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A COMPARISON OF AQUATIC SPECIES COMPOSITION AND DIVERSITY IN DISTURBED AND UNDISTURBED PINELANDS WATERS

Mark D. Morgan

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CCES

Center for Coastal and Environmental Studies

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Mark D. Morgan[1], Project Director

and

Robert Hastings[1], G. William Wolfe[2], and Kurt R. Philipp[3]

[1]Department of Biology
Rutgers Univerity
Camden, NJ 08102

[2]Department of Entomology
Rutgers University
New Brunswick, NJ 08903

[3]College of Marine Studies
University of Delaware
Lewes, DE 19958

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Dr. Norbert P. Psuty, Director
Center for Coastal and Environmental Studies
Rutgers - The State University of New Jersey
Doolittle Hall - Busch Campus
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FINAL REPORT

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Abstract

The biological, chemical, and physical characteristics of three disturbed (pH > 5.5, NO_3-N > 200 ug/l) and three undisturbed (pH < 4.5, NO_3-N < 100 ug/l) Pine Barrens second and third order streams were investigated from March 1982 - February 1983. Monthly sampling revealed that except for pH, nitrogen, and alkalinity, disturbed and undisturbed streams share virtually identical physical and chemical characteristics. However, the differences in pH, nitrogen, and alkalinity resulted in significantly altered biological communities. Both algal species richness and relative diversity increased in disturbed streams. In addition, some algal species appear to prefer, and may be largely restricted to, undisturbed streams, while others clearly are associated with disturbed streams. The presence of _Tabellaria flocculosa_ seems to be a particularly good indicator of disturbed conditions. The major response of the macrophytes to disturbance is a shift in the dominant species from _Eleocharis_ spp. and _Scirpus subterminalis_ to _Sparganium americanum_, _Callitriche heterophylla_, and _Potomogeton epihydrus_. The aquatic insects exhibited greater species richness in the disturbed streams. Several of the major groups of insects also showed skewed distribution between disturbed and undisturbed streams. Elmid beetles and caddisflies were particularly prevalent at the disturbed sites. Leuctrid stoneflies and various odonates appear more characteristic of undisturbed sites. The response of the fish was much more subtle, with both disturbed and undisturbed streams containing mostly characteristic Pine Barrens species. The presence and abundance of tessellated darter and golden shiner is probably the best indicator of disturbance, along with a general decrease in the abundance of eastern mudminnow, blackbanded sunfish, banded sunfish, mud sunfish, and redfin pickerel. There also appears to be a shift in dominance among the characteristic fishes from restricted to widespread species.

Acknowledgments

The tireless efforts of many people were necessary to bring this project to a successful conclusion. Janet Mead helped with much of the field and laboratory work. Dan Sprenger and especially Sule Oygur helped to collect, sort, catalogue and identify the insects. Insect species identification was aided by the generous help of several experts from around the country. Jackie White-Reimer identified the algae, and Ernie Schuyler confirmed our identifications of the macrophytes. We thank R. Good, F. Trama, and R. Zampella for helpful criticisms of the text. This project was supported by a grant from the New Jersey Pinelands Commission.

Introduction

The sandy, nutrient poor soils of the New Jersey Pine Barrens result in surface waters characteristically low in pH and nutrients (Patrick et al. 1979). Various activities of man, particularly agricultural and residential development, tend to significantly alter these conditions by elevating both nutrients and pH (Durand and Zimmer 1982). Low pH and nutrients represent quite stressful conditions for most aquatic organisms, and severely restrict their distributions (Haines 1981). Consequently, the plant and animal communities which have developed in undisturbed Pine Barrens surface waters are quite different from those in neighboring ecosystems (Smith 1960, McCormick 1970, Fisklin and Montgomery 1971, Hastings 1979, Moul and Buell 1979). The influence of man, then, might result in communities quite different from those naturally occurring, by allowing peripheral species to colonize Pine Barrens habitats previously inaccessible to them.

The purpose of this study is to characterize the physical, chemical, and biological features of six Pine Barrens second or third order streams, with an aim towards development of a biological water quality index. The streams were chosen to fit into two groups, disturbed and undisturbed. Previous analyses of Pine Barrens surface water quality indicated that the main impact of disturbance was to raise pH consistently above 5.5 and NO_3-N concentrations above 0.2 mg/l (Zimmer 1981, Durand and Zimmer 1982). Thus the three disturbed streams were chosen based on initial observations of pH and NO_3-N at or above these levels. The three undisturbed streams exhibited pH <4.5 and NO_3-N levels below 0.05 mg/l. Disturbed and undisturbed streams were chosen in pairs within the same watershed and with approximately the same drainage areas to better facilitate comparison among the streams.

Study sites

The location of the six study streams within the Pine Barrens is illustrated in Fig. 1, and a comparison of the major habitat characteristics of each stream can be found in Table 1. A detailed description of each stream follows:

Sleeper Branch- The sampling area is located at a foot bridge approximately 0.5 km from Rt. 542 at Pleasant Mills. Sleeper is part of the Mullica River drainage and originates near Chesilhurst, NJ. Although disturbed at its headwaters by residential and agricultural development, most of its length passes through undisturbed oak-pine and pitch pine lowland forest, and just upstream of the sampling area is an extensive swamp. The sampling site vegetation is characterized as cedar swamp. The drainage area above its confluence with the Mullica River (approximately 100 m downstream from the sampling site) is about 9200 hectares.

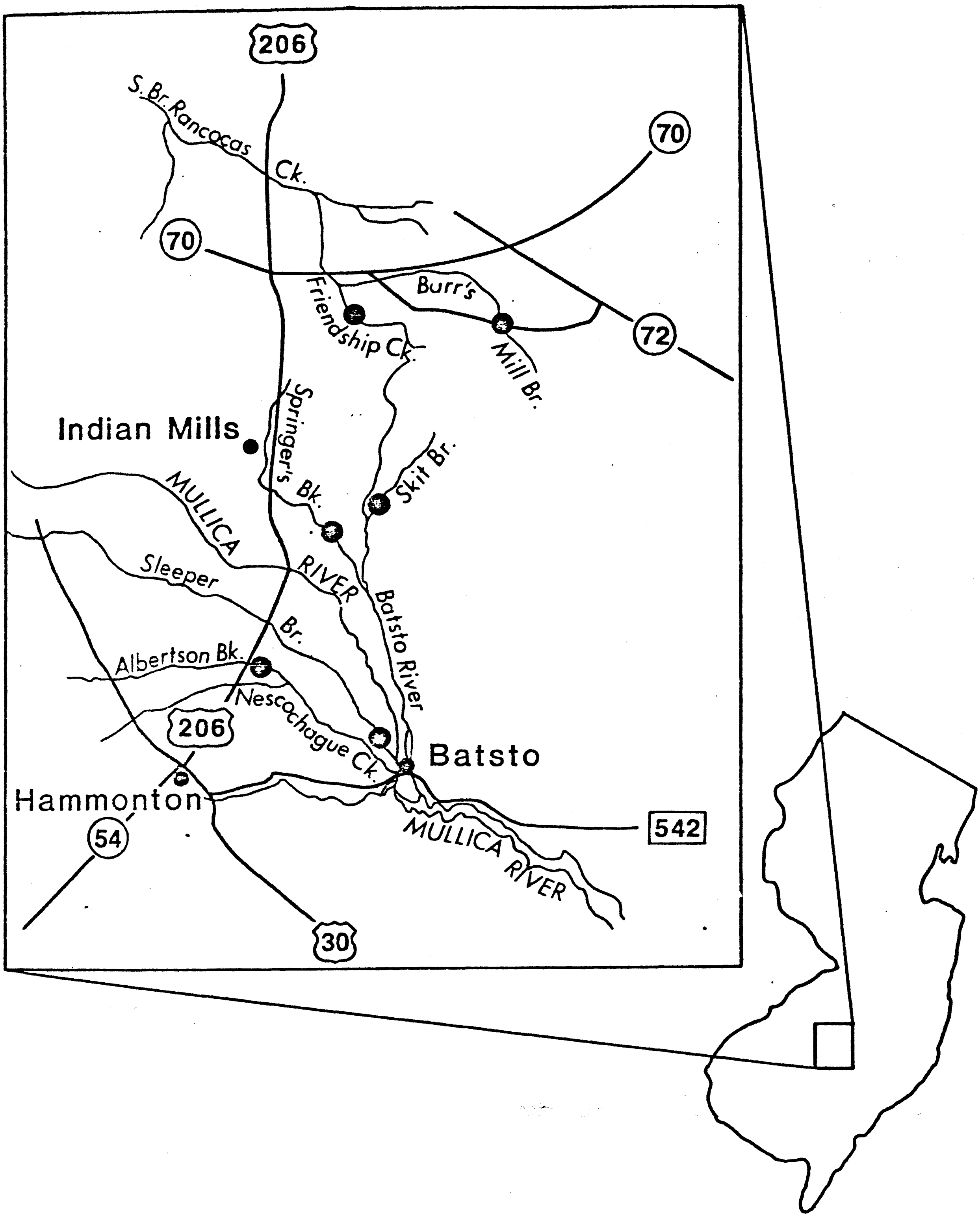

Figure 1. Map of central Pine Barrens region of New Jersey showing the six sampling sites (solid dots).

Table 1. Comparison of the general habitat characteristics of the six study streams and two supplemental sampling areas at Burr's Mill (bog) and Friendship (feeder). Tree canopy along the bank is described as predominately coniferous (C) or hardwood (H) and as closed - adjacent canopies touching, open - mostly direct sunlight on stream, or a mixture of the two - Mod.

		Habitat Features		
Stream	Canopy	Bank	Backwaters	Bog
Sleeper	Open C	Shallow	Extensive	Extensive
Albertson	Open/Mod C	Steep	Moderate	Moderate
Skit	Open/Closed C	Steep/Shallow	Few	Extensive
Springers	Open/Closed H	Steep/Shallow	Moderate	None
Burr's Mill	Closed H	Shallow/Steep	Moderate	None (upstream)
Friendship	Closed/open H	Steep/Shallow	Moderate	None (upstream)
Feeder	Open H	Shallow	None	None (upstream)
Burr's Mill Bog	Open H	Shallow	None	Extensive

Sleeper is characterized as undisturbed.

Albertson Brook- The sampling area is located at an abandoned car bridge about 0.5 km off Rt. 206 toward Paradise Lakes Campground. Albertson originates in Winslow Township, NJ, and passes through heavily used agricultural areas over most of its length. Its lower reaches drain pine-oak and pitch pine lowland forest, and hardwood swamp. The vegetation at the sampling site, however, is cedar swamp. Albertson is a part of the Mullica River system via Nescochague Creek, with a drainage area above its confluence with Nescochague Creek of approximately 5200 hectares. Albertson is characterized as disturbed.

Skit Branch- The sampling area is located on High Crossing Road at the old car bridge (a new car bridge was constructed during the study) about 8 km off Rt. 206, just past Hampton Furnace. Skit originates deep within the Pine Barrens and drains undisturbed pine-oak and pitch pine lowland forest. There are also large tracks of cranberry bogs within the drainage. The vegetation at the sampling site is characterized as cedar swamp. Skit is part of the Batsto drainage, with a drainage area above its confluence with the Batsto River of approximately 2800 hectares. Skit is undisturbed.

Springers Brook- The sampling area is located at the Hampton Road bridge about 2 km off Rt. 206 toward Hampton Furnace. Springers Brook originates in heavy agricultural and residential areas near Indian Mills, NJ. Its lower reaches drain pine-oak, oak-pine, pitch pine lowland forest, and extensive hardwood swamp. The vegetation at the sampling site is hardwood swamp. Springers is part of the Batsto drainage, with a drainage area above the sampling site of approximately 4700 hectares. Springers is disturbed.

Burr's Mill (South Branch)- The sampling area is located at the bridge where Sooy Road crosses the stream, just south of Rt. 70. The stream originates in mostly undisturbed pine-oak and pitch pine lowland forest, although an extensive network of cranberry bogs occurs within the drainage. The lower reaches of the stream pass through hardwood swamp vegetation, which also characterizes the sampling site. Burr's Mill is part of the South Branch Rancocas drainage with a drainage area above the sampling site of about 1900 hectares. Burr's Mill is undisturbed.

Friendship Creek- The sampling area is located just below the confluence of its two main tributaries at the bridge on Powell Place Road, just south of Rt. 70. The stream originates near Tabernacle, NJ. One tributary drains mostly undisturbed wetlands while the other drains extensive agricultural areas. The sampling site is characterized as hardwood swamp vegetation. Friendship is part of the South Branch Rancocas drainage with a drainage area above the sampling site of about 2000 hectares. Friendship is disturbed.

Water Quality

Water temperature and dissolved oxygen (DO) were measured in flowing water using a YSI model 57 meter. A YSI SCT meter was used to measure conductivity in the same manner. Alkalinity and pH were determined from a grab sample at the site. An Accumet model 640 field pH meter was used for pH, and alkalinity was calculated from titration with 0.02N H_2SO_4 to 4.5 pH (Lind 1979). Current velocity was obtained from employment of a General Oceanics model 2030 current meter and/or the timed passage of neutrally bouyant objects. Maximum water depth was recorded monthly and referenced to stream cross-sectional areas taken periodically to determine discharge (Lind 1979). Two water samples were collected in acid rinsed 500 ml polyethylene containers and kept on ice in a cooler during transport to the Camden laboratory.

Upon return to the laboratory ammonia-nitrogen (NH_3-N) was immediately determined by the phenol-hypochlorite method (Lind 1979). Total dissolved solids (TDS) were determined by evaporating 150 ml aliquots in preweighed oven dried crucibles, which were then weighed to yield mg/l values. Analysis for TDS was not performed in March and April. The two 500 ml water samples were frozen for later total-P and NO_3-N analysis. After June an additional 500 ml sample was taken and frozen as a reference.

At two to three month intervals accumulated samples were unfrozen and analyzed for nitrate-nitrogen and total phosphorus. Cadmium reduction (American Public Health Association (APHA) 1979) was used to determine nitrate nitrogen and total-P was determined after Lind (1979). Standard curves were used in the spectrophotometric methods for determining nutrient concentrations. Duplicates and spikes were run on 10% of all samples after June 1982 to verify the analytic procedures.

Pine Barrens water appears to significantly reduce the efficiency of cadmium reduction columns, particularly during periods of low flow when dissolved substances are concentrated. Under the worst conditions, this reduction appeared to be about 3% per sample. For the purpose of calculating sample concentrations from standard curves, it was necessary to assume that this decrease was linear from sample to sample. Since this introduces an unknown error due to interpolation, no more than four samples were run (after August when the problem first became serious) between standards, and the columns were changed after one or two days of use. Although the loss in column efficiency was annoying, the potential error it introduced is not substantial, since even if no corrections were made, the sample concentrations would be off by no more than 15%. The main implication of this problem is that small fluctuations (less than 20%) in stream nitrogen concentrations cannot be interpreted with confidence. A recent modified Cadmium reduction method may eliminate this problem (APHA 1980).

Biological Data

All biological sampling occurred on the same dates as water quality sampling except for aquatic insects. Because of the time necessary to conduct the insect sampling, these samples were collected separately from the others. Table 2 lists the specific sampling dates for each task.

Dominant aquatic macrophytes were collected and/or recorded monthly along the stream station lengths. Identification guides used were: Fassett (1957), Magee (1981), Hotchkiss (1972), Fernald (1950), Fairbrothers et al. (1965), Gleason (1952) and Newcomb (1977). Assistance in identification and verification was provided by Dr. E. Schuyler of the Philadelphia Academy of Natural Sciences. A voucher specimen collection has been retained at Rutgers University, Camden, New Jersey.

Algal samples were collected bimonthly from three basic substrate habitats; submerged vegetation stems, submerged logs and submerged backwater or bank detritus. Another major habitat, sand and gravel, was not sampled because it typically is not stable enough to support a significant algal community. Samples were preserved in Formalin and later identified and enumerated by Jacquelyn White-Reimer.

Identification and enumeration was accomplished by examining randomly chosen subsamples of all samples on wet mount slide preparations under 100 and 430 magnification. Each slide was scanned using 100 magnification to determine general algal type and distribution. Identifications were made under 430 magnification. For samples with numerous diatoms that could not be identified from a wet mount slide, burn mount slides were prepared. An aliquot of sample was placed on the cover slip with distilled water and hydrogen peroxide, 30% stabilized (to break down organic matter) and the liquid evaporated. The cover slips were then heated to approximately 500°F for 15-20 minutes and mounted on slides using Hydrax mounting medium. Major diatom types were identified using a 90 X oil immersion objective. Algal identification was aided by use of the following references (Smith 1933, Drouet and Dailey 1956, Prescott 1962, Drouet 1968, Drouet 1973, Patrick and Reimer 1975, Prescott 1975, Hustedt 1976, Hustedt 1977, Ruzjicka 1977, Drouet 1978, Drouet 1981).

The relative abundance determinations are rather subjective due to varying growth forms, size of cells, and clumping of populations on the slide, but the general catagories are as follows:

- Dominant- predominant type throughout sample;
- Abundant- observed in most fields when examined under high dry magnification;
- Common- observed in approximately one out of five fields;
- Occasional- Observed in less than one out of ten fields.

Table 2. List of the sampling dates for each major task of this project. The January 6 insect collection corresponds to the December 27 water quality collections.

Sampling Date	Water Quality	Macrophytes	Algae	Fish	Aquatic Insects
March 23, 24, 1982	X	X	X	X	3/23, 24, 29
April 10	X	X			4/14
May 19	X	X	X		5/17
June 14, 15	X	X		X	6/3
July 21, 22	X	X	X	X	7/11
August 17*	X	X			
September 15	X	X	X	X	9/7
October 13	X	X			10/16
November 15	X	X	X		11/26
December 27	X	X		X	1/6
January 21, 1983	X	X	X		1/28
February 10	X	X			2/26

* Note that no samples for aquatic insects were collected in August

A voucher collection has been retained and is to be integrated with the algal collection at the Philadelphia Academy of Natural Sciences.

Dip nets and kick samplers were used to make qualitative aquatic insect collections approximately monthly from the six sampled streams. At each collecting site, specimens were partitioned into one of two classes of habitat; riffle (R) or non-riffle (NR). Because continuums between habitats were so gradual in space and time, further subdivisions of the non-riffle habitat (into vegetation, undercut bank, and logs) was not possible. Even with only riffle and non-riffle habitats, site to site habitat variability made it particularly difficult to equate the same habitat from stream to stream.

Riffle habitat (for collected aquatic insects discussed herein) is very narrowly defined as the middle 2/3 of a stream channel with gravel and sand substrate with preceptibly flowing water. Obviously, there is habitat overlap for most aquatic insects; but use of this definition of riffle means that some riffle organisms will be recorded from non-riffle areas (eg. submerged vegetation in flowing water), but usually not visa versa. Approximately 90 minutes of effort was allocated per stream.

In the laboratory, specimens were sorted to genus and members of each genus from each sample placed in individual vials which were labeled and numbered. Numbered vials are currently catalogued by order, family, genus, and species via a card file. About 1500 vials are cataloged to species.

Species level identification for Hemiptera and Coleoptera were based primarily on adults. All other identifications are based on examination of immature states. Because of non-availability of a dipteran taxonomist, specimens in this order were identified only to family level. These specimens are available for further study.

Generic level identifications have been aided by the following references (Wiggins 1927, Usinger 1956, Needham et al. 1975, Meritt and Cummins 1978, Edmunds et al. 1979, Hilsenholf 1981, Brigham and Brigham 1982).

Species identifications were aided by the following individuals:

Gyrinidae- Sule Oygur, Cook College, Rutgers University, New Brunswick, New Jersey;
Aquatic Coleoptera, Megaloptera, aquatic Hemiptera (exclusive of surface dwellers)- G. William Wolfe, Cook College, Rutgers Univeristy, New Brunswick, NJ;
Surface Dwelling Hemiptera- P. Kittle, Southeast Missouri State University, Cape Girardeaw, MO;
Trichoptera- G. A. Schuster, Eastern Kentucky University;
Plecoptera- R. F. Surdich, Front Royal, VA;
Ephemeroptera- P. Carlson, South Carolina Department of Health and Environmental Control, Columbia, S.C.;

Lepidoptera and Odonata- D. Huggins, State Biological Survey of Kansas, Lawrence, Kansas.

Fish collection with a small mesh nylon seine (3/16" mesh, 10' long) occurred every three months (March, June-July, Sept., Dec.). High stream discharges in June resulted in poor sampling and led to a second summer sampling period in July. Sampling lasted approximately one hour per stream, covering three major microhabitats; vegetation, backwaters, and open water (pools and riffles). Occasionally bog meadow habitat was also sampled. A voucher collection of specimens was preserved.

Water Quality

The original grouping of the study streams into disturbed and undisturbed catagories based on pH and NO_3-N values proved justified by measurements throughout the year (Fig 2). The pH and NO_3-N values for the disturbed streams averaged 5.9 and 426 ug/l, respectively, compared with 4.3 and 19 ug/l in the undisturbed streams. These differences were statisticaly significant ($F=25.6$; $p < 0.01$ for pH and $F=10.6$; $p < 0.05$ for NO_3-N). However, except for pH, the associated parameter alkalinity, and NO_3-N, no other physical or chemical parameter differed significantly between disturbed and undisturbed streams (Table 3; Appendix I). The ranges of all parameters overlapped almost completely.

Among the disturbed streams, Springers exhibited the highest average pH as well as the lowest average NO_3-N, which from May to August, was in the range of values reported for the undisturbed streams (< 50 ug/l). The large decrease in NO_3 in late spring and summer was unexpected, but has been observed before. New Jersey Department of Environmental Protection (NJDEP) STORET System data indicate NO_3 concentrations at a nearby site in Springers ranged from 60 to 630 ug/l between June 1, 1977, and January 5, 1978. Friendship exhibited the lowest average pH and the greatest average NO_3-N. Previous data at a nearby Friendship sampling site confirm these trends. For 44 dates between February 21, 1978 and May 15, 1979 pH averaged 5.2 and NO_2 + NO_3 averaged 819 ug/l (NJDEP STORET System).

Among the undisturbed streams, Burr's Mill differed from the rest in a number of ways. Average NH_3-N was three times greater than in any other stream (disturbed or undisturbed), and average total-P was very near the highest. Average percent O_2 saturation was also lowest in Burr's Mill. The high NH_3 is strongly correlated with the low DO. From July - October, percent O_2 saturation averaged 53.5% compared with 86% throughout the rest of the year. NH_3 concentration during the same period averaged 146 ug/l compared with an average of 55 ug/l for the rest of the year. Just upstream from the sampling site is an impounded bog. During low flow (average discharge from Burr's Mill from July - October was only 0.0175 m^3/sec) a high proportion of the stream flow apparently results from seepage under the bog dam. Decompositional processes at the bog bottom no doubt result in low O_2 and high NH_3 which then predominate in the stream water just below the dam. No other water quality parameters seemed to be affected during this period. Burr's Mill also exhibited the lowest pH values of any of the streams. Previous pH measurements at a nearby location from February 21, 1978 through February 26, 1979 show similarly low pH values (average of 33 measurements = 3.7; NJDEP STORET System). It is not clear why Burr's Mill is so much more acidic than the other

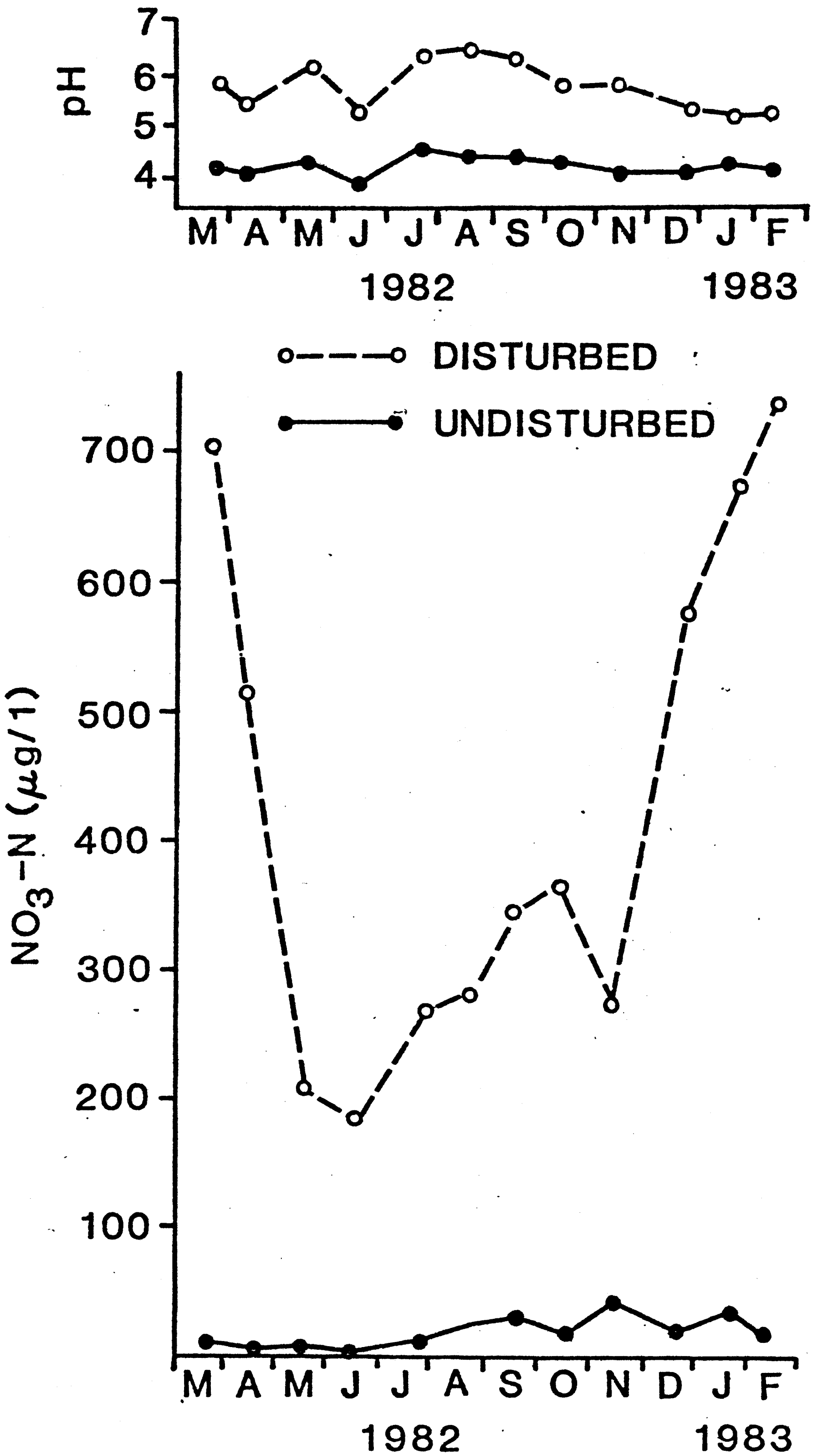

Figure 2. Average pH (top panel) and NO_3-N (bottom panel) in disturbed and undisturbed streams during the study period.

Table 3. Summary of water quality data collected from each stream. Values given are means (ranges). The pH mean is based on Hydrogen ion concentration. F value is from Analysis of variance on each parameter from disturbed and undisturbed streams. Units: Alkalinity mg $CaCO_3$/l; NH_3-N µg/l; NO_3-N µg/l; Total-P µg/l; Conductivity µmhos; TDS mg/l; DO % saturation; Temperature °C; Velocity m/s; Discharge m^3/s.

		Stream					
	F	Albertson	Springer	Friendship	Sleeper	Skit	Burr's Mill
pH	25.6**	5.9(5.3-6.4)	6.2(4.2-6.8)	5.3(4.3-5.7)	4.2(4.0-4.4)	4.5(4.1-4.9)	3.9(3.6-4.2)
Alkalinity	8.7*	6(1-30)	8(0-22)	2(0-6)	0	.1(0-1)	0
NH_3-N	1.52	20(3-63)	28(0-79)	27(5-83)	30(0-87)	28(0-104)	85(24-217)
NO_3-N	10.6*	511(116-960)	180(2-695)	588(271-1385)	22(2-56)	14(0-34)	21(3-46)
Total P	0.4	28(6-90)	13(5-34)	9(3-22)	8(2-18)	6(2-14)	21(2-80)
Conductivity	0.4	57(32-174)	125(50-254)	75(35-218)	59(38-155)	67(20-239)	88(31-252)
TDS	0.3	54(33-78)	79(61-123)	51(25-78)	59(33-92)	33(5-83)	73(43-125)
DO	4.6	92(82-97)	87(64-103)	93(78-103)	82(75-89)	88(77-100)	75(52-108)
Temperature	0.3	12(2-22)	12(1-24)	13(3-23)	11(0-21)	13(0-26)	15(4-25)
Velocity	1.4	.26(.19-.35)	.20(.08-.32)	.46(.35-.61)	.19(.05-.34)	.25(.03-.37)	.21(.09-.26)
Discharge	0.3	.95(.54-1.65)	.60(.02-2.56)	.47(.12-1.56)	.35(.03-.82)	.48(.04-2.33)	.21(.01-.74)

*$p < .05$
**$p < .01$

undisturbed streams.

Skit was severely disturbed during the study in November and December by bridge construction immediately upstream from the sampling site. However, detailed examination of the water quality data show no obvious effects (Appendix I). This is despite heavy siltation of the sampling area and significant alteration of the stream channel.

The sampling site at Sleeper was also the location of intense sampling by Zimmer (1981) and Durand and Zimmer (1982) from June 1978 - May 1980. Their values for pH, NH_3, and NO_3, are similar to the values reported in this study. For the two year study, they reported a median pH of 4.25, and average NH3-N and NO_3-N of 35 and 102 ug/l, respectively. While the NH_3 and NO_3concentrations are somewhat greater than those reported here, closer examination of their data reveals that concentrations of both nutrients decreased significantly over the two year study. By the second year, NH_3-N and NO_3-N averaged 23 and 59 ug/l, respectively. These data are quite close to the values reported in this study, especially when the downward trend in nutrient concentrations is considered.

The association of the various water quality parameters with each other was examined by correlation analysis on pooled data from the disturbed and undisturbed streams separately. The resulting correlation matrixes of significant correlation coefficients ($p < 0.05$, $r=0.325$; $p < 0.01$, $r=0.418$) are illustrated in Tables 4 and 5. Some of the more interesting associations are described below.

NO_3 and pH show significant correlation with temperature in the disturbed streams, but not in the undisturbed streams. Since temperature is a marker for seasonality, NO_3 in the disturbed streams is significantly more abundant in the winter while pH is significantly lower. This phenomenon is clearly illustrated by Fig. 2. The tendency for NO_3 to rise in Pine Barrens waters in the winter has been documented before (Durand 1979). It was believed to result from the shutdown of biological uptake of NO_3 by the drainage area vegetation. This would also appear to be the case among the disturbed streams studied here. Springers is a particularly good example with extremely low NO_3 values in the summer during peak production and very high NO_3 in the winter. The lack of a similar response among the undisturbed streams can be explained by their already low NO_3 concentrations which tends to mask any seasonal variation.

The seasonal response of pH only in the disturbed streams suggests that elevated pH may not be totally an intrinsic characteristic of these streams. Much of the elevated pH, particularly in the summer, may be instead a by product of their higher nutrient concentrations, and associated greater primary productivity. With higher nutrients, the productivity of the vegetation both within and along the stream is increased. Photosynthesis directly elevates pH (Wetzel 1983), but in most natural waters, the buffering capacity is such that fluctuations in

Table 4. Correlation matrix of significant correlation coefficients for pooled water quality data from the three disturbed streams (Albertson, Springers, Friendship).

	pH	Alkalinity	NH_3-N	NO_3-N	Total P	Conductivity	TDS	DO	Temperature	Velocity	Discharge
pH	1.0	.531							.503	-.605	
Alkalinity		1.0		-.488	.454		.390		.508	-.406	
NH_3-N			1.0								-.360
NO_3-N				1.0		-.492	-.518	.479	-.490	.445	
Total P					1.0				.441		
Conductivity						1.0	.403	-.344	.362		
TDS							1.0	-.560			
DO								1.0			-.337
Temperature									1.0		
Velocity										1.0	
Discharge											1.0

Table 5. Significant correlation coefficient matrix of pooled water quality data from the undisturbed streams (Sleeper, Skit, Burr's Mill).

	pH	Alkalinity	NH_3-N	NO_3-N	Total P	Conductivity	TDS	DO	Temperature	Velocity	Discharge
pH	1.0	.593									
Alkalinity		1.0							.376		
NH_3-N			1.0		.810		.492	-.632	.515		-.404
NO_3-N				1.0		-.419					
Total P					1.0		.657	-.689	.496		
Conductivity						1.0					.456
TDS							1.0	-.671	.361		
DO								1.0	-.445		
Temperature									1.0	-.411	
Velocity										1.0	.518
Discharge											1.0

pH are minimal. However, because of the naturally low buffering capacity of Pine Barrens waters (note that alkalinity even in the disturbed streams is extremely low), the higher levels of photosynthesis appear to be translated into greatly elevated pH. Thus, in the winter when biological productivity is greatly reduced, the pH of disturbed streams decreases, in some cases, approaching the pH of undisturbed streams (Appendix I). A similar relationship between pH and productivity has been documented in disturbed and undisturbed Pine Barrens ponds (Morgan unpubl. data).

Both sets of streams show a positive correlation between total-P and temperature. This probably does not represent a true increase in phosphorus loading during the summer, but simply a reflection of the additional P bound up in organic production during the summer, which is part of the total-P measurement. Ammonia shows no relationship with temperature in the disturbed streams, but a significant positive association in the undisturbed streams. The significant relationship, however, is almost entirely due to Burr's Mill, with its high NH_3 values in the summer during the conditions of low flow and O_2 discussed above (note the highly significant relationship between O_2 and NH_3).

Another significant relationship which deserves special mention is the relationship (or general lack of) between TDS and conductivity. In most inland waters, there is a fairly tight relationship between TDS and conductivity (Lind 1979), but this clearly is not true for Pine Barrens waters. This suggests that there is a large and variable fraction of non-ionic (or ionic and of variable molecular weight) dissolved substances in these waters.

Algae

A total of 52 algal species were collected in the 6 study streams (Table 6). A complete listing of the occurrence and relative abundance of each species in each stream by sampling date and microhabitat (stem, log, bank) is presented in Appendix II. These species represent a significant fraction of the 350+ species so far recorded from the entire Pine Barrens region (Moul and Buell 1979).

All but 11 species have been reported by other investigators as occurring in the Pine Barrens (Moul and Buell 1979, Patrick et al. 1979, Lloyd et al. 1980), and only 4 species (*Chaetophora* sp., *Radiofilum* sp., *Vaucheria* sp. and *Porphyrosiphon splendidus*) represent members of genera newly reported from the Pine Barrens. Three out of 4 of the new records were reported only from the disturbed streams (Table 7). Five of the new records are filamentous blue-green algae. Previous workers have stated that blue-greens are not abundant in the Pine Barrens, and this study supports this conclusion (Appendix II). The fact that several new records are reported here is probably most related to the sampling method (blue-greens tend to favor hard substrates) and repeated

Table 6. List of all algal species collected from the study streams from March 1982 - January 1983.

Algal species list

Chlorophyta (Green algae)
- Bulbochaete sp.
- *Chaetophora sp.
- Closterium sp.
- *Closterium kuetzingii Bréb
- Closterium ralfsii var. ralfsii Bréb ex. Ralfs
- Cosmarium sp.
- Micrasterias rotata (Grev) Ralfs
- Micrasterias sp.
- Microspora sp.
- Mougeotia sp.
- Penium sp.
- Pleurotaenium sp.
- *Radiofilum sp.
- Spirogyra sp.
- Staurastrum sp.
- Tetraspora sp.
- Ulothrix sp.
- *Vaucheria sp.
- Zygogoneum ericetorum Kütz

Rhodophyta (Red algae)
- Audouinella violacea (Kütz) Hamel
- Batrachospermum sp.

Cyanophyta (Blue-green algae)
- Calothrix sp.
- *Porphyrosiphon splendidus (Grev.) Dr.
- *Schizothrix calcicola (Ag.) Gom.
- *Schizothrix friesii (Ag.) Gom.
- Schizothrix mexicana Gom.
- *Schizothrix sp.

Bacillariophyta (Diatoms)
- Actinella punctata Lewis
- Asterionella formosa Hass.
- Eunotia sp.
- Eunotia curvata (Kütz) Lagerst.
- Eunotia exigua (Bréb. ex Kütz) Rabh.
- Eunotia fluxulosa Bréb ex Kütz
- Eunotia incisa W. Sm. ex Greg.
- Eunotia pectinalis (O.F.Mull) Rabh.
- Eunotia serra Ehr.
- *Eunotia tautoniensis Hust. ex Patr.
- Frustulia rhomboides (Ehr.) Det.
- Frustulia rhomboides var. capitata (A.Mager) Patr.
- Frustulia rhomboides var. saxonica
- *Frustulia vulgaris (Thwaites) Det.
- Gomphonema parvulum Kütz
- Nitzschia obtusa W. Sm.
- Nitzschia sp.
- Pinnularia gibba Ehr.
- Pinnularia substomatophora Hust.
- *Pinnularia socialis (T.C.Palm) Hust.
- Pinnularia viridis (Nitz.) Ehr.
- Synedra ulna (Nitz.) Ehr.
- Tabellaria fenestrata (Lyrgb.) Kütz
- Tabellaria flocculosa (Roth) Kütz

* Species not in previous lists of Pine Barrens algal species.

Table 7. Algal species restricted in their distribution to only disturbed or undisturbed streams. * = found in 2 or more streams.

Disturbed	Undisturbed
**Chaetophora* sp.*	**Micrasterias* sp.*
**Staurastrum* sp.*	**Penium* sp.*
**Schizothrix mexicana*	**Eunotia flexulosa*
Bulbochaete sp.	*Micrasterias rotata*
Closterium kuetzingii	*Schizothrix calcicola*
Closterium ralfsii	*Eunotia exigua*
Pleurotaenum sp.	*Eunotia tautoniensis*
Vaucheria sp.	*Pinnularia substomatophora*
Calothrix sp.	*Pinnularia socialis*
Porphyrosiphon splendicus	*Pinnularia viridis*
Schizothrix sp.	
Actinella punctata	
Gomphonema parvulum	
Nitzschia obtusa	
Nitzschia sp.	
Pinnularia sp.	
Synedra ulna	
**Tabellaria flocculosa*	

samplings throughout the year.

Table 7 lists those species which occurred only in either disturbed or undisturbed streams. Since most of these species occurred in only one stream (and many on only one or two occasions), it is difficult to conclude that the restriction to one stream type or another is primarily controlled by water quality. Unrecognized characteristics peculiar to a particular stream may have more of an impact. However, the restricted distribution of Chaetophora sp., Staurastrum sp., and Schizothrix mexicana to two, and Tabellaria flocculosa to three disturbed streams, and Micrasterias sp., Penium sp., and Eunotia flexulosa to two undisturbed streams suggests that these species may in fact be responding to water quality.

Species richness, based simply on the number of species present, was significantly greater in the disturbed streams (6.4 vs 4.8 species, respectively; $F=6.73$, $p < 0.05$). Although traditional diversity indices cannot be calculated from these data, because of the lack of quantitative abundance data, an attempt was made to weight the number of species by their relative abundance. Numerical values from 0-4 were assigned for species recorded as being absent to dominant. These numbers were then used to calculate a relative diversity index (RDI) by the following formula:

$$RDI_j = \sqrt{n_j \Sigma (A_{ij})}$$

where n_j= total number of species in sample j, and A_{ij}= abundance value (0-4) for species i.

This method places more weight in the index on the number of species than on relative abundance, which seems appropriate given the subjective nature of the relative abundance values. Thus, a sample with 8 species, each with an abundance value of 2, would have a higher diversity index than one with 4 species, each with an abundance value of 4 (11.3 vs 8.0).

Analysis of variance of this diversity index indicates that disturbed streams also have a significantly higher relative diversity than undisturbed streams ($F=5.06$, $p < 0.05$). It is well documented that desmids tend to predominate in acid waters (Patrick et al. 1979). Since disturbed streams were significantly less acidic than undisturbed streams, a shift in the importance of desmids might be expected. Statistical comparision of both the absolute number of desmids and the proportion of desmids showed no significant difference between disturbed and undisturbed streams.

Of the 52 algal species encountered during the study, only 14 occurred regularly (in at least 5 samples and at least 2 streams). A correlation analysis of water quality and relative abundance (as defined above) was performed on these species. The resulting significant correlation coefficients ($r=0.232$, $p < 0.05$; $r=0.302$, $p < 0.01$) are presented in Table 8. Except for Tabellaria flocculosa, which occurred only in disturbed streams, these species would be

Table 8. Significant correlation coefficients for 14 common algal species versus pooled water quality data from all streams.

Parameter	*Closterium sp*	*Cosmarium sp*	*Microspora sp*	*Mougeotia sp*	*Spirogyra sp*	*Tetraspora sp*	*Zygogoneum ericetorum*	*Audovinella violacea*	*Batrachospermum sp*	*Eunotia pectinalis*	*Eunotia sp*	*Frustulia rhomboides*	*Tabellaria fennestrata*	*Tabellaria flocculosa*
pH	.411	.278		.310	-.254		-.270			.654	.446	-.240		.313
Alkalinity	.588									.476	.318			
NH_3-N										-.316				
NO_3-N										.663	.472	-.365	.437	.618
Total P	.263	.318	-.236	.344										
Conductivity														
TDS	.274	-.234	-.323			-.476						.283		
DO										.241		-.358		.334
Temperature	.275				.263									
Velocity	-.254							-.261		.413		-.538	.592	.429
Discharge		.238			-.262		-.238					-.368		

considered more or less cosmopolitan as they occurred in at least 3 streams, including at least one characterized as disturbed and undisturbed.

The abundance of most of these regularly occurring species was significantly affected by pH, with 6 species being positively correlated and 3 species being negatively correlated (i.e., more abundant as pH decreases). NO_3 was positively correlated with the abundance of 4 species and negatively correlated with 1, and total-P was positively correlated with 3 species and negatively correlated with 1. Species significantly correlated with NO_3 were not correlated with total-P, and visa versa. A third group of 4 species were not correlated with any nutrient measured. Frustulia rhomboides was the only species negatively correlated with both pH and nitrate, and Eunotia pectinalis, Eunotia sp., and Tabellaria flocculosa were the only species positively correlated with both pH and nitrate.

Only 2 species were significantly correlated with temperature, suggesting surprisingly that for most species, seasonality had little effect on abundance. A similar result was obtained from the analysis of variance of species number and relative diversity; time of year had no statistically significant effect on either parameter.

Moul and Buell (1979) and Patrick et al. (1979) have listed several species that they consider characteristic of acid Pine Barrens waters. Among these are Zygogoneum ericetoreum, Mougeotia sp., Tabellaria flocculosa, Frustulia rhomboides, Actinella punctata, and Batrachospermum sp. It might therefore be concluded that these species would be better represented in the undisturbed streams in this study. While two of these species (Z. ericetoreum and F. rhomboides) do tend to be especially prevalent in the undisturbed streams, two other species (Mougeotia sp. and T. flocculosa) are more closely associated with the disturbed streams (especially T. flocculosa) and the remaining two (Batrachospermum sp. and A. punctata) occur equally well in either stream type. This illustrates the difficulty in defining and distinguishing an algal assemblage characteristic of disturbed or undisturbed streams. It appears that even the disturbed streams are sufficiently acid (none had a pH $>$ 6.8) to restrict its flora to primarily acid loving species, thus blurring the distinction between the stream types. Consequently, even though 28 species were found restricted to one stream type or another, it is difficult to conclude they are only responding to water quality (especially considering their general rarity in any stream). There are several species, however, which may be described as more characteristic of one stream type than another. These are (disturbed) Chaetophora sp., Staurastrum sp., Schizothrix mexicana, Tabellaria flocculosa, Closterium sp., Mougeotia sp., Eunotia pectinalis, and Eunotia sp., and (undisturbed) Micrasterias sp., Penium sp., Eunotia flexulosa, Spirogyra sp., Zygogoneum ericetorum, and Frustulia rhomboides.

The major difference between disturbed and undisturbed streams demonstrated by this study is an increase in species number and relative diversity in disturbed streams. This is the classic response described for Pine Barrens streams when disturbed, and is usually related to the elevated pH which allows non Pine Barrens species to colonize otherwise inaccessible Pine Barrens habitats. However, given that acid loving species also seem characteristic of disturbed streams, it appears that increased nutrients (NO_3) may be at least partially responsible for these differences, perhaps by reducing competition for otherwise scarce nutrients.

Macrophytes

The relative abundance and general habitat of the 75 macrophyte species collected in this study are presented in Table 9. Vegetation maps of each stream length sampled are presented in figures 3 to 8. These maps illustrate the distribution of dominant species for each stream generalized over the collection period.

The stream lengths sampled are relatively small for a botanical survey, but are sufficient to allow an initial comparison of stream environments. Only dominant and/or readily apparent species were collected along with subjective, generalized indications of abundance and habitat. No attempt was made to quantify macrophyte distribution and abundance based on physical differences in habitat, such as available light, degree of inundation, substrate, water velocity, and upstream seed sources. Because of the manner in which streams were chosen (second and third order, paired from the same watershed and with similar drainage areas), most of these factors were reasonably well controlled among streams.

Although each stream exhibited unique characteristics, they are broadly comparable in most habitat features (Table 1). The most important difference among the streams is the openness of the canopy and the extensiveness of the bog habitat. An open canopy and extensive bog tended to greatly increase macrophyte species diversity. The Sleeper and Skit sampling areas include portions of abandoned cranberry bogs, and their species lists strongly reflect this. Albertson has some backwater bogs, but nothing comparable to Sleeper and Skit. The area sampled at Springers includes no bog habitats, although there were a great diversity of bank habitats which also tended to increase species diversity. The canopy of all four streams was generally open.

The sample area at Burr's Mill is a densely closed canopy. The only plants recorded at this location occurred in the small open, unshaded area immediately around the bridge. Utricularia was the only exception. It occurred elsewhere along the stream throughout the year and appeared to have been washed downstream during high flows from the large bog several hundred meters upstream.

Table 9. Species list of macrophytes collected in each stream by general habitat from March 1982 to February 1983. Open circle indicates species was present. Solid circles indicates it was dominant. * = Also collected in bog habitats.

General Collection Habitat

Submerged/Emergent/Floating

Species	Common Name	Sleeper	Albertson	Skit	Springer	Burrs Mill	Bog	Friendship	Feeder
Sparganium americanum	Branching Furreed		●		●			●	0
Potamogeton epihydrus	Ribbon leaf Pondweed				●			●	
Potamogeton pusillus	Slender Pondweed			●	●				
Eleocharis Robinsii	Spike rush			0					
Eleocharis tenuis	Spike rush	0							
Eleocharis olivacea	Spike rush	0		0		0			
Eleocharis acicularis	Spike rush	0							
Eleocharis tuberculosa	Spike rush	0							
Scirpus subterminalis	Swaying bulrush	●	0	●					
Peltandra virginica	Arrow arum	0	0	0				0	
Xyris difformis	Yellow-eyed grass	0		0			0		
Eriocaulon compressum	Pipewort			0					
Juncus militaris	Bayonet rush	●	●	●					
Pontederia cordata	Pickerelweed				0				
Nuphar variegatum	Bullhead lily/Spatterdock	0	0			0			
Nymphaea odorata	Fragrant water lily	●				0			
Callitriche heterophylla	Water starwort		●		●				
Ludwigia palustris	Water purslane		0	0	●			0	
Utricularia fibrosa	Bladderwort	0				0			

0 Occurrence
● Dominant occurrence

Table 9 - Continued

		Sleeper	Albertson	Skit	Springer	Burrs Mill	Bog	Friendship	Feeder
Water Margin - Bank									
Lycopodium alopecuroides	Foxtail Clubmoss	0							
Sagittaria englemanniana	Arrowhead	●		0				0	
Glyceria obtusa	Blunt manna grass	0	0	0	0			0	0
Agrostis scabra	Hairgrass								0
Agrostis perennans	Upland Bent grass				0				
**Leersia oryzoides*	Rice Cutgrass	0	0	0	0			0	0
Panicum clandestinum	Panic grass				0				
**Panicum commutatum*	Panic grass	0			0	0			0
**Panicum virgatum*	Switchgrass	0		0					0
**Panicum agrostoides*	Panic grass				0				
**Panicum Sp.A*	Panic grass	0			0				
**Panicum Sp.B*	Panic grass	0				0			
**Panicum Sp.C*	Panic grass			0	0				
Echinochloa sp.	Millet								0
Cyperus strigosus	Umbrella Sedge		0						0
Cyperus dentatus	Umbrella Sedge	0		0					
**Dulichium arundinaceum*	3 Way Sedge	●	●	●	●		●		0
**Scirpus cyperinus*	Woolgrass		0	0					0
Carex crinita	Fringed Sedge				●				
Carex Walteriana	Sedge	0							0
Carex canescens	Sedge	0			0				0

*Also collected in bog habitat

Table 9 - Continued

		Sleeper	Albertson	Skit	Springer	Burrs Mill	Bog	Friendship	Feeder
Water Margin - Bank									
Carex atlantica	Sedge								0
Carex lurida	Sallow Sedge	0							0
Juncus effusus	Soft rush	0		0	0				0
Helonia bullata	Swamp Pink							0	
Sisyrinchium Sp.								0	
Iris versicolor	Blue flag				0			0	
Polygonum punctatum	Dotted Smartweed		●		●				
Polygonum sagittatum	Arrow-leaved Tear Thumb		0		0				0
Polygonum arifolium	Halbred Tear Thumb				0				0
Impatiens capensis	Spotted Touch me not		0					0	
Triadenum mutilum	Dwarf St. John's wort	0	●						
**Triadenum virginicum*	Marsh St. John's wort	●	●	●	●	0		0	0
Triadenum canadense	St. John's wort	0							
Decodon verticillatus	Swamp loosestrife	0							0
**Rhexia virginica*	Meadow Beauty	●	●	●		0			
**Vaccinium macrocarpon*	Cranberry	●	0	●					
Lysimachia terrestris	Yellow loosestrife	0		0					
Lycopus virginicus	Mint				0			0	
Galium tinctorium	Stiffmarsh bedstraw		0		0				
Lobelia cardinalis	Cardinal flower		0		●				
Mikania scandens	Climbing Hempweed				0			0	
Bidens cernua	Beggars tick				0				

Table 9 - Continued

		Sleeper	Albertson	Skit	Springer	Burrs Mill	Bog	Friendship	Feeder
Bog									
Agrostis altissma	Hairgrass	O		O					
Andropogon virginicus-glomeratus	Broomsedge			O					
Scirpus pungens	Rush			O					
Eriophorum virginicum	Virginia cottongrass			O					
Rhynchospora capitellata	Beakrush	O		O					
Cladium mariscoides	Twigrush	O		O					
Carex stricta	Sedge	O		O					
Carex bullata	Sedge	O		O					
Juncus canadensis	Rush	O		O					
Lochnanthes tinctoria	Redroot	O		O		O			
Drosera intermedia	Sundew	O		O					
Polygala cruciata	Milkwort	O		O					

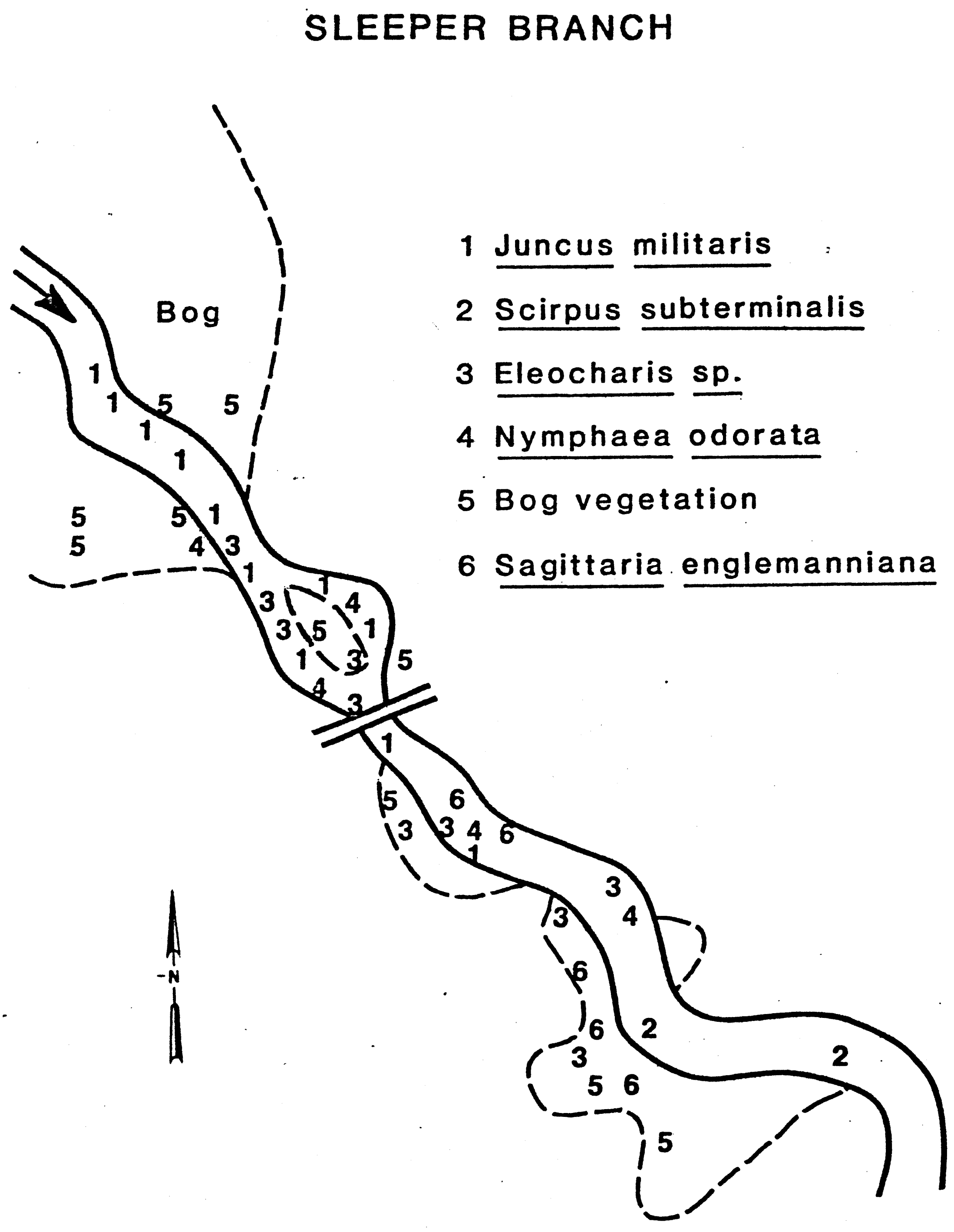

Figure 3. Composite dominant macrophyte vegetation map of Sleeper Branch Branch from March 1982 - February 1983. Dashed lines represent limits of bog habitats. Arrow indicates direction of water flow. See Table 9 for the types of bog vegetation encountered.

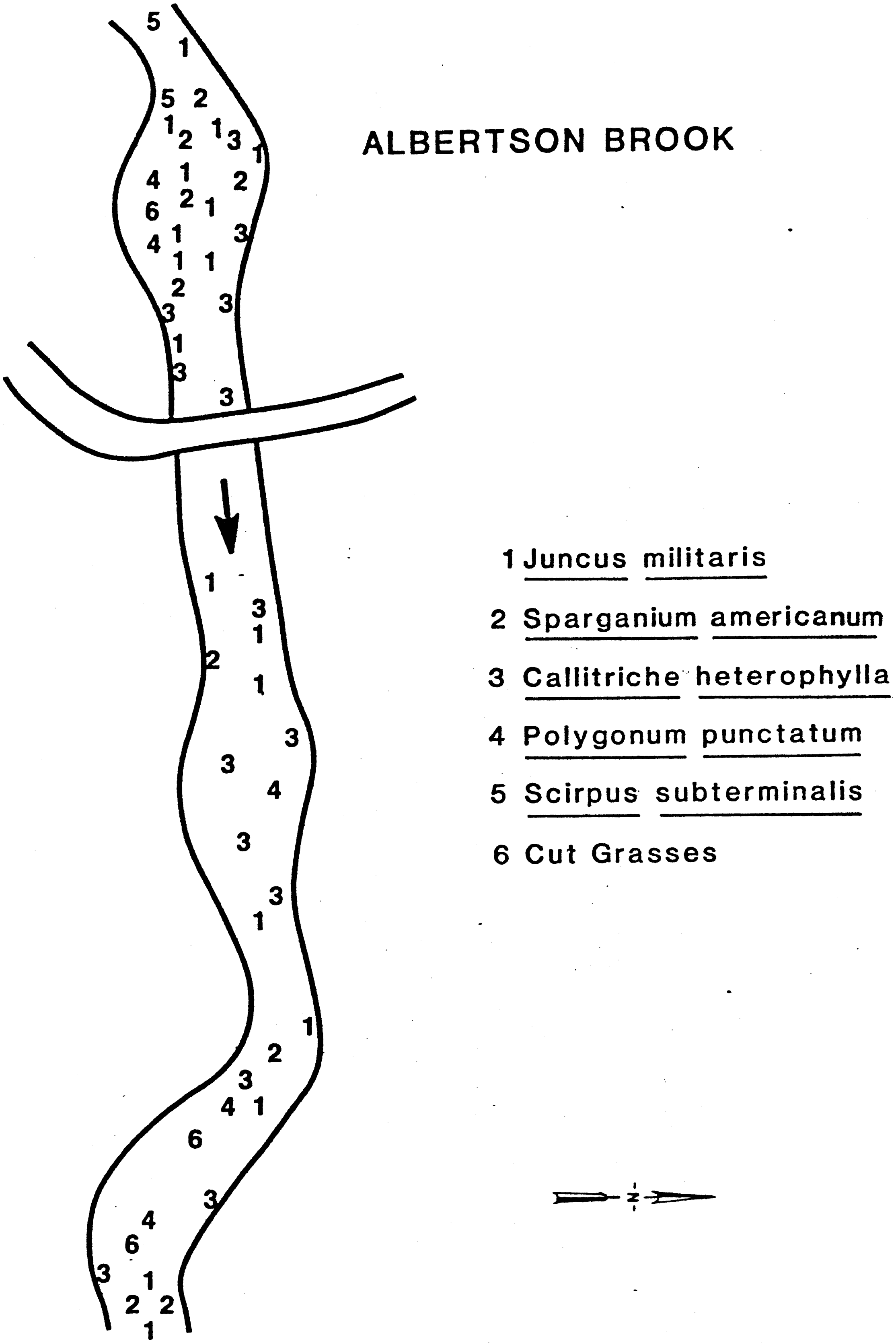

Figure 4. Composite dominant vegetation map of Albertson Brook from March 1982 - February 1983. Dashed lines represent intermittently submerged sand bars. Arrow indicates direction of water flow. See Table 9 for the types of cut grasses encountered.

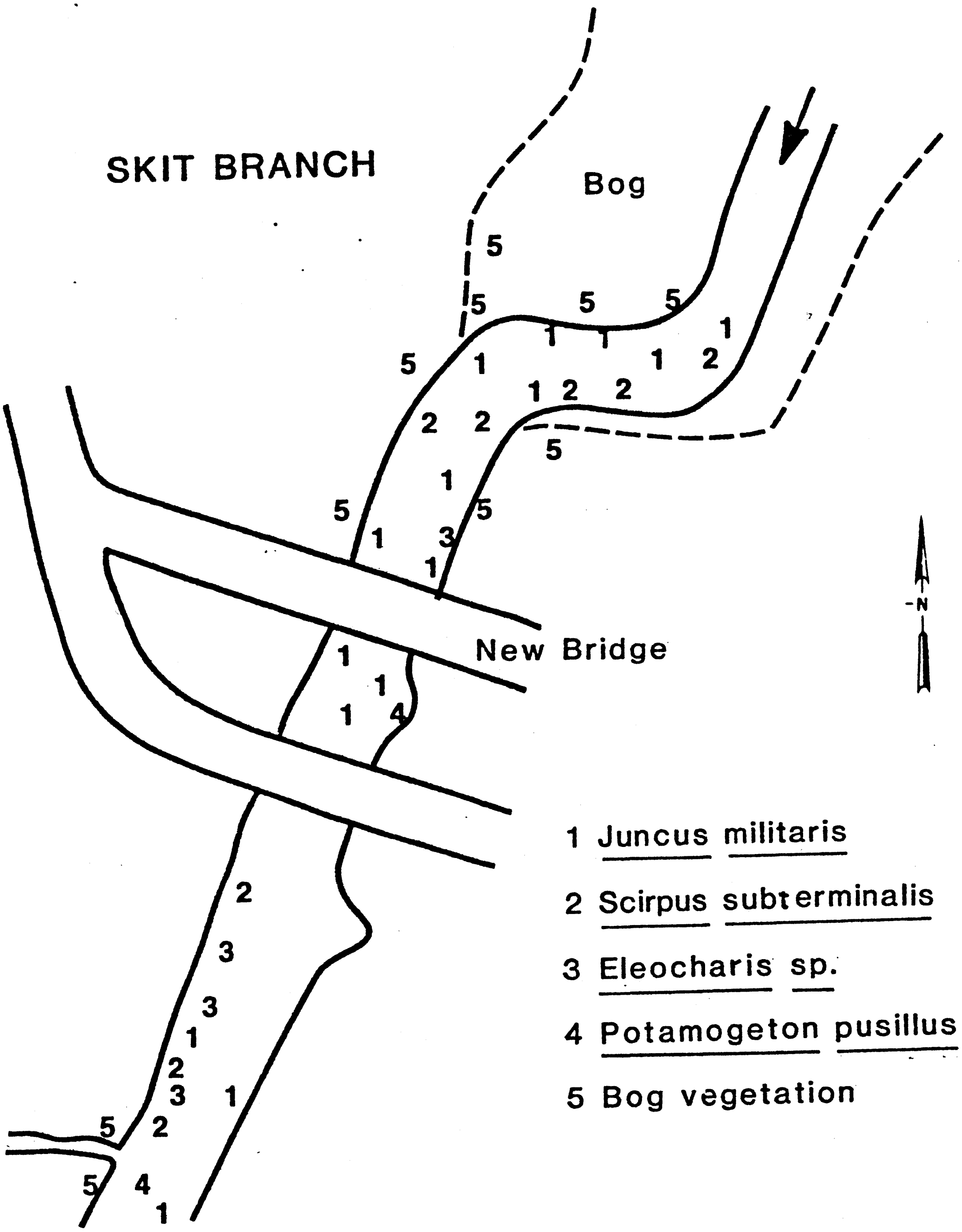

Figure 5. Composite dominant macrophyte vegetation map of Skit Branch from March 1982 - February 1983. Dashed lines indicate limit of bog habitat. Arrow indicates direction of water flow. See Table 9 for the types of bog vegetation encountered.

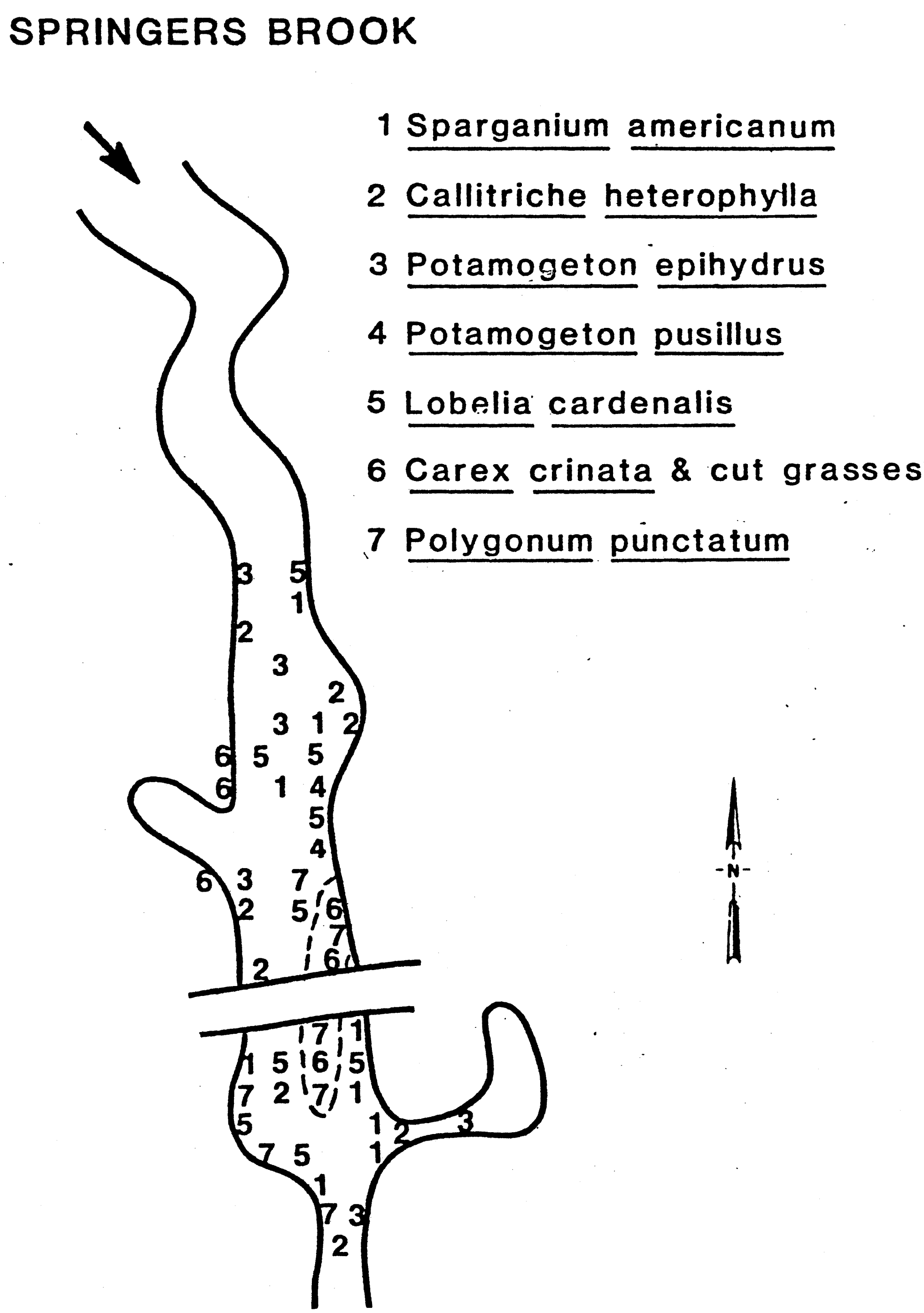

Figure 6. Composite macrophyte vegetation map of Springers Brook from March 1982 - February 1983. Dashed line represents intermittently submerged sand bars. Arrow indicates direction of water flow. See Table 9 for the types of cut grasses encountered.

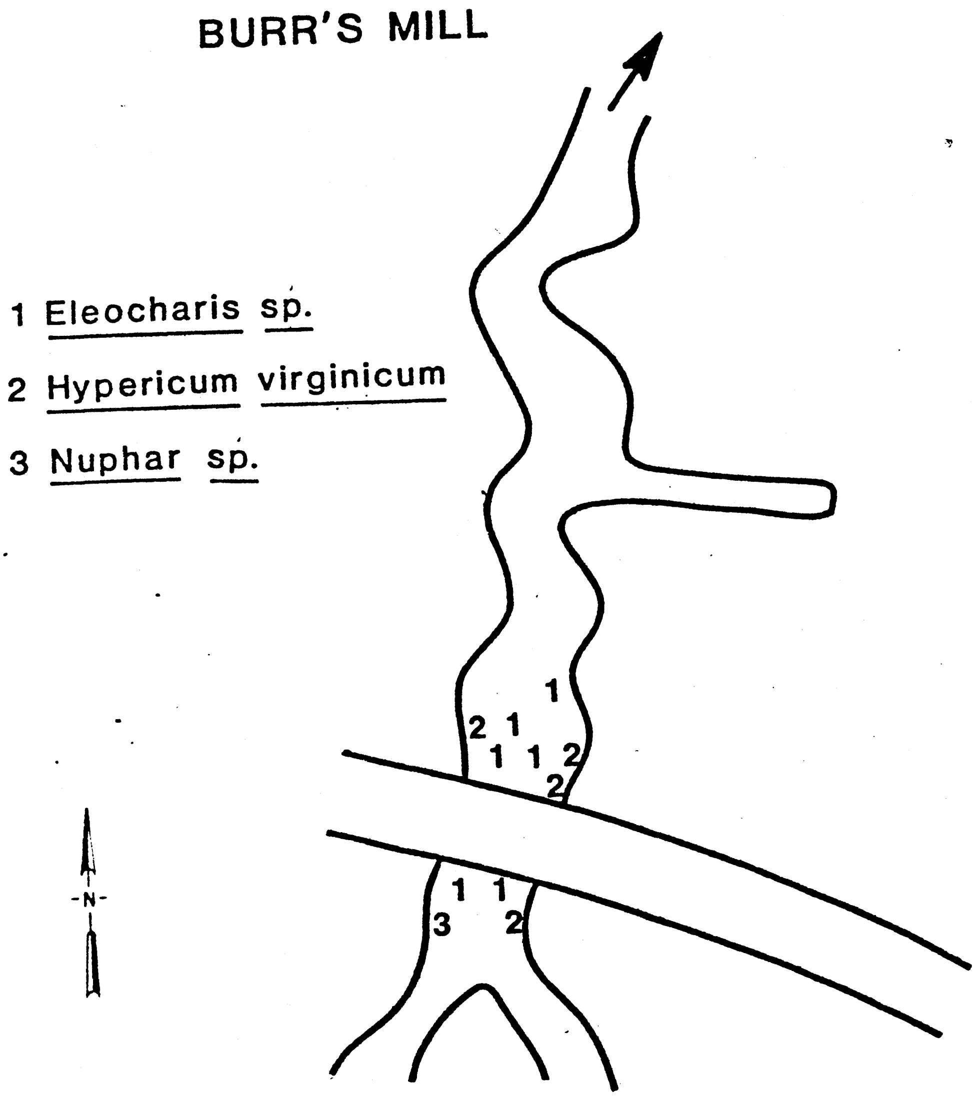

Figure 7. Composite macrophyte vegetation map of Burr's Mill from March 1982 - February 1983. Arrow indicates direction of water flow.

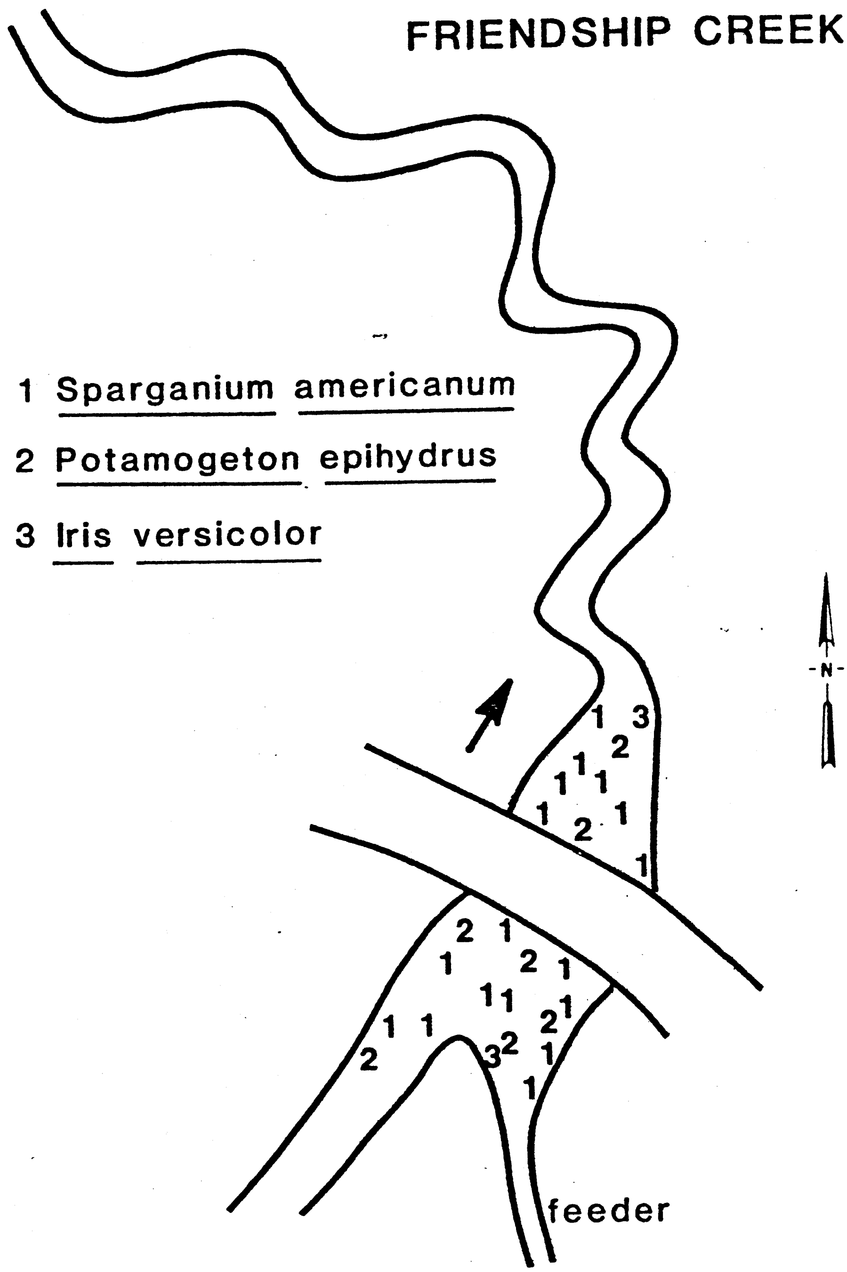

Figure 8. Composite macrophyte vegetation map of Friendship Creek from March 1982 - February 1983. Arrow indicates direction of water flow.

Friendship also is characterized by a closed canopy and no bog habitats, so that most of the species occurred only in the area around the bridge. A small stream discharging into the mainstream just upcurrent from the bridge was surveyed as a supplemental sampling area (feeder). This shallow, open canopy stream was choked with emergent plants, many of which were characteristic of bogs from the other streams.

Juncus militaris was the dominant submerged species at both Sleeper and Albertson, forming dense and extensive beds in channels and shallows (Fig. 3 and 4). The major difference between these two streams was the abundance of Sparganium americanum and Callitriche heterophylla at Albertson. Both species formed dense bottom-to-surface beds in shallow water along the stream bank. At Sleeper, Polygonum punctatus, along with Leersia oryzoides, occupied high sand bars that were submerged during periods of high water. Various species of Eleocharis were also common on the exposed sand bars, and dense stands of Scirpus subterminalis occupied the stream channels with Juncus.

Juncus militaris and Scirpus subterminalis were the dominant submerged species throughout bog and non-bog portions of Skit (Fig 5). Potamogeton pusillus formed dense bottom-to-surface beds in shallow water along the bank in both Skit and Springers. Sparganium americanum and Potamogeton epihydrus were dominant in slightly deeper water at Springers (Fig 6). As it did in Albertson, Callitriche heterophylla formed dense beds in Springers. Lobelia cardinalis and Polygonum punctatum were dominant on the vertical banks and Polygonum punctatum, Carex crinita, and Leersia oryzoides dominated the occasionally submerged sand bars at Springers.

The general absence of aquatic plants at Burr's Mill is puzzling, particularly in light of the near upstream bog seed source. As mentioned, only in an open area receiving direct sunlight on bottom sediment exposed during the minimum flow period, did a few species (Eleocharis olivacea, Nuphar variegatum, Triadenum virginicum, and Panicum spp.) take a brief hold (Fig. 7). The vegetation at Friendship chiefly consisted of an open area around the bridge which was choked with Sparganium americanum and Potamogeton epihydrus, despite the diverse feeder stream immediately upstream (Fig. 8).

In order to compare species distribution between disturbed and undisturbed streams, species occurring in 2 or 3 undisturbed streams only were labeled "undisturbed". Similarly, species occurring in 2 or 3 disturbed streams only were labeled "disturbed". Species occurring in most streams, regardless of type, were listed as "common" and those found only in one stream were listed as "uncommon" (Table 10). Nearly all of the common species have been described as part of the characteristic Pine Barrens aquatic flora by previous workers (McCormick 1979, Olsson 1979, Pinelands Commission 1980). Seventy percent of the species in the undisturbed group are characteristic of the Pine Barrens, while only 36% of the disturbed group are so characterized

Table 10. Macrophyte species classified based on distribution patterns among streams. * = described by previous workers as a member of the characteristic Pine Barrens flora (McCormick 1979, Olsson 1979, Pinelands Commission 1980).

Disturbed	Undisturbed	Common	Uncommon
**Sparganium americanum*	*Agrostis altissima*	**Potamogeton pusillus*	*Lycopodium alopecuroides*
**Potamogeton epihydrus*	*Panicum virgatum*	**Sagittaria Englemanniana*	*Agrostis scabra*
**Iris versicolor*	*Panicum* Sp B	**Glyceria obtusa*	*Agrostis perennans*
Polygonum punctatum	**Cyperus dentatus*	**Leersia oryzoides*	*Panicum clandestinum*
Polygonum sagittatum	**Eleocharis olivacea*	*Panicum commutatum*	*Panicum agrostoides*
Callitriche heterophylla	**Rhynchospora alba*	*Panicum* Sp A	*Panicum* Sp C
Impatiens capensis	**Cladium mariscoides*	**Dulichium arundinaceum*	**Andropogon virginicus*
Lycopus virginicus	*Carex stricta*	**Scirpus cyperinus*	*Echinochloa* sp.
Galium tinocotorium	**Carex bullata*	**Scirpus subterminalis*	*Cyperus strigosus*
**Lobelia cardinalis*	**Xyris difformis*	**Peltandra virginica*	**Eleocharis Robbinsii*
Mikania scandens	**Juncus canadensis*	**Juncus militaris*	**Eleocharis tenuis*
	**Lachnanthes tinctoria*	**Juncus effusus*	**Eleocharis acicularis*
	**Nymphaea odorata*	**Triadenum virginicum*	**Eleocharis tuberculosa*
	**Drosera intermedia*	**Rhexia virginica*	**Scirpus pungens*
	**Polygala cruciata*	*Ludwigia palustris*	**Eriophorum virginicum*
	Lysimachia terrestris	**Vaccinium macrocarpon*	*Rhynchospora capitellata*
	**Utricularia fibrosa*		*Carex crinita*
			Carex Walteriana
			**Eriocaulon compressum*
			**Pontederia cordata*
			**Helonias bullata*
			Sisyrinchium sp.
			Polygonum arifolium
			**Nuphar variegatum*
			Triadenum mutilum
			Triadenum canadense
			**Decodon verticillatus*
			Bidens cernua
			Carex canescens
			Carex atlantica
			Carex lurida

according to these references. Some of this difference may be due to the extensive bog habitats sampled in undisturbed streams (Skit and Sleeper), but this difference also suggests that colonization by non-Pine Barrens species is a result of disturbance.

This conclusion is echoed by analysis of Stone's (1910) survey of the southern New Jersey flora, which occurred before the types of disturbance investigated here (elevated pH and nutrients) were a serious concern. Distribution data on 8 of the 11 species classified as characteristic of disturbed sites (in this study) and 12 of the 17 species characteristic of undisturbed sites are provided in Stone's study (Table 11). The species are grouped as either occurring in the Pine Barrens, or in the state, but not the Pine Barrens, based on Stone's description. The data clearly indicate that the species described by Stone as being found in the Pine Barrens are found predominately in the undisturbed streams, and that the disturbed streams now contain many species which formerly were not considered part of the Pine Barrens flora.

The numbers of species occurring at each stream according to various groupings are presented in Table 12. (Note that the sum of submerged, bog, and margin species need not equal the total number of species, since there may be some species present that could not be conveniently classified, or some species may have occurred in more than one habitat.) Once again, the high number of bog species at Sleeper and Skit is primarily responsible for the greater total number of species in these streams. Comparison of submerged and floating species between disturbed and undisturbed streams does not show any obvious trends. Similarly, the number of species in the water margin or bank grouping shows no consistent trend between groups. There are relatively more bank species in Sleeper, Springers, and the feeder stream at Friendship. This is consistent with field observations of greater margin habitat at these locations, and probably not related to differences in water quality.

In summary, a major effect of disturbance, based on observations of these streams, appears to be a shift in species dominance from Eleocharis spp. and Scirpus subterminalis to Sparganium americanum, Callitriche heterophylla and Potamogeton epihydrus. Juncus militaris can be dominant in either stream type. In addition, there appears to be a significant incursion of non-Pine Barrens species into the disturbed streams. However, this conclusion must be tempered by the general lack of comprehensive field surveys of Pine Barrens macrophytes. The large number of species apparently restricted to only disturbed or undisturbed streams, and comparison with Stone's (1910) early work, though, strongly suggests that disturbance acts directly on species composition by allowing non-Pine Barrens species to colonize these streams. Overall species diversity, at least in the non-bog habitats, is apparently little affected.

Table 11. Distribution of macrophytes characteristic of present day disturbed and undisturbed Pine Barrens streams in early part of the century (Stone 1910).

	Common in State, but not Pine Barrens	Found in Pine Barrens
Disturbed	*Iris versicolor* *Polygonum punctatum* *Polygenum sagittatum* *Callitriche heterophylla* *Lobelia cardinalis*	*Sparganium americanum* *Potamogeton epihydrus* *Lycopus virginicus*
Undisturbed	*Carex stricta*	*Panicum virgatum* *Cyperus dentatus* *Eleocharis olivacea* *Rhynchospora alba* *Carex bullata* *Juncus canadensis* *Lachnanthes tinctoria* *Nymphaea odorata* *Drosera intermedia* *Polygata cruciata* *Lysimachia terrestris* *Utricularia fibrosa*

Table 12. Number of macrophyte species by various categories in the six study streams and one supplemental sampling site at Friendship (feeder).

	Species Number					
Stream	Undisturbed	Disturbed	Submerged/ floating	Bog	Margin	Total
Sleeper	16	-	11	20	15	42
Albertson	-	7	7	7	7	21
Skit	14	-	9	24	5	34
Springers	-	10	6	5	16	28
Burr's Mill	3	-	4	5	7	8
Friendship	-	6	4	4	8	15
Feeder	2	1	2	8	11	21

Aquatic Insects

Identifications. It is often difficult to identify immature stages of insects to species level because they are not taxonomically as well known as adults. In order to be consistent and objective, we have been maximally taxonomically conservative.

In situations where it was possilbe to separate different species but not to confidently assign a name to each, each species was assigned a number (eg. Sigara spp. 1-8; Table 16; Hemiptera). In some genera, no species identifications were possible, therefore, all specimens were classified as sp. or spp. (eg. Leptoceridae; Table 16; Tricoptera). Genera in which no species identifications were possible were always considered monotypic when computing species richness.

Sometimes one or more species could be identified in a genus, yet there were still a residual of unidentifiable specimens which may or may not have been unique species. These individuals are listed in Tables 13 and 16 as sp.(?) or spp.(?). Species classified in this category were never included in species richness analyses.

When identifications are based only on adults, it sometimes is difficult to determine whether or not occurrence is fortuitous. A major advantage of working with immatures is that it conclusively establishes that a species reproduces in a given habitat. This is critical information when species are being assessed as potential indicator organisms and it partially counter-balances the taxonomic drawbacks discussed above.

Species Richness. There is a dearth of information regarding insect diversity in the Pinelands. Most available information is too general (i.e., no species level identifications), antiquated (Smith 1910), or inaccurate because it is based on antiquated data (usually Smith 1910). The list of insects collected in this study (Table 13) considerably expands portions of lists of lotic insects provided by McCormick (1970), Patrick et al. (1979), and Lloyd et al. (1980). This is especially true for Coleoptera, Ephemeroptera, and Plecoptera. We record a total of 147 species of insects (excluding Diptera) for the six study sites. This number could easily exceed 200 when dipterans are eventually identified and the taxonomy of numerous genera is clarified. It is interesting to note that generic diversity of insects (104) exceeds species richness of the other groups (algae, macrophytes, fish) analyzed in this project.

Total species richness, excluding Diptera, was somewhat higher in disturbed (122 species) than undisturbed streams (104 species; Table 16). Species richness of undisturbed vs disturbed streams, either by insect order, stream, or habitat, is difficult to assess because there are no apparent trends (Tables 14,15). However, species counts tended to be a little higher in disturbed

Table 13

List of collected taxa that could be identified and/or named. Taxa are listed alphabetically by order, family, genus, and species (if species are designated by number, they are listed chronologically).

COLEOPTERA

Chrysomelidae
- Donacia Fabricius
  - Donacia spp.

Curculionidae
- Onychylis LeConte
  - Onychylis sp.

Dytiscidae
- Acilius Leach
  - A. mediatus (Say)
- Agabus Leach
  - A. gagates Aube
  - A. semivittatus (LeConte)
- Bidessonotus Regimbart
  - B. inconspicuus (LeConte)
- Copelatus Erichson
  - C. punctulatus Aube
- Coptotomus Say
  - C. interrogatus (Fabricius)
  - C. lenticus Hilsenhoff
- Desmopachria Babington
  - D. convexa (Aube)
- Hydroporus Clairville
  - H. blanchardi Sherman
  - H. clypealis Sharp
  - H. dilitatus Fall
  - H. lobatus Sharp
  - H. mellitus LeConte
  - H. triangularis Fall
  - H. undulatus Say
- Ilybius Erichson
  - I. biguttulus (Germar)
- Laccophilus Leach
  - L. maculosus maculosus Say
- Matus Aube
  - M. bicarinatus (Say)
  - M. ovatus ovatus Leech

Elmidae
- Ancyronyx Erichson
  - A. variegata (Germar)
- Macronychus Muller
  - M. glabratus Say
- Microcylloepus Hinton
  - M. pusillus pusillus (LeConte)
- Optioservus Sanderson
  - O. sp. 1
- Oulimnius Des Gozis
  - O. latiusculus (LeConte)
- Promoresia Sanderson
  - P. tardella (Fall)
- Stenelmis Dufour
  - S. sp 1
  - S. sp. 2
  - S. sp. 3
  - S. sp. 4

Gyrinidae
- Dineutus Mac Leay
  - D. ciliatus (Forsberg)
  - D. discolor Aube
  - D. nigrior Roberts
- Gyrinus Geoffroy
  - G. sp. 1
  - G. sp. 2

Haliplidae
- Haliplus Latreille
  - H. fasciatus Aube
  - H. leopardus Roberts
- Peltodytes Regimbart
  - P. bradleyi Young
  - P. muticus (LeConte)

Hydrophilidae
- Berosus Leach
  - B. sp. 1

Table 13 (continued)

Cymbiodyta Bedel
C. rotunda (Say)
C. vindicata Fall

Enochrus Thomson
E. cinctus (Say)

Sperchopsis LeConte
S. tessellatus (Ziegler)

Tropisternus Solier
T. natator d'Orchymont

Hydrochidae
Hydrochus Leach
H. sp. 1

Noteridae
Hydrocanthus Say
H. iricolor Say

DIPTERA

Ceratopogonidae
Chironomidae
Culicidae
Ptychopteridae
Simulidae
Tabanidae

EPHEMEROPTERA

Baetidae
Baetis Leach
Baetis sp. 1
Baetis sp. 2

Baetiscidae
Baetisca Walsh
B. laurentina Mc Dunnough

Ephemerellidae
Eurylophella Tiensuu
E. bicolor (Clemens)
E. temporalis (Mc Dunnough)

Heptageniidae
Stenonema Traver
S. modestum (Banks)

Leptophlebiidae
Leptophlebia Westwood
L. cupida (Say)

Paraleptophlebia Lestage
P. spp.

Metretopodidae
Siphloplecton Clemens
S. basale (Walker)

HEMIPTERA
Belostomatidae
Abedus Stal
Belostoma Latreille ?

Corixidae
Hesperocorixa Kirkaldy
H. lucida (Abbott)
H. minor (Abbott)

Palmacorixa Abbott
P. nana nana Walley

Sigara Fabricius
S. sp. 1
S. sp. 2
S. sp. 3
S. sp. 4
S. sp. 5
S. sp. 6
S. sp. 7
S. sp. 8

Trichocorixa Kirkaldy
T. calva (Say)
T. macroceps (Kirkaldy)

Gerridae
Gerris Fabricius
G. argenticollis Parshley
G. insperatus Drake and Hottes
G. remigis Say

Limnoporus Stal
L. canaliculatus (Say)

Trepobates Uhler
T. pictus (Herrich Schaeffer)

Mesoveliidae
Mesovelia Mulsant and Rey
M. spp.

Nepidae
Nepa Linnaeus
N. apiculata Uhler

Ranatra Fabricius
R. fusca Palisot-Beauvois
R. kirkaldyi Torre-Bueno

Table 13 (continued)

Notonectidae
- Notonecta Linnaeus
  - N. irrorata Uhler
  - N. uhleri Kirkaldy
  - N. petrunkevitchi Hutchinson

Veliidae
- Microvelia Westwood
  - M. pulchella Westwood
- Rhagovelia Mayr
  - R. obesa Uhler

LEPIDOPTERA

Pyralidae
- Parapoynx Hubner
  - P. maculasis (Clemens)
- Petrophila Guilding
  - P. sp.

MEGALOPTERA

Corydalidae
- Chauliodes Latreille
  - C. pectinicornis (Linnaeus)
- Nigronia Banks
  - N. serricornis(Say)

Sialidae
- Sialis
  - S. spp. Latreille

NEUROPTERA

Sisyridae
- Climacia Mac Lachlan
  - C. areolaris (Hagen)

ODONATA

Aeshnidae
- Basiaeschna Selys
  - B. janata (Say)
- Boyeria MacLachlan
  - B. vinosa (Say)

Calopterygidae
- Calopteryx Leach
  - C. dimidiata Burmeister
  - C. maculata (Beauvois)
- Hataerina Hagen
  - H. americana (Fabricius)

Coenagrionidae
- Argia Rambur
  - A. fumipennis fumipennis(Burmeister)
  - A. sedula (Hagen)
- Chromagrion Needham
  - C. conditum Hagen
- Enallagma
  - E. divagans Selys
  - E. pallidum Root
  - E. signatum(Hagen)
- Ischnura Charpentier
  - I. posita(Hagen)

Cordulegastridae
- Cordulegaster Leach
  - C. diastatops (Selys)
  - C. maculata Selys

Corduliidae
- Somatochlora Selys
  - S. sp.
- Tetragoneuria Hagen
  - T. semiaquea (Burmeister)

Gomphidae
- Gomphus Leach
  - G. exilis Selys
  - G. parvidens Currie
- Progomphus Selys
  - P. obscurus (Rambur)

Lestidae
- Lestes Leach
  - L. inaequalis Walsh

Libellulidae
- Ladona Needham
  - L. sp.1
- Libellula
  - L. flavida Rambur

Macromiidae
- Didymops Rambur
  - D. transversa(Say)
- Macromia Rambur
  - M. alleghaniensis Williamson

PLECOPTERA

Leuctridae
- Leuctra Stephens
  - L. spp.

Nemouridae
- Paraneumoura Needham and Claassen
  - P. perfecta (Walker)

Perlidae
- Acroneuria Pictet
  - A. lycorias (Newman)
- Perlesta Banks
  - P. placida (Hagen)
- Perlinella Banks
  - P. drymo (Newman)

Table 13 (continued)

- Perlodidae
  - Isogenoides Klapalek
    - Isogenoides sp.
  - Isoperla Banks
    - I. marlynia Needham and Claassen
- Taeniopterygidae
  - Taeniopteryx Pictet
    - T. parvula Banks

TRICHOPTERA

- Brachycentridae
  - Brachycentrus Curtis
    - B. numerosus (Say)
    - B. spp.
- Hydropsychidae
  - Ceratopsyche Ross and Unzicker
    - C. sparna (Ross)
  - Cheumatopsyche Wallengren
    - C. spp.
  - Diplectrona Westwood
    - D. modesta Banks
  - Hydropsyche Pictet
    - H. betteni Ross
    - H. decalda Ross
    - H. venularis Banks
- Hydroptilidae
  - Hydroptila Dalman
    - H. sp.
  - Oxyethira Eaton
    - O. spp.
- Lepidostomatidae
  - Lepidostoma Rambur
    - L. sp.
- Leptoceridae
  - Ceraclea Stephens
    - C. sp.
  - Nectopsyche Muller
    - N. sp.
  - Triaenodes Mac Lachlan
    - T. sp.
- Limnephilidae
  - Goera Stephens
    - G. sp.
  - Hydatophylax Wallengren
    - H. argus (Harris)
  - Ironoquia Banks
    - I. sp.
  - Limnephilus Leach
    - L. sp.
  - Neophylax MacLachlan
    - N. sp.
  - Platycentropus Ulmer
    - P. sp.
  - Pycnopsyche Banks
    - P. scabripennis (Rambur)
    - P. sp.
- Molannidae
  - Molanna Curtis
    - M. tryphena Betten
- Philopotamidae
  - Chimarra Stephens
    - C. sp.
- Phryganeidae
  - Ptilostomis Kolenati
    - P. sp.
- Polycentropodidae
  - Neureclipsis MacLachlan
    - N. sp.
  - Nyctiophylax Brauer
    - N. sp.
  - Polycentropus Curtis
    - P. sp.

Table 14

Species richness for each stream by insect order and habitat. R= riffle; NR= non riffle; T= total. The first three streams are undisturbed; the second three disturbed.

habitat / Area	Coleop.			Ephem.			Hemip.			Lepid.			Megalop.			Neurop.			Odonata			Plecop.			Trichop.			Totals		
	R	NR	T	R	NR	T	R	NR	T	R	NR	T	R	NR	T	R	NR	T	R	NR	T	R	NR	T	R	NR	T	R	NR	T
Skit	2	21	23	1	4	5	1	9	9	0	0	0	1	2	2	0	0	0	0	11	11	0	6	6	1	10	11	6	62	66
Sleeper	0	11	11	2	4	5	0	11	11	0	0	0	1	2	2	0	1	1	1	14	14	0	6	6	3	15	18	7	62	66
Burrs Mill	1	15	15	0	0	0	0	7	7	0	0	0	2	3	3	0	0	0	1	7	8	0	0	0	0	9	9	4	41	42
Albertson	2	18	19	3	6	7	1	9	10	0	1	1	0	3	3	0	1	1	2	12	13	0	4	4	9	18	27	17	71	81
Friendship	2	18	19	0	3	3	0	6	6	0	0	0	1	2	2	0	0	0	1	14	14	0	1	1	4	14	18	8	58	63
Springers	1	17	17	0	4	4	4	14	15	0	0	6	0	1	1	0	0	0	1	9	9	2	3	4	0	7	7	8	55	57

Table 15

Species richness for undisturbed streams (UD= Skit, Sleeper, Burrs Mill) and disturbed streams (D= Albertson, Friendship, Springers). R= riffle; NR= non-riffle; T= total.

habitat / Area	Coleop.			Ephem.			Hemip.			Lepidop.			Megalop.			Neurop.			Odonata			Plecop.			Tricop.					
	R	NR	T	R	NR	T	R	NR	T	R	NR	T	R	NR	T	R	NR	T	R	NR	T	R	NR	T	R	NR	T			
UD	3	32	32	2	5	7	2	20	20	0	0	0	2	3	3	0	1	1	4	24	25	0	7	7	3	19	21			
D	5	39	40	3	7	8	4	21	22	0	1	1	1	3	3	0	1	1	3	26	26	2	6	6	10	23	23			

situations. The highest species number by stream was found in Albertson Brook (84 species) and the lowest in Burr's Mill (42 species).

Distribution and Disturbed and Undisturbed Conditions. Analysis of distribution and abundance patterns of individual species appears more important than consideration of species richness in assessing the potential impact of stream disturbance on the insects. Since adult coleopterans and hemipterans tend to favor backwater habitats, which may experience unpredictable oxygen regimes, and are highly mobile (both within and between streams) and so poorly known, trends in their distributional patterns are difficult to assess based a single sampling location in each stream. In addition, in the case of Dytiscidae, which was one of the most commonly collected families of the two orders, extensive collecting experience of many of these species in a variety of habitats, both lotic and lentic, permanent and temporary, indicates distributional patterns too variable to allow interpretation of our data at this time (Wolfe unpubl. data). These groups are therefore excluded from the following analysis. An exception is the beetle family, Elmidae. Individuals in this family are not nearly as mobile, and tend to occupy habitats in moving water. In addition, elmid sensitivity to stream disturbance in other localities has been shown, making preliminary interpretation of their distributional patterns useful.

Although most insect species were present at some time during the study in both disturbed and undisturbed streams, a number of species showed a distinct preference for one stream type over the other (Table 16). Considering only those species occurring exclusively in two or three streams of a particular type, Eurylophella bicolor (Ephemeroptera), Perlinella drymo and Isoperla marlyia (Plecoptera), and Chromagrion conditum, Somatochlora spp., Tetraogoneuria semiaquea, and Ladona spp. (Odonata) were found in undisturbed streams. Species found only in disturbed streams were Ancyronyx variegata (Coleoptera), and Brachycentrus numerosus, Cheumatopsyche sp., and Ceraclea sp. (Tricoptera).

Analysis of the relative abundance of the collected insects reveals additional trends in species distribution between disturbed and undisturbed streams. The discussion below is generally limited to taxa represented by 10 or more individuals collected from more than one stream within a stream group.

The possible impact of stream disturbance is particularly evident for elmid beetle (Table 16; Coleoptera). All elmids, except for one specimen of Stenelmis sp.1, were collected from disturbed sites. However, this trend requires further clarification because most elmid species were only rarely collected, some being represented by only one or two specimens from one stream. An exception to this rarity is Macronychus glabratus.

Among ephemeropterans, Stenonema modestum was most abundant in disturbed streams, while Baetisca laurentina was most commonly

Table 16

Species occurrence and abundance by stream, habitat, and date. Each occurrence is represented by a number followed by another number (the latter in parentheses). Dates of collections are coded and are indicated by the first number; the number of specimens collected on each collecting date is represented by the following number, in parentheses. Coded dates are as follows: 1-23,24,29 March 1982; 2-14 April 1982; 3-17 May 1982; 4-3 June 1982; 5-11 July 1982; 6-7 September 1982; 11-26 February 1983. R= riffle; NR= non-riffle. The first three streams in each table are undisturbed and the second three streams are disturbed. Taxa are listed alphabetically, first by order, then by family, genus, and species.

Table 16. Coleoptera

		Chrysomelidae	Curculionidae	Dytiscidae					
AREA \ SPECIES		Donacia spp.	Onychylis spp.	Acilius mediatus	Agabus gagates	A. semivittatus	Bidessonotus inconspicuus	Copelatus punctulatus	Coptotomus interrogatus
SKIT	R								10(1)
	NR	4(3)			7(1)				2(1),9(1)
SLEEPER	R								
	NR								
BURRS MILL	R								
	NR				2(1)				1(2),2(4),4(1),5(6),6(2),7(3),8(2),9(1),10(2),11(6)
ALBERTSON	R								
	NR								
FRIENDSHIP	R								
	NR	3(6),4(1)	3(1)						2(7),3(7),9(4)
SPRINGERS	R								
	NR			10(1)		1(1)	1(1),4(1),5(2),6(4)	1(2)	1(4)

Table 16. Coleoptera (continued)

SPECIES / AREA	C. lenticus	Desmopachria convexa	Hydroporus blanchardi	H. clypealis	H. dilitatus	H. lobatus	H. mellitus	H. triangularis
SKIT								
R								
NR	6(1)		1(1),9(1)	2(1),4(1) 5(2),7(1) 8(2)	1(1),2(1) 3(4),5(7) 7(2),9(2)		2(1)	
SLEEPER								
R								
NR			5(1)	4(2),7(2)	9(1)	3(2),7(1)		
BURRSMILL								
R								
NR		6(1)		1(7),2(3) 3(8),4(1) 5(3),6(10) 7(4),8(1)	7(8)	1(23),2(2) 3(15),4(7) 5(8),6(20) 8(14),10(5) 11(2)		
ALBERTSON								
R	1(2)							
NR					3(3),4(1) 5(13),6(7) 7(2),11(1)		3(1),4(4) 5(4)	7(1)
FRIENDSHIP								
R								
NR			2(1)	2(1)	6(1),11(1)			
SPRINGERS								
R								
NR			2(1)	1(1),2(5), 3(6),5(2), 6(2),7(5), 9(2),11(5)	2(6),3(13) 4(2),5(2) 6(6),7(3)	1(1)		

Table 16. Coleoptera (continued)

SPECIES / AREA	H. undulatus	H. spp.	Ilybius biguttulus	I. sp.(?)	Laccophilus m.maculosus	Matus bicarinatus	H. o.ovatus	
SKIT								
R								
NR			5(1)	1(1)	1(1),6(1)	5(1)	2(1)9(1)	
SLEEPER								
R								
NR								
BURRS MILL								
R								
NR	4(1)	1(1)				2(1),3(1)	3(6)	
ALBERTSON								
R								
NR		1(3),4(2)			7(1),8(1) 9(2)			
FRIENDSHIP								
R								
NR	4(1),9(21)			9(2)	2(1),8(1)			
SPRINGERS								
R								
NR		3(8)			7(2),9(2) 10(1)			

Table 16. Coleoptera (continued)

SPECIES / AREA	Hydrophilidae							
	H. leopardus	Peltodytes bradleyi	P. spp.(?)	P. muricus	Berosus sp.	Cymbiodyta rotunda	C. vindicata	Enochrus cinctus
SKIT R			8(3)					
SKIT NR							7(1)	
SLEEPER R								
SLEEPER NR		8(1)						
BURRSMILL R								
BURRSMILL NR					3(1)	5(1)		
ALBERTSON R								
ALBERTSON NR								
FRIENDSHIP R								
FRIENDSHIP NR				2(1),6(1)				5(1)
SPRINGERS R								
SPRINGERS NR	3(2)	2(4),4(3) 10(3)	3(2), 5(3)	1(1),4(2) 6(1)				

Table 16. Coleoptera (continued)

SPECIES / AREA	Hydrochidae			Noteridae			
	Sperchopsis tessellatus	Tropisternus natator	Hydrochus sp.	Hydrocanthus iricolor			
SKIT R							
SKIT NR	1(1)			4(2)			
SLEEPER R							
SLEEPER NR				3(2)			
BURRS MILL R							
BURRS MILL NR		2(1)		1(1),4(1), 6(4),10(1)			
ALBERTSON R							
ALBERTSON NR	1(1)	1(1)					
FRIENDSHIP R		7(1)					
FRIENDSHIP NR	2(1)		5(1)	4(1),9(14)			
SPRINGERS R							
SPRINGERS NR							

Table 16. Coleoptera (continued)

SPECIES / AREA	Elmidae Ancyronyx variegata	Macronychus glabratus	Microcyll-oepus p. pusillus	Optioservus latiusculus	Promoresia tardella	Stenelmis sp1	S sp2	S sp3
SKIT R								
NR						1(1)		
SLEEPER R								
NR								
BURRS MILL R								
NR								
ALBERTSON R		7(1)						
NR	4(1),6(1)	1(18),2(7),3(6),4(30),5(11),6(24),7(1),9(1)	7(1)	3(1)	1(1),7(1)	1(1)	1(4)	1(2)
FRIENDSHIP R						3(2)		
NR	4(1),6(1)					6(1)		
SPRINGERS R								
NR	5(5),6(1)							

Table 16. Coleoptera (continued)

SPECIES / AREA	S. sp.4	Gyrinidae Dineutus ciliatus	D. discolor	D. nigrior	D. sp.	Gyrinus sp.1	G. sp.2	Haliplidae Haliplus fasciatus
SKIT R		7(1)						
NR		1(1),2(3),3(3),4(1),5(2),6(1)	2(1),3(1),4(6),5(11),6(1),7(1)		4(3),5(2)	1(4),2(5),3(3),5(1),8(1),9(6),11(7)	4(2),9(1)	
SLEEPER R								
NR		3(1),6(4),8(1)	3(1),4(5),6(1),8(1)		3(1),5(1)	4(1)		9(1)
BURRS MILL R		6(12)						
NR		3(9),5(2),6(6),7(8),8(2)	3(3),5(1),6(7),7(8),8(1)		5(1)			
ALBERTSON R								
NR	1(6)	4(2),5(3),7(2)	2(2),3(2),4(7),5(1),8(1)		4(2)	6(1),11(1)		
FRIENDSHIP R								
NR		1(3),2(2),6(1)	1(2),2(7),3(1),4(1),5(9),6(7),8(2)	2(1),4(1),6(1)	5(2)			
SPRINGERS R						7(2)		
NR		2(4),3(6),5(1)	2(8),4(1),7(1)		8(1)	3(2),5(1),8(1)		

Table 16. Diptera

AREA / SPECIES		Ceratopogonidae	Chironomidae	Culicidae	Ptychopteridae	Simulidae	Tabanidae		
SKIT	R								
	NR		1,2,3,6,10	3	5,6,7	1,5	3		
SLEEPER	R		1,10			10			
	NR		1,2,3,4,5,7,8			1,2,3,8	2,4		
BURRS MILL	R		7,10			8			
	NR		1,2,3,5,6,7,8,11			1,3,8,9,10,11	2		
ALBERTSON	R					9			
	NR		1,2,3,4,5,6,8,9,10,11		2	1,2,3,6,9,10,11	3,5		
FRIENDSHIP	R		1,3			8,9,10,11			
	NR		1,2,3,5,6,8,9,10,11	1,6		1,2,3,4,8,9,10,11	4		
SPRINGERS	R						3		
	NR	4	1,2,4,6,8,9,11	3	8	1,2,3,6,9			

Table 16. Ephemeroptera

		Baetidae		Baetiscidae	Ephemerellidae		Heptageniidae	Leptophlebiidae		Metretopodidae
AREA / SPECIES		Baetis sp. 1	B. sp. 2	Baetisca laurentia	Eurylophella bicolor	E. temporalis	Stenonema modestum	Leptophlebia cupida	Paraleptophlebia spp.	Siphloplecton basale
SKIT	R			1(25),2(2),3(6),7(1)						
	NR				4(1)	3(1)		1(1), 2(1), 9(1)		1(9),2(2)
SLEEPER	R			2(1), 11(1)						7(4)
	NR				11(2)		8(1)	1(21),3(1) 8(4),11(5)		1(5),2(1),7(2),8(2) 9(14),10(5) 11(2)
BURRS MILL	R									
	NR									
ALBERTSON	R			2(1)		2(2)	11(2)			
	NR		4(1)			1(1),3(16) 4(9),5(2)	1(5),2(2) 3(8),4(10) 5(3),7(4) 8(1),11(2)	9(1),11(2)	4(8),5(1) 6(4)	1(2),9(1) 11(1)
FRIENDSHIP	R									
	NR					2(1)	1(4),2(4) 3(2),5(15) 6(13),7(8) 11(6)	1(17),2(16) 6(1),8(1) 9(22),11(12)		
SPRINGERS	R									
	NR	3(18),4(13)				3(1)	5(1),11(4)			9(1)

Table 16. Hemiptera

SPECIES / AREA	Belostomatidae: Abedus-Belostoma(?) sp.	Corixidae: Hesperocorixa lucida	H. minor	Palmacorixa n.nana	Sigara sp.1	S. sp.2	S. sp.3	S. sp.4
SKIT R			5(1),7(2) 10(1)					
SKIT NR			3(1),4(2) 5(3),6(2), 9(1),10(1)					
SLEEPER R								
SLEEPER NR		1(3)		3(1),6(1)	9(1)			
BURRS MILL R								
BURRS MILL NR			7(1)	4(1)				1(2)
ALBERTSON R			6(2)					
ALBERTSON NR				5(1)				
FRIENDSHIP R								
FRIENDSHIP NR			9(1)					
SPRINGERS R			6(2),9(2)					
SPRINGERS NR	5(1)		5(1),6(3), 7(1),10(1) 11(2)	4(1),5(1) 9(1)		1(1)	5(1)	

Table 16. Hemiptera (continued)

SPECIES / AREA	S. sp.5	S. sp.6	S. sp.7	S. sp.8	S. spp.(?)	Trichocorixa calva	T. macroceps
SKIT R					4(3)		
SKIT NR	5(1)	8(10)		4(1)	9(10)		
SLEEPER R							
SLEEPER NR	5(1)	8(2)	8(1)		6(2),8(4)	6(1)	
BURRSMILL R							
BURRSMILL NR					11(1)		
ALBERTSON R							
ALBERTSON NR		6(1)	5(5)		1(3),2(1) 5(6),6(2)		
FRIENDSHIP R							
FRIENDSHIP NR	5(1)						
SPRINGERS R							3(1)
SPRINGERS NR	1(2),5(1)	5(1),9(1), 11(3)	5(1),11(4)				

Table 16. Hemiptera (continued)

SPECIES / AREA	Gerridae: Gerris argenticollis	G. insperatus	G. remigis	G. sp.(?)	Limnophorus canaliculatus*	Trepobates* pictus	Mesoveliidae: Mesovelia* spp.	Nepidae: Nepa apiculata	Ranatra fusca
SKIT									
R									
NR		3(1)		3(1),5(1)					
SLEEPER									
R									
NR			8(1)						
BURRS MILL									
R									
NR		3(2)		6(1)					
ALBERTSON									
R									
NR			1(2),2(1) 4(9),6(12), 10(1)					2(1)	6(1)
FRIENDSHIP									
R									
NR				3(1)					
SPRINGERS									
R									
NR	8(3)		4(3)	5(1)					

*Specimens of these species were lost in the mail and the label data could not be recorded. These species were not counted in computations for species richness.

Table 16. Hemiptera (continued)

SPECIES / AREA	R. kirkaldyi	Notonectidae: Notonecta irrorata	N. uhleri	N. petrunkevitchi	Veliidae: Microvelia pulchella	M. spp.	Rhagovelia obesa	R. spp.(?)
SKIT								
R								
NR	4(1),9(1)	5(5),6(4) 7(2)	6(2),7(2) 10(1)	6(1),7(1)			4(11),5(1)	4(1)
SLEEPER								
R								
NR	3(3),5(1) 6(1),9(1)		1(2),6(1) 8(1),10(1)	1(5),9(1)		6(5)	8(1)	
BURRS MILL								
R								
NR	1(1),7(1)	5(1)	1(1),11(1)					
ALBERTSON								
R								
NR	6(1)	5(1),6(1) 7(1),8(1)				2(1),3(6) 4(1),5(1) 7(1),9(2)	5(1)	3(15) 4(6)
FRIENDSHIP								
R								
NR	2(1)	10(1)			7(4)	3(8),6(1) 7(1)	4(2),6(3) 7(4)	3(1)
SPRINGERS								
R		6(1),8(2)					6(7)	
NR	8(1)	6(1),8(4) 10(1)	3(3),7(1) 10(2)			3(1),4(1) 6(3),7(1)	4(3),5(4) 6(8),7(4)	3(2)4(1) 5(7)6(1)

Table 16. Lepidoptera — Table16 . Megaloptera — Table 16.Neuroptera

	Pyralidae			Corydalidae		Sialidae	Sisyridae	
SPECIES / AREA	Paraponynx maculasis	P. spp.(?)	Pterophila sp.	Chauliodes pectini-cornis	Nigronia serricornis	Sialis spp.	Climacia areolaris	
SKIT R						7(1),8(1)		
SKIT NR		7(1)	5(1)		2(1),6(1)	1(5),8(5)		
SLEEPER R						7(2)		
SLEEPER NR					1(4),2(1), 3(2),6(3) 7(3)	1(1),6(6) 7(2),11(1)	3(20),4(3) 5(5)	
BURRS MILL R					8(1)	7(2),8(3)		
BURRS MILL NR				1(1),5(4), 6(1)	1(2),3(1); 5(1);6(2); 7(6)	1(2);5(3); 7(3);8(1); 6(10)		
ALBERTSON R								
ALBERTSON NR	1(2)			2(1)	1(1),2(2), 4(2),5(5); 6(1),7(8)	2(2),6(1), 7(3),11(3)	5(2)	
FRIENDSHIP R					3(1)			
FRIENDSHIP NR		8(2)			1(5),3(2), 4(2),5(1) 6(10),7(4), 8(3),9(1) 10(2),11(3)	8(3)		
SPRINGERS R								
SPRINGERS NR						5(2),6(3), 7(6),9(1)		

Table 16. Odonata

	Aeshnidae		Calopterygidae				Coenagrionidae	
SPECIES / AREA	Basiaeschna janata	Boyeria vinosa	Calopteryx dimidiata	C. maculata	C. sp.(?)	Hetaerina americana	Argia fumipennis	A. sedula
SKIT R								
SKIT NR	1(1)	1(2)		3(1)			3(3),4(1)	
SLEEPER R							6(1)	
SLEEPER NR	1(2),6(1)	1(5),3(4), 4(5)		6(1),7(1)			2(1),3(1), 6(1),7(3)	5(1)
BURRS MILL R								
BURRS MILL NR				3(1),6(1), 7(3)	7(1)		3(1),7(4)	
ALBERTSON R		7(4)						
ALBERTSON NR	1(2),6(1), 8(1),11(1)	2(1),5(7), 8(1),9(1)	3(1),9(1)	1(7),3(1), 6(4),11(2)	1(1),2(1),	2(1)	4(2),5(1)	
FRIENDSHIP R		5(4),8(2)						
FRIENDSHIP NR	6(1)	1(1),5(3) 6(2)		1(5),3(5) 5(1),6(8) 7(8),8(1) 10(1)	2(1), 11(1)		2(1),3(6), 4(3),5(6), 6(2),7(5), 8(6),9(2), 10(1)	
SPRINGERS R								
SPRINGERS NR		5(1),6(1) 7(2)		3(4),4(1), 5(1),7(4)	3(1)		8(2)	4(1),5(3)

Table 16. Odonata (continued)

AREA \ SPECIES	A. sp.(?)	Chromagrion conditum	Enallagma divagans	E. pallidum	E. signatum	E. sp.(?)	Ischnura posita	I. sp(?)
SKIT								
R								
NR	6(3),7(1), 9(1)	8(1)						
SLEEPER								
R						6(1)		
NR			1(4),2(1), 3(11),4(1), 6(1)			2(3),3(9), 4(4),7(4), 11(1)		8(1)
BURRS MILL								
R							7(1)	8(1)
NR		7(1)						
ALBERTSON								
R								
NR	2(1)		4(1)			5(4)		
FRIENDSHIP								
R								
NR	5(1),9(1), 10(1)		2(1),3(9), 9(1)	3(2)		3(8)	5(1)	8(1)
SPRINGERS								
R								
NR			3(2)		3(1)	6(2),7(1)		

Table 16. Odonata (continued)

	Cordulegastridae		Corduliidae				Gamphidae	
AREA \ SPECIES	Cordulegaster diastatops	C. maculata	C. sp.(?)	Somatochlora spp.	Tetragoneuria semiaquea	T. sp.(?)	Gomphus exilis	G. parvidens
SKIT								
R								
NR		1(2),9(1)	1(1),3(1) 8(1),11(5)	4(1)				
SLEEPER								
R								
NR		1(1),6(1)	7(1)	6(1)	2(3)	5(1)	7(4)	
BURRS MILL								
R								
NR		3(1)		7(11)	1(1)	6(1),7(1), 8(1)		
ALBERTSON								
R			8(1)					
NR		7(4),11(2)	1(1),3(2), 5(3),6(1), 7(1),8(1), 11(1)				6(1),8(1)	1(1)
FRIENDSHIP								
R								
NR	4(1)	3(1)	2(1),6(1)				2(1),3(2)	
SPRINGERS								
R								
NR			3(2)					

Table 16. Odonata (continued)

SPECIES / AREA	G. sp.(?)	Progomphus obscurus	Lestidae: Lestes inaequalis	Libellulidae: Ladona spp.	Libellula flavida	L. sp.	Macromiidae: Didymops transversa	Macromia alleghaniensis	Macromia spp.(?)
SKIT R									
NR	1(3),2(1), 3(7),4(1); 5(2),6(2); 9(1)	1(2),2(1) 4(1),5(6) 6(5)		1(1)	3(1)				
SLEEPER R									
NR	1(4),4(1); 5(4),8(1);	1(9)		1(1),3(1) 7(1)		4(2)	3(2)		1(1),5(1), 8(1)
BURRS MILL R									
NR				3(1),7(1)		3(1)			
ALBERTSON R									6(1)
NR	6(1)	1(2),3(4), 4(1),5(1)							
FRIENDSHIP R									
NR	1(2)	1(1)				3(1)		1(1)	1(1)
SPRINGERS R		7(4)							
NR	3(2),5(1) 8(1)	5(1)	11(1)			3(1)			2(1),3(1) 5(1),8(1)

Table 16. Plecoptera

SPECIES / AREA	Leuctridae: Leuctra spp.	Nemouridae: Paranemoura perfecta	Perlidae: Acroneuria lycorias	Perlesta placida	Perlodidae: Perlinella drymo	Isogenoides spp.	Isoperla marlyia	Taeniopterygidae: Taeniopteryx parvula	T. spp.(?)
SKIT R									
NR	1(6),2(1), 3(2),4(1) 6(3)		1(2)		2(2)	1(1)	1(1)		8(1),9(1)
SLEEPER R									
NR	6(3)		8(1)		8(1),9(1),		9(1)	9(2)	8(2),9(4)
BURRS MILL R									
NR									
ALBERTSON R									
NR	6(1)		1(4),3(5), 5(3),8(1)	4(9),5(3)					9(1)
FRIENDSHIP R									
NR									8(1),9(2)
SPRINGERS R			9(1)						9(1)
NR		2(1)						1(2)	9(12)

Table 16. Trichoptera

AREA / SPECIES	Brachycentridae: Brachycentrus numerosus	B. sp. (?)	Hydropsychidae: Ceratopsyche sparna	Cheumatopsyche sp.	Diplectrona modesta	Hydropsyche betteni	H. decaida	H. venularis	H. sp. (?)
SKIT R				2(2)					
SKIT NR					2(3)		1(7),3(1),6(1),7(1),9(2)		
SLEEPER R							6(1),10(1)		
SLEEPER NR			5(1),8(10)		7(1)	4(6),7(1)	1(18),2(8),3(7),4(1),5(5),6(25),7(19),8(4),9(7),11(7)	8(1)	
BURRS MILL R									
BURRS MILL NR						8(1)	[illegible],2(1),6(4),8(10),9(4)		3(2),6(16)
ALBERTSON R	4(11),6(1),7(4),9(4),11(4)	5(3)		2(2)	7(3)	2(1),7(1),9(1)			
ALBERTSON NR	1(14),6(12),7(10),8(8),9(18),11(19)	2(1),4(7)	1(3),3(2),7(2),11(4),12(1)	1(15),2(6),3(1),4(1),6(2),7(2),11(15)	1(1),2(1),3(1),4(1),5(1),6(2),7(1)	1(10),3(4),4(3),7(1)	1(3),9(1)		3(2)
FRIENDSHIP R	1(5),7(3),9(9),10(10)					5(9),7(4),9(9),11(6)	3(3),6(1),7(2),9(2),11(7)		
FRIENDSHIP NR	1(5),2(8),4(1),6(1),7(8),9(16),10(6),11(5)		7(1)	1(6),2(5),3(2),6(3),7(1)		1(9),2(3),3(3),4(1),5(3),6(14),7(16),8(7),9(9),11(3)	1(11),2(1),3(7),5(1),6(4),7(10),8(13),9(17),10(2),11(15)		
SPRINGERS R									
SPRINGERS NR			6(2)	2(3),6(6),9(4)		1(3),2(7),4(3),5(1),7(1)	1(4),4(3),6(1),7(1),9(8)		

Table 16. Trichoptera (continued)

AREA / SPECIES	Hydroptilidae: Hydroptila sp.	Oxyethira sp.	Lepidostomatidae: Lepidostoma sp.	Leptoceridae: Ceraclea sp.	Nectopsyche sp.	Triaenodes sp.	Limnephilidae: Goera sp.	Hydatophylax
SKIT R								
SKIT NR					1(5)	7(1)		
SLEEPER R		11(1)						
SLEEPER NR	8(1)					4(1)	8(1)	
BURRS MILL R								
BURRS MILL NR								
ALBERTSON R		1(12),5(1),6(1)					1(6),5(1),7(7)	
ALBERTSON NR			2(8),3(22),4(1),5(17)	4(2),8(9)		3(6),4(2),5(4)	1(5),2(7),3(7),4(2),6(1),9(2)	1(1)
FRIENDSHIP R								
FRIENDSHIP NR		11(1)		5(1)		3(2),5(1),6(1)		
SPRINGERS R								
SPRINGERS NR								

Table 16. Trichoptera (continued)

						Molannidae	Philopotamidae	Phryganeidae
SPECIES / AREA	Ironoquia sp.	Limnephilus sp.	Neophylax sp.	Platycentropus sp.	Pycnopsyche scabripennis	Molanna tryphena	Chimarra sp.	Ptilostomis sp.
SKIT R								
NR		2(2)		1(4), 9(1)		7(1)		1(2)
SLEEPER R						2(1),7(1) 10(1)		
NR		1(2),2(4) 3(1),4(1)		1(5), 4(1) 9(1)		6(1),7(1)	[illegible](17),4(1) 5(2),8(21) 7(17)	1(15)2(3) 3(2)
BURRS MILL R								
NR		1(6),4(2) 8(1)		1(5),3(1)	6(2)	1(1)		1(7),2(1) 8(1)
ALBERTSON R			10(1)			8(5),10(1)		
NR		1(2),2(2)	1(5),3(5) 4(3) 5(3) 9(7)			4(1)5(1) 6(5),7(1) 8(3),9(1)	1(1),3(1) 5(3),7(1)	1(2),8(1)
FRIENDSHIP R						10(1)		
NR		2(1)		2(1),5(1)		2(2)	1(2),2(3) 3(3),4(2) 6(1),10(2)	1(2),5(1) 9(2)
SPRINGERS R								
NR	2(1)	1(1),2(1)		2(3),9(14)				

Table 16. Trichoptera (continued)

	Polycentropodidae		
SPECIES / AREA	Neureclipsis sp.	Nyctiophylax sp.	Polycentropus sp.
SKIT R			
NR	2(2)		2(2)
SLEEPER R			
NR	8(1)	1(1),2(2) 3(1), 6(1) 7(4)	1(3),2(3) 3(2),5(2) 7(1),8(1)
BURRSMILL R			
NR			7(1)
ALBERTSON R			
NR	1(3),6(4) 7(2)		1(2),2(1) 3(4),4(9) 5(1),11(1)
FRIENDSHIP R			
NR	6(1),7(1)		1(1),2(2) 3(1),5(2) 10(1)
SPRINGERS R			
NR	2(1),9(1)		

collected in undisturbed streams, particularly Skit Branch (Table 16; Ephemeroptera). The odonate, Somatochlora spp. showed a preference for undisturbed streams along with leutrid plecopterans (Table 16; Odonata, Plecoptera). The most dramatically skewed distributions are evident in Tricoptera. Brachycentrus numerosus, Cheumatopsyche sp., Hydropsyche betteni, and Ceraclea sp. are all more abundant in disturbed streams.

Zoogeographic Comments. The Pinelands of New Jersey is at or near the northern limit of distribution for a number of plants (McCormick 1970), amphibians (Corant 1979), and birds (Leck 1979). Insect distributions are imperfectly known and it is impossible to review the distributions of all insect species collected in this project; however, the above northern limit of distributions seems to be true for Hydrophyche decalda (Tricoptera; Schuster pers. comm.) and Hesperocorixa minor (Hemiptera; Hungerford 1948).

Although not collected in this study, this pattern has been noticed in two aquatic coleopteran species recently collected from the Pinelands: Uvarus inflatus (Young) and Agabus johannis Fall (Wolfe unpubl. data). Both of these latter two species formerly were known only from Florida and the southern Gulf coastal plain.

Another interesting observation is that some "normally" non-coastal species of insects are apparently relatively common in the Pinelands. Species in this category are Hydroporus mellitus (Wolfe unpubl. data) and Laccophilus maculosus maculosus (Zimmerman 1970). A similar distributional pattern was mentioned for plants by McCormick (1970).

Fish

Seventeen fish species were collected during this study. Thirteen are regarded as characteristic Pine Barrens species, two are peripheral, and two are introduced species (Table 17; Hastings 1979). The introduced species (bluegill, Lepomis macrochirus, and largemouth bass, Micropterus salmoides) were represented by single, small juveniles collected at disturbed sites; bluegill at Springers Brook and largemouth bass at Albertson Brook. This suggests they are not established at the sites sampled but probably resulted from spawnings in nearby lakes.

One peripheral species (golden shiner, Notemigonus crysoleucas) was collected only at Springers Brook, where it was present in relatively large numbers in both July (13 individuals collected) and in December (24 individuals). Five golden shiners were found dead in December but the cause of death is not known. This species does not occur in typical Pine Barrens waters, but only at sites with disturbed water conditions. The habitat at Springers Brook may thus be marginal for survival of the species.

The other species considered a peripheral Pine Barrens fish is the tessellated darter (Etheostoma olmstedi). Although originally

Table 17. Abundance of fish species collected in individual streams, and by stream type (disturbed and undisturbed) for all dates sampled. Sl = Sleeper, Sk = Skit, Br = Burr's Mill, Al = Albertson, Sp = Springer, Fr = Friendship.

		Number of Individuals**								
		Undisturbed				Disturbed				Grand
Species	Category*	Sl	Sk	Br	Total	Al	Sp	Fr	Total	Total
<u>Etheostoma fusiforme</u>	RC	52(3)	28(2)	39(4)	119(9)	96(24)	58	25(1)	179(25)	298(34)
<u>Umbra pygmaea</u>	WC	55(3)	12	36(3)	103(6)	3	11	3(1)	17(1)	120(7)
<u>Erimyzon oblongus</u>	WC	1	0	0	1	107(1)	7	6	120(1)	121(1)
<u>Enneacanthus chaetodon</u>	RC	14	0	60(8)	78(8)	6	0	27(3)	33(3)	107(11)
<u>Ennaecanthus obesus</u>	RC	30(1)	5	45(6)	80(7)	0	9	3(3)	12(3)	92(10)
<u>Etheostoma olmstedi</u>	P	7(1)	0	0	7(1)	44(5)	37	0	81(5)	88(6)
<u>Esox niger</u>	WC	22(1)	8(1)	1	31(2)	10(7)	9	8(1)	27(8)	58(10)
<u>Anguilla rostrata</u>	WC	8(1)	1	0	9(1)	11(2)	24	1	36(2)	45(3)
<u>Notemigonus crysoleucas</u>	P	0	0	0	0	0	37	0	37	37
<u>Acantharchus pomotis</u>	RC	18(2)	2	3	23(2)	1	2	5	8	31(2)
<u>Aphredoderus sayanus</u>	RC	4	5	2	11	5	6	3	14	25
<u>Esox americanus</u>	WC	10	1	2	13	0	3	0	3	16
<u>Noturus gyrinus</u>	WC	0	0	0	0	8	5	0	13	13
<u>Ictaluris natalis</u>	RC	1	0	0	1	0	1	7(3)	8(3)	9(3)
<u>Enneacanthus gloriosus</u>	WC	0	3	0	3	1	0	0	1	4
<u>Lepomis macrochirus</u>	I	0	0	0	0	1	0	0	1	1
<u>Micropterus salmoides</u>	I	0	0	0	0	1	0	0	1	1

* Pine Barrens categories: RC-restricted characterstic, WC-widespread characteristic, P-peripheral, I-introduced (after Hastings 1979)

**Numbers in parenthesis indicate collections in June, when Springers could not be sampled due to high water.

classified by Hastings (1979) as characteristic, recent studies have indicated that it is only found at modified sites (Hastings unpubl. data). This species was common and consistently present at Albertson Brook and Springers Brook, the two most disturbed sites (Table 3). It was not present at Friendship Creek, another disturbed site, but was present in small numbers in three of five collections at Sleeper Branch. Its presence at the latter site may be related to the proximity of the tidal mainstem Mullica River, where the species is common. Perhaps individuals disperse upstream from such areas, finding suitable habitat and surviving in tributaries such as Albertson and Springers, but not surviving in tributaries such as Sleeper and Skit. Conversely, the absence of the species at Friendship Creek, where water conditions are modified, may reflect a lack of suitable sources and/or dispersal routes. Friendship Creek exhibited the lowest pH of the disturbed streams, which may also explain its absence. Correlation analysis of fish abundance on water quality showed the tessellated darter to be the fish species most positively correlated with pH ($r = 0.604$, $p < 0.01$).

Several of the characteristic Pine Barrens species show an uneven distribution among the sampling sites (Table 17). Creek chubsucker (Erimyzon oblongus) was found almost exclusively at disturbed sites (except for one individual collected at Sleeper Branch in March). This species is quite widely distributed throughout the Pine Barrens, so the significance of this pattern is not known. It may be mostly artificial, since 82 of the 122 collected (67%) were very small juveniles collected at Albertson Brook in July.

American eel (Anguilla rostrata), tadpole madtom (Noturus gyrinus), and yellow bullhead (Ictalurus natalis) were also more numerous at disturbed sites, but their numbers in the collections are small and their occurrence patterns difficult to interpret. American eel shows a distribution pattern similar to that of tessellated darter, although in lower numbers, but still indicating a positive correlation with pH ($r = 0.561$, $p < 0.01$). The tadpole madtom also shows a positive correlation with pH ($r = 0.489$, $p < 0.01$), and was collected only at Albertson Brook and Springers Brook (13 individuals), where water conditions are most indicative of disturbance. This and other evidence could justify classifying this species as peripheral Pine Barrens, but it does occur at a few rather typical Pine Barrens locations. The yellow bullhead is widely distributed in the Pine Barrens, but secretive during daylight hours and sometimes difficult to collect. Thus, the pattern demonstrated by collections taken during this study may be an artifact.

Eastern mudminnow (Umbra pygmaea), blackbanded sunfish (Enneacanthus chaetodon), banded sunfish (Enneacanthus obesus), mud sunfish (Acantharchus pomotis), and redfin pickerel (Esox americanus) were more numerous in undisturbed streams. Ratios of numbers collected in undisturbed streams to disturbed streams for the five species are 6.1:1, 2.4:1, 5.8:1, 3.1:1, and 4.3:1, respectively. However, blackbanded sunfish was not collected in either Skit Branch or Springers Brook, nor at seven other sites sampled previously in the upper Batsto River drainage, although the species is common downstream at Quaker Bridge on the Batsto. Its absence from such places is not readily explained, since much of the upper Batsto is relatively undisturbed and appears to be ideal habitat. The banded sunfish was the only species to show a significant negative correlation with pH ($r = -0.368$, $p < 0.05$).

Most species were numerous in and characterisitic of vegetation and backwater habitats (Table 18). This is especially true for eastern mudminnow, banded sunfish, chain pickerel, mud sunfish, pirate perch, tadpole madtom, and yellow bullhead. In contrast, creek chubsucker and american eel were about equally distributed in open stream and vegetation habitats. Blackbanded sunfish was most characteristic of vegetation at the disturbed sites, but of open stream at the undisturbed sites; especially as a result of the collections at Burr's Mill, where there was almost no aquatic vegetation and yet blackbanded sunfish was common. It may be that the numerous submerged logs and other objects at Burr's Mill provided sufficient cover in the absence of vegetation.

The two darter species show an interesting pattern of distribution (Table 19). Tessellated darter was found almost exclusively in open stream habitat (88% with 11% in vegetation), and mostly at disturbed sites (91%). In contrast swamp darter (Etheostoma fusiforme) was found at all sites and in all available habitats, although it was most numerous in vegetation. This preference for vegetation was most obvious at Albertson Brook, where tessellated darter was most common. There appears to be some interaction between these two species, with both species being most numerous at Albertson Brook, possibly because of a more abundant food supply, but with swamp darter restricted mostly to vegetation, while tessellated darter occupies the open stream habitat.

The six streams sampled are mostly characterized by typical Pine Barrens fish faunas (Table 20). Only four non-Pine Barrens species were collected, and no more than two were collected at any of the six sites. Two of the non-Pine Barrens species were represented in the collections by single, small juveniles. Despite these similarities, there are some subtle patterns which allow some characterization of each stream, based upon the fish fauna present.

Skit Branch and Burr's Mill Branch appear to be most typical of undisturbed Pine Barrens streams. They yielded the fewest species (and also rather few individuals), all of which were characteristic Pine Barrens species. The two streams are quite different in some respects, however. Skit Branch had few fish of any species, with only swamp darter, mud minnow, and chain pickerel consistently present. Burr's Mill Brook had fewer species, but several were common, such as blackbanded sunfish, banded sunfish, swamp darter, and mudminnow. Burr's Mill may represent the most stressful aquatic habitat since it was always the most darkly stained and had the lowest pH. Skit Branch in contrast lacked

Table 18. Abundance of fish in disturbed and undisturbed streams by microhabitat during the study period.

	Undisturbed Sites				Disturbed Sites			
Species	Meadow	Open Stream	Vegetation	Backwater	Meadow	Open Stream	Vegetation	Backwater
Etheostoma fusiforme	15	59	37	18	(none sampled)	52	130	22
Umbra pygmaea	1	7	41	60		2	7	9
Erimyzon oblongus			1			59	55	7
Enneacanthus chaetodon	3	61	9	10		1	34	1
Enneacanthus obesus	6	18	20	43			3	12
Etheostoma olmstedi	1	6	1			77	9	
Esox niger	9	6	10	8		6	20	9
Anguilla rostrata	1	5	4			18	19	1
Notemigonus crysoleucas						10	1	26
Acantharchus pomotis	6	5	13	1			6	2
Aphredoderus sayanus	1	2	8			1	8	5
Esox americanus	4		1	8			1	2
Noturus gyrinus						2	10	1
Ictalurus natalis			1			1	10	
Enneacanthus gloriosus	1		2				1	
Lepomis macrochirus								1
Micropteras salmoides						1		
Total Number of species	11	9	13	7		12	15	13

Table 19. Detailed collection data for two darter species (Etheostoma). M = meadow, O = open stream, V = vegetation, and B = backwater. Dashes indicate that the microhabitat was not present in the stream. X's = no collection in Springers in June.

		Sleeper				Skit				Burrs Mill				Albertson				Springers				Friendship			
Species	Date	M	O	V	B	M	O	V	B	M	O	V	B	M	O	V	B	M	O	V	B	M	O	V	B
Swamp Darter	Mar	2	5	1	12	3	1	1		(-)	6	1	4	(-)	2	13		(-)	3	1	2	(-)	2	2	1
Etheostoma fusiforme	June		3					2		(-)	1	3		(-)	3	20	1	(-)	X	X	X	(-)		1	
	July	1	1	2	1		1	10		(-)	11			(-)	4	9		(-)	3	4	5	(-)	2	5	
	Sept	6	9	5				6		(-)	12			(-)	7	14		(-)	18	7	7			7	
	Dec	3	1	2	1		2	4		(-)	6			(-)	5	42		(-)	2		6	(-)	1	5	
	Totals	12	19	10	14	3	4	23	0	(-)	36	4	4	(-)	21	98	1	(-)	26	12	20	(-)	5	20	1
Tressellated Darter	Mar									(-)				(-)	15			(-)	4			(-)			
Etheostoma olmstedi	June		1							(-)				(-)	5			(-)	X	X	X	(-)			
	July		3	1						(-)				(-)	2			(-)	4			(-)			
	Sept	1	2							(-)				(-)	9	1		(-)	17	8		(-)			
	Dec									(-)				(-)	17			(-)	4			(-)			
	Totals	1	6	1	0	0	0	0	0	(-)	0	0	0	(-)	48	1	0	(-)	29	8	0	(-)	0	0	0

Table 20. Summary of the number of fish species collected in each stream based on their relationship to the Pine Barrens fish fauna.

	Number Species						
Category	Sleeper	Skit	Burrs Mill	Albertson	Springer	Friendship	Total
Widespread Characteristic	5	5	3	6	6	4	7
Restricted Characteristic	6	4	5	4	5	6	6
Peripheral	1	0	0	1	2	0	2
Introduced	0	0	0	1	1	0	2
Total	12	9	8	12	14	10	17
Total individuals*	222(12)	65(3)	188(21)	293(39)	210	88(12)	1066(87)

* Numbers in parenthesis are number collected in June when Springers could not be sampled.

suitable cover such as vegetation or logs and branches in the stream.

Sleeper Branch also appears to be typical of undisturbed Pine Barrens streams, except for the presence of tessellated darter, considered a peripheral Pine Barrens species. The species was not common, however, and did not appear to be well established at the site. It seems possible that the proximity of this site to the mainstem Mullica River could result in occasional upstream dispersal of peripheral species such as the tessellated darter into the area. This and other peripheral Pine Barrens species occur in the Mullica River, just a short distance downstream. In contrast, the most common species at Sleeper Branch were typical Pine Barrens species, such as mudminnow, swamp darter, banded sunfish, chain pickerel, mud sunfish, and blackbanded sunfish.

Of the disturbed sites, Friendship Creek was most similar to the undisturbed sites, and also had the lowest pH. Only characteristic Pine Barrens species were collected at this site. Its uniqueness might be correlated with its moderate level of disturbance, or it could reflect a lack of suitable recruitment sources for peripheral and introduced species. Three characteristic Pine Barrens species (blackbanded sunfish, mud sunfish, and yellow bullhead) were considerably more numerous at Friendship than at the other disturbed sites. Conversely, american eel was less numerous and tadpole madtom was not collected at Friendship.

Albertson Brook and Springers Brook were significantly more disturbed than any of the other four streams sampled and also showed the greatest difference in their fish fauna. Albertson Brook yielded two non-Pine Barrens species (tessellated darter and largemouth bass) and Springers Brook yielded three (tessellated darter, golden shiner, and bluegill). Only tessellated darter was collected at any of the other sites, and only at Sleeper, where it was considerably less numerous than at Albertson and Springers. Largemouth bass and bluegill are more characteristic of lake habitats than streams so the presence of single, small juveniles most likely resulted from spawnings in nearby lakes. Largemouth bass have been widely stocked in Pine Barrens lakes and may be well established in Paradise Lakes, just downstream from our site on Albertson Brook. Bluegill are also widely stocked and are known to be common at Indian Mills Lake, upstream from our site on Springers Brook. Golden shiner is common upstream in Springers Brook, as well as downstream in the tidal Batsto and Mullica. Albertson Brook yielded considerably more creek chubsuckers than any of the other sites, but this finding is difficult to interpret since most were small juveniles only recently spawned. American eel and tadpole madtom were more numerous at both Albertson and Springers than in any of the other streams, indicating that these two species, although widely distributed in the Pine Barrens, may be somewhat sensitive to typical Pine Barrens waters.

Two categories of characteristic Pine Barrens fishes have been recognized based on their overall distribution in New Jersey freshwaters (Pinelands Commission 1980). Restricted characteristic Pine Barrens species are those occurring within the Pine Barrens region but not elsewhere in the state. In contrast, widesspread characteristic Pine Barrens species occur more or less throughout New Jersey, and are not restricted to the Pine Barrens region. Of the 13 characteristic Pine Barrens species collected during this study, seven are widespread and 6 are restricted (Table 20). Although the numbers are small and inconsistent, there tends to be a greater number of widespread species at disturbed sites (Albertson and Springers), and more restricted species at undisturbed sites (Sleeper and Burr's Mill). Skit and Friendship do not follow this pattern. However, if only the 5 most numerous species at each site are considered (which always accounted for more than 75% of the total number of species), this pattern is more consistent, with only Friendship being the exception. The ratios of restricted to widespread to peripheral species for the 5 most numerous species are 3:2:0, 3:2:0, 4:1:0 for the undisturbed sites, and 1:3:1, 1:2:2, and 3:2:0 for the disturbed sites (the latter inconsistent value being for Friendship). Thus, there appears to be a replacement of dominant species at disturbed sites, with this replacement correlated with the degree of disturbance and a large, upstream undeveloped sub-basin. Sites such as Friendship, with moderate disturbance retain a mostly Pine Barrens fish fauna.

Summary and Concluding Remarks

The purpose of this study was to compare the water quality and biota of disturbed and undisturbed Pine Barrens streams towards the ultimate goal of establishing a biological water quality index of stream disturbance. A stream is a complex and dynamic physical, chemical, and biological system. No two streams, regardless of how carefully matched, respond identically to the same stimuli. Thus, a great deal of variability is observed among streams, even within carefully controlled groups. Despite this inherent variability, significant qualitative and quantitative differences between disturbed and undisturbed Pine Barrens streams are demonstrated by this study. The water quality data show that disturbed streams are characterized by elevated NO_3-N, pH, and alkalinity. Interestingly, these streams do not consistently differ in any other physical or chemical parameter measured. Thus, the observed differences in biota appear directly related to differences in these three variables.

Both algal species richness and relative diversity increased in disturbed streams. In addition, some algal species appear to prefer, and may be largely restricted to, undisturbed streams, while others clearly are associated with disturbed streams. The presence of *Tabellaria flocculosa* seems to be a particularly good indicator of disturbed conditions. The major response of the macrophytes to disturbance is a shift in the dominant species from *Eleocharis* spp. and *Scirpus subterminalis* to *Sparganium americanum*, *Callitriche heterophylla*, and *Potomogeton epihydrus*. The aquatic insects exhibited greater species richness in the disturbed streams. Several of the major groups of insects also showed skewed distribution between disturbed and undisturbed streams. Elmid beetles and caddis flies were particularly prevalent at the disturbed sites. Leuctrid stoneflies appear more characteristic of undisturbed sites. The response of the fish was much more subtle, with both disturbed and undisturbed streams containing mostly characteristic Pine Barrens species. The presence and abundance of tessellated darter and golden shiner is probably the best indicator of disturbance, along with a general decrease in the abundance of eastern mudminnow, blackbanded sunfish, banded sunfish, mud sunfish, and redfin pickerel. There also appears to be a shift in dominance among the characteristic fishes from restricted to widespread species.

While the differences between disturbed and undisturbed streams are significant, they are not as dramatic as might be expected, given the observed 100 fold increase in pH and nitrogen. The reasons for this are not clear, but may be related to total-P concentrations. Total-P in both disturbed and undisturbed streams is similar and quite low. Undisturbed Pine Barrens streams are generally considered nitrogen limited (Durand 1979), which is supported by the N:P ratios obtained in this study. Adding nitrogen (which is the effect of disturbance) then, should increase productivity and result in a general change in species composition. This apparently occurs to a limited extent (cf. changes in algal diversity and relative abundance), but stops short of largescale changes because the phosphorus concentrations are so low. Streams apparently quickly become phosphorus limited, so that additional nitrogen has little effect. Thus, disturbance of Pine Barrens streams may be visualized as a two step process. An increase in nitrogen initially results in significant changes in characteristic stream biota (as documented in this study). At the same time, the stream switches from nitrogen to phosphorus limitation. A second change in stream biota, perhaps even more dramatic, would occur if phosphorus is increased (this was not investigated by this study). If further investigation confirms this scenario of stream response to nutrient enrichment, effective management will necessitate closer control of both nitrogen and phosphorus.

This study then, identifies several additional areas which require further research. First, it is not clear why phosphorus in the disturbed streams is so low. The same factors which act to elevate nitrogen (agricultural fertilizers and residential sewage) should also increase phosphorus. Studies should be initiated to determine the fate of phosphorus in these watersheds. Is phosphorus effectively removed from the drainage, and how? If it is not, will it eventually find its way into the streams, and when? Second, the hypothesis that disturbed streams are phosphorus limited could be tested by studies on streams with elevated phosphorus. If phosphorus is limiting, the prediction would be that increased phosphorus will result in a biota dramatically different from that found in even the most disturbed stream in this study. Finally, although this study has demonstrated relationships between certain organisms and pH and NO_3-N, the general use of these key species as biological indicators of water quality should be rigorously tested on a regional basis by comprehensive surveys of a large number of Pine Barrens streams.

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APPENDIX I

Water quality data from March 23, 1982 to February 10, 1983 in Sleeper Branch (Sl), Albertson Brook (Al), Skit Branch (Sk), Springers Brook (Sp), Burr's Mill (Br), and Friendship Creek (Fr).

pH

Date	Stream					
	Sl	Al	Sk	Sp	Br	Fr
3/23	4.2	5.8	4.4	5.9	3.8	5.6
4/10	4.1	5.8	4.2	5.2	4.0	4.4
5/19	4.3	6.1	4.4	6.3	3.9	5.1
6/14	4.0	5.3	4.1	5.4	3.8	4.4
7/21	4.4	5.7	4.9	6.7	4.0	5.5
8/17	4.3	6.2	4.7	6.8	4.0	5.8
9/15	4.3	6.4	4.6	6.3	4.2	5.6
10/13	4.1	5.9	4.6	5.8	4.1	5.7
11/15	4.1	5.8	4.1	6.0	3.8	5.3
12/27	4.0	5.8	4.3	4.2	3.7	4.4
1/21	4.1	5.6	4.5	5.2	3.6	4.3
2/10	4.2	5.7	4.2	5.0	3.7	4.5

Alkalinity (mg $CaCO_3/l$)

Date	Stream					
	Sl	Al	Sk	Sp	Br	Fr
3/23	-*	5.0	-	4.0	-	6.0
4/10	-	1.0	-	-	-	-
5/19	-	11.0	-	9.0	-	1.5
6/14	-	30.0	-	4.5	-	-
7/21	-	7.0	1.0	21.0	-	4.0
8/17	-	5.1	0.5	21.5	-	2.8
9/15	-	3.0	0.3	15.5	-	3.0
10/13	-	5.0	-	16.5	-	6.0
11/15	-	1.0	-	4.0	-	-
12/27	-	3.0	-	-	-	-
1/21	-	2.0	-	1.0	-	-
2/10	-	1.0	-	1.0	-	-

*Alkalinity not measured if stream pH was below 4.5.

NH_3-N (mg/L)

Date	Stream					
	Sl	Al	Sk	Sp	Br	Fr
3/23	.050	.024	.029	.034	.026	.028
4/10	.022	.019	.015	.015	.026	.019
5/19	.050	.007	.004	.018	.102	.006
6/14	.000	.003	.000	.000	.041	.021
7/21	.087	.063	.104	.062	.217	.083
8/16	.026	.021	.034	.023	.159	.031
9/15	.029	.019	.023	.024	.077	.024
10/13	.019	.012	.041	.022	.130	.023
11/15	.040	.024	.036	.031	.072	.038
12/27	.024	.030	.036	.079	.087	.034
1/21	.016	.014	.010	.020	.063	.010
2/10	.000	.006	.010	.008	.024	.005

NO_3-N (mg/L)

Date	Stream					
	Sl	Al	Sk	Sp	Br	Fr
3/23	.009	.478	.012	.266	.015	1.385
4/10	.009	.659	.0002	.239	.005	.659
5/19	.015	.274	.000	.004	.005	.342
6/14	.002	.116	.000	.002	.003	.429
7/21	.016	.284	.013	.049	.010	.468
8/17	.043	.344	.015	.041	.021	.455
9/15	.011	.361	.034	.126	.041	.544
10/13	.017	.543	.011	.078	.026	.461
11/15	.056	.481	.025	.073	.046	.271
12/27	.027	.805	.013	.103	.019	.708
1/21	.048	.826	.025	.491	.035	.714
2/10	.016	.960	.022	.695	.020	.622

Total Phosphorus-P (mg/l)

Date	Stream					
	Sl	Al	Sk	Sp	Br	Fr
3/23	.002	.006	.004	.006	.002	.004
4/10	.002	.009	.002	.005	.004	.003
5/19	.007	.039	.014	.014	.019	.007
6/14	.008	.049	.010	.011	.017	.010
7/21	.018	.090	.011	.034	.086	.022
8/17	.011	.042	.004	.017	.028	.011
9/15	.012	.020	.005	.014	.033	.014
10/13	.008	.016	.004	.017	.024	.011
11/15	.010	.007	.005	.012	.013	.008
12/27	.008	.021	.004	.009	.010	.007
1/21	.005	.018	.003	.011	.009	.006
2/10	.004	.014	.004	.008	.008	.006

Conductivity (umhos)

Date	Stream					
	Sl	Al	Sk	Sp	Br	Fr
3/23	45	45	28	78	65	79
4/10	39	32	30	50	59	48
5/19	112	174	239	231	240	205
6/14	155	103	155	172	252	218
7/21	40	48	22	89	50	55
8/17	38	42	20	105	50	45
9/15	38	40	20	235	41	50
10/13	42	47	20	80-810 *	31-271*	45
11/15	50	42	31	80-108*	60	35
12/27	60	50	180	254	73	40
1/21	48	32	25	65	75	39
2/10	38	35	30	60	65	40

*On these occassions conductivity varied for some unknown reason over the range indicated. The lower value however, was the most consistent.

Total Dissolved Solids - TDS (mg/l)

Date	Stream					
	Sl	Al	Sk	Sp	Br	Fr
3/23	-*	-	-	-	-	-
4/10	-	-	-	-	-	-
5/19	60.0	56.0	24.0	96.7	78.7	62.0
6/14	62.0	78.0	39.3	84.0	68.7	38.7
7/21	69.4	48.0	32.7	91.4	125.4	49.4
8/17	32.7	61.3	9.3	62.7	62.0	24.7
9/15	92.0	34.7	83.3	122.7	104.7	78.0
10/13	44.7	47.3	24.7	79.3	58.0	46.7
11/15	60.7	72.7	55.3	118.0	78.7	74.0
12/27	66.0	46.7	18.7	60.7	43.3	41.3
1/21	35.3	32.7	5.3	72.0	58.7	38.0
2/10	66.0	59.0	41.0	81.0	53.0	57.0

*No data.

Temperature (°C)

Date	Stream					
	Sl	Al	Sk	Sp	Br	Fr
3/23	7.2	10.0	11.8	10.0	13.7	10.4
4/10	5.1	5.1	8.2	5.1	8.9	7.0
5/19	17.0	17.0	20.3	20.0	25.0	22.0
6/14	15.5	14.7	15.0	15.9	19.5	17.5
7/21	21.0	21.6	26.0	24.5	23.7	21.0
8/17	19.0	19.0	20.8	22.2	23.6	22.5
9/15	17.8	18.6	19.0	19.5	21.2	20.5
10/13	13.1	13.5	13.8	13.8	15.1	15.0
11/15	8.0	8.0	7.3	7.2	8.0	8.5
12/27	7.5	8.8	10.4	6.8	8.5	8.0
1/21	0.0	2.0	1.0	1.5	4.0	3.0
2/10	-0.5	2.5	2.0	1.0	4.0	3.0

Dissolved Oxygen (% Saturation)

Date	Stream					
	Sl	Al	Sk	Sp	Br	Fr
3/23	84	94	100	103	108	103
4/10	89	94	93	93	91	99
5/19	82	93	97	87	81	103
6/14	77	82	77	64	68	89
7/21	84	89	87	91	55	78
8/17	75	91	83	95	53	87
9/15	76	98	80	78	52	85
10/13	84	93	85	88	54	86
11/15	82	88	88	84	86	96
12/27	80	91	91	83	85	95
1/21	83	96	89	91	83	98
2/10	86	93	91	91	89	96

Velocity (m/sec)

Date	Stream					
	Sl	Al	Sk	Sp	Br	Fr
3/23	.18	.27	.30	.18	.19	.44
4/10	.22	.24	.31	.26	.21	.35
5/19	.22	.23	.34	.23	.26	.54
6/14	.22	.35	.37	.32	.22	.46
7/21	.09	.27	.12	.20	.26	.46
8/17	.10	.19	.22	.14	.22	.41
9/15	.05	.21	.03	.08	.17	.46
10/13	.14	.22	.16	.09	.09	.43
11/15	.22	.24	.21	.18	.22	.48
12/27	.26	.31	.22	.24	.21	.45
1/21	.22	.33	.32	.22	.22	.45
2/10	.34	.29	.23	.21	.22	.61

Discharge (m^3/sec)

Date	Stream					
	Sl	Al	Sk	Sl	Br	Fr
3/23	.47	.95	.33	.35	.19	.40
4/10	.57	.89	.04	1.18	.50	.35
5/19	.24	.75	1.22	.38	.07	.49
6/14	.56	1.65	2.33	2.56	.74	1.56
7/21	.08	.95	.34	.20	.04	.12
8/17	.05	.73	.10	.04	.01	.14
9/15	.03	.54	.08	.02	.02	.14
10/13	.05	.68	.15	.07	.01	.21
11/15	.35	1.03	.21	.81	.22	.71
12/27	.42	1.09	.22	.43	.21	.52
1/21	.65	1.12	.32	.57	.19	.50
2/10	.82	1.02	.44	.64	.31	.55

APPENDIX II

Algal collection data for March, May, July, September and November by microhabitat (stem, bank, log) and stream. Symbols represent various levels of abundance (O=occasional, C=common, A=abundant, D=dominant). A blank indicates species not found.

March 1982 Algal Samples

Species	Sleeper			Albertson			Skit			Springer			Burrs Mill			Friendship		
	Bank	Log	Stem	Bank	Log	Stem	Bank	Log	Stem	Bank	Log	Stem	Bank	Log	Stem	Bank	Log	Stem
CHLOROPHYTA green algae																		
Chaetophora sp.											O							
Closterium sp.				C	C													
Cosmarium sp.				O							O	O						
Microspora sp.				C	C		O				D		C	C	C	C	D	D
Mougeota sp.											O							O
Penium sp.																		
Radiofilum sp.						O												
Spirogyra sp.													D	D	D			
Tetraspora sp.		D			D							D						
Zigogoneum ericetorum													C	C	C			
CYANOPHYTA blue green algae																		
Calothrix sp.						D												
Schizothrix sp.						C												
BACILLARIOPHYTA diatoms																		
Actinella punctata																	O	O
Asterionella formosa																	O	O
Eunotia sp.			C															
E. curvata	C									O		O						
E. exigua	C		D															
E. pectinalis				A	C	C		O		O	C	C				D	C	O
Frustulia rhomboides	C																	
F. rhomboides var *saxonica*	C																	
Tabellaria fenestrata	D		C													D	A	A
T. flocculosa										O	O	C				C	O	O
RHODOPHYTA red algae																		
Audouinella violacea						C		O										
Batrachospermum sp.								O	D									

May 1982 Algal Samples

Species	Sleeper			Albertson			Skit			Springer			Burrs Mill			Friendship		
	Bank	Log	Stem	Bank	Log	Stem	Bank	Log	Stem	Bank	Log	Stem	Bank	Log	Stem	Bank	Log	Stem
CHLOROPHYTA																		
green algae																		
Closterium sp.				O			O											
Cosmarium sp.					O													
Microspora sp.		O					D	O	O					O				
Mougeotia sp.	O									O					O			
Penium sp.	O																	
Spirogyra sp.										O		O	D	O	D			O
Zygoneum ericetorum								O						O	O			O
CYANOPHYTA																		
blue green algae																		
Schizothrix mexicana						D												
BACILLARIOPHYTA																		
diatoms																		
Asterionella formosa	O	O	O															
Eunotia exigua			C															
E. pectinalis	O	O	O	D	C					D		O					O	O
E. serra	O																	
Frustulia rhomboides	O	A	C															
Tabellaria fenestrata		C		O				O								C	O	O
T. flocculosa										O		O						
RHODOPHYTA																		
red algae																		
Audouinella violacea						C												
Batrachospermum sp.								D			D							

July 1982 Algal Samples

	Sleeper			Albertson			Skit			Springer			Burs Mill			Friendship		
Species	Bank	Log	Stem	Bank	Log	Stem	Bank	Log	Stem	Bank	Log	Stem	Bank	Log	Stem	Bank	Log	Stem
CHLOROPHYTA																		
green algae																		
Closterium sp.		O				O					C							
C. kuetzingli											O							
Cosmarium sp.	O					O												
Micrasterias sp.		O											O					
Microspora sp.							D	C	D								O	
Mougeotia sp.					C												C	
Staurastrum sp.						O												
Vaucheria sp.						D												
Zygogoneum ericetorum							A	O	C									
CYANOPHYTA																		
blue green algae																		
Porphyrosiphon splendidus										A	A							
Schiyothrix calcicola							A											
S. friesii							O											
BACILLARIOPHYTA																		
diatoms																		
Actinella punctata																O		C
Eunotia exigua			D															
E. incisa			O															
E. pectinalis				C							O	O				D	D	
E. serra																C		
Frustulia rhomboides	A	A	A								O	O						
Nitzschia sp.										C								
Pinnularia substomatophora			O															
Tabellaria fenestrata				O												C	A	
RHODOPHYTA																		
red algae																		
Audouinella violacea								A										
Batrachospermum sp.								O										

September 1982 Algal Samples

Species	Sleeper			Alberston			Skit			Springer			Burrs Mill			Friendship		
	Bank	Log	Stem	Bank	Log	Stem	Bank	Log	Stem	Bank	Log	Stem	Bank	Log	Stem	Bank	Log	Stem
CHLOROPHYTA																		
green algae																		
Bulbochaeta sp.																		O
Closterium sp.										O	O	C	C					
Microspora sp.	D								O						C		C	
Penium sp.		C																
Spirogyra sp.													O	O	D	O		O
Staurastrum sp.											O							
Vaucheria sp.					D	D												
Zygogoneum ericetorum									O								A	
CYANOPHYTA																		
blue green algae																		
Schizothrix friesii									O	O								
BACILLARIOPHYTA																		
diatoms																		
Actinella punctata																		O
Eunotia exigua		C	D															
E. flexulosa		C																
E. incisa			D															
E. pectinalis		C		O						A	C	O				D	O	
E. serra		O	O															
E. tautoniensis																		
Frustulia rhomboides		A							O	O	C			O				
F. rhomboides var. *capitata*											C							
Nitzschia sp.											O							
Pinnularia socialis													O					
Synedra ulna										C	O	C						
Tabellaria fenestrata							O		O							C		O
T. flocculosa																C		O
RHODOPHYTA																		
red algae																		
Audouinella violacea								C	C		C							O
Batrachospermum sp.							D	C										

November 1982 Algal Samples

	Sleeper			Albertson			Skit			Springer			Burrs Mill			Friendship		
Species	Bank	Log	Stem	Bank	Log	Stem	Bank	Log	Stem	Bank	Log	Stem	Bank	Log	Stem	Bank	Log	Stem
CHLOROPHYTA																		
green algae																		
<u>Chaetophore</u> <u>sp.</u>																	D	
<u>Closterium</u> <u>sp.</u>						O				O								
<u>Micrasterias</u> <u>rotata</u>	O		O															
<u>Microspora</u> <u>sp.</u>		O	O						O							O		
<u>Mougeotia</u> <u>sp.</u>												O						
<u>Penium</u> <u>sp.</u>	O												O		O			
<u>Spirogyra</u> <u>sp.</u>																O		C
<u>Zygogoneum</u> <u>ericetorum</u>								D	D				O	O				
CYANOPHYTA																		
blue green algae																		
<u>Schizothrix</u> <u>mexicana</u>																		O
BACILLARIOPHYTA																		
diatoms																		
<u>Eunotia</u> <u>flexulosa</u>													O		O			
<u>E.</u> <u>incisa</u>						O							O		O			
<u>E.</u> <u>pectinalis</u>				O		C				O	O	O	O	O	O	C		
<u>Frustulia</u> <u>rhomboides</u>	O		O							O	O	O	O	O	C			
<u>F.</u> <u>vulgaris</u>					C													
<u>Gomphonema</u> <u>parvulum</u>						O												
<u>Nitzschia</u> <u>obtusa</u>						C												
<u>N.</u> <u>sp.</u>										O								
<u>Pinnularia</u> <u>gibba</u>						O												
<u>P.</u> <u>viridis</u>													O		O			
<u>Synedra</u> <u>ulna</u>										O	O	O						
<u>Tabellaria</u> <u>fenestrata</u>			O						O				O		O	D	O	C
<u>T.</u> <u>flocculosa</u>																O		O
RHODOPHYTA																		
red algae																		
<u>Audouinella</u> <u>violacea</u>								D										

January 1983 Algal Samples

Species	Sleepter Bank	Sleepter Log	Sleepter Stem	Albertson Bank	Albertson Log	Albertson Stem	Skit Bank	Skit Log	Skit Stem	Springer Bank	Springer Log	Springer Stem	Burrs Mill Bank	Burrs Mill Log	Burrs Mill Stem	Friendship Bank	Friendship Log	Friendship Stem
CHLOROPHYTA																		
green algae																		
Closterium keutyingii										O								
C. ralfsii var. *ralfsii*					A	O												
Microspora sp.														C				
Pleurotaenium sp.											O							
Staurastrum sp.					O	O												
Tetraspora sp.					O													
Ulothrix sp.				A														
Zygogoneum ericetorum									O				O					
BACILLARIOPHYTA																		
diatoms																		
Actinella punctata																	C	C
Asterionella formosa																		C
Eunotia pectinalis				A	C	C				O						C	A	C
E. tautoniensis													O	O				
Frustulia rhomboides			O						O	O	O							
Synedra ulna											O							
Tabellaria fenestrata																O	A	A
T. flocculosa				O		O												O
RHODOPHYTA																		
red algae																		
Batrachospermum sp.					A													

APPENDIX III

Fish collections at six study streams, listed by micro-habitat, in March, June-July, September, and December 1982. Meadow habitat was not sampled in Albertson, Springers, and Burr's Mill.

FISH SAMPLING - MARCH , 1982

Sleeper Branch at Pleasant Mills - March 23, 1982

Species	Meadow	Microhabitats Sampled Open Stream	Vegetation	Backwater
Redfin Pickerel *Esox americanus*				3
Chain Pickerel *Esox niger*	2			6
Eastern Mudminnow *Umbra pygmaea*		1	15	25
Creek Chubsucker *Erimyzon oblongus*			1	
Pirate Perch *Aphredoderus sayanus*			1	
Blackbanded Sunfish *Enneacanthus chaetodon*	1			5
Banded Sunfish *Enneacanthus obsus*	1		1	6
Swamp Darter *Etheostoma fusiforme*	2	5	1	12

Albertson Brook upstream of Paradise Lakes Campground - March 23, 1982

Species	Meadow	Microhabitats Sampled Open Stream	Vegetation	Backwater*
American Eel *Anguilla rostrata*		1		
Eastern Mudminnow *Umbra pygmaea*				1
Creek Chubsucker *Erimyzon oblongus*			10	
Tadpole Madtom *Noturus gyrinus*			1	
Pirate Perch *Aphredoderus sayanus*			2	1
Blackbanded Sunfish *Enneacanthus chaetodon*			4	
Swamp Darter *Etheostoma fusiforme*		2	13	
Tessellated Darter *Etheostoma olmstedi*		15		

* Almost none, only one small area.

Skit Branch near Hampton Furnace - March 24, 19824, 1982

Species	Microhabitats Sampled Meadow*	Open Stream	Vegetation**	Backwaterr
Redfin Pickerel *Esox americanus*	1			
Chain Pickerel *Esox niger*			1	
Swamp Darter *Etheostoma fusiforme*	3	1	1	

* Open area upstream from bridge, all ars included (Backwater, vegetation,etc.)

** Very little downstream from bridge.

Springers Brook at Hampton Furnace Road - March 24, 1982

Species	Meadow	Open Stream	Vegetation*	Backwater
	Microhabitats Sampled			
American Eel *Anguilla rostrota*			1	
Chain Pickerel *Esox niger*			1	3
Eastern Mudminnow *Umbra pygmaca*		1		1
Yellow Bullhead *Ictalurus natalis*		1		
Pirate Perch *Aphredoderus sayanus*			1	2
Banded Sunfish *Enneacanthus obesus*				2
Swamp Darter *Etheostoma fusiforme*		3	1	2
Tessellated Darter *Etheostoma olmstedi*		4		

* Very little aquatic vegetation except narrow band along edges. One crayfish (Procambarus blandingi) collected.

Burrs Mill Brook at Johnson Place Road - March 24, 1982

Species	Microhabitats Sampled Meadow	Open Stream	Vegetation*	Backwater
Redfin Pickerel *Esox americanus*				2
Eastern Mudminnow *Umbra pygmaca*		2		14
Banded Sunfish *Enneacanthus obesus*			2	27
Swamp Darter *Etheostoma fusiforme*		6	1	4

* Very litte, except masses of algae on vines and branches.

Friendship Creek at Powell Place Road - March 24,1982

Species	Meadow	Microhabitats Sampled Open Stream	Vegetation*	Backwater**
Chain Pickerel *Esox niger*		1	3	
Eastern Mudminnow *Umbra pygmaca*			1	
Creek Chubsucker *Erimyzon oblongus*		1		
Blackbanded Sunfish *Enneacanthus chaetodon*				1
Swamp Darter *Etheostoma fusiforme*		2	2	1

* Very litte, mostly near bridge.

** Very litte.

FISH SAMPLING - JUNE - JULY , 1982

Sleeper Branch at Pleasant Mills - July 21, 1982 (June 14)

Species	Meadow	Microhabitats Sampled Open Stream	Vegetation	Backwater
American Eel Anguilla rostrata		3	(1)	
Redfin Pickerel Esox americanus			1	2
Chain Pickerel Esox niger	3	3	(1)	1
Eastern Mudminnow Umbra pygmaea	1		3(4)	
Golden Shiner Notemigonus crysoleucas				
Creek Chubsucker Erimyzon oblongus				
Tadpole Madtom Noturus gyrinus				
Yellow Bullhead Ictalurus natalis				
Pirate Perch Aphredoderus sayanus				
Mud Sunfish Acantharchus pomotis			2(2)	
Bluespotted Sunfish Enneacanthus glorious				
Blackbanded Sunfish Enneacanthus chaetodon		2		
Banded Sunfish Enneacanthus obesus	2(1)		8	3
Largemouth Bass Micropterus salmoides				
Swamp Darter Etheostoma fusiforme	1	(1)3	2	1
Tessellated Darter Etheostoma olmstedi		3(1)	1	

Albertson Brook upstream of Paradise Lakes Campground - July 21,1982
(June 14)

Species	Meadow	Microhabitats Sampled Open Stream	Vegetation	Backwater
American Eel *Anguilla rostrata*		(1)	1(1)	
Redfin Pickerel *Esox americanus*				
Chain Pickerel *Esox niger*		(2)	3(4)	(1)
Eastern Mudminnow *Umbra pygmaea*				
Golden Shiner *Notemigonus crysoleucas*				
Creek Chubsucker *Erimyzon oblongus*		58	24	(1)
Tadpole Madtom *Noturus gyrinus*				
Yellow Bullhead *Ictalurus natalis*				
Pirate Perch *Aphredoderus sayanus*			2	
Mud Sunfish *Acantharchus pomotis*			1	
Bluespotted Sunfish *Enneacanthus glorious*			1	
Blackbanded Sunfish *Enneacanthus chaetodon*				
Banded Sunfish *Enneacanthus obesus*				
Largemouth Bass *Micropterus salmoides*		1		
Swamp Darter *Etheostoma fusiforme*		4(3)	9(20)	(1)
Tessellated Darter *Etheostoma olmstedi*		2(5)		

Skit Branch near Hampton Furnace - July 21, 1982
(June 15)

Species	Meadow	Microhabitats Sampled Open Stream	Vegetation	Backwater*
American Eel *Anguilla rostrata*			1	
Redfin Pickerel *Esox americanus*				
Chain Pickerel *Esox niger*	1		3(1)	
Eastern Mudminnow *Umbra pygmaea*			3	
Golden Shiner *Notemigonus crysoleucas*				
Creek Chubsucker *Erimyzon oblongus*				
Tadpole Madtom *Noturus gyrinus*				
Yellow Bullhead *Ictalurus natalis*				
Pirate Perch *Aphredoderus sayanus*			2	
Mud Sunfish *Acantharchus pomotis*			1	
Bluespotted Sunfish *Enneacanthus glorious*	1		1	
Blackbanded Sunfish *Enneacanthus chaetodon*				
Banded Sunfish *Enneacanthus obesus*			1	
Largemouth Bass *Micropterus salmoides*				
Swamp Darter *Etheostoma fusiforme*		1	10(2)	
Tessellated Darter *Etheostoma olmstedi*				

*Almost none; one area flooded on June 15, mostly dry and stagnant on March 24; Sampled on June 15, but on fish collected, not sampled on July21.

Springers Brook at Hampton Furnace Road - July 21, 1982
June 15, High water-Not Sampled

Species	Meadow	Open Stream	Vegetation	Backwater
		Microhabitats Sampled		
American Eel Anguilla rostrata		2	4	
Redfin Pickerel Esox americanus			1	1
Chain Pickerel Esox niger				2
Eastern Mudminnow Umbra pygmaea			1	
Golden Shiner Notemigonus crysoleucas		10	1	2
Creek Chubsucker Erimyzon oblongus				5
Tadpole Madtom Noturus gyrinus				
Yellow Bullhead Ictalurus natalis				
Pirate Perch Aphredoderus sayanus				
Mud Sunfish Acantharchus pomotis				
Bluespotted Sunfish Enneacanthus glorious				
Blackbanded Sunfish Enneacanthus chaetodon				
Banded Sunfish Enneacanthus obesus				3
Largemouth Bass Micropterus salmoides				
Swamp Darter Etheostoma fusiforme		3	4	5
Tessellated Darter Etheostoma olmstedi		4		

Burr's Mill Brook at Johnson Place Road - July 22, 1982
(June 15)

Species	Meadow	Microhabitats Sampled Open Stream	Vegetation*	Backwater
American Eel *Anguilla rostrata*				
Redfin Pickerel *Esox americanus*				
Chain Pickerel *Esox niger*				
Eastern Mudminnow *Umbra pygmaea*		1		1(3)
Golden Shiner *Notemigonus crysoleucas*				
Creek Chubsucker *Erimyzon oblongus*				
Tadpole Madtom *Noturus gyrinus*				
Yellow Bullhead *Ictalurus natalis*				
Pirate Perch *Aphredoderus sayanus*				
Mud Sunfish *Acantharchus pomotis*		1		
Bluespotted Sunfish *Enneacanthus glorious*				
Blackbanded Sunfish *Enneacanthus chaetodon*		22	(6)	1(2)
Banded Sunfish *Enneacanthus obesus*		6(1)	(3)	(2)
Largemouth Bass *Micropterus salmoides*				
Swamp Darter *Etheostoma fusiforme*		11(1)	(3)	
Tessellated Darter *Etheostoma olmstedi*				

*None sampled on July 22.

Friendship Creek at Powell Place Road - July 22, 1982
(June 15)

Species	Meadow	Microhabitats Sampled Open Stream	Vegetation	Backwater*
American Eel *Anguilla rostrata*				
Redfin Pickerel *Esox americanus*				
Chain Pickerel *Esox niger*		1	1	(1)
Eastern Mudminnow *Umbra pygmaea*			1	(1)
Golden Shiner *Notemigonus crysoleucas*				
Creek Chubsucker *Erimyzon oblongus*				
Tadpole Madtom *Noturus gyrinus*				
Yellow Bullhead *Ictalurus natalis*			3(3)	
Pirate Perch *Aphredoderus sayanus*				
Mud Sunfish *Acantharchus pomotis*				
Bluespotted Sunfish *Enneacanthus glorious*				
Blackbanded Sunfish *Enneacanthus chaetodon*			13(3)	
Banded Sunfish *Enneacanthus obesus*			1	(3)
Largemouth Bass *Micropterus salmoides*				
Swamp Darter *Etheostoma fusiforme*		2	5(1)	
Tessellated Darter *Etheostoma olmstedi*				

*Very little on March 24; extensive on June 15, wooded areas well-flooded; none sampled on July 22.

FISH SAMPLING

Sleeper Branch at Pleasant Mills - September 15, 19

Species	Meadow	Open Stream	Vegetation	Backwater
	Microhabitats Sampled			
American Eel *Anguilla rostrata*	1	2	2	
Redfin Pickerel *Esox americanus*	3			
Chain Pickerel *Esox niger*	3	1	1	1
Eastern Mudminnow *Umbra pygmaea*		1		
Golden Shiner *Notemigonus crysoleucas*				
Creek Chubsucker *Erimyzon oblongus*				
Tadpole Madtom *Noturus gyrinus*				
Yellow Bullhead *Ictalurus natalis*				
Pirate Perch *Aphredoderus sayanus*			1	
Mud Sunfish *Acantharchus pomotis*	6	2	5	
Bluespotted Sunfish *Enneacanthus glorious*				
Blackbanded Sunfish *Enneacanthus chaetodon*	1	1		
Banded Sunfish *Enneacanthus obesus*	2	4	3	
Largemouth Bass *Micropterus salmoides*				
Swamp Darter *Etheostoma fusiforme*	6	9	5	
Tessellated Darter *Etheostoma olmstedi*	1	2		

...eam of Paradise Lakes -September 15, 1982

...pecies	Meadow	Open Stream	Vegetation	Backwater
	Microhabitats Sampled			
American Eel Anguilla rostrata		3	3	
Redfin Pickerel Esox americanus				
Chain Pickerel Esox niger		1	2	
Eastern Mudminnow Umbra pygmaea				
Golden Shiner Notemigonus crysoleucas				
Creek Chubsucker Erimyzon oblongus			1	
Tadpole Madtom Noturus gyrinus			2	
Yellow Bullhead Ictalurus natalis				
Pirate Perch Aphredoderus sayanus				
Mud Sunfish Acantharchus pomotis				
Bluespotted Sunfish Enneacanthus glorious				
Blackbanded Sunfish Enneacanthus chaetodon		1	1	
Banded Sunfisn Enneacanthus obesus				
Largemouth Bass Micropterus salmoides				
Swamp Darter Etheostoma fusiforme		7	14	
Tessellated Darter Etheostoma olmstedi		9	1	

Skit Branch near Hampton Furnace -September 16, 1982

Species	Meadow	Microhabitats Sampled Open Stream	Vegetation	Backwater
American Eel *Anguilla rostrata*				
Redfin Pickerel *Esox americanus*				
Chain Pickerel *Esox niger*		1	1	
Eastern Mudminnow *Umbra pygmaea*			7	
Golden Shiner *Notemigonus crysoleucas*				
Creek Chubsucker *Erimyzon oblongus*				
Tadpole Madtom *Noturus gyrinus*				
Yellow Bullhead *Ictalurus natalis*				
Pirate Perch *Aphredoderus sayanus*			3	
Mud Sunfish *Acantharchus pomotis*			1	
Bluespotted Sunfish *Enneacanthus glorious*				
Blackbanded Sunfish *Enneacanthus chaetodon*				
Banded Sunfish *Enneacanthus obesus*			1	2
Largemouth Bass *Micropterus salmoides*				
Swamp Darter *Etheostoma fusiforme*			6	
Tessellated Darter *Etheostoma olmstedi*				

Springers Brook at Hampton Furnace Road -September 16, 1982

Species	Meadow	Microhabitats Sampled Open Stream	Vegetation	Backwater
American Eel *Anguilla rostrata*		10	4	1
Redfin Pickerel *Esox americanus*				
Chain Pickerel *Esox niger*			1	1
Eastern Mudminnow *Umbra pygmaea*		1	1	3
Golden Shiner *Notemigonus crysoleucas*				
Creek Chubsucker *Erimyzon oblongus*				
Tadpole Madtom *Noturus gyrinus*		2	2	1
Yellow Bullhead *Ictalurus natalis*				
Pirate Perch *Aphredoderus sayanus*		1	1	
Mud Sunfish *Acantharchus pomotis*				1
Bluespotted Sunfish *Enneacanthus glorious*				
Blackbanded Sunfish *Enneacanthus chaetodon*				
Banded Sunfish *Enneacanthus obesus*				4
Bluegill Sunfish *Lepomis macrochirus*				1
Largemouth Bass *Micropterus salmoides*				
Swamp Darter *Etheostoma fusiforme*		18	7	7
Tessellated darter *Etheostoma olmstedi*		17	8	

Burr's Mill Brook at Johnson Place Road -September 16, 1982

Species	Meadow	Microhabitats Sampled Open Stream	Vegetation	Backwater
American Eel *Anguilla rostrata*				
Redfin Pickerel *Esox americanus*				
Chain Pickerel *Esox niger*		1		
Eastern Mudminnow *Umbra pygmaea*		2		
Golden Shiner *Notemigonus crysoleucas*				
Creek Chubsucker *Erimyzon oblongus*				
Tadpole Madtom *Noturus gyrinus*				
Yellow Bullhead *Ictalurus natalis*				
Pirate Perch *Aphredoderus sayanus*		2		
Mud Sunfish *Acantharchus pomotis*		2		
Bluespotted Sunfish *Enneacanthus glorious*				
Blackbanded Sunfish *Enneacanthus chaetodon*		36		
Banded Sunfish *Enneacanthus obesus*		6		
Largemouth Bass *Micropterus salmoides*				
Swamp Darter *Etheostoma fusiforme*		12		
Tessellated Darter *Etheostoma olmstedi*				

Friendship Creek at Powell Place Road -September 16, 1982

Species	Meadow	Microhabitats Sampled Open Stream	Vegetation	Backwater
American Eel *Anguilla rostrata*			1	
Redfin Pickerel *Esox americanus*				
Chain Pickerel *Esox niger*		1	1	
Eastern Mudminnow *Umbra pygmaea*				
Golden Shiner *Notemigonus crysoleucas*				
Creek Chubsucker *Erimyzon oblongus*				
Tadpole Madtom *Noturus gyrinus*				
Yellow Bullhead *Ictalurus natalis*			4	
Pirate Perch *Aphredoderus sayanus*			2	
Mud Sunfish *Acantharchus pomotis*			5	
Bluespotted Sunfish *Enneacanthus glorious*				
Blackbanded Sunfish *Enneacanthus chaetodon*			6	
Banded Sunfish *Enneacanthus obesus*			1	
Largemouth Bass *Micropterus salmoides*				
Swamp Darter *Etheostoma fusiforme*			7	
Tessellated Darter *Etheostoma olmstedi*				

Fish Sampling - December

Sleeper Branch at Pleasant Mills - December 27, 1982

Species	Meadow	Microhabitats Sampled Open Stream	Vegetation	Backwater
American Eel *Anguilla rostrata*				
Redfin Pickerel *Esox americanus*				1
Chain Pickerel *Esox niger*			1	
Eastern Mudminnow *Umbra pygmaea*			7	1
Golden Shiner *Notemigonus crysoleucas*				
Creek Chubsucker *Erimyzon oblongus*				
Tadpole Madtom *Noturus gyrinus*				
Yellow Bullhead *Ictalurus natalis*			1	
Pirate Perch *Aphredoderus sayanus*	1		1	
Mud Sunfish *Acantharchus pomotis*			2	1
Bluespotted Sunfish *Enneacanthus glorious*				
Blackbanded Sunfish *Enneacanthus chaetodon*	1		2	2
Banded Sunfish *Enneacanthus obesus*				
Largemouth Bass *Micropterus salmoides*				
Swamp Darter *Etheostoma fusiforme*	3	1	2	1
Tessellated Darter *Etheostoma olmstedi*				

Albertson Brook upstream of Paradise Lakes Campground -December 27, 1982

Species	Microhabitats Sampled Meadow	Open Stream	Vegetation	Backwater
American Eel *Anguilla rostrata*			3	
Redfin Pickerel *Esox americanus*				
Chain Pickerel *Esox niger*			4	
Eastern Mudminnow *Umbra pygmaea*			2	
Golden Shiner *Notemigonus crysoleucas*				
Creek Chubsucker *Erimyzon oblongus*			14	
Tadpole Madtom *Noturus gyrinus*			5	
Yellow Bullhead *Ictalurus natalis*				
Pirate Perch *Aphredoderus sayanus*				
Mud Sunfish *Acantharchus pomotis*				
Bluespotted Sunfish *Enneacanthus glorious*				
Blackbanded Sunfish *Enneacanthus chaetodon*				
Banded Sunfish *Enneacanthus obesus*				
Largemouth Bass *Micropterus salmoides*				
Swamp Darter *Etheostoma fusiforme*		5	42	
Tessellated Darter *Etheostoma olmstedi*		17		

Skit Branch near Hampton Furnace -December 27, 1982

Species	Meadow	Microhabitats Sampled Open Stream	Vegetation	Backwater
American Eel Anguilla rostrata				
Redfin Pickerel Esox americanus				
Chain Pickerel Esox niger			1	
Eastern Mudminnow Umbra pygmaea			2	
Golden Shiner Notemigonus crysoleucas				
Creek Chubsucker Erimyzon oblongus				
Tadpole Madtom Noturus gyrinus				
Yellow Bullhead Ictalurus natalis				
Pirate Perch Aphredoderus sayanus				
Mud Sunfish Acantharchus pomotis				
Bluespotted Sunfish Enneacanthus glorious			1	
Blackbanded Sunfish Enneacanthus chaetodon				
Banded Sunfish Enneacanthus obesus			1	
Largemouth Bass Micropterus salmoides				
Swamp Darter Etheostoma fusiforme		2	4	
Tessellated Darter Etheostoma olmstedi				

Springers Brook at Hampton Furnace Road -December 27, 1982

Species	Meadow	Microhabitats Sampled Open Stream	Vegetation	Backwater
American Eel Anguilla rostrata		1	1	
Redfin Pickerel Esox americanus				1
Chain Pickerel Esox niger				1
Eastern Mudminnow Umbra pygmaea			1	2
Golden Shiner Notemigonus crysoleucas				24
Creek Chubsucker Erimyzon oblongus			1	1
Tadpole Madtom Noturus gyrinus				
Yellow Bullhead Ictalurus natalis				
Pirate Perch Aphredoderus sayanus				1
Mud Sunfish Acantharchus pomotis				1
Bluespotted Sunfish Enneacanthus glorious				
Blackbanded Sunfish Enneacanthus chaetodon				
Banded Sunfish Enneacanthus obesus				
Largemouth Bass Micropterus salmoides				
Swamp Darter Etheostoma fusiforme		2		6
Tessellated Darter Etheostoma olmstedi		4		

Burrs's Mill Brook at Johnson Place Road -December 28, 1982

Species	Meadow	Open Stream	Vegetation	Backwater
	Microhabitats Sampled			
American Eel *Anguilla rostrata*				
Redfin Pickerel *Esox americanus*				
Chain Pickerel *Esox niger*				
Eastern Mudminnow *Umbra pygmaea*				16
Golden Shiner *Notemigonus crysoleucas*				
Creek Chubsucker *Erimyzon oblongus*				
Tadpole Madtom *Noturus gyrinus*				
Yellow Bullhead *Ictalurus natalis*				
Pirate Perch *Aphredoderus sayanus*				
Mud Sunfish *Acantharchus pomotis*				
Bluespotted Sunfish *Enneacanthus glorious*				
Blackbanded Sunfish *Enneacanthus chaetodon*			1	
Banded Sunfish *Enneacanthus obesus*		1		3
Largemouth Bass *Micropterus salmoides*				
Swamp Darter *Etheostoma fusiforme*		6		
Tessellated Darter *Etheostoma olmstedi*				

Friendship Creek at Powell Place Road -December 28, 1982

Species	Meadow	Open Stream	Vegetation	Backwater
		Microhabitats Sampled		
American Eel *Anguilla rostrata*				
Redfin Pickerel *Esox americanus*				
Chain Pickerel *Esox niger*				
Eastern Mudminnow *Umbra pygmaea*				1
Golden Shiner *Notemigonus crysoleucas*				
Creek Chubsucker *Erimyzon oblongus*			5	
Tadpole Madtom *Noturus gyrinus*				
Yellow Bullhead *Ictalurus natalis*				
Pirate Perch *Aphredoderus sayanus*				1
Mud Sunfish *Acantharchus pomotis*				
Bluespotted Sunfish *Enneacanthus glorious*				
Blackbanded Sunfish *Enneacanthus chaetodon*			7	
Banded Sunfish *Enneacanthus obesus*			1	
Largemouth Bass *Micropterus salmoides*				
Swamp Darter *Etheostoma fusiforme*		1	5	
Tessellated Darter *Etheostoma olmstedi*				

ERRATA AUGUST 1983

P. 3, Table 3. Summary of water quality data collected from each stream.

The mean pH value for each stream should read as follows:

Stream	pH
Albertson	5.8
Springer	5.1
Friendship	4.7
Sleeper	4.2
Skit	4.4

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