	270	0	1025	621
Rheosmittia sp.	37	0	37	2081	258	0
Thienemanniella sp.	2385	73	7715	1277	492	2952
unidentifiable Orthocladinae	0	73	0	0	0	37
Cladotanytarsus sp.	183	2233	0	0	7631	11831
Tanytarsus sp	970	1430	10572	16855	1776	1388
Paratanytarsus sp. A	110	0	0	0	0	0
Rheotanytarsus sp.	751	49	2353	768	0	512
Stempellina sp.	0	219	0	0	0	318
Stempellinella sp.	206	0	544	0	101	0
Chironomus sp.	0	37	271	714	511	0
Cryptochironomus sp.	307	0	1699	1475	37	80
Cryptotendipes sp.	0	120	0	0	0	0
Goeldichironomus sp.	0	0	0	0	0	0
Paracladopelma sp.	212	970	1797	329	619	1461
Paralauterborniella sp.	0	678	162	2277	693	0
Phaenosectra sp.	0	0	0	1730	175	0
Polypedilum convictum	31970	85	1335	1392	504	2203
Polypedilum fallax	0	0	0	0	0	0
Polypedilum halterale	144	0	37	231	0	335
Polypedilum illinoense	0	0	0	0	0	0
Polypedilum scalaenum	4067	0	9561	12699	14096	13023
Polypedilum tritum	170	37	0	0	0	0
Polypedilum sp.	0	0	0	0	0	0
Stenochironomus sp.	0	0	281	0	110	0
Tribelos jucundum	0	0	125	566	0	0
Xestochironomus sp.	0	73	453	0	0	0
unknown chironomid	0	37	0	0	0	0
chironomid pupa	584	0	292	437	292	73
Total Chironomidae	55976	6935	46722	47706	29401	35770
Bezzia	292	1278	548	146	1095	1168
Dashyelinae Sp. B	0	0	0	0	0	0
Mallochohelia sp.	1387	110	0	37	146	37
Total Ceratopogonidae	1679	1387	548	183	1241	1205
Aquatic Mite	73	37	73	73	110	37
Bivalvia	0	0	0	0	0	0
Elliptio buckleyi	0	0	0	0	0	0
Corbicula fluminea	1314	4307	110	402	840	1022
Gastropoda	0	0	0	0	0	0
Ferrissia sp.	329	1606	146	73	1460	73
Melanoides tuberculata	0	0	0	0	0	0
Physella sp.	0	0	37	0	0	0
immature Planorbidae	0	0	0	0	37	37
Viviparus georgiana	0	0	0	0	0	0
Total Mollusca	1643	5913	292	475	2336	1132
GRAND TOTAL	116894	53984	67454	93039	59915	138128

Appendix C. Taxa of Benthic Invertebrates at twelve headwater stream sites during the Summer.

	Density in No. m^{-2}					
Stream Site	**01A**	**01B**	**02A**	**02B**	**03A**	**03B**
Taxon						
Hydra sp. (Cnidaria)	0	0	0	0	0	0
Dugesia sp. (Tubellaria)	37	37	110	0	256	183
Helobdella sp. (Hirudinea)	0	0	0	0	0	0
Nematoda (several species)	1752	365	1095	73	183	840
Nemertea	0	0	0	0	0	0
Total Miscellaneous Phyla	1789	402	1205	73	438	1022
Bratislavia bilongata	0	0	0	0	0	0
Chaetogaster diaphanus	0	0	0	0	0	0
Chaetogaster diastrophus	1679	511	0	0	0	0
Chaetogaster limnaei	1132	1095	0	0	0	0
Dero furcata	0	37	37	0	0	0
Dero nivea	0	0	0	0	0	0
Dero sp.	0	0	0	0	0	0
Haber speciosus	0	0	2993	0	0	37
Nais bretscheri	0	0	0	0	0	0
Nais communis	0	0	0	0	0	0
Nais paradalis	0	0	0	0	0	0
Nais pseudobtusa	0	0	0	0	0	0
Nais variablis	0	73	0	0	0	0
Ophidonais serpentina	73	110	0	0	0	0
Pristina aequiseta	0	37	37	0	0	0
Pristina longiseta bidentata	110	949	0	0	37	730
Pristina longiseta longiseta	0	73	37	0	0	0
Pristina longisoma	0	0	0	0	0	0
Pristina osborni	657	37	0	0	0	0
Pristina sima	0	0	37	0	0	0
Pristina synclites	183	0	37	0	0	37
Pristina sp.	0	0	0	0	0	0
Pristinella jenkinae	913	1862	5804	0	0	37
Slavina appendiculata	37	37	0	0	0	0
Specaria josinae	0	0	0	0	0	0
Stephensonia tandyi	0	0	0	0	0	0
Stephensonia trivandrana	0	0	0	0	0	0
Stylaria fossularis	0	0	73	37	0	0
Total Naididae	4782	4818	9052	37	37	876
Crustipellis tribranchiata	0	73	37	0	0	0
Eclipidrilus sp.	0	0	0	0	0	0
Enchytraeidae	0	37	219	0	0	0
Lumbricus varigatus	146	37	219	73	292	767
Aulodrilius pigueti	0	0	0	0	0	0
Spirosperma sp.	1935	1789	256	0	0	0
Limnodrilus hoffmeisteri	292	183	110	0	0	73
Quistadrilus multisetosus	0	0	0	0	0	0

Appendix C. Taxa of Benthic Invertebrates at twelve headwater stream sites during the Summer.

	Density in No. m^{-2}					
Stream Site	**04A**	**04B**	**05A**	**05B**	**06A**	**06B**
Taxon						
Hydra sp. (Cnidaria)	73	110	110	37	0	37
Dugesia sp. (Tubellaria)	0	0	37	37	0	0
Helobdella sp. (Hirudinea)	0	0	0	0	0	0
Nematoda (several species)	2154	876	110	511	110	806
Nemertea	0	0	0	0	0	0
Total Miscellaneous Phyla	2227	986	256	584	110	842
Bratislavia bilongata	0	0	0	0	0	0
Chaetogaster diaphanus	0	73	0	0	0	0
Chaetogaster diastrophus	3139	256	37	146	0	73
Chaetogaster limnaei	1716	183	0	0	73	295
Dero furcata	0	0	256	37	0	0
Dero nivea	0	0	0	37	0	0
Dero sp.	0	0	0	0	0	0
Haber speciosus	82	438	0	0	329	37
Nais bretscheri	0	0	0	0	0	0
Nais communis	0	0	0	0	0	0
Nais paradalis	0	0	0	0	0	0
Nais pseudobtusa	0	0	0	0	0	0
Nais variablis	73	0	0	0	0	9837
Ophidonais serpentina	0	0	0	0	0	0
Pristina aequiseta	0	73	0	0	0	0
Pristina longiseta bidentata	438	110	146	0	134	0
Pristina longiseta longiseta	0	0	0	0	0	0
Pristina longisoma	0	0	0	0	0	0
Pristina osborni	219	110	0	0	37	0
Pristina sima	0	0	0	0	0	0
Pristina synclites	840	329	37	0	913	392
Pristina sp.	0	0	0	0	0	0
Pristinella jenkinae	1834	256	256	803	73	1387
Slavina appendiculata	37	0	876	292	0	0
Specaria josinae	0	0	0	0	0	0
Stephensonia tandyi	0	0	0	0	0	0
Stephensonia trivandrana	0	73	0	0	0	0
Stylaria fossularis	383	0	0	0	49	82
Total Naididae	8760	1898	1606	1314	1606	12103
Crustipellis tribranchiata	0	0	37	0	0	0
Eclipidrilus sp.	0	0	0	0	0	0
Enchytraeidae	0	37	0	0	0	0
Lumbricus varigatus	0	0	0	0	0	0
Aulodrilius pigueti	183	73	0	0	0	0
Spirosperma sp.	0	0	0	0	0	0
Limnodrilus hoffmeisteri	0	365	475	548	2336	130517
Quistadrilus multisetosus	1132	5183	1022	73	1789	15021

Tubifex harmani	0	0	0	0	0	37
unidentifiable Tubificid	0	0	0	0	0	0
Total Tubificidae	2227	1971	365	0	0	110
Total Annelida	7154	6935	9892	110	329	1716
Malacostraca: Astacidae (imm)	0	0	0	0	0	0
Palaemonetes paludosus	0	0	0	0	0	0
Ostracoda	621	256	13469	8724	1205	15732
Gammarus sp. (Amphipoda)	0	0	0	0	0	0
Hyalella azteca (Amphipoda)	730	0	6278	37	0	0
Asellus sp. (Isopoda)	0	0	0	0	0	0
Eucyclops agilis	219	0	256	37	256	0
Paracyclops fimbriatus poppei	49	0	0	0	0	0
Macrocyclops albidus	134	0	0	73	0	0
Cyclopoid copepodids (unid.)	1095	110	438	292	329	511
Cyclopoid nauplii	402	37	0	73	0	0
Harpacticoida	1059	73	146	0	37	0
Total Copepoda	2957	219	840	475	621	511
Alona circumfimbriata	694	329	0	329	0	37
Alona quadrangularis	0	0	0	0	0	0
Alona rustica	0	0	0	0	0	0
Camptocercus rectirostris	0	0	0	0	0	0
Ceriodaphnia riguadi	0	0	0	0	0	0
Daphnia ambigua	0	0	0	0	0	0
Ilyocryptus spinifer	0	0	0	0	0	0
Leydigia quadrangularis	657	0	256	0	0	0
Macrothrix laticornis	0	0	0	0	0	0
Simocephalus expinosus	0	0	0	0	0	0
Total Cladocera	1351	329	256	329	0	37
Total Crustacea	5658	803	20842	9563	1825	16279
Insecta	0	0	0	0	0	0
Onychiurus sp. (Collembola)	0	37	0	0	0	0
Sminthurides sp. (Collembola)	0	0	0	0	0	0
Hypogastrura denticulata(Collemb	0	0	0	0	0	0
Entomobrya assata (Collembola)	0	0	0	0	73	37
unid. Entomobryiidae (Collembola)	0	0	0	0	0	0
Isotomurus palustris (Collembola)	0	0	0	0	0	0
Salina banksii (Collembola)	37	0	0	0	0	0
Stenonema sp.	0	0	0	0	0	0
immature Heptageneidae	0	0	0	0	0	0
Caenis diminuta	0	0	0	0	0	0
immature Baetidae	0	0	0	0	0	0
Baetis intercalaris	0	0	0	0	0	0
Pseudocleon sp.	0	0	0	0	0	0
Eurylophella temporalis	0	0	0	0	0	0
Macromia taeniolata	0	0	0	0	0	0
Immature Aeshnidae	0	0	0	0	0	0
Libellula vibrans	0	0	0	0	0	0
Miathyria marcella	0	0	0	0	0	0
Dromogomphus spinosus	0	0	0	0	0	0

Tubifex harmani	0	0	0	0	0	0
unidentifiable Tubificid	0	0	0	0	0	0
Total Tubificidae	1132	5548	1497	621	4125	145538
Total Annelida	10074	7556	3139	1935	5731	157641
Malacostraca: Astacidae (imm)	0	0	0	0	0	0
Palaemonetes paludosus	0	0	0	0	0	0
Ostracoda	949	73	146	694	73	0
Gammarus sp. (Amphipoda)	0	986	0	0	110	292
Hyalella azteca (Amphipoda)	329	0	37	0	0	0
Asellus sp. (Isopoda)	0	0	0	0	0	0
Eucyclops agilis	353	73	0	0	37	37
Paracyclops fimbriatus poppei	786	37	0	0	110	0
Macrocyclops albidus	110	37	0	0	0	0
Cyclopoid copepodids (unid.)	905	37	0	146	73	0
Cyclopoid nauplii	183	73	0	0	0	37
Harpacticoida	1314	256	37	146	365	0
Total Copepoda	3650	511	37	292	584	73
Alona circumfimbriata	20659	694	73	183	146	73
Alona quadrangularis	0	0	0	0	0	0
Alona rustica	0	0	0	0	0	0
Camptocercus rectirostris	0	0	0	0	0	0
Ceriodaphnia riguadi	0	0	0	0	0	0
Daphnia ambigua	0	0	0	0	0	0
Ilyocryptus spinifer	0	0	0	0	0	0
Leydigia quadrangularis	0	0	0	0	0	0
Macrothrix laticornis	0	0	0	0	0	0
Simocephalus expinosus	0	0	0	0	0	0
Total Cladocera	20659	694	73	183	146	73
Total Crustacea	25587	2263	292	1168	913	438
Insecta	0	0	0	0	0	0
Onychiurus sp. (Collembola)	0	0	0	0	0	0
Sminthurides sp. (Collembola)	0	0	0	0	0	0
Hypogastrura denticulata(Collemb	0	0	0	0	0	0
Entomobrya assata (Collembola)	0	0	0	0	0	0
unid. Entomobryiidae (Collembola)	0	0	0	0	0	0
Isotomurus palustris (Collembola)	0	0	0	0	0	0
Salina banksii (Collembola)	0	0	0	0	0	0
Stenonema sp.	0	0	0	0	0	256
immature Heptageneidae	0	0	0	0	110	0
Caenis diminuta	0	0	0	0	0	0
immature Baetidae	110	0	0	0	0	0
Baetis intercalaris	146	0	0	0	110	146
Pseudocleon sp.	0	37	37	0	0	0
Eurylophella temporalis	0	0	0	0	0	0
Macromia taeniolata	0	0	0	0	0	0
Immature Aeshnidae	0	0	0	0	0	0
Libellula vibrans	0	0	0	73	0	0
Miathyria marcella	0	0	0	0	0	0
Dromogomphus spinosus	0	0	0	0	0	0

Gomphus sp.	0	37	0	0	0	0
Calopteryx maculata	37	0	0	0	0	0
immature Anisoptera	0	37	37	0	0	0
dmgd & imm. Zygoptera	37	37	0	0	0	0
Hemiptera (unid., immature)	0	0	0	0	0	0
Rhagovelia sp.	0	0	0	0	0	0
Corydalus cornutus (Megaloptera)	0	0	0	0	0	0
imm. Hydropsychidae (Tricoptera)	37	0	0	0	0	0
Cheumatopsyche sp.	0	0	0	0	0	0
Hydropsyche sp.	0	0	0	0	0	0
immature Hydroptilidae	0	0	0	0	0	0
Orthotrichia sp.	0	0	0	0	0	0
Neotrichia sp.	0	37	0	0	0	0
Oecetis sp.	0	0	0	0	0	0
Immature Polycentropodidae	0	0	0	0	0	0
Polycentropus sp.	0	0	0	0	0	0
Triaenodes sp.	0	0	0	0	0	0
Chimarra sp.	0	0	0	0	0	0
Parapoynx sp. (Lepidoptera)	0	0	0	0	0	37
Petrophila confusalis	0	0	0	0	0	0
Hydrophilidae (Coleoptera)	0	0	0	0	0	37
Dubiraphia sp. (larva)	0	37	0	0	37	0
Dubiraphia sp. (adults)	0	0	0	0	0	0
Stenelmis sp. (larva)	146	73	0	0	0	0
Stenelmis sp. (adult)	37	0	0	0	0	0
Dryopidae larva	0	0	0	0	0	0
Pelonomus obscurus (Dryopidae)	0	0	0	0	0	37
Elmidae (Adults)	0	0	0	0	0	0
Dineutus sp. (Gyrinidae)	0	0	0	0	0	0
Bidessus sp. (Dytiscidae)	0	0	0	0	0	0
Immature beetle larva	0	0	0	0	0	0
Wyeomyia sp. (Diptera: Culicidae)	0	0	0	0	0	0
Simulidae (Diptera: larva)	0	0	0	0	0	0
Bittacomorpha sp. (Diptera)	0	0	0	0	0	0
Pseudolimnophila sp. (Diptera)	0	0	0	0	0	0
Pericoma sp. (Diptera: Psychodidae	0	0	0	0	0	0
Empididae (Diptera)	0	0	0	0	0	0
Sciomyzidae (Diptera)	0	0	0	0	0	0
Allognosta sp. (Diptera: Syrphidae)	0	0	0	0	0	0
Chrysops sp. (Diptera:Tabanidae)	0	0	0	0	0	0
Total Miscellaneous Insects	329	292	37	0	110	146
Chironomidae	0	0	0	0	0	0
Ablabesmyia mallochi	156	80	0	0	0	37
Ablabesmyia rhamphe	46	183	110	0	0	0
Ablabesmyia sp.	0	0	37	0	0	0
Denopelopia sp.	0	0	0	0	0	0
Djalmabatista sp.	0	0	0	0	0	0
Clinotanypus	0	0	37	0	0	0
Coleotanypus sp.	0	0	0	0	0	0

Gomphus sp.	0	0	0	0	37	0
Calopteryx maculata	0	0	0	0	0	0
immature Anisoptera	0	0	0	0	0	0
dmgd & imm. Zygoptera	37	0	0	0	0	0
Hemiptera (unid., immature)	0	0	0	0	0	0
Rhagovelia sp.	0	0	0	0	0	0
Corydalus cornutus (Megaloptera)	0	0	0	0	0	0
imm. Hydropsychidae (Tricoptera)	37	0	0	0	0	0
Cheumatopsyche sp.	37	37	402	0	0	0
Hydropsyche sp.	0	0	0	0	0	0
immature Hydroptilidae	0	0	0	0	0	0
Orthotrichia sp.	0	0	0	0	0	0
Neotrichia sp.	73	0	0	73	37	0
Oecetis sp.	0	0	0	0	0	0
Immature Polycentropodidae	0	0	0	0	0	0
Polycentropus sp.	0	0	0	0	0	0
Triaenodes sp.	0	0	0	0	0	0
Chimarra sp.	0	0	0	0	0	0
Parapoynx sp. (Lepidoptera)	0	0	0	0	0	0
Petrophila confusalis	0	0	0	0	0	0
Hydrophilidae (Coleoptera)	0	0	0	0	0	0
Dubiraphia sp. (larva)	292	110	0	73	37	438
Dubiraphia sp. (adults)	0	0	0	0	0	0
Stenelmis sp. (larva)	1424	110	0	37	0	438
Stenelmis sp. (adult)	37	37	0	0	0	73
Dryopidae larva	0	0	0	0	0	0
Pelonomus obscurus (Dryopidae)	0	0	0	0	0	0
Elmidae (Adults)	0	0	0	0	0	0
Dineutus sp. (Gyrinidae)	0	0	0	0	0	0
Bidessus sp. (Dytiscidae)	0	0	0	0	0	0
Immature beetle larva	0	0	0	0	0	0
Wyeomyia sp. (Diptera: Culicidae)	0	0	0	0	0	0
Simulidae (Diptera: larva)	73	0	37	0	0	0
Bittacomorpha sp. (Diptera)	0	0	0	0	0	0
Pseudolimnophila sp. (Diptera)	0	0	0	0	0	0
Pericoma sp. (Diptera: Psychodidae	0	0	0	0	0	0
Empididae (Diptera)	0	0	0	0	0	0
Sciomyzidae (Diptera)	0	0	0	0	0	0
Allognosta sp. (Diptera: Syrphidae)	0	0	0	0	0	0
Chrysops sp. (Diptera:Tabanidae)	0	0	0	0	0	0
Total Miscellaneous Insects	2263	329	511	256	329	1351
Chironomidae	0	0	0	0	0	0
Ablabesmyia mallochi	0	0	37	523	0	0
Ablabesmyia rhamphe	0	0	0	0	0	0
Ablabesmyia sp.	0	0	0	0	0	0
Denopelopia sp.	0	0	0	0	0	0
Djalmabatista sp.	0	0	0	0	0	0
Clinotanypus	0	0	0	0	0	0
Coleotanypus sp.	0	0	0	0	0	0

Larsia sp.	0	0	0	0	0	0
Labrundinea sp.	0	0	0	0	0	0
Labrundinea pilosella	0	0	0	0	0	0
Natarsia sp	91	0	183	0	146	292
Nilotanypus sp.	0	0	0	0	0	0
Pentaneura inconspicua	46	0	0	0	0	0
Procladius sp.	0	0	0	0	0	0
Tanypus sp.	0	0	0	0	0	0
unidentifiable Tanypodinae	0	0	0	37	0	37
Corynoneura sp	402	0	803	0	0	0
Cricotopus sp.	0	0	0	0	0	0
Nanocladius sp.	0	0	0	0	0	0
Orthocladinae Sp. F	0	0	0	0	0	0
Rheocricotopus sp.	0	0	0	0	0	0
Rheosmittia sp.	2117	651	0	0	0	0
Thienemanniella sp.	292	209	73	0	0	0
unidentifiable Orthocladinae	0	0	0	0	0	0
Cladotanytarsus sp.	791	2235	0	37	0	0
Tanytarsus sp	2280	153	365	73	0	365
Paratanytarsus sp. A	0	0	0	0	0	0
Rheotanytarsus sp.	73	0	0	0	0	0
Stempellina sp.	0	0	0	0	0	0
Stempellinella sp.	0	0	0	73	0	0
Chironomus sp.	0	0	37	0	0	0
Cryptochironomus sp.	1133	0	183	37	0	0
Cryptotendipes sp.	0	0	0	0	0	0
Dicrotendipes sp.	0	0	146	0	0	0
Goeldichironomus sp.	942	0	0	0	0	0
Paracladopelma sp.	0	0	0	0	0	0
Paralauterborniella sp.	0	0	0	0	0	0
Phaenosectra sp.	0	0	0	0	0	0
Polypedilum convictum	188	0	0	37	0	0
Polypedilum fallax	0	0	0	0	0	0
Polypedilum halterale	781	664	146	0	0	0
Polypedilum illinoense	0	0	0	37	0	37
Polypedilum scalaenum	4535	6734	0	292	0	0
Polypedilum tritum	139	0	0	0	0	73
Polypedilum sp.	0	0	0	0	0	0
Stenochironomus sp.	188	43	0	0	0	0
Tribelos jucundum	37	0	37	0	0	0
Xestochironomus sp.	0	0	0	0	0	0
unknown chironomid	0	0	0	0	0	0
chironomid pupa	110	0	37	0	0	37
Total Chironomidae	14344	10950	2190	621	146	876
Bezzia	913	183	0	37	0	0
Dashyelinae Sp. B	0	0	0	0	0	0
Mallochohelia sp.	0	0	657	256	0	73
Total Ceratopogonidae	913	183	657	292	0	73
Aquatic Mite	110	110	146	73	0	329

Larsia sp.	110	0	0	0	0	0
Labrundinea sp.	73	37	0	0	0	0
Labrundinea pilosella	0	0	0	207	39	0
Natarsia sp	183	0	0	0	0	0
Nilotanypus sp.	0	0	0	0	0	0
Pentaneura inconspicua	256	73	0	0	219	0
Procladius sp.	0	0	0	0	0	0
Tanypus sp.	0	0	0	0	0	0
unidentifiable Tanypodinae	0	0	0	73	0	0
Corynoneura sp	146	110	0	37	292	292
Cricotopus sp.	0	0	0	0	0	0
Nanocladius sp.	0	0	0	0	0	0
Orthocladinae Sp. F	0	0	0	0	0	0
Rheocricotopus sp.	0	0	0	0	0	774
Rheosmittia sp.	0	0	0	0	37	73
Thienemanniella sp.	292	475	146	0	0	0
unidentifiable Orthocladinae	0	0	0	0	0	0
Cladotanytarsus sp.	237	1789	0	37	1935	4207
Tanytarsus sp	230	256	341	219	110	1719
Paratanytarsus sp. A	0	0	0	0	37	0
Rheotanytarsus sp.	2599	0	97	0	0	0
Stempellina sp.	0	0	0	0	0	0
Stempellinella sp.	0	0	0	0	0	0
Chironomus sp.	214	0	0	0	0	0
Cryptochironomus sp.	1071	292	37	256	481	110
Cryptotendipes sp.	0	0	0	0	0	0
Dicrotendipes sp.	0	0	0	0	0	0
Goeldichironomus sp.	0	0	0	0	0	0
Paracladopelma sp.	0	840	0	0	0	162
Paralauterborniella sp.	0	231	0	0	183	0
Phaenosectra sp.	0	0	0	0	0	0
Polypedilum convictum	5765	183	475	37	37	37
Polypedilum fallax	0	0	0	0	0	0
Polypedilum halterale	0	61	168	0	0	73
Polypedilum illinoense	1585	0	0	0	0	0
Polypedilum scalaenum	1232	1132	672	146	1417	548
Polypedilum tritum	1047	0	0	0	0	0
Polypedilum sp.	0	0	0	0	0	0
Stenochironomus sp.	0	0	0	0	0	0
Tribelos jucundum	0	146	0	0	0	0
Xestochironomus sp.	0	0	0	0	0	0
unknown chironomid	0	0	0	0	0	0
chironomid pupa	73	37	37	37	0	37
Total Chironomidae	15111	5658	2008	1570	4782	8030
Bezzia	37	110	183	37	146	110
Dashyelinae Sp. B	0	0	0	0	0	0
Mallochohelia sp.	37	0	0	0	0	0
Total Ceratopogonidae	73	110	183	37	146	110
Aquatic Mite	0	73	37	0	73	146

Bivalvia	0	0	0	0	0	0
Elliptio buckleyi	0	0	0	0	0	0
Corbicula fluminea	2482	1278	511	110	183	0
Gastropoda	37	0	0	0	0	0
Ferrissia sp.	0	37	110	0	0	0
Physella sp.	37	0	0	37	37	37
immature Planorbidae	0	0	0	0	0	0
Viviparus georgiana	0	0	0	0	0	0
Total Mollusca	2555	1314	621	146	219	37
GRAND TOTAL	32850	20988	35588	10877	3066	20477

Bivalvia	0	0	0	0	0	0
Elliptio buckleyi	0	0	73	0	0	0
Corbicula fluminea	183	27485	183	73	1387	1205
Gastropoda	0	0	0	0	0	0
Ferrissia sp.	73	0	73	0	0	110
Physella sp.	0	0	0	0	0	0
immature Planorbidae	0	0	0	0	0	0
Viviparus georgiana	0	0	0	0	0	0
Total Mollusca	256	27485	329	73	1387	1314
GRAND TOTAL	55590	44457	6753	5621	13469	169871

Appendix D. Seasonal and Annual Means for Physical Characteristics of Twelve Headwater Streams of the Alafia River during 1993-1994.

Stream Site	**01A**	**01B**	**02A**	**02B**	**03A**	**03B**
Depth (cm)						
Fall	6.41	11.53	8.03	14.19	12.41	7.31
Winter	7.63	12.75	9.50	10.56	16.38	6.63
Spring	3.73	10.38	8.31	10.14	0.00	0.00
Summer	5.13	15.75	6.28	13.91	17.81	4.64
Annual Mean	5.72	12.60	8.03	12.20	11.65	4.65
Width (cm)						
Fall	129.73	122.56	129.5	123.75	406.625	208.75
Winter	111.25	129.06	124.375	128.75	121.25	107.5
Spring	77.63	102.00	99.06	180.81	0.00	0.00
Summer	97.06	135.94	106.38	278.44	137.31	138.75
Annual Mean	103.92	122.39	114.83	177.94	166.30	113.75
Velocity (cm/sec)						
Fall	5.81	9.69	0.63	2.69	0.06	2.31
Winter	6.94	9.69	2.375	2.94	0.813	3.81
Spring	4.75	9.00	0.94	3.88	0.00	0.00
Summer	8.00	12.06	2.94	1.25	1.13	1.06
Annual Mean	6.38	10.11	1.72	2.69	0.50	1.80
Discharge in cubic cm/sec						
Fall	4828	13687	650	4718	315	3526
Winter	5887	15945	2806	3998	1614	2715
Spring	1376	9524	772	7116	0	0
Summer	3980	25821	1964	4840	2752	685
Annual Mean	4018	16244	1548	5168	1170	1732
Discharge in cubic m/sec						
Fall	4.83E-03	1.37E-02	6.50E-04	4.72E-03	3.15E-04	3.53E-03
Winter	5.89E-03	1.59E-02	2.81E-03	4.00E-03	1.61E-03	2.72E-03
Spring	1.38E-03	9.52E-03	7.72E-04	7.12E-03	0.00E+00	0.00E+00
Summer	3.98E-03	2.58E-02	1.96E-03	4.84E-03	2.75E-03	6.85E-04
Annual Mean	4.02E-03	1.62E-02	1.55E-03	5.17E-03	1.17E-03	1.73E-03

Note: n = 16 for each Season and 64 for each annual mean.

Appendix D. **Seasonal and Annual Means for Physical Characteristics of Twelve Headwater Streams of the Alafia River during 1993-1994.**

Stream Site	**04A**	**04B**	**05A**	**05B**	**06A**	**06B**
Depth (cm)						
Fall	10.59	8.63	14.63	34.50	15.06	23.19
Winter	13.69	18.25	7.66	20.25	18.75	32.25
Spring	0.00	2.97	8.06	11.63	9.94	15.44
Summer	15.34	19.09	9.34	44.44	24.69	31.56
Annual Mean	9.91	12.23	9.92	27.70	17.11	25.61
Width (cm)						
Fall	104.95	195.063	242.5	240.875	273.75	197
Winter	161.25	238.75	202.813	210.94	320.63	233.75
Spring	0.00	105.00	189.75	187.75	142.31	181.56
Summer	171.88	275.50	193.31	217.00	339.06	267.31
Annual Mean	109.52	203.58	207.09	214.14	268.94	219.91
Velocity (cm/sec)						
Fall	10.25	5.25	12.69	5.50	9.38	8.31
Winter	14.88	9.88	5	5.44	15.94	17
Spring	0.00	1.25	3.63	5.81	4.81	3.31
Summer	21.16	11.13	26.94	1.81	13.00	18.06
Annual Mean	11.57	6.88	12.06	4.64	10.78	11.67
Discharge in cubic cm/sec						
Fall	11396	8833	45006	45706	38678	37960
Winter	32843	43049	7768	23237	95828	128153
Spring	0	390	5546	12687	6802	9278
Summer	55803	58521	48661	17478	108818	152394
Annual Mean	25011	27698	26745	24777	62532	81946
Discharge in cubic m/sec						
Fall	1.14E-02	8.83E-03	4.50E-02	4.57E-02	3.87E-02	3.80E-02
Winter	3.28E-02	4.30E-02	7.77E-03	2.32E-02	9.58E-02	1.28E-01
Spring	0.00E+00	3.90E-04	5.55E-03	1.27E-02	6.80E-03	9.28E-03
Summer	5.58E-02	5.85E-02	4.87E-02	1.75E-02	1.09E-01	1.52E-01
Annual Mean	2.50E-02	2.77E-02	2.67E-02	2.48E-02	6.25E-02	8.19E-02

Note: n = 16 for each Season and 64 for each annual mean.

Appendix E.

VEGETATION ANALYSES OF THE TWELVE STREAM SITES USED BY BRUCE COWELL FOR HIS FIPR GRANT

PREPARED BY: INGRID BARTSCH AND HENRY MUSHINSKY

DATE: 20 July 1994

SUMMARY

Differences in the vegetation between sites were reflected in species composition (specifically deciduous vs. persistent/evergreen leaves and natural vs. introduced species), in levels of canopy and ground cover, and in the aerial extent of the forested (wetland) area. A deciduous canopy would vary from a persistent/mixed canopy in that: (1) a "flush" of plant material would be produced (rather than a more gradual loss); (2) deciduous leaves decay more quickly than typical sclerophyllous, evergreen leaves; and (3) the understory would be exposed during some portion of the year (approximately October to late February in west central Florida).

Vegetation data for the predominant species within the canopy, shrub, and ground strata at each site are summarized in Tables 1 and 2. Plants were also ranked according to their cover and Kruskal-Wallis tests (results not shown) were used to determine whether there were significant differences among and between sites. These tests indicated that there were significant differences between the dominant canopy tree at natural vs. reclaimed sites (2B, 3A, and 3B). Disturbed and reclaimed sites had significantly different ground cover and significantly greater cover by introduced plant species.

VEGETATIVE DESCRIPTIONS

Stream 1 - Pollard Branch

Upstream (1A)

This floodplain forest extends approximately 20 - 30 m away from the stream. The tree canopy contains both deciduous and persistent leaves *(ie.* mixed), with cover of approximately 75%. Cover by plants at ground level is approximately 75% and predominated by ferns. There is some debris in contact with the stream.

Downstream (1B)

This floodplain forest extends approximately 30 - 40 m away from the stream. The tree canopy contains both deciduous and persistent leaves (ie. mixed), with cover of approximately 50%. Cover by plants at ground level is approximately 50% and predominated by grasses and ferns. There is some debris in contact with the stream.

Stream 2 - Dogleg

Upstream (2A)

This floodplain forest extends approximately 40 m away from the stream and is composed of both deciduous and persistent leaves *(ie.* mixed), with cover of approximately 80%. Large palms exist at the edge of the forest. Cover by plants at ground level is approximately 50% and predominated by ferns and herbs. There is a relatively large amount of plant material in contact with the stream.

Downstream(2B)

This forest extends approximately 20 m away from the stream. Beyond this, the vegetation consists of plants characterister of disturbed areas (Bahia grass, hairy indigo). The canopy contains primarily deciduous plants such as *Myrica cerifera, Acer rubrum,* and some *Salix caroliniana.* Cover ranges from 0% to 50% There *are* several exotic or nuisance species at *this* site, including cogon *grass (Imperata cylindrica),* cat-tail *(Typha latifilia)* (2 - 3 m tall), and primrose willow *(Ludwigia peruviana)* (2 m tall and establishing itself up to 10 m away from the stream).

Stream 3 - Hall's Branch

Upstream (3A)

This forest extends approximately 5 m away from the stream and is composed of deciduous trees with cover of approximately 50%. The canopy is taller than at the downstream site and is covered, in part, by *Vitis.* At the ground level, cover is primarily by ferns and herbs.

Downstream (3B)

This forest extends approximately 5 m away from the stream and is predominated by *Salix caroliniana.* Canopy cover ranges from 20 - 50%. *Typha latifolia* and *Eupatorium capillifolium* are common at this site.

Stream 4 - Poley

Upstream (4A)
This forest extends approximately 50 m away from the stream on the north side and 100 m on the south side. The canopy is mixed with cover of approximately 60%. At the ground level, cover is primarily by grasses to the north and by ferns and herbs to the south. Some exotic species, including *Salix caroliniana,* cogon grass and *Phragmites australis*, are present within 20 - 25 m of the stream.

Downstream (4B)
This floodplain forest extends approximately 100 m away from the stream on the south side but only 20 - 25 m on the north side, adjacent to a residential development. On the north side the vegetation contains numerous exotics *(Impatiens*, banana, ginger, elephant ear) which have clearly been discarded. Near the stream and in the more extensive part of the forest to the south, the canopy is mixed with cover of approximately 85%. Ground cover is primarily by ferns, which are relatively diverse at this site.

Stream 5 - Hurrah

Upstream (5A)
This floodplain forest extends approximately 50 m to either side of the stream and is mixed with cover of approximately 90%. The canopy has a dense *Vitis* cover. Ground cover is lush (90% cover) and predominated by ferns.

Downstream (5B)
This forest extends approximately 25 m to either side of the stream and is mixed
with cover of approximately 80%. Ground cover is very sparse (15% cover) due to trampling by cattle.

Stream 6 - Poley

Upstream (6A)
This forest extends approximately 100 m to the north and 50 m to the south of the stream, with a mixed canopy cover of approximately 80%. Ground cover is moderate (50% cover) and predominated by ferns and grasses *(Panicum hemitomum).* Three exotic or nuisance species (bamboo, hemp vine, and *Salix caroliniana)* are present near the road at this site.

Downstream (6B)
This forest extends approximately 100 m to either side of the stream, with a largely deciduous canopy cover of approximately 75%. Ground cover is sparse (80% cover by litter) and *Serenoa repens* (palmetto) grows along the bank of the stream on the east side.

Table 1. Presence/absence for predominant plant species.

SPECIES		SITE											
1. Canopy (> 5 m)		1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B
Liquidambar styraciflua	Sweetgum	+	+	+	+			+	+			+	+
Acer rubrum	Red maple	+	+		+	+	+	+	+	+	+	+	+
Quercus laurifolia	Laurel oak		+					+	+	+	+	+	
Quercus nigra	Water oak			+				+		+	+	+	+
Ulmus americana	Elm	+	+	+	+	+	+				+	+	+
Magnolia virginiana	Sweet bay	+		+	+	+				+	+	+	+
Magnolia grandiflora	Magnolia												+
Taxodium distichum	Bald cypress				+	+	+						
Sabal palmetto	Cabbage palm	+	+										
Fraxinus caroliniana	Water ash		+	+	+				+				
Nyssa sylvatica	Tupelo										+		
Carpinus americana	Ironwood		+										+
Chamaecyparis thyoides	Red cedar			+									
2. Shrub layer (2 - 5 m)													
Myrica cerifera	Wax myrtle				+		+	+					
Baccharus occidentalis	Saltbush				+				+				
Sabal palmetto	Cabbage palm	+	+	+				+	+	+			+
Serenoa repens	Palmetto												+
Acer rubrum	Red maple									+			
Ilex cassine	Dahoon holly						+				+		

Table 1. Presence/absence for predominant plant species.

SPECIES		SITE											
3. Ground Cover		1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B
Osmunda cinnamomea	Cinnamon fern	+		+	+	+		+	+	+			
Osmunda regalis	Regal fern								+				
Woodwordia virginica	Virginia chain fern	+	+	+		+						+	
Woodwordia aerolata	Netted chain fern	+							+	+	+		
Thelypteris palustris	Marsh fern	+						+					
Saururus cernuus	Lizard's tail	+		+				+		+			
Boehmeria cylindrica	False nettle	+		+		+	+				+		
Arisaema triphyllum	Jack-in-the-Pulpit		+						+				
Dichanthelium spp.	Grass	+											
Panicum hemitomom	Grass											+	
Iris tridentata	Iris								+				
4. Exotics/Nuisance spp.													
Salix caroliniana	Carolina-willow				+	+	+					+	
Typha latifolia	Cat-tail				+		+						
Bambusa spp.	Bamboo											+	
Eupatorium capillifolium	Dog fennel				+		+						
Rhus copallina	Winged sumac				+								
Phragmites australis	Giant reed							+					
Ludwigia peruviana	Primrose willow				+							+	

Table 2. Percent cover

SPECIES		SITE											
1. Canopy layer		1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B
Liquidambar styraciflua	Sweet gum	25	10	40	10			20	20			50	25
Acer rubrum	Red maple	25	10		20	10	10	30	5	10	40		15
Quercus laurifolia	Laurel oak		10					30	15	10		5	
Quercus nigra	Water oak			5				10		75	15	10	5
Ulmus americana	Elm	5	10	30	5	10	10		40			25	40
Magnolia virginiana	Sweet bay	5		10	5	5	5				25	5	5
Magnolia grandiflora	Magnolia												5
Taxodium distichum	Bald cypress				10	15	10						
Sabal palmetto	Cabbage palm	10	10	5									
Fraxinus caroliniana	Water ash			5	5	10			20		5		
Carpinus americana	Ironwood										5		5
Nyssa sylvatica	Tupelo										5		
Ilex cassine	Dahoon holly										5		
Myrica cerifera	Wax myrtle				30								
Baccharus occidentalis	Saltbush				5								
Salix caroliniana	Carolina-willow				10	50	65	10		5	5		
2. Ground layer													
Pteridophytes		40	20	35	20	10		30	35	80	5	15	
Grasses			10		50	40	60	40	5			15	
Herbs		35	20	30	20	30	30	10	30	10	10	20	20
Litter/bare ground		25	50	35	10	20	10	20	30	10	85	50	80

Appendix F. Physical-Chemical Parameters in Twelve Headwater Streams of the Alafia River, during the Fall of 1993.

Parameter	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	Mean
NH3 (mg/L)	0.039	0.015	0.441	0	0.029	0.007	0.023	0.051	0.057	0	0.005	0	0.056
NO2-NO3 (mg/L)	0.059	0.096	0.186	0.129	0.006	0.006	0.008	0.04	1.247	1.018	0.245	0.203	0.27
Total Nitrogen (mg/L)	0.62	0.8	1.61	0.39	0.98	2.12	0.56	0.43	1.46	1.16	0.72	0.8	0.971
Ortho-Phosphorus (mg/L)	0.567	1.048	0.574	0.447	0.768	1.403	0.29	0.407	0.425	0.365	0.487	0.46	0.603
Total Phosphorus (mg/L)	0.62	1.19	0.905	0.62	0.905	2.72	0.332	0.52	0.585	0.62	0.65	0.68	0.862
Fe (ug/L)	122	193	115	128	1900	675	163	148	475	460	217	179	397.9
Mn (ug/L)	6.6	21.3	62.9	22.6	853	610	14.3	21.5	28.8	22.7	14.1	15.3	141.1
Temperature (C)	22.8	23	24.5	25	23	24.9	17	16	26	25.5	23.5	24	22.93
Conductivity (uS/cm)	225	241	450	430	500	480	230	295	130	125	285	280	305.9
pH	6.47	6.51	6.95	7.04	6.89	7.1	7.23	7.16	6.54	5.42	6.71	6.79	6.734
Color (APHA Pt-Co unit)	70	100	60	70	>500	>500	42	50	325	310	60	60	95.58
Turbidity (NTU)	22	44	36	40	225	>500	10	13	70	65	18	15	46.5
Alkalinity (mg/L CaCO3)	62	88	238	240	236	219	61	67	12	9	109	114	121.3
Dissolved Oxygen (mg/L)	7.12	7.4	4.25	5.75	2	5.25	6.71	8.67	3.45	5.4	6.45	7.83	5.857

Appendix F. Physical-Chemical Parameters in Twelve Headwater Streams of the Alafia River, during the Winter of 1993.

Parameter	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	Mean
NH3 (mg/L)	0.055	0.026	0.108	0.023	0.54	0.009	0.015	0.045	0.144	0.033	0.056	0.063	0.093
NO2-NO3 (mg/L)	0.11	0.087	0.312	0.197	0.043	0	0.045	0.068	0.706	1.69	0.187	0.199	0.304
Total Nitrogen (mg/L)	0.54	0.55	0.56	0.68	1.28	0.67	0.51	0.56	1	0.75	0.69	0.77	0.713
Ortho-Phosphorus (mg/L)	0.729	0.597	0.306	0.413	0.137	0.181	0.63	0.834	0.277	0.322	0.73	0.674	0.486
Total Phosphorus (mg/L)	0.824	0.728	0.337	0.498	0.189	0.303	0.683	0.973	0.333	0.431	0.779	0.843	0.577
Fe (ug/L)	185	154	143	210	1911	98	276	245	232	248	375	284	363.4
Mn (ug/L)	35.6	25.2	64.3	38.7	417	63.44	14.6	26.6	26.6	12.8	18.4	15.2	63.2
Temperature (C)	23	22	22	20	19.8	21	25	23.3	21.2	21	23.5	23.6	22.12
Conductivity (uS/cm)	240	250	330	420	460	500	220	260	160	130	295	290	296.3
pH	6.83	7.4	7.31	7.98	7.19	7.78	7.4	7.45	7.09	7.05	6.31	7.42	7.268
Color (APHA Pt-Co unit)	40	60	40	60	120	80	60	95	80	120	100	95	79.17
Turbidity (NTU)	1	0.6	1.5	1.8	8.5	1.7	3.9	7.3	1.3	3.3	5.8	4.7	3.45
Alkalinity (mg/L CaCO3)	70	89	237	220	242	262	75	95	25	20	100	90	127.1
Dissolved Oxygen (mg/L)	7.1	8.02	3.6	6.4	2.8	5.55	6	6.8	5.05	7.05	6.45	6.5	5.943

Appendix F. Physical-Chemical Parameters in Twelve Headwater Streams of the Alafia River, during the Spring of 1994.

Parameter	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	Mean
NH3 (mg/L)	0.082	0.013	0.143	0.051				2.343	0.08	0.034	0.073	0.388	0.267
NO2-NO3 (mg/L)	0.077	0.106	0.179	0.003				0.37	4.343	2.413	0.23	0.015	0.645
Total Nitrogen (mg/L)	0.226	0.252	0.882	0.306				1.959	0.472	0.274	0.834	0.967	0.514
Ortho-Phosphorus (mg/L)	0.692	0.613	1.03	0.482				1.76	0.18	0.256	0.676	0.635	0.527
Total Phosphorus (mg/L)	0.741	0.595	1.401	0.491				2.422	0.184	0.224	0.765	0.658	0.623
Fe (ug/L)	348	142	137	143				227	95	100	206	169	130.6
Mn (ug/L)	56	16	38	103				114	33	22	36	48	38.83
Temperature (C)	25.5	24.5	25	24	DRY	DRY	DRY	28	25	25.5	24.2	26.5	19.02
Conductivity (uS/cm)	255	260	520	480				340	170	145	460	390	251.7
pH	7.29	7.77	7.48	7.6				7.59	6.4	6.61	7.79	7.76	5.524
Color (APHA Pt-Co unit)	80	55	50	60				80	55	45	70	40	44.58
Turbidity (NTU)	4.3	1.7	1.6	0.8				7	2	1.4	8.2	3.3	2.525
Alkalinity (mg/L CaCO3)	71	80	245	250				125	22	21	148	149	92.58
Dissolved Oxygen (mg/L)	6.2	8.25	3.6	5.4				3.1	4.5	6.65	5.25	4.6	3.963

Appendix F. Physical-Chemical Parameters in Twelve Headwater Streams of the Alafia River, during the Summerl of 1994.

Parameter	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	Mean
NH3 (mg/L)	0.025	0.021	0.21	0.068	0.315	0.021	0.012	0.037	0.061	0.045	0.057	0.036	0.076
NO2-NO3 (mg/L)	0.102	0.074	0.312	0.026	0.001	0.005	0	0.057	1.443	1.001	0.145	0.161	0.277
Total Nitrogen (mg/L)	0.07	0.98	0.86	1.38	1.37	1.89	0.96	1.23	1.16	1.93	1.15	1.71	1.224
Ortho-Phosphorus (mg/L)	0.779	0.584	0.275	0.703	0.145	0.525	0.727	0.436	0.433	0.379	0.885	0.885	0.563
Total Phosphorus (mg/L)	0.755	0.639	0.276	0.82	0.072	0.63	0.725	0.983	0.472	0.432	0.887	0.776	0.622
Fe (ug/L)	190	156	178	118	4699	203	681	787	373	361	998	985	810.8
Mn (ug/L)	16	0	108	4	661	267	14	26	3	23	18	32	97.67
Temperature (C)	28	28	29	26.5	26	31	27	27	30	29	27	28	28.04
Conductivity (uS/cm)	240	240	450	420	530	480	190	240	140	120	260	260	297.5
pH	7.2	7.5	7.32	7.53	7.15	7.65	7.04	7.31	6.35	6.23	7.38	7.36	7.168
Color (APHA Pt-Co unit)	75	100	55	75	230	160	70	120	220	220	150	175	137.5
Turbidity (NTU)	1.3	1.5	2.4	4.6	7	2.5	5.9	6.9	1.9	1.8	5.8	5.6	3.933
Alkalinity (mg/L CaCO3)	61	95	230	210	260	243	62	82	18	15	92	80	120.7
Dissolved Oxygen (mg/L)	5.7	6.25	2.92	4.27	1.52	4.45	3.83	6.25	4.28	5.25	5.92	5.88	4.71