

SP
6678

EFFECTS OF TROUT HABITAT ALTERATION
ON PLUM CREEK, SAYNER, WISCONSIN

by

Robert R. Jackson

A Thesis

submitted in partial fulfillment of the
requirements for the degree
MASTER OF SCIENCE

College of Natural Resources

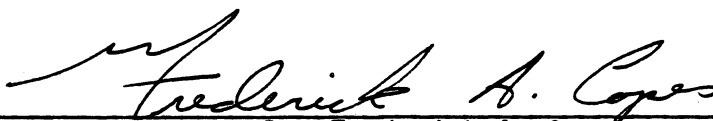
UNIVERSITY OF WISCONSIN
Stevens Point, Wisconsin

May 1983

APPROVED BY THE GRADUATE COMMITTEE OF:



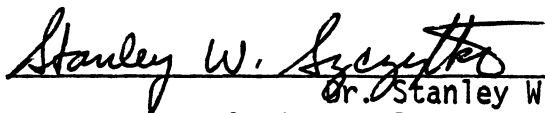
Dr. John R. Heaton, Committee Chairman
Professor of Fisheries



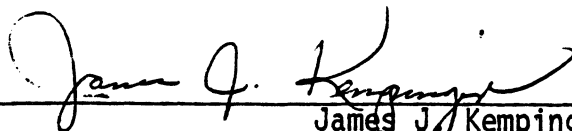
Dr. Frederick A. Copes
Professor of Biology and Fisheries



Dr. Theodore S. Roeder
Associate Professor of Water Science



Dr. Stanley W. Szczytko
Assistant Professor of Water Science



James J. Kempinger
Fisheries Research Biologist
Wisconsin Department of Natural Resources

ABSTRACT

The effects of habitat alteration on substrate composition, permanent trout cover and stream surface area; the benthic invertebrate community and drift of these invertebrates; rates of colonization, species preference and density of invertebrates inhabiting the wood used for habitat structures and changes in the availability of food organisms for brook and brown trout were assessed in Plum Creek, Wisconsin. Two 37-m study zones in areas not altered by habitat work and a 146-m study zone in an area altered by the 1976 habitat program were sampled during ice-free periods from May, 1976 to October, 1977.

Surface area and the percentage of sand bottom decreased by 11 and 13%, respectively, following habitat alteration. Permanent overhanging bank cover increased by 9%, while gravel substrate increased by 10%.

Habitat alteration did not decrease the number of benthic invertebrate taxa. There was a drastic initial reduction in mean numbers and biomass, however, 17 months (October, 1977) after habitat alteration gravel and sand substrate invertebrate numbers and weights were higher in the altered zone than the unaltered zone. Trichoptera and Diptera accounted for 86.6% of the total numbers and 75.2% by weight for gravel substrate in the altered zone. Pelecypoda was most abundant in the unaltered zone sand substrate with 66.0% occurrence. Plum Lake appears to have the greatest influence on the invertebrate composition found in both study zones.

Habitat alteration did not change the number of taxa found in the drift. The unaltered zone, however, contained significantly higher ($P < .05$) numbers and biomass of drifting organisms. Seasonal and diel

variations occurred in the drift. Mean numbers and biomass of aquatic invertebrates in the drift were significantly higher ($P < .05$) than terrestrial invertebrates. Differences in correlations existed between monthly particulate organic carbon and invertebrate number densities by habitat zones.

Colonization of invertebrates increased with the amount of time the artificial substrates were left in the stream. The number of taxa, however, decreased with time. Chironomidae and Hydropsycidae accounted for 76.9% of the total numbers and 60.3% by weight for combined artificial substrate intervals. Artificial substrate invertebrate numbers and biomass were comparable with gravel and sand substrate totals in both the altered and unaltered areas.

Habitat alteration in Plum Creek did not appear to affect the availability of food organisms for brook and brown trout. There was no significant difference for mean number of food items per stomach between the altered and unaltered habitat zones. The contents of the trout stomachs in the altered habitat zone contained the greatest variety of taxa. Major aquatic and terrestrial insect orders and families found in the benthos, drift and artificial substrate samples were utilized by the trout.

ACKNOWLEDGEMENTS

I am most grateful to my two major professors, Dr. Gerald Z. Jacobi, who initially advised me on this project, and Dr. John R. Heaton, for his guidance and encouragement upon inheriting the committee chairmanship. I also wish to thank the other members of my graduate committee, Dr. Frederick A. Copes, Dr. Stanley W. Szczytko, Dr. Theodore S. Roeder and James J. Kempinger, for their advice and review of this manuscript. The help Mr. Thomas R. Zeisler gave me with the computer programming is appreciated.

This thesis would not have been possible without the financial support and cooperation of the Wisconsin Department of Natural Resources, Woodruff Area Headquarters. I acknowledge Lloyd M. Andrews, Arthur E. Ensign, James J. Kempinger, Ronald L. Theis, D. K. Tyler and Richard W. Wendt for their assistance. Jack Lantta, field foreman for the Plum Creek habitat project, deserves special thanks for his friendship and encouragement.

I also acknowledge Michael H. Hoff for his review of the manuscript and Connie Griesbach for typing the manuscript.

I especially wish to thank my wife, Chris, for her patience, understanding, love and encouragement.

This thesis is dedicated to my father, Rene Jackson and my son, Steven: A generation that instilled in me the appreciation of our valuable trout resources and a generation I hope will also learn to appreciate these important values.

TABLE OF CONTENTS

ABSTRACT -----	iii
ACKNOWLEDGEMENTS -----	v
LIST OF TABLES -----	vii
LIST OF FIGURES -----	ix
LIST OF APPENDICES -----	x
INTRODUCTION -----	1
STUDY AREA -----	3
Management Chronicle -----	5
METHODS AND MATERIALS -----	7
Study Site Selection -----	7
Physical Changes -----	8
Benthic Invertebrates -----	8
Drift -----	8
Artificial Substrate -----	9
Trout Stomachs -----	10
Data Analysis -----	11
RESULTS AND DISCUSSION -----	12
Physical Changes -----	12
Benthic Invertebrates -----	15
Drift -----	31
Artificial Substrate -----	46
Trout Feeding -----	53
CONCLUSION -----	61
LITERATURE CITED -----	63
APPENDIX -----	70

LIST OF TABLES

Table 1.	Mean monthly benthic invertebrate numbers, biomass and standard deviation (s.d.) for gravel and sand substrates in the altered and unaltered habitat zones of Plum Creek, 1976-1977. -----	16
Table 2.	Mean numbers, biomass, standard deviation (s.d.) and level of significance (students t test $P < .05$ - $P < .5$) of benthic invertebrate class and orders for 1976 and 1977 sand substrate in the unaltered zone, Plum Creek. -----	19
Table 3.	Mean numbers (no./m ²) and biomass (g/m ²) of benthic invertebrates by major identifiable taxa equal to or exceeding 2% of the average total collected in either gravel or sand substrate for the altered zone of Plum Creek, 1976-1977. -----	23
Table 4.	Mean numbers (no./m ²) and biomass (g/m ²) of benthic invertebrates by major identifiable taxa equal to or exceeding 2% of the average total collected in either gravel or sand substrate for the unaltered zone of Plum Creek, 1976-1977. -----	26
Table 5.	Monthly and time sampling period total numbers (no./100m ³) and biomass (g/100m ³) of aquatic (A), terrestrial (T) and total (TO) drift by habitat zones in Plum Creek, May to October, 1977. -----	32
Table 6.	Mean numbers, biomass, standard deviation (s.d.) and level of significance (students t test $P < .05$ - $P < .5$) of major drifting invertebrate class and orders and fish in the altered and unaltered habitat zones of Plum Creek, 1977. -----	36
Table 7.	Total numbers (no./100m ³) and biomass (g/100m ³) of drifting organisms by major identifiable taxa equal to or exceeding 2% of the average total collected in either the altered or unaltered zone of Plum Creek, May to October, 1977. -----	41
Table 8.	Monthly total density (g/100m ³) of drifting particulate organic carbon for time periods combined by study zone in Plum Creek, May to October, 1977. ----	44
Table 9.	Means, range and standard deviation of numbers and biomass of invertebrates on artificial substrates after time intervals of one, two, three and four months compared to benthic substrate types in the two study zones in Plum Creek, 1976-1977. -----	48

- Table 10. Mean number (no./m²) and biomass (g/m²) differences in colonization rates of invertebrates by major identifiable taxa equal to or exceeding 2% of the average total collected from artificial substrates installed in Plum Creek for different time intervals from 1976-1977. ----- 50
- Table 11. Mean number (\bar{X}) of food items per stomach with standard deviation (s.d.), students t test for level of significance and number of identifiable taxa from the two habitat study zones in Plum Creek, 1976-1977. Number of stomachs analyzed in parentheses. ----- 54
- Table 12. Benthic, drift and artificial substrate major aquatic insect orders and families percent occurrence and their corresponding percentages in the stomachs of trout species collected in the altered and unaltered habitat zones, Plum Creek, 1976-1977. ----- 56
- Table 13. Terrestrial percentages by numbers and weight found in the drift and trout stomach contents by habitat zones in Plum Creek, 1976-1977. Chi Square (χ^2) analysis of the hypothesis: The proportion of terrestrials in the drift and trout stomach contents would not be statistically different. Probability of accepting the hypothesis ($P >$). ----- 60

LIST OF FIGURES

Figure 1. Plum Creek, Vilas County, Wisconsin, with habitat zones and invertebrate sampling stations. -----	4
Figure 2. Average changes in several physical characteristics following completion of habitat alteration on Plum Creek, 1976-1977. -----	13
Figure 3. Monthly discharge ($m^3/sec.$) in the altered and unaltered areas of Plum Creek, May to October, 1977. -----	14
Figure 4. Invertebrate families Hydropsychidae and Chironomidae monthly mean benthic $no./m^2$ for gravel substrate in the altered and unaltered habitat zones in Plum Creek, 1976-1977. -----	28
Figure 5. Invertebrate families Hydropsychidae and Chironomidae monthly mean benthic $no./m^2$ for sand substrate in the altered and unaltered habitat zones in Plum Creek, 1976-1977. -----	29
Figure 6. Seasonal drift mean numbers ($no./100m^3$) and weight ($g/100m^3$) for the altered and unaltered study zones in Plum Creek, May to October, 1977. -----	38
Figure 7. Diel drift mean numbers ($no./100m^3$) and weight ($g/100m^3$) for the altered and unaltered study zones in Plum Creek, May to October, 1977. -----	40
Figure 8. Mean number and biomass of organisms found on the artificial substrates by time intervals in Plum Creek, 1976-1977. -----	47
Figure 9. Invertebrate orders, Diptera, Trichoptera, Ephemeroptera, and families, Chironomidae and Hydropsychidae mean numbers and biomass percent occurrence by time interval on the artificial substrates in Plum Creek, 1976-1977. -----	51

LIST OF APPENDICES

Appendix A.	Indices of relative food value assigned to each food item in the diet of trout in Plum Creek from 1976-1977. -----	70
Appendix B.	Significance levels (*) of student t test comparisons between means for numbers and biomass of benthic invertebrates by substrate type in the altered (A) and unaltered (U) habitat zones in Plum Creek for 1976, 1977 and 1976-1977 combined. -----	71
Appendix C.	Distribution of taxa in Plum Creek by habitat zone collected from the benthic, drift and artificial substrate and trout stomach samples, 1976-1977. -----	73
Appendix D.	Major taxa percentages found in the benthic substrate and drift by habitat zones. Chi Square (X^2) analysis of the following hypothesis: The proportion of major insect taxa in the benthic substrates combined and drift would not be statistically different. Probability of accepting the hypothesis ($P >$). -----	81
Appendix E.	Significance levels (*) of student t test comparisons between means for numbers and biomass of invertebrates on artificial substrates after time intervals of one, two, three and four months in Plum Creek, 1976-1977. -----	82
Appendix F.	Significance levels (*) of student t test comparisons between means for numbers and biomass of invertebrates on artificial substrates after time intervals of one, two, three and four months compared to benthic substrate types in the altered (A) and unaltered (U) habitat zones in Plum Creek, 1976-1977. -----	83
Appendix G.	Mean number and percentage of weight of organisms equal to or exceeding 2% of the total found in trout stomachs in the altered or unaltered habitat zones of Plum Creek (May 1976-September 1977). -----	84
Appendix H.	Chi Square (X^2) analysis of the hypothesis: The percent occurrence of major aquatic insect taxa from the benthic, drift and artificial substrate samples in Plum Creek, 1976-1977 are not statistically different than those taxa percentages found in the trout stomachs. Probability of accepting the hypothesis ($P >$). -----	87

Trout habitat development, man's attempts to improve living conditions for trout, is one of the procedures used to manage the valuable trout resource in Wisconsin. Few programs in fish management are so readily accepted by the public as the improvement of trout streams.

Many of the early techniques developed in the United States were derived from Europe (Hazzard 1937). A surge of stream improvement programs began in the United States in the early 1930's with most of the initial work concentrated in Michigan (Hubbs, Greeley and Tarzwell 1933; Tarzwell 1936 and Tarzwell 1937) and in northern New York (Greeley 1933). Wisconsin initiated a substantial statewide program of trout habitat management in the early 1960's which resulted in major refinements of these techniques (White and Brynildson 1967).

Numerous investigations have demonstrated an increase in trout abundance and/or yield to anglers, resulting from habitat alterations (White 1975). Habitat development has produced substantial positive physical changes in stream characteristics (Hunt 1971) and increases in benthic standing crops (Tarzwell 1936; Hazzard 1937; Shetter, Clark and Hazzard 1946; Carufel 1968; Jester and McKirdy 1966; Hunter, Thorp and Grosvenor 1940; Gard 1961). The relationship between substrate type and abundance of benthic food organisms has also been documented (Needham 1928, 1929, 1938).

Increased abundance in drift due to physical disturbances have been reported (Horton 1961, Minckley 1964). While these studies dealt primarily with high water conditions, habitat alteration is also a considerable physical disturbance. Waters (1965) classified three basic types of aquatic drift as, behavioral (diel periodicity), constant (no diel periodicity) and catastrophic (related to perturbations).

Artificial substrates have been used extensively in the aquatic environment to collect invertebrates. The attraction of invertebrates to artificial substrates has been well substantiated in literature reviews by Cooke (1956), Lund and Talling (1957), Sladeckova (1962) and Pardue (1973).

Food items found most frequently in the diet of trout are Trichoptera, Ephemeroptera, Diptera, Plecoptera and Megaloptera (Needham 1935; Clemens 1928; Lord 1934; Pate 1933, 1934). Shetter, Clark and Hazzard (1946) found that habitat alteration resulted in greater number and bulk of organisms of proven value in the diet of trout.

The purpose of this study on Plum Creek, Sayner, Vilas County, Wisconsin, was to determine the effects of habitat alteration on: (1) substrate composition, permanent trout cover and stream surface area, (2) the benthic invertebrate community and drift of these invertebrates, (3) rates of colonization, species preference and density of invertebrates inhabiting the wood used for habitat structures, and (4) changes in the availability of food organisms for brook and brown trout.

This study was a structure versus control evaluation, which contrasted unaltered areas with areas altered by habitat work. Most of the past evaluations of stream improvement in the United States have involved "before and after" studies. The principal advantage of the structure versus control approach to stream evaluation is the shorter time period needed for the study and elimination of biases due to changes in climatological factors, population trends, or differences in efficiency of sampling caused by changes in investigators.

STUDY AREA

Plum Creek is located in Vilas County, Wisconsin, approximately two km west of the village of Sayner (Fig. 1). It is the outlet stream of Plum Lake and flows for 7.9 km into Big St. Germain Lake. Surface area of Plum Creek was 6.2 ha, mean width 10.2 m and mean depth approximately 45.7 cm. Bottom composition was silt (50%), sand (35%), gravel (12%), rubble (2%) and boulders (1%). Aquatic vegetation covered 29% of the stream bottom and consisted of Elodea sp. (20%), Potamogeton sp. (5%), Typha sp. (2%) and Lemma sp. (2%).

Plum Creek is a soft water (M.P.A. - 36 mg/l), near neutral (pH - 6.9) stream with low conductivity (C77 - 89 mmhos) and light brown color.

Wild forested lands in public ownership dominate the watershed. Watershed soil types consist of light sandy loams and sandy soil. Vegetation type was mostly upland hardwoods consisting of white birch (Betula papyrifera), red oak (Quercus rubra), maple (Acer spp.), red pine (Pinus resinosa), white pine (Pinus strobus), hemlock (Tsuga canadensis), balsam fir (Abies balsamea), aspen (Populus tremuloides), alder (Alnus spp.), grasses (Granicie spp.) and sedges (Carex spp). Permanent and seasonal riparian dwellings are located on the lower one-half of Plum Creek.

Brook trout (Salvelinus fontinalis) and brown trout (Salmo trutta) were the most numerous game fish present. Also found seasonally were: northern pike (Esox lucius), muskellunge (Esox masquinongy), yellow perch (Perca flavescens), bluegill (Lepomis macrochirus), rock bass (Ambloplites rupestris), smallmouth bass (Micropterus dolomieu), white sucker (Catostomus commersoni), and shorthead redhorse (Moxostoma

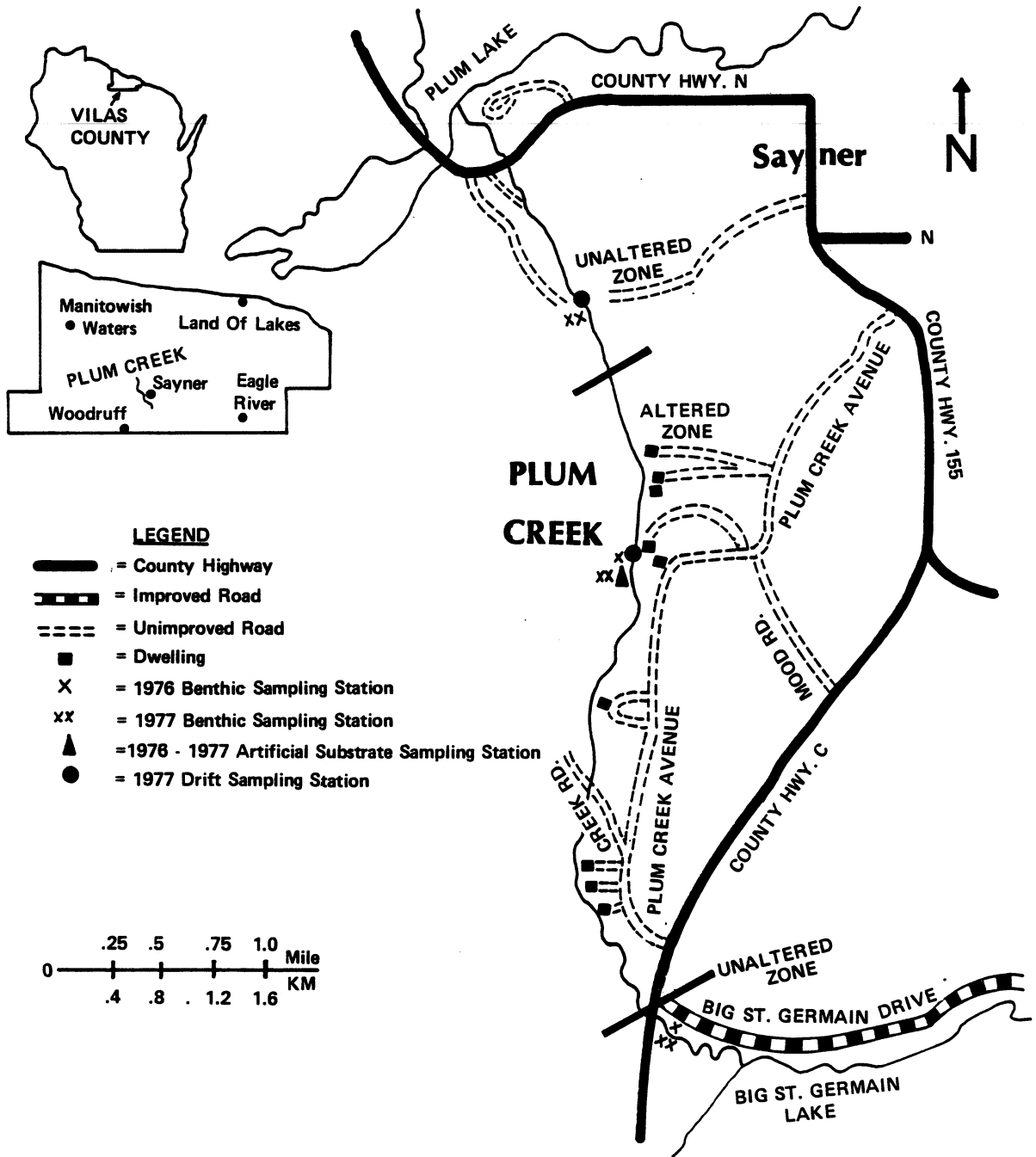


Figure 1. Plum Creek, Vilas County, Wisconsin, with habitat zones and invertebrate sampling stations.

macrolepidotum). Other species present were: mottled sculpin (Cottus bairdi), Johnny darter (Etheostoma nigrum), Iowa darter (Etheostoma exile), blacknose dace (Rhinichthys atratulus), bluntnose minnow (Pimephales notatus), creek chub (Semotilus atromaculatus), hornyhead chub (Nocomis biguttatus), rosyface shiner (Notropis rubellus), and northern brook lamprey (Ichthyomyzon fossor).

Management Chronicle

Plum Creek was first modified with log deflectors by Civilian Conservation Corps and Works Progress Administration crews during the 1930's, however, these devices quickly washed out. Stocking of trout began in 1944 with the planting of 75 fingerling brook trout. Trout populations were evaluated with a creel census during 1950 to 1951. In 1952 the Wisconsin Conservation Department fish management section recommended that Plum Creek should be removed from the trout stream list and no trout stocked because of the warmwater fish population present and its warmwater source and outlet.

This recommendation was opposed by the public, and as a result a cooperative habitat project was set up between the Wisconsin Department of Natural Resources and Star Lake-Plum Lake Conservation Club. The club could not get enough members to do the work, so the stream was set up as a state project. During this 1958-1960 habitat program 121 devices were installed. Most of these devices were single wing deflectors with a total length of 1,135 m. Initial electrofishing surveys indicated an increase in the brook trout population and carryover of stocked brown trout after habitat alteration.

Stocking of brook and brown trout was continued after habitat alteration, however in 1965 brook trout stocking was discontinued in

favor of brown trout. Recent quotas specify 2,000 brown trout yearlings annually (D.N.R. Woodruff Area file). Over 100,000 brook and brown trout have been stocked since 1944.

Habitat work was initiated again in 1975, as maintenance was needed throughout the 1958-1960 project area. A maintenance and redevelopment project was conducted from 1975 through 1978 in the original 4.7 km project zone. In 1979 to 1981 Wisconsin trout stamp funds supported additional intensive bank cover and redevelopment habitat work, expanding the project area to 5.1 km. Habitat alteration has occurred on 65% of Plum Creek.

MATERIALS AND METHODS

Study Site Selection

Study areas for Plum Creek were divided into natural (unaltered) areas and areas altered by instream habitat work (Fig. 1). The unaltered and altered areas in Plum Creek consisted of 3.1 km and 4.8 km of stream, respectively.

Unaltered Sites

Two 37-m study zones were selected in areas not altered by habitat work (Fig. 1). Study areas were located 1.1 and 6.5 km downstream from Plum Lake. Sites were selected on physical similarities to the areas altered by habitat work, biological similarities based on data from previous investigations (Jackson and Miller 1976) and location above and below the habitat alteration.

Altered Sites

A 146-m study zone was selected in an area to be altered by the 1976 habitat program (Fig. 1). This area was 3.0 km downstream from Plum Lake and included four specific 37-m habitat alteration zones. These habitat sites consisted of the following instream alternatives: Site 2, a 7 m overhang bank cover structure; Site 3, a 47 m rock bank deflector; Site 4, a 12 m single wing bank deflector; and Site 5, a combination 42 m single wing bank deflector and 7 m overhang bank cover. All habitat structures were back filled with sand and completed by adding a top dressing of sod to establish a solid turf mat and then seeded. Vegetative growth after a season or two obscured the underlying rock and wood.

Physical Changes

Detailed morphometric measurements were made in May, 1976, before habitat alteration occurred and after habitat alteration in July and August, 1976, and in June and October, 1977. Surface area, bottom types (sand or gravel) and permanent overhang bank cover were measured at 3.7-m intervals at the four 37-m habitat alteration sites. Substrate composition was determined subjectively while permanent bank cover was arbitrarily defined as all streambank providing at least .2 m of overhang having at least .4 m of water beneath it. The tabular results were averaged from the October, 1977 samples.

Current velocity was measured monthly using a Gurley meter from May to October, 1977 in the altered and unaltered study areas. Measurements were made at .4-m intervals at each site.

Benthic Invertebrates

Four replicate quantitative benthos samples were collected monthly from sand and gravel substrates in each 37-m study site during ice-free periods between May, 1976 and October, 1977. Substrate-stratified sampling suggested by Pennak and VanGerpen (1947), Bourdeau (1953), Cummins (1962), and Barber and Kevern (1973) was used to reduce sampling variation. A standard Ekman grab (0.025 m^2) was used to collect the benthos samples.

Drift

Drift was sampled monthly from May to October, 1977 in the altered and unaltered study areas in Plum Creek. Fifteen-minute samples were collected in nets with a 750 μm aperture opening and mesh size of 760 μm on a 0.1 m^2 frame at midday and one-half hour before and after sunrise

and sunset periods to correspond with major periods of drift. Drift net frames were equipped with welded split rings that slid over 1.27 cm diameter steel rods. The steel rods were driven into the stream bottom. One set of rods was positioned in the thalweg with the other two in the side currents. Drift nets and frames were stacked on the rods to cover the entire column of water from bottom to surface. Stream discharge, and discharge through the drift columns were determined using a Gurley meter. Sample biomass and density were weighted into total drift biomass ($\text{g}/100 \text{ m}^3$) and drift density ($\text{organisms}/100 \text{ m}^3$) according to the percent of the total discharge that flowed through the drift columns. Drift rates (number or weight per unit time) are not presented because of differences in discharge, water depth, and water velocity among the two study sites.

Artificial Substrate

Red pine boards used in construction of habitat structures constituted the artificial substrates. Two- m^2 pieces were attached with eye hooks and screws beneath the water surface to two newly installed single wing deflector habitat devices. Sampling was conducted monthly from June to October, 1976. In 1977 four identical two- m^2 pieces were attached to the same structures. One artificial substrate was sampled monthly, while the others were sampled at two-, three- and four-month intervals from June to October.

The boards were removed from the structure encompassed in fine mesh nets to prevent invertebrate escapement. The boards were then scraped to remove all invertebrates and the boards were reattached to the devices.

Eckman, drift and artificial substrate samples collected were

labeled and preserved in the field in a 9:1 mixture of 70% isopropyl alcohol and 10% formalin. In the laboratory samples were washed on a No. 35 soil screen. Invertebrates were sorted from detritus, identified to genus when possible, and counted (Hilsenhoff 1975; Pennak 1953). Invertebrates were not weighed because of weight change in preservative (Leonard, 1939; Howmiller, 1972). Invertebrate biomass, excluding Decapoda, Oligochaeta, and large insects such as Nepidae and Zygoptera, were calculated from organism length with the method described by Hynes and Coleman (1968), which assumes that insect shape is that of a cylinder, its volume increases by the cube of the length, and its specific gravity is 1.05. Weights of 1 mm length units were 3.3×10^{-5} g for insects excluding Chironomidae and Ceratopogonidae, 1.4×10^{-5} g for Chironomidae and Ceratopogonidae, and 5.0×10^{-4} g for Mollusca, which were considered spheres. Nepidae, Zygoptera and Decapoda were soaked in water for 30 min., blotted dry, and weighed to the nearest .01 g. Oligochaeta were soaked in water for 30 min., centrifuged at 650 rpm for three min. including acceleration and deceleration, and weighed to the nearest 0.01 g (Stanford, 1973). Particulate organic carbon was dried at 65°C for three days and weighed to the nearest 0.001 g. Results were expressed as total monthly particulate organic carbon density in a gram dry wt/100 m³.

Trout Stomachs

Four hundred six trout stomachs were obtained from angler-caught trout during the 1976 unstratified and 1977 stratified creel census (Jackson 1983). Location of the trout caught in relation to habitat zones was identified by the creel clerks. Stomachs were removed and placed in 10% formalin for subsequent analysis.

Stomach contents were identified to family when possible, and counted. To obtain weights for food bulk, each kind of food item was assigned a permanent index of relative value, based on the size and weight of the organisms (Hynes 1950). Chironomidae was arbitrarily designated as the standard organism and assigned the index value of one. The index values for the other organisms were determined in relation to the size of Chironomidae (Appendix A).

Data Analysis

Numbers and biomass of benthic and artificial substrate invertebrates were presented as no./m² and g/m². Extrapolation of mean numbers of organisms ft.² to mean numbers m² was accomplished after multiplying the former by a conversion factor (10.764). Drift organisms were quantitatively characterized utilizing no./100 m³ and g/100 m³. Arithmetic means (\bar{x}), standard deviations (SD) and standard error (SE) were calculated for all benthic, drift, artificial substrate and trout stomach study zone samples.

The Student's t-test was then employed to statistically evaluate the similarities and differences exhibited by the quantitative sample means (\bar{x}) collected from each study zone.

The Chi Square test (χ^2) was used to compare benthic, drift and artificial substrate number and biomass percentages to trout stomachs percent occurrences. Drifting terrestrial invertebrate frequencies between habitat zones and benthic and drift invertebrate composition percentages were also compared.

Linear regression was used to determine the correlation (r) between monthly aquatic invertebrate number and particulate organic carbon densities.

RESULTS AND DISCUSSION

Physical Changes

Surface area and the percentage of sand bottom decreased by 11 and 13%, respectively, following habitat alteration in Plum Creek (Fig. 2). Permanent overhanging bank cover increased by 9%, while gravel substrate increased by 10%. The benefits of gravel substrate compared with sand substrate is well documented in terms of benthic production (Needham 1928, 1938; Pate 1932, 1933, 1934; Tarzwell 1937) and as a spawning substrate for trout. The importance of cover has also been well documented. Positive morphological changes were also documented by Hunt (1971). Surface area and sand bottom decreased by 51 and 40%, respectively in Lawrence Creek three years following completion of habitat development. Permanent bank cover and gravel bottom increased by 416 and 11%, respectively. Positive substrate and cover changes resulting from the installation of stream channel structures were also found by Tarzwell (1937) and Horton (1957).

Groundwater additions caused a slightly higher stream discharge in the altered area versus the upstream unaltered area from May to October, 1977 (Fig. 3). Stream discharge varied seasonally. The altered area ranged from a low of $0.22 \text{ m}^3/\text{sec.}$ in July, 1977 to $.84 \text{ m}^3/\text{sec.}$ in September, 1977.

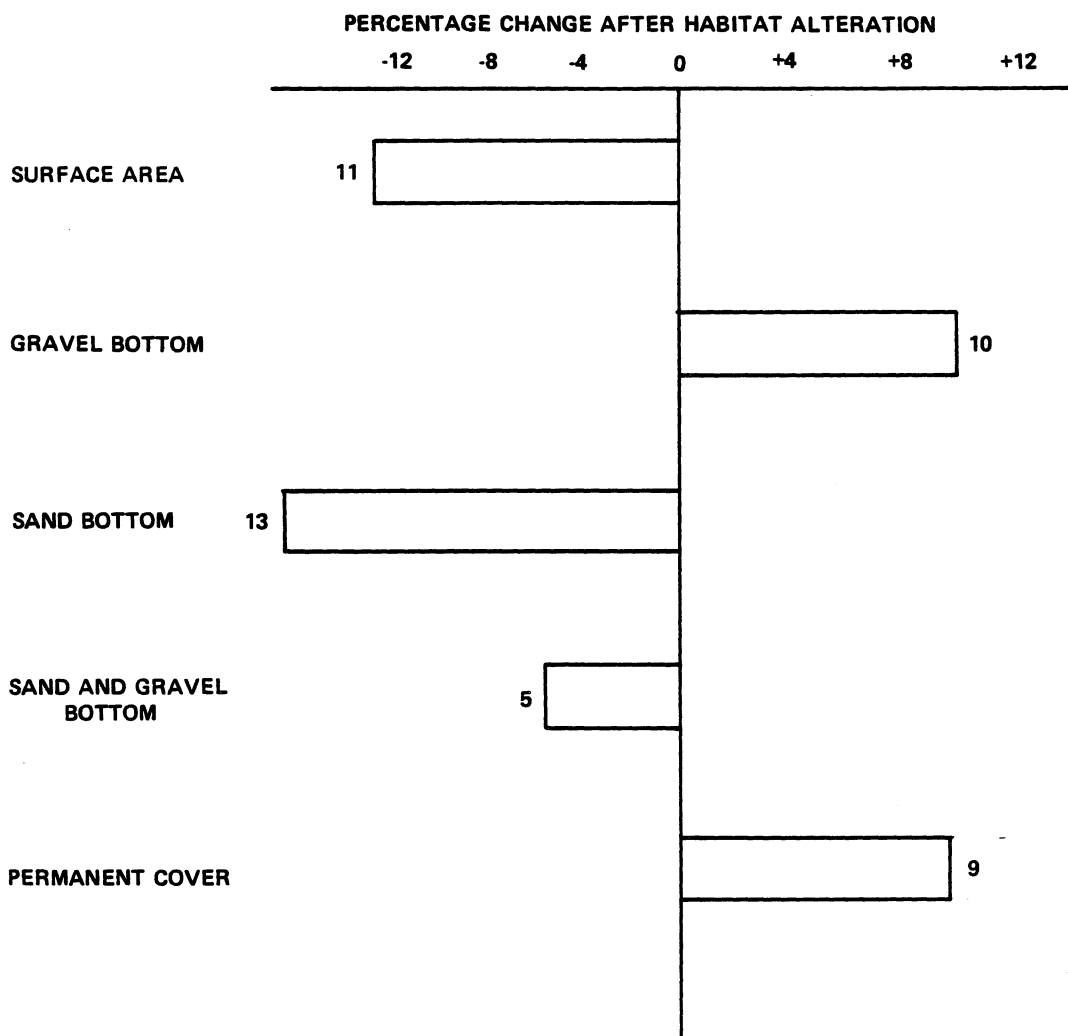


Figure 2. Average changes in several physical characteristics following completion of habitat alteration on Plum Creek, 1976-1977.

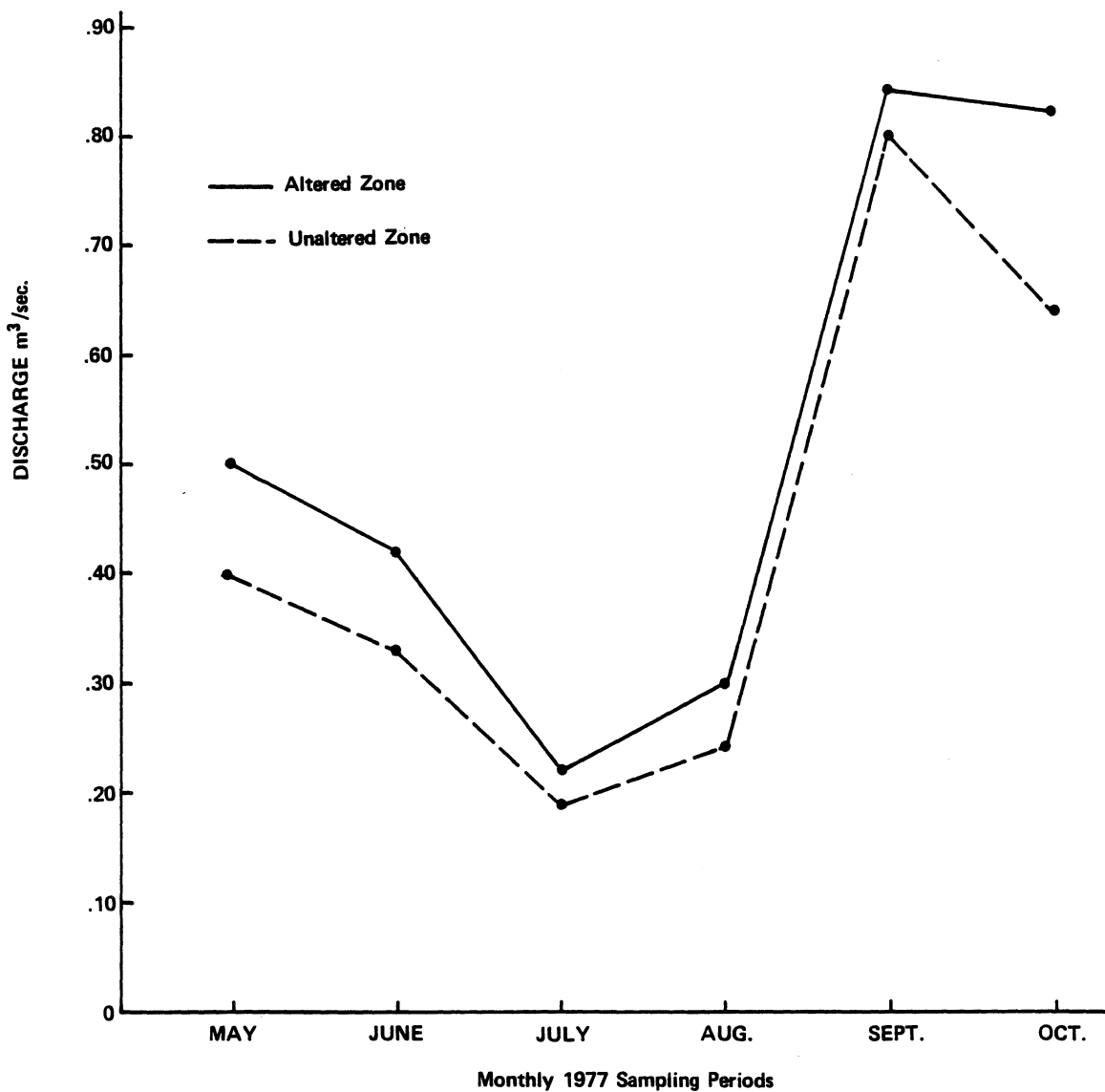


Figure 3. Monthly discharge ($\text{m}^3/\text{sec.}$) in the altered and unaltered areas of Plum Creek, May to October, 1977.

Benthic Invertebrates

Habitat alteration did not decrease the number of taxa present. There was a drastic initial reduction in mean numbers and biomass of benthic invertebrates. Seventeen months (October, 1977) after habitat alteration invertebrate numbers and weights from gravel and sand substrates were higher in the altered zone than the unaltered zone (Table 1). Trichoptera and Diptera accounted for 86.6% of the total numbers and 75.2% by weight for gravel substrate in the altered zone. Pelecypoda was most abundant in the unaltered zone sand substrate with 66.0% occurrence. Gravel substrate in the altered zone contained higher numbers and biomass of invertebrates than sand substrate.

The altered zone produced 76 identifiable taxa for gravel and sand substrates combined compared to 71 taxa for the unaltered zone (Table 1). Sand substrate yielded the highest number of taxa with 64 found in the altered zone to 57 for the unaltered zone. Gravel substrate in the unaltered zone contained 56 different taxa to 54 taxa in the altered zone.

Mean numbers and biomass for the altered zone gravel and sand substrates were significantly higher ($P < .05$) in 1977 than for 1976 (Table 1) (Appendix B). The physical disturbance of habitat alteration decreased mean numbers and biomass for altered zone gravel substrate ($1490/m^2$; $17.51 g/m^2$) and sand substrate ($317/m^2$; $14.50 g/m^2$) in 1976. The ability of invertebrates to repopulate disturbed areas after habitat alteration was shown by the higher 1977 mean numbers and biomass for both gravel and sand substrates. Gravel substrate recovered in 1977 with an increase in mean numbers ($5286/m^2$) of 255% and a 295% increase in weight ($79.4 g/m^2$) from 1976 means. The slowest recovery after

Table 1. Mean monthly benthic invertebrate numbers, biomass and standard deviation (s.d.) for gravel and sand substrates in the altered and unaltered habitat zones of Plum Creek, 1976-1977.

	Gravel				Sand			
	Altered		Unaltered		Altered		Unaltered	
	<u>Average Numbers/m²</u>							
May - 1976	1458.7	(3.2%)	2884.7	(6.2%)	465.6	(2.0%)	1690.1	(3.1%)
June	258.5	(0.6)	2142.0	(4.6)	131.9	(0.6)	818.2	(1.5)
July	452.3	(1.0)	1033.4	(2.2)	118.6	(0.5)	344.5	(0.6)
August	530.4	(1.2)	1571.7	(3.4)	113.2	(0.5)	177.6	(3.2)
September	2484.0	(5.4)	3842.8	(8.2)	342.1	(1.5)	1873.0	(3.4)
October	3756.7	(8.2)	9128.1	(19.5)	694.6	(3.0)	6512.3	(11.8)
1976 AVERAGE	1490	(19.6)	3434	(44.1)	327	(8.1)	1903	(23.6)
s.d.	1575		2959		306		2361	
April - 1977	7034.8	(15.3)	3870.2	(8.3)	2548.9	(10.9)	6561.1	(11.9)
May	3455.4	(7.5)	3429.7	(7.3)	1789.9	(7.7)	5840.0	(10.6)
June	5153.6	(11.2)	2977.2	(6.4)	2992.8	(12.8)	8170.7	(14.8)
July	4712.3	(10.3)	3816.3	(8.2)	3934.8	(16.8)	7234.3	(13.1)
August	2430.4	(5.3)	3157.1	(6.8)	2260.8	(9.7)	4876.2	(8.9)
September	6831.1	(14.9)	5248.4	(11.2)	3340.0	(14.3)	5362.7	(9.7)
October	7405.9	(16.1)	3725.6	(8.0)	4629.2	(19.8)	4060.3	(7.4)
1977 AVERAGE	5286	(80.4)	3746	(55.9)	3071	(91.9)	6179	(76.4)
s.d.	2773		1700		1973		3173	
TOTAL AVERAGE	3535.7		3602.1		1797.1		4240.0	
s.d.	2973		2074		2003		3521	
	<u>Average Weight g/m²</u>							
May - 1976	20.97	(3.2)	39.12	(4.6)	26.01	(5.3)	34.49	(1.8)
June	2.12	(0.3)	33.87	(4.0)	1.43	(0.3)	61.47	(3.1)
July	4.80	(0.7)	19.12	(2.3)	7.07	(1.4)	35.35	(1.8)
August	4.55	(0.7)	22.13	(2.6)	7.69	(1.6)	43.26	(2.2)
September	31.80	(4.8)	158.68	(18.7)	18.82	(3.8)	75.11	(3.8)
October	40.83	(6.2)	138.89	(16.3)	26.34	(5.4)	81.56	(4.2)
1976 AVERAGE	17.5	(15.9)	68.5	(48.5)	14.5	(17.8)	55.2	(16.9)
s.d.	19.5		62.9		16.6		20.5	
April - 1977	119.80	(18.1)	61.24	(7.2)	62.84	(12.8)	220.21	(11.2)
May	9.135	(15.0)	59.91	(7.1)	21.31	(4.4)	133.16	(6.8)
June	40.61	(6.2)	28.58	(3.4)	21.67	(4.4)	197.90	(10.1)
July	35.76	(5.4)	46.02	(5.4)	38.53	(7.9)	305.24	(15.5)
August	28.26	(4.3)	53.07	(6.2)	32.73	(6.7)	155.15	(7.9)

Table 1, continued.

	<u>Gravel</u>		<u>Sand</u>	
	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Unaltered</u>
	<u>Average Weight g/m², cont.</u>			
September	110.57 (16.7)	106.02 (12.5)	128.21 (26.2)	541.52 (27.5)
October	121.39 (18.4)	83.70 (9.8)	97.46 (19.9)	81.75 (4.2)
1977 AVERAGE	79.4 (84.1)	62.6 (51.5)	57.5 (82.2)	253.9 (83.1)
s.d.	70.4	38.6	51.9	190.4
TOTAL AVERAGE	50.8	65.4	37.7	151.2
s.d.	61.6	45.5	45.0	183.4

() = Percentage of total numbers and biomass

	<u>Number of Major Taxa</u>		
	<u>Gravel Substrate</u>	<u>Sand Substrate</u>	<u>Gravel and Sand Combined</u>
Altered Zone	54	64	76
Unaltered Zone	56	57	71

habitat alteration was in the sand substrate although the largest increase in numbers and weight occurred there. Sand substrate for 1977 yielded an 888% increase in mean numbers ($3071/m^2$) and a 295% increase in biomass ($57.5 g/m^2$). Denuded areas can quickly recover from physical disturbances (Moffett 1936; Kennedy 1955; Williams and Hynes 1976). Waters (1964) reported rapid colonization of a denuded gravel riffle by a drifting mayfly, Baetis sp., and the scud, Gammarus sp. Investigations showing rapid recovery of benthos following channelization (Rees 1959, Warner and Porter 1960, Burkhard 1967, Winger 1972) occurred in streams with stable gravel, rubble and vegetation-silt substrates for reattachment of drifting organisms.

Gravel substrate in the unaltered zone had a nine percent increase in mean numbers from 1976 to 1977 (1976, $3434/m^2$; 1977, $3746/m^2$) and a nine percent decrease in biomass (1976, $68.5 g/m^2$; 1977, $62.6 g/m^2$) (Table 1). Mean numbers and biomass of benthic invertebrates from sand substrate, however, were significantly higher ($P < .05$) in 1977 (Appendix B). All major benthic classes and orders except Oligochaeta displayed higher mean numbers and biomass in 1977 (Table 2). Ephemeroptera, Trichoptera and Diptera yearly differences were significant ($P < .05$) for both mean numbers and biomass. The inconsistency in the 1976-1977 sand substrate samples may have been due to the low 1976 stream flows and the addition of another 1977 sampling site.

A significant difference existed between 1977 mean numbers ($P < .2$) and biomass ($P < .5$) for gravel substrate between the altered and unaltered habitat zones (Table 1) (Appendix B). Gravel substrate numbers ($7406/m^2$) and biomass ($121.39 g/m^2$) in the altered zone 17 months (October, 1977) after habitat alteration were 99% and 45% higher,

Table 2. Mean numbers, biomass, standard deviation (s.d.) and level of significance (students t test $P < .05 - P < .5$) of benthic invertebrate class and orders for 1976 and 1977 sand substrate in the unaltered zone, Plum Creek.

	<u>Sand Substrate</u>							
	<u>1976 AVG.</u>		VS	<u>1977 AVG.</u>		<u>LEVEL OF SIGNIFICANCE</u>		
	<u>No./m²</u>	<u>Wt. g/m²</u>		<u>No./m²</u>	<u>Wt. g/m²</u>	P	<u>No.</u>	<u>Wt.</u>
OLIGOCHAETA	1281.0	0.21		608.0	0.06		.5	.4
(s.d.)	1613.0	0.23		1052.0	0.10			
ASELLOTA	0.0	0.0		65.0	0.44		.1	.2
(s.d.)			(s.d.)	114.0	1.0			
PLECOPTERA	0.0	0.0		66.0	0.61		.1	.1
(s.d.)			(s.d.)	123.0	1.18			
EPHEMEROPTERA	23.0	0.11		464.0	2.82		.05	.05
(s.d.)	12.0	1.0		706.0	3.95			
ODONATA	56.0	10.37		91.0	17.55		.4	.4
(s.d.)	43.0	10.5		61.0	13.1			
HEMIPTERA	0.0	0.0		1.5	0.01		-	-
(s.d.)			(s.d.)	6.0	0.005			
TRICHOPTERA	65.0	1.38		517.0	17.07		.05	.05
(s.d.)	54.0	1.74		453.0	7.73			
MEGALOPTERA	0.0	0.0		3.1	0.08		.2	.4
(s.d.)			(s.d.)	7.0	0.21			
COLEOPTERA	5.0	0.01		48.0	0.43		.1	.05
(s.d.)	6.0	.01		65.0	0.59			

Table 2, continued.

		<u>Sand Substrate</u>				<u>LEVEL OF SIGNIFICANCE</u>			
		<u>1976 AVG.</u>		VS	<u>1977 AVG.</u>		P	<u>No.</u>	<u>Wt.</u>
		<u>No./m²</u>	<u>Wt. g/m²</u>		<u>No./m²</u>	<u>Wt. g/m²</u>			
DIPTERA		397.0	3.79		3259.0	28.6		.05	.05
	(s.d.)	266.0	3.74		2586.0	26.2			
GASTROPODA		9.0	1.25		70.0	9.6		.1	.1
	(s.d.)	17.0	1.99		90.0	12.5			
PELECYPODA		370.0	37.9		969.0	171.2		.2	.05
	(s.d.)	328.0	15.3		754.0	173.2			

respectively, than the unaltered zone. Unaltered zone mean numbers ($6179/m^2$) and biomass ($253.9 g/m^2$) from sand substrate in 1977 were significantly ($P < .05$) higher than the altered zone. However, in the October, 1977 samples sand substrate in the altered zone contained 14% and 19% higher numbers and biomass ($4629/m^2$; $97.46 g/m^2$) than the unaltered zone ($4060/m^2$; $81.75 g/m^2$).

Most investigations show an increase in benthic invertebrate standing crop following from habitat alteration. Tarzwell (1936) found food was increased about three times, while Hazzard (1937) showed an increase of four to nine times that of the original bottom fauna. In a study of 10 improved New Mexico trout streams, seven showed an increase in invertebrate standing crop, two exhibited no change, and one decreased (Carufel 1968). Studies in Connecticut (Hunter et al. 1940), New Mexico (McKirdy 1965) and California (Gard 1961) also showed an increase in number and weight of desirable trout food items after structure installation. Negative responses in benthic standing crops by habitat alteration were reported by Madsen (1938), who claimed areas around devices contained 25% fewer food items, and Horton (1957) in a Rhode Island stream where numbers, diversity and weight declined. Horton, however, did not find the important fish food items to be affected. Shetter, Clark and Hazzard (1946) claimed that total number and bulk of organisms were slightly less after improvement, although number and bulk of organisms of proven value in trout nutrition were greater than before. He noted that some unimportant trout food organisms showed little tendency to invade the improved section.

Plum Lake appears to have the greatest influence on the invertebrate composition found in both Plum Creek habitat study zones. Filter

feeding invertebrates, particularly Hydropsychidae and Simuliidae are abundant below lakes because of an increase in planktonic food (Hynes 1970). Cushing (1963) found filter-feeding Trichoptera (primarily Hydropsyche sp.) and Ephemeroptera (primarily Ephemerella sp.) larvae were more abundant below a series of productive lakes than above the lakes. The benthic invertebrate community in Plum Creek was also dominated by filter-feeding invertebrates.

Diptera and Trichoptera, which are important trout food, dominated the gravel substrates in both the altered and unaltered 1976-1977 habitat zones (Tables 3-4). Diptera, Odonata and Pelecypoda were the most abundant in sand substrate.

The altered habitat zone was dominated by Diptera and Trichoptera (Table 3). These orders accounted for 86.6% by numbers and 75.2% by weight for gravel substrate and 71.7% by numbers and 31.4% by weight for sand substrate. The majority (52%) of the sand substrate biomass was comprised of Pelecypoda and Odonata.

Major invertebrate families in the altered zone within the Diptera, Trichoptera and Odonata orders were Chironomidae, Hydropsychidae and Gomphidae, respectively. These families accounted for 72.9% by numbers and 83.2% by weight for gravel substrate and 60.2% for sand substrate numbers and 39.6% by weight. The family Gomphidae are primarily burrowers in silt or sand substrate. Their carnivorous feeding habits and the displacement caused by habitat alteration would also explain their abundance in gravel substrate. Chironomidae and Hydropsychidae are among the most abundant and widespread aquatic insect families, adapting rapidly to substrate and niche changes (Hilsenhoff 1975). Their feeding habits, which are stimulated by the amount of organic drift found in

Table 3. Mean numbers (no./m²) and biomass (g/m²) of benthic invertebrates by major identifiable taxa equal to or exceeding 2% of the average total collected in either gravel or sand substrate for the altered zone of Plum Creek, 1976-1977.

	<u>GRAVEL SUBSTRATE</u>				<u>SAND SUBSTRATE</u>			
		<u>No./m²</u>		<u>g/m²</u>		<u>No./m²</u>		<u>g/m²</u>
OLIGOCHAETA	34	(1.0)	.01	(.02)	93	(5.2)	.03	(.08)
DECAPODA					.2	(.01)	1.0	(2.8)
PLECOPTERA	104	(2.9)	.75	(1.4)	26	(1.4)	.15	(.4)
Nemouridae								
<u>Nemoura</u>	86	(2.4)	.58	(1.1)	11	(.6)	.08	(.2)
Ephemeroptera	107	(3.2)	1.07	(2.1)	136	(7.7)	.6	(1.4)
EphemereIllidae								
<u>EphemereIIa</u>	80	(2.3)	.95	(1.9)	10	(.6)	.05	(.1)
Tricorythidae								
<u>Tricorythodes</u>	9	(.3)	.03	(.06)	102	(5.7)	.40	(1.0)
ODONATA	79	(2.3)	9.64	(19.0)	60	(3.3)	9.5	(25.2)
Gomphidae	79	(2.3)	9.24	(18.2)	55	(3.1)	7.8	(20.7)
<u>Ophiogomphus</u>	76	(2.2)	9.18	(18.1)	44	(2.5)	5.5	(14.5)
<u>Stylurus</u>	3	(.1)	.06	(.1)	11	(.6)	2.3	(6.2)
Libellulidae					2	(.1)	.8	(2.1)
<u>Ladona</u>					.8	(.05)	.7	(2.0)
TRICHOPTERA	1373	(38.9)	27.4	(53.9)	169	(9.3)	3.3	(8.7)
Hydropsycidae	1231	(34.8)	25.5	(50.2)	124	(6.9)	2.2	(5.8)
Rhyacophilidae								
<u>Rhyacophilia</u>	78	(2.2)	.52	(1.0)	11	(.6)	.05	(.1)
COLEOPTERA	136	(3.9)	.64	(1.3)	17	(1.0)	.1	(.3)
Elmidae	135	(3.9)	.63	(1.3)	16	(1.0)	.1	(.3)
<u>Optioservus</u>	69	(2.0)	.35	(.7)	11	(.6)	.06	(.2)
DIPTERA	1685	(47.7)	10.8	(21.3)	1027	(57.1)	8.6	(22.7)
Chironomidae	1267	(35.8)	7.5	(14.8)	903	(50.2)	4.9	(13.1)
Simuliidae	197	(5.6)	1.5	(2.9)	35	(1.9)	.2	(.5)

Table 3, continued.

	<u>GRAVEL SUBSTRATE</u>				<u>SAND SUBSTRATE</u>			
		<u>No./m²</u>		<u>g/m²</u>		<u>No./m²</u>		<u>g/m²</u>
Ceratopogonidae	6	(.2)	.01	(.02)	41	(2.3)	.3	(.7)
Tipulidae	147	(4.1)	1.66	(3.3)	14	(.8)	2.7	(7.2)
<u>Antocha</u>	132	(3.7)	.8	(1.6)	9	(.5)	.1	(.3)
<u>Tipula</u>	8	(.2)	.83	(1.6)	4	(.2)	2.6	(6.9)
GASTROPODA	.4	(.01)	.09	(.2)	21	(1.2)	2.8	(7.5)
PELECYPODA	12	(.4)	.32	(.6)	241	(13.4)	10.2	(27.0)
TOTAL	3530	(100.3)	50.72	(99.8)	1790	(99.6)	36.28	(96.1)
OVERALL TOTAL	3538		50.80		1797		37.7	

() Percentages of the total numbers and weight

streams below a lake outlet, also contribute greatly to their abundance.

Diptera and Trichoptera in the unaltered zone gravel substrate accounted for 80.8% by numbers and 61.4% by weight occurrence (Table 4). Oligochaeta, Pelecypoda and Diptera comprised 81.5% of the total numbers and 77.4% of the weight for sand substrate. Chironomidae and Hydropsychidae were the only insect families which accounted for over 20.0% of the total unaltered zone numbers or biomass. These families comprised 58.3% by numbers and 28.8% by weight for gravel substrate and 43.2% for sand substrate, although only 7.7% by numbers for sand substrate.

Chironomidae and Hydropsychidae were the most consistent and abundant insect families found by substrate type in both habitat zones. These families also displayed considerable monthly fluctuations (Fig. 4-5). Hydropsychidae in the unaltered zone gravel substrate ranged from a low of 178/m² in June, 1977 to 5,242/m² in October, 1976. Chironomidae ranged from 124/m² in August, 1976 to 3,592/m² in June, 1977 for the altered zone gravel substrate (Fig. 4). Chironomidae in the unaltered zone sand substrate ranged from 43/m² in August, 1976 to 2,546/m² for July, 1977 (Fig. 5). These families demonstrated the ability to recover rapidly from the initial disturbance effect of the 1976 habitat alteration and adapt to almost every type of aquatic habitat.

The months of September and October for both 1976 and 1977 contained the highest invertebrate totals. September and October, 1976 in the unaltered zone accounted for 35% by weight of the 1976-1977 monthly totals (Table 1). September, 1977 sand substrates in the altered and unaltered zones accounted for 26.2% and 27.5% respectively by weight of the 1976-1977 monthly totals. October, 1977 gravel substrate in the altered zone accounted for 18.4% occurrence by weight.

Table 4. Mean numbers (no./m²) and biomass (g/m²) of benthic invertebrates by major identifiable taxa equal to or exceeding 2% of the average total collected in either gravel or sand substrate for the unaltered zone of Plum Creek, 1976-1977.

	<u>GRAVEL SUBSTRATE</u>				<u>SAND SUBSTRATE</u>			
	<u>No./m²</u>		<u>g/m²</u>		<u>No./m²</u>		<u>g/m²</u>	
OLIGOCHAETA	32	(.9)	.01	(.01)	919	(21.7)	.13	(.08)
PLECOPTERA	42	(1.3)	1.61	(2.4)	35	(.8)	.33	(.2)
EPHEMEROPTERA	322	(9.0)	1.17	(1.8)	261	(6.2)	1.57	(1.1)
Ephemerellidae								
<u>Ephemerella</u>	241	(6.7)	.87	(1.3)	46	(1.1)	.25	(.2)
Tricorythidae								
<u>Tricorythodes</u>	53	(1.5)	.17	(.3)	156	(3.7)	.54	(.4)
ODONATA	74	(2.0)	11.31	(17.3)	75	(1.8)	14.2	(9.4)
Gomphidae	74	(2.0)	11.31	(17.3)	62	(1.5)	11.0	(7.3)
<u>Ophiogomphus</u>	73	(2.0)	11.30	(17.3)	55	(1.3)	9.8	(6.5)
Cordulegastridae								
<u>Cordulegaster</u>					4	(.1)	3.0	(2.0)
TRICHOPTERA	1597	(44.6)	22.83	(34.8)	308	(7.3)	9.83	(6.4)
Hydropsycidae	1259	(35.0)	16.42	(25.1)	210	(5.0)	4.13	(2.7)
Brachycentridae					36	(.8)	.41	(.3)
<u>Brachycentrus</u>	88	(2.5)	1.19	(1.8)	31	(.7)	.38	(.3)
Helicopsychidae								
<u>Helicopsyche</u>	129	(3.6)	3.47	(5.3)	39	(.9)	1.72	(1.1)
Rhyacophilidae								
<u>Rhyacophila</u>	71	(2.0)	.4	(.6)	2	(.05)	.02	(.02)
Limnephilidae	6	(.2)	1.02	(1.5)	15	(.4)	3.5	(2.2)
<u>Pycnopsyche</u>	4	(.1)	.81	(1.2)	11	(.3)	3.1	(2.0)
COLEOPTERA	151	(4.8)	.73	(1.1)	28	(.7)	.24	(.2)
Elmidae	150	(4.2)	.71	(1.1)	28	(.7)	.24	(.2)
<u>Optioservus</u>	99	(2.8)	.44	(.7)	20	(.5)	.14	(.09)

Table 4, continued.

	<u>GRAVEL SUBSTRATE</u>				<u>SAND SUBSTRATE</u>			
	<u>No./m²</u>		<u>g/m²</u>		<u>No./m²</u>		<u>g/m²</u>	
DIPTERA	1299	(36.2)	17.4	(26.6)	1917	(45.4)	17.2	(11.3)
Chironomidae	841	(23.3)	2.39	(3.7)	1620	(38.2)	7.6	(5.0)
Simuliidae	131	(3.6)	.9	(1.4)	178	(4.2)	1.2	(.8)
Tipulidae	245	(6.9)	12.63	(19.3)	38	(1.0)	4.1	(2.6)
<u>Antocha</u>	98	(2.7)	.4	(.6)	6	(.2)	.01	(.01)
<u>Dicranota</u>	101	(2.8)	2.16	(3.3)	7	(.2)	.16	(.1)
<u>Tipula</u>	13	(.4)	8.89	(13.6)	8	(.2)	3.2	(2.1)
Rhagionidae								
<u>Atherix</u>	57	(1.6)	1.34	(2.0)	26	(.6)	3.1	(2.1)
GASTROPODA	12	(.3)	1.85	(2.8)	35	(.8)	4.7	(3.1)
PELECYPODA	68	(1.9)	8.19	(12.5)	612	(14.4)	99.8	(66.0)
TOTAL	3597	(101.0)	65.1	(99.3)	4190	(99.1)	148	(97.8)
OVERALL TOTAL	3602		65.4		4240		151.2	

() Percentages of the total numbers and weight

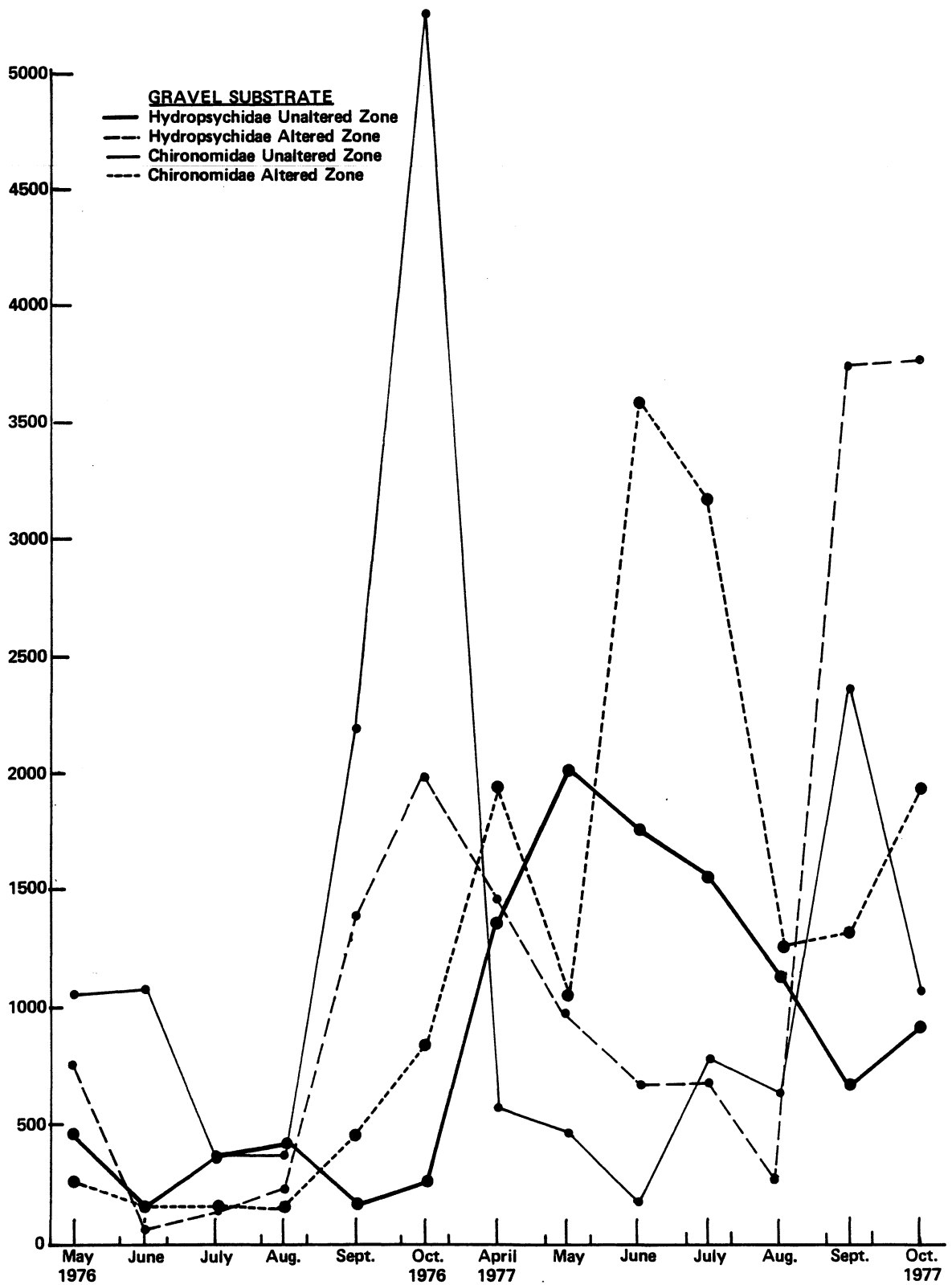


Figure 4. Invertebrate families Hydropsychidae and Chironomidae monthly mean benthic no./m² for gravel substrate in the altered and unaltered habitat zones in Plum Creek, 1976-1977.

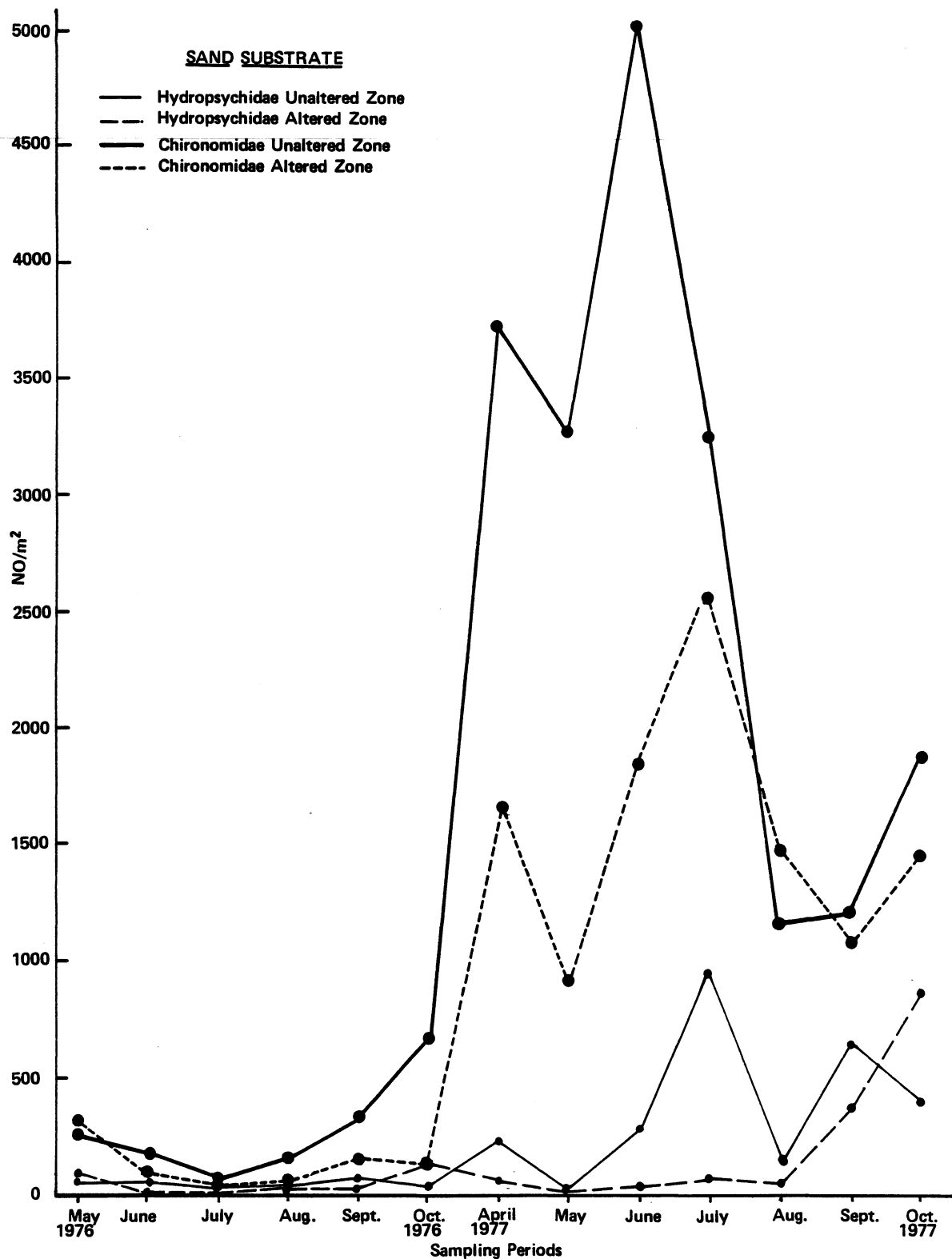


Figure 5. Invertebrate families Hydropsychidae and Chironomidae monthly mean benthic no./m² for sand substrate in the altered and unaltered habitat zones in Plum Creek, 1976-1977.

Substrate is an important environmental factor affecting the qualitative and quantitative distribution and abundance of benthic macro invertebrates (Tarzwell 1937, Smith and Moyle 1944, Pennak and Van Gerpen 1947, Cummins 1966, Eriksen 1966, Thorup 1966, Egglshaw 1969, Barber and Kerven 1973). Gravel substrate in the altered zone was significantly higher ($P < .05$) than sand substrate when comparing mean numbers for 1976, 1977 and 1976-1977 (Appendix B). Mean biomass comparisons between altered zone gravel and sand substrates were not highly significant, only $P < .4$ for 1976 and 1976-1977. A general increase in benthic populations has been found to occur with increasing sediment particle size (Smith and Moyle 1944, Pennak and Van Gerpen 1947). There was, however, no significant difference between the unaltered zone gravel and sand substrate in 1976. Gravel substrate was significantly lower for 1977 unaltered mean numbers ($P < .1$), biomass ($P < .05$) and 1976-1977 mean numbers ($P < .4$) and biomass ($P < .05$).

Drift

Habitat alteration did not change the number of taxa found in the drift (Table 5). The unaltered zone, however, contained significantly higher ($P < .05$) numbers and biomass of drifting organisms (Table 5). Seasonal and diel variations occurred in the drift. Mean numbers and biomass of aquatic invertebrates in the drift were significantly higher ($P < .05$) than terrestrial invertebrates. Differences in correlations existed between monthly particulate organic carbon and invertebrate number densities by habitat zones.

Eighty-six identifiable taxa were found in the altered zone compared to 84 in the unaltered zone (Table 5). The highest number of taxa found by time period was one-half hour after sunset for the altered (52) and unaltered (54) habitat zones. There were 27 benthic taxa not found in the drift in both study zones (Appendix C).

The unaltered zone contained 86% higher numbers and 310% higher biomass (7013/100 m³; 166.18 g/100 m³) of drifting organisms than the altered zone (3772/100 m³; 40.53 g/100 m³). Of the aquatic insects, Diptera and Plecoptera had the largest significant differences between mean numbers and biomass by habitat zones (Table 6). In the unaltered zone Diptera, primarily Chironomidae larvae and adult Diptera, accounted for 2328/100 m³ more organisms than the altered zone. Decapoda, which comprised 48.4% of the unaltered zone biomass, accounted for 80.0 g/100 m³ more weight than the altered zone totals. There was no significant difference in mean numbers and biomass of any other taxa.

The proportional occurrence of species in the drift is generally very similar to that in the stream benthos (McLay 1968; Dimond 1967; Muller 1954; Waters 1961, 1962, 1965, 1966). This population density

Table 5. Monthly and time sampling period total numbers (No./100m³) and biomass (g/100m³) of aquatic (A), terrestrial (T) and total (TO) drift by habitat zones in Plum Creek, May to October, 1977.

		<u>½ Hour Before Sunrise</u>		<u>½ Hour After Sunrise</u>		<u>Noon</u>		<u>½ Hour Before Sunset</u>		<u>½ Hour After Sunset</u>		<u>Total (Percentages)</u>		
		<u>No./100m³</u>	<u>g/100m³</u>	<u>No.</u>	<u>Wt.</u>	<u>No.</u>	<u>Wt.</u>	<u>No.</u>	<u>Wt.</u>	<u>No.</u>	<u>Wt.</u>	<u>No.</u>	<u>Wt.</u>	
<u>May -</u>	<u>Unaltered</u>	A	320.4	1.54	281.5	1.56	194.2	1.37	269.5	9.46	1067.0	24.16	2131.8 (97.2)	37.95 (98.5)
		T	16.2	.26	6.5	.03	15.1	.10	3.3	.02	20.5	.22	61.5 (2.8)	.57 (1.5)
		TO	336.6	1.80	288.0	1.59	209.3	1.47	272.8	9.48	1087.5	24.38	2193.3	38.52
	<u>Altered</u>	A	28.0	1.11	24.8	1.57	33.6	2.24	48.0	2.51	357.7	4.43	492.1 (99.2)	11.75 (99.2)
		T	.8	.01	2.4	.01	1.6	.07	0	0	6.4	.03	4.0 (.8)	.10 (.8)
		TO	28.8	1.12	27.2	1.58	35.2	2.31	48.0	2.51	364.1	4.46	496.1	11.85
<u>June -</u>	<u>Unaltered</u>	A	161.6	2.38	85.0	4.68	185.8	2.01	173.0	.98	364.9	3.57	965.7 (89.0)	13.63 (97.0)
		T	35.4	.09	5.7	.03	59.5	.20	11.4	.07	7.1	.03	119.1 (11.0)	.42 (3.0)
		TO	197.0	2.47	90.7	4.71	245.3	2.21	184.4	1.05	372.0	3.60	1084.8	14.05
	<u>Altered</u>	A	105.9	1.73	73.8	.39	62.2	1.23	90.9	.35	134.8	1.34	466.8 (97.0)	5.01 (98.6)
		T	1.9	.01	1.9	.01	3.9	.05	3.8	.02	2.9	.02	14.3 (3.0)	.07 (1.4)
		TO	107.8	1.74	75.7	.40	66.1	1.28	94.7	.37	137.7	1.36	481.1	5.08

Table 5, continued.

		<u>½ Hour Before Sunrise</u>		<u>½ Hour After Sunrise</u>		<u>Noon</u>		<u>½ Hour Before Sunset</u>		<u>½ Hour After Sunset</u>		<u>Total (Percentages)</u>	
		<u>No./100m³</u>	<u>g/100m³</u>	<u>No.</u>	<u>Wt.</u>	<u>No.</u>	<u>Wt.</u>	<u>No.</u>	<u>Wt.</u>	<u>No.</u>	<u>Wt.</u>	<u>No.</u>	<u>Wt.</u>
<u>July -</u> Unaltered	A	58.4	.57	41.9	.81	79.6	.19	65.3	1.84	459.3	81.67	699.3 (88.7)	85.02 (99.5)
	T	16.4	.05	4.6	.02	28.1	.12	18.8	.16	21.1	.09	89.2 (11.3)	.42 (.5)
	T0	74.8	.62	46.5	.83	107.7	.31	84.1	2.0	480.4	81.76	788.5	85.44
Altered	A	91.5	.31	41.4	.65	121.1	2.38	158.9	.67	136.7	1.13	567.4 (89.4)	5.08 (85.0)
	T	3.5	.01	3.5	.05	36.3	.12	19.0	.72	5.2	.04	67.4 (10.6)	.90 (15.0)
	T0	95.0	.32	44.9	.70	157.4	2.50	177.9	1.39	141.9	1.17	634.8	5.98
<u>August -</u> Unaltered	A	409.4	2.09	225.6	4.76	139.5	1.36	285.8	2.06	523.8	7.76	1529.4 (84.4)	17.97 (95.7)
	T	5.4	.07	169.3	.42	56.4	.17	8.9	.04	42.4	.13	282.0 (15.6)	.80 (4.3)
	T0	414.8	2.16	394.9	5.18	195.9	1.53	294.7	2.10	566.2	7.89	1811.4	18.77
Altered	A	367.8	1.66	404.7	3.02	170.9	1.04	161.6	1.54	186.5	2.13	1291.8 (94.1)	8.33 (96.0)
	T	14.3	.06	28.7	.11	20.9	.06	5.2	.09	11.7	.06	80.9 (5.9)	.35 (4.0)
	T0	382.1	1.72	433.4	3.13	191.8	1.10	166.8	1.63	198.2	2.19	1372.7	8.68

Table 5, continued.

		<u>½ Hour Before Sunrise</u>		<u>½ Hour After Sunrise</u>		<u>Noon</u>		<u>½ Hour Before Sunset</u>		<u>½ Hour After Sunset</u>		<u>Total (Percentages)</u>	
		<u>No./100m³</u>	<u>g/100m³</u>	<u>No.</u>	<u>Wt.</u>	<u>No.</u>	<u>Wt.</u>	<u>No.</u>	<u>Wt.</u>	<u>No.</u>	<u>Wt.</u>	<u>No.</u>	<u>Wt.</u>
<u>September - Unaltered</u>	A	141.6	.69	105.3	.45	143.8	.45	58.4	.17	93.1	.87	606.3 (97.6)	2.47 (81.3)
	T	2.8	.50	3.8	.02	2.8	.06	1.8	.02	3.8	.02	15.1 (2.4)	.57 (18.7)
	T0	144.4	1.19	109.1	.47	146.6	.51	60.2	.19	96.9	.89	621.4	3.04
<u>Altered</u>	A	166.8	1.04	117.2	.25	76.8	1.14	106.9	1.38	81.3	.68	551.5 (93.2)	4.22 (95.1)
	T	23.7	.05	3.6	.03	3.5	.10	5.0	.04	5.7	.07	40.3 (6.8)	.22 (4.9)
	T0	190.5	1.09	120.8	.28	80.3	1.24	14.9	1.42	87.0	.75	591.8	4.44
<u>October - Unaltered</u>	A	27.8	1.08	21.2	.20	78.4	1.14	219.6	1.28	162.0	2.06	507.5 (99.2)	5.47 (99.5)
	T	0	0	0	0	2.3	.01	1.6	.02	0	0	3.9 (.8)	.03 (.5)
	T0	27.8	1.08	21.2	.20	80.7	1.15	221.2	1.30	162.0	2.06	511.4	5.50
<u>Altered</u>	A	31.5	.40	17.0	.48	39.1	.43	59.4	.22	56.9	1.20	203.4 (98.6)	2.32 (98.7)
	T	.5	.01	1.0	.01	.5	.01	1.0	.01	0	0	2.9 (1.4)	.03 (1.3)
	T0	32.0	.41	18.0	.49	39.6	.44	60.4	.23	56.9	1.20	206.3	2.35

Table 5, continued.

	<u>½ Hour Before Sunrise</u>		<u>½ Hour After Sunrise</u>		<u>Noon</u>		<u>½ Hour Before Sunset</u>		<u>½ Hour After Sunset</u>		<u>Total (Percentages)</u>		
	<u>No./100m³</u>	<u>g/100m³</u>	<u>No.</u>	<u>Wt.</u>	<u>No.</u>	<u>Wt.</u>	<u>No.</u>	<u>Wt.</u>	<u>No.</u>	<u>Wt.</u>	<u>No.</u>	<u>Wt.</u>	
<u>TOTAL -</u>													
<u>Unaltered</u>	A	1119.2 (93.6)	8.35 (89.6)	760.5 (80.0)	12.46 (96.0)	821.3 (83.3)	6.52 (90.8)	1071.6 (95.9)	15.79 (98.0)	2670.1 (96.6)	120.09 (96.6)	6440.0 (91.9)	162.51 (98.3)
	T	76.2 (6.4)	.97 (10.4)	189.9 (20.0)	.52 (4.0)	164.2 (16.7)	.66 (9.2)	45.8 (4.1)	.33 (2.0)	94.9 (3.4)	.49 (.4)	570.8 (8.1)	2.81 (1.7)
	T0	1195.4	9.32	950.4	12.98	985.5	7.18	1117.4	16.12	2765.0	120.58	7010.8	165.32
<u>Altered</u>	A	791.5 (94.7)	6.25 (97.7)	678.9 (94.3)	6.36 (96.7)	503.7 (88.3)	8.46 (95.4)	625.7 (94.8)	6.67 (88.8)	953.9 (96.8)	10.91 (98.0)	3573.0 (94.5)	36.71 (95.7)
	T	44.7 (5.3)	.15 (2.3)	41.1 (5.7)	.22 (3.3)	66.7 (11.7)	.41 (4.6)	34.0 (5.2)	.88 (11.2)	31.9 (3.2)	.22 (2.0)	209.8 (5.5)	1.67 (4.3)
	T0	836.2	6.40	720.0	6.58	570.4	8.87	659.7	7.55	985.8	11.13	3782.8	38.38
<u>NUMBER OF TAXA -</u>													
<u>Unaltered</u>			51		42		37		49		56		84
<u>Altered</u>			50		43		51		51		52		86

Table 6. Mean numbers, biomass, standard deviation (s.d.) and level of significance (students t test $P < .05$ - $P < .5$) of major drifting invertebrate class and orders and fish in the altered and unaltered habitat zones of Plum Creek, 1977.

	<u>Altered Zone</u>		<u>Unaltered Zone</u>		<u>Level of Significance</u>	
	<u>No./100m³</u>	<u>g/100m³</u>	<u>No./100m³</u>	<u>g/100m³</u>	<u>No.</u>	<u>Wt.</u>
DECAPODA	0.03	.0007	.31	2.67	-	.05
(s.d.)	.18	.004	1.72	14.61		
PLECOPTERA	1.4	0.03	4.27	0.25	.05	.05
(s.d.)	1.5	0.05	4.8	0.46		
EPHEMEROPTERA	9.5	0.05	12.4	0.07	-	.5
(s.d.)	11.1	0.04	13.6	0.09		
ODONATA	4.1	0.60	3.8	0.70	-	-
(s.d.)	5.1	0.70	5.2	0.85		
TRICHOPTERA	16.4	0.22	19.4	0.53	-	.4
(s.d.)	12.3	0.23	23.7	1.26		
DIPTERA	76.8	0.17	155.0	0.40	.1	.2
(s.d.)	81.7	0.19	147.6	0.59		
PELECYPODA	2.0	0.07	0.63	0.05	.4	-
(s.d.)	6.0	0.19	1.5	0.11		
FISH	1.6	0.06	7.2	0.60	.5	.4
(s.d.)	6.9	0.25	6.5	0.56		

related theory was analyzed in Plum Creek by the Chi Square (X^2) test with the following hypothesis: The proportion of major aquatic insect taxa in the combined benthic substrates and drift would not be statistically different. The unaltered zone overall displayed higher similarities, although for the major insect orders (Odonata, Trichoptera, Diptera) and families (Gomphidae, Hydropsychidae, Chironomidae, Simuliidae) combined the hypothesis would be accepted for both habitat zones (Appendix D). Individual taxa deviations can be accounted for in terms of behavior or structure of the organisms (McLay 1968).

Lake plankters as well as benthic organisms from the lake outlet are swept by the current away from their habitual environments and transported downstream. The effect of Plum Lake on drift density between habitat zones is unknown, although the lake outflow should produce higher densities in the unaltered zone. Several studies have been conducted on the fate of lake or reservoir plankton in the outlet stream (Chandler 1937, 1939; Reif 1939; Hartman and Heines 1961) with the general consensus that there is a decrease in numbers of organisms with distance below the outlet. The unaltered zone is 1.1 km below Plum Lake compared to 6.5 km for the altered zone.

Invertebrate drift in May and August for the unaltered zone comprised 57.9% of the total monthly numbers and by biomass May and July accounted for 74.8%. In the altered zone July and August drift contained 52.7% of the total monthly numbers with May and July drift accounting for 44.6% by weight (Fig. 6). Diel variations were also found. The one-half hour before and after sunset drift samples accounted for a large proportion (55.4 and 43.6% by numbers and 82.3 and 46.1% by weight) of the diel drift for the unaltered and altered zones, respectively

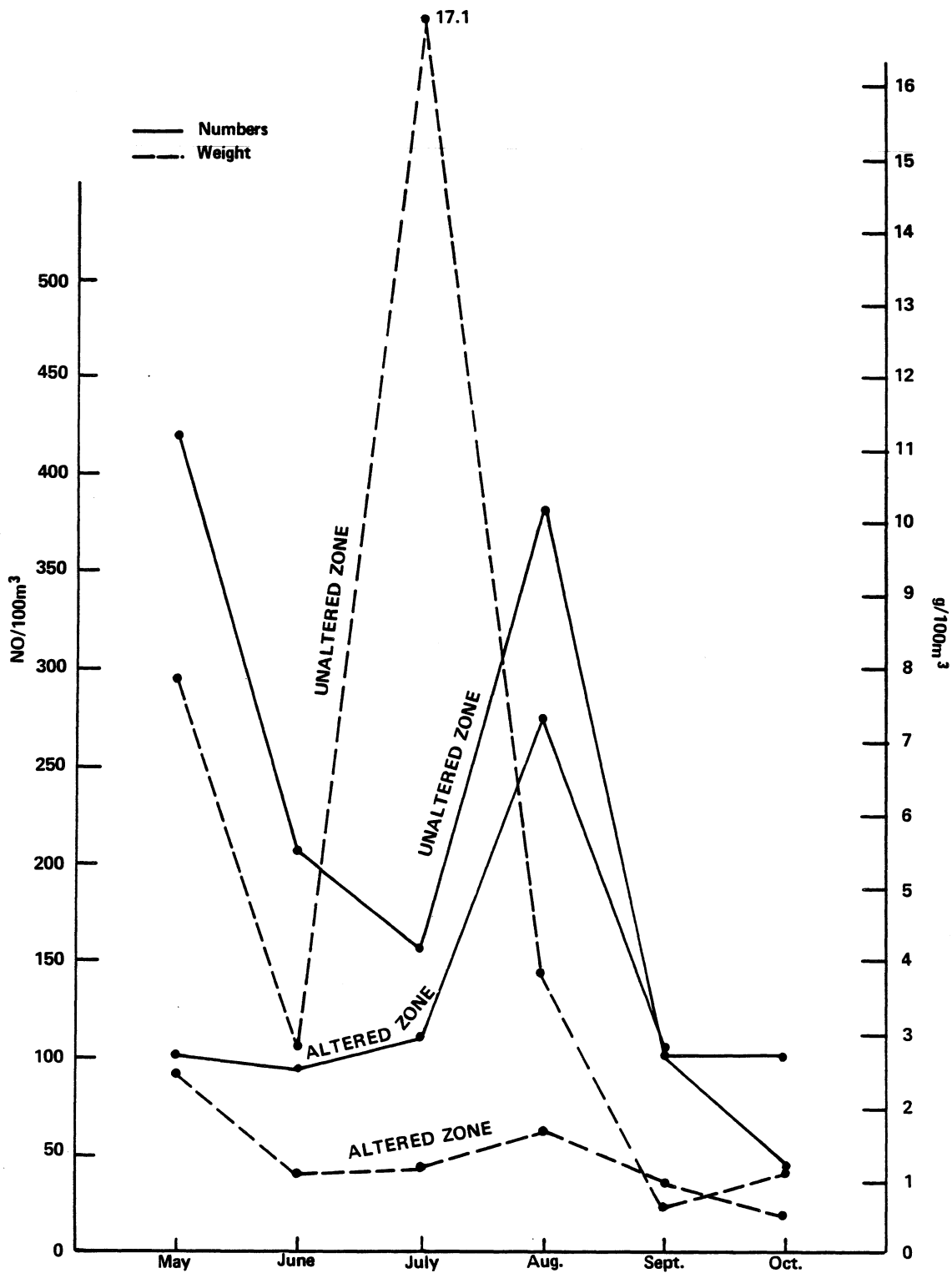


Figure 6. Seasonal drift mean numbers (no./100m³) and weight (g/100m³) for the altered and unaltered study zones in Plum Creek, May to October, 1977.

(Fig. 7). Several different drift patterns for aquatic invertebrates have been reported. Many species have a nocturnal drift peak (Waters 1962; Kroger 1974), while others drift with no apparent diel rhythm (Dendy 1944; Horton 1961; Waters 1961, 1962).

Terrestrial invertebrates in the drift vary by order and abundance on a diel and seasonal basis. Aquatic invertebrates in Plum Creek dominated the drift by time periods and months in both the altered and unaltered zones (Table 5). Terrestrial invertebrates comprised only 4.3% and 1.7% of the altered and unaltered zones' biomass, respectively, by time period. The July sample from the altered zone contained the highest number of terrestrials (10.6% by numbers and 15.0% by biomass), while the August sample by numbers (15.6%) and September (18.7% by weight) were high in the unaltered zone. The one-half hour after sunrise and noon diel time periods by numbers in the unaltered zone contained 20.0% and 16.7% terrestrial invertebrates, respectively. The altered zone noon time period was high with 11.7% terrestrials by numbers. Elliott (1967) reported that terrestrial drift in a small English stream was most abundant during the summer days. Chaston (1969) found terrestrial drift most abundant in the summer and fall days. Jenkins et al. (1970) observed more terrestrial drift during the summer midday and afternoon periods.

Diptera, Trichoptera and Odonata, the most abundant insect orders found in the benthic samples, were also the most frequent in the drift (Table 7). Diptera dominated the drift for both the altered and unaltered habitat zones, comprising 61.4% and 66.3% of the total numbers, respectively. Trichoptera, Diptera and Odonata accounted for 75.0% of the total, by weight, in the altered zone and 55.7% in the unaltered zone.

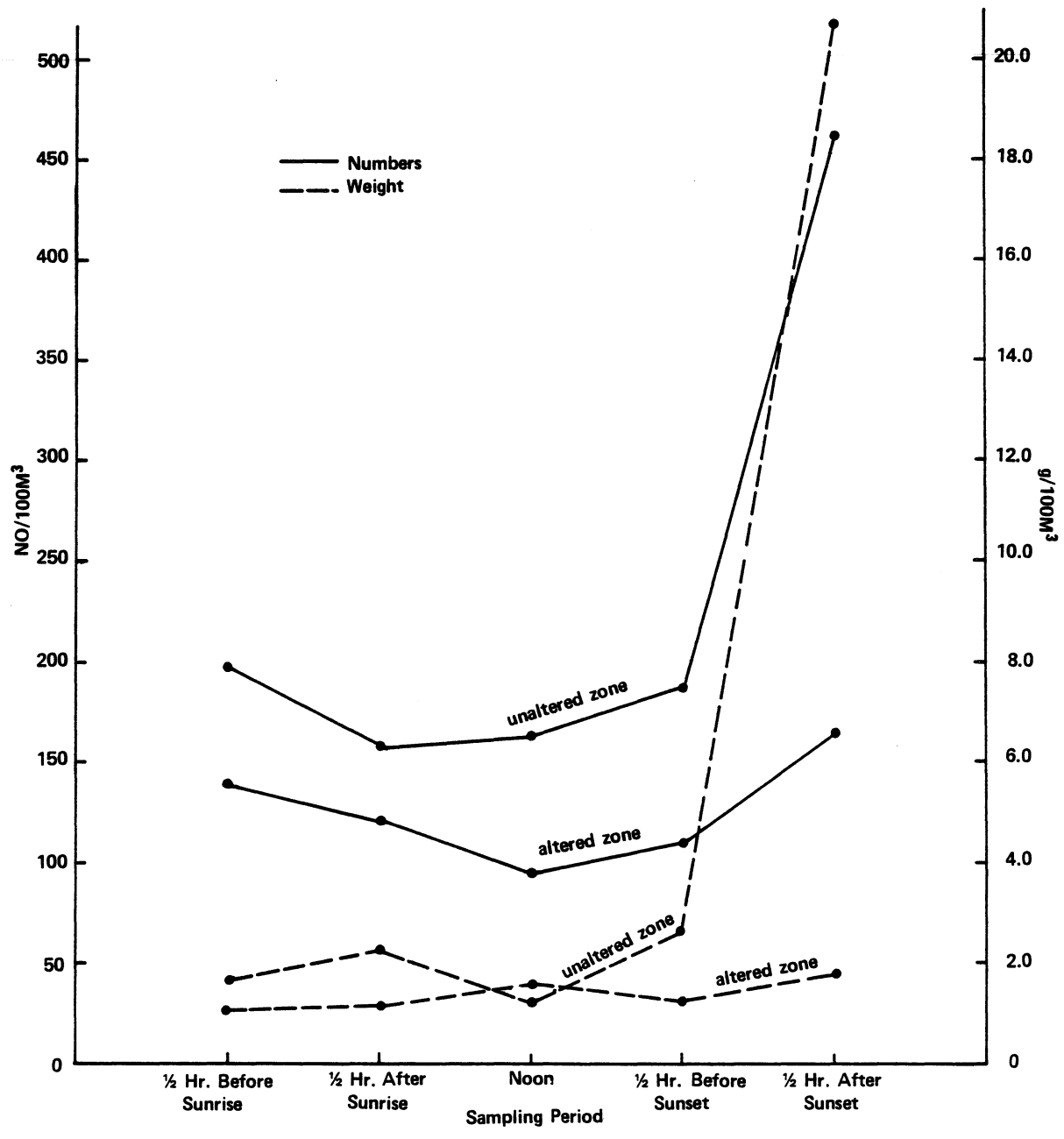


Figure 7. Diel drift mean numbers (no./100m³) and weight (g/100m³) for the altered and unaltered study zones in Plum Creek, May to October, 1977.

Table 7. Total numbers (No./100m³) and biomass (g/100m³) of drifting organisms by major identifiable taxa equal to or exceeding 2% of the average total collected in either the altered or unaltered zone of Plum Creek, May to October, 1977.

	<u>Altered Zone</u>				<u>Unaltered Zone</u>			
	<u>No.</u>		<u>Wt.</u>		<u>No.</u>		<u>Wt.</u>	
DECAPODA	1	(.03)	.02	(.05)	9	(.1)	80.02	(48.4)
PLECOPTERA	42	(1.1)	.67	(1.9)	125	(1.8)	7.35	(4.5)
Perlidae	19	(.5)	.54	(1.5)	75	(1.0)	5.77	(3.5)
<u>Perlesta</u>	5.5	(.15)	.26	(.7)	58	(.8)	4.5	(2.7)
EPHEMEROPTERA	286	(7.6)	1.3	(3.4)	371	(5.3)	1.89	(1.1)
Ephemerellidae								
<u>Ephemerella</u>	94	(2.5)	.38	(1.0)	169	(2.4)	.81	(.5)
ODONATA	124	(3.3)	18.04	(47.0)	227	(3.2)	21.05	(12.7)
Gomphidae								
<u>Ophiogomphus</u>	117	(3.1)	17.5	(45.6)	105	(1.5)	20.04	(12.1)
HEMIPTERA	80	(2.1)	1.2	(3.1)	113	(1.6)	2.59	(1.6)
TRICHOPTERA	491	(13.0)	6.46	(16.8)	594	(8.5)	15.6	(9.4)
Brachycentridae								
<u>Brachycentrus</u>	136	(3.6)	.99	(2.6)	9	(.1)	.10	(.06)
Hydropsycidae	279	(7.4)	4.20	(10.9)	360	(5.1)	10.95	(6.6)
Adult Trichoptera	19	(.5)	.22	(.6)	159	(2.3)	1.58	(1.0)
DIPTERA	2323	(61.4)	3.79	(9.8)	4651	(66.3)	11.87	(7.2)
Chironomidae	746	(19.7)	1.23	(3.2)	2008	(28.6)	2.45	(1.5)
Simuliidae	711	(18.8)	.73	(1.9)	644	(9.2)	1.22	(.7)
Adult Diptera	837	(22.1)	1.62	(4.2)	1959	(27.9)	5.86	(3.5)
PELECYPODA	59	(1.6)	2.10	(5.5)	18	(.3)	1.31	(.8)

Table 7, continued.

	<u>Altered Zone</u>		<u>Unaltered Zone</u>	
	<u>No.</u>	<u>Wt.</u>	<u>No.</u>	<u>Wt.</u>
TERRESTRIAL ARACHNIDA	73 (1.9)	.17 (.4)	170 (2.4)	.34 (.2)
TERRESTRIAL HEMIPTERA	27 (.7)	.83 (2.2)	33 (.5)	.14 (.08)
TERRESTRIAL HYMENOPTERA	74 (2)	.36 (.9)	334 (4.8)	1.55 (.9)
FISH	47 (1.2)	1.84 (4.8)	217 (3.1)	18.01 (10.9)
TOTAL	3481.0 (92.0)	37.78 (98.4)	6862.0 (97.9)	161.72 (97.8)
OVERALL TOTAL	3782.8	38.38	7010.8	165.32

The main invertebrate families drifting were Chironomidae larvae, Simuliidae larvae, Gomphidae, Hydropsychidae and all Diptera family adults combined (Table 7). Adult Diptera, Chironomidae larvae and Simuliidae larvae were the most abundant. In the altered zone they comprised 60.6% of the total by numbers and 65.7% in the unaltered zone. Gomphidae and Hydropsychidae accounted for 56.5% of the total biomass in the altered zone though only 18.7% of the total biomass in the unaltered zone. All of these families were abundant in the benthic samples for both study zones. The stabilization of the altered zone benthic community by the April, 1977 benthic sampling period presumably contributed to the lack of major differences found in the 1977 drift between the two habitat study zones. The similarities in the benthic communities between the two study zones appear to be influenced by the unaltered drift. Recolonization of denuded areas by drift already has been discussed.

Monthly density ($\text{g}/100 \text{ m}^3$) of drifting particulate organic carbon was higher in the altered zone than the unaltered zone (Table 8), however, there was no significant difference between the two zones. The highest monthly total, found in September, 1977, contained $137.3 \text{ g}/100 \text{ m}^3$ and $72.5 \text{ g}/100 \text{ m}^3$ for the altered and unaltered zones, respectively. The bulk of the September samples were comprised of leaves. Habitat alteration, with its vegetative manipulation and physical disturbance of the bottom substrate affected the correlation between monthly aquatic invertebrate number density (Y) and monthly particulate organic carbon density (X), $r = 0.22$. The unaltered zone was positively correlated, $r = .56$. Such correlation may be expected since the particle size of particulate organic carbon caught in a 760 μ drift net is about the

Table 8. Monthly total density ($\text{g}/100\text{m}^3$) of drifting particulate organic carbon for time periods combined by study zone in Plum Creek, May to October, 1977.

	<u>Altered Zone</u>	<u>Unaltered Zone</u>
	<u>$\text{g}/100\text{m}^3$</u>	<u>$\text{g}/100\text{m}^3$</u>
May	19.3	12.0
June	3.6	6.7
July	1.8	2.4
August	8.5	7.0
September	137.3	72.5
October	50.0	38.7
AVERAGE TOTAL	36.8	23.2

same size and density of the invertebrates caught. Positive correlations of $r = 0.60$ and 0.82 were also found by Holey (1978) and Braatz (1974), respectively.

Artificial Substrate

Colonization of invertebrates increased with the amount of time the artificial substrates were left in the stream (Fig. 8). The number of taxa, however, decreased with time. Mean numbers and biomass of invertebrates ranged from a low of 496/m² and 6.67 g/m² for one month 1976 intervals to 7491/m² and 62.70 g/m² for the 1977 three-month interval (Table 9). Chironomidae and Hydropsycidae accounted for 76.9% of the total numbers and 60.3% by weight for combined artificial substrate intervals. Artificial substrate invertebrate numbers and biomass were comparable with gravel and sand substrate totals in both the altered and unaltered areas.

Thirty major identifiable taxa inhabited the wood structures at the end of the one month interval in 1976 and 1977. The number of taxa declined with only 26, 25 and 21 taxa found after the artificial substrates were left in the stream for two, three and four month intervals, respectively. There were two and three aquatic insect invertebrate families and eight and nine genera found on the artificial substrates that were not found in the drift and benthic samples, respectively (Appendix C).

Invertebrate colonization on the wood structures should increase with time as a plant and organic debris food base is established. Mean numbers and biomass differences between artificial substrate time intervals, however, were not highly significant (Appendix E). A significant ($P < .05$) difference in mean numbers was found between one month 1976 and two month 1977 intervals and ($P < .1$) between one month 1976 and one month 1977 intervals. Mean biomass differences were only fairly significant ($P < .2$) between one month 1976 and two month 1977 intervals.

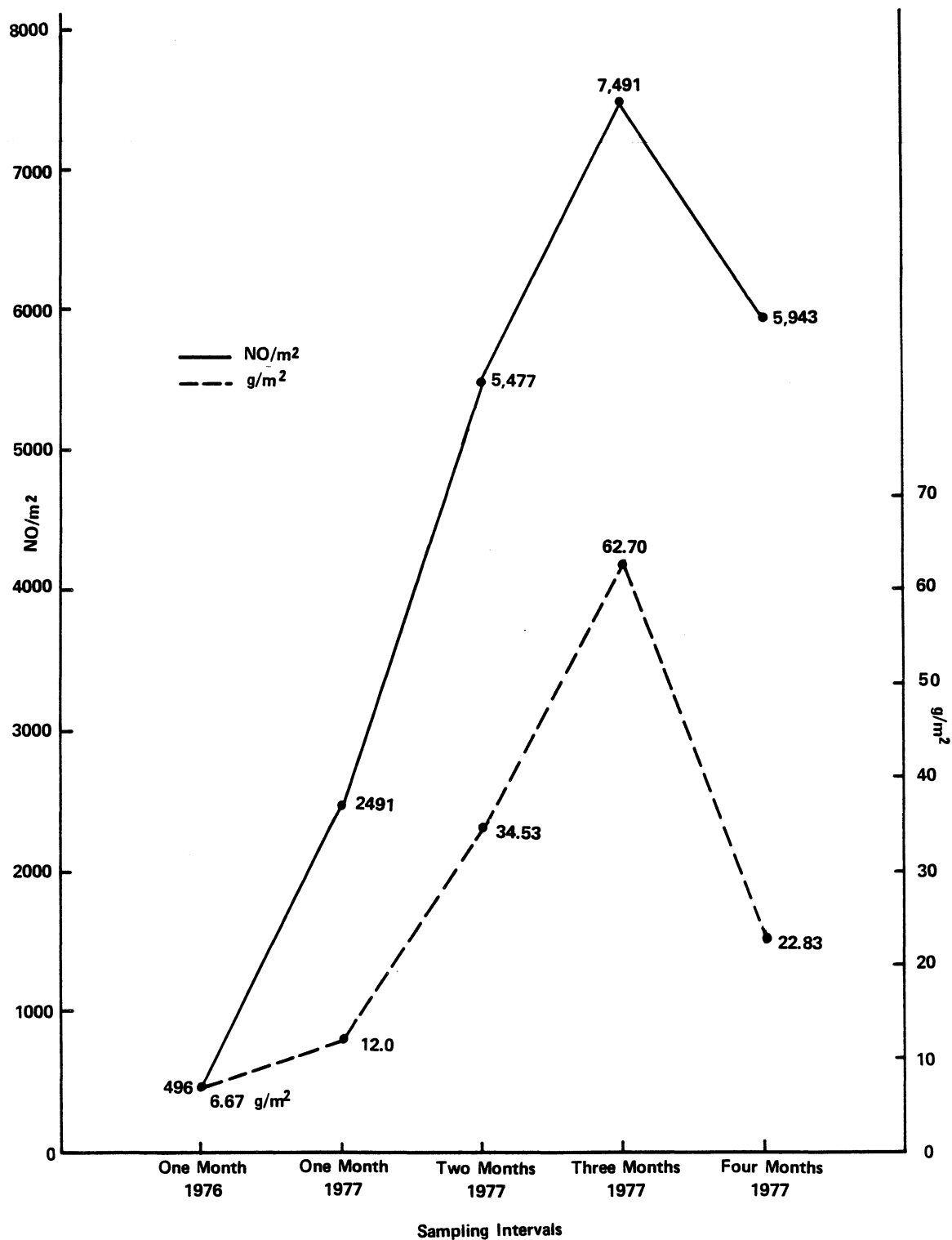


Figure 8. Mean number and biomass of organisms found on the artificial substrates by time intervals in Plum Creek, 1976-1977.

Table 9. Means, range and standard deviation of numbers and biomass of invertebrates on artificial substrates after time intervals of one, two, three and four months compared to benthic substrate types in the two study zones in Plum Creek, 1976-1977.

		<u>No./m²</u>			<u>g/m²</u>		
		<u>X̄</u>	<u>Range</u>	<u>s.d.</u>	<u>X̄</u>	<u>Range</u>	<u>s.d.</u>
<u>Artificial Substrate</u>							
One Month 1976	(8)	496	99- 1,841	596	6.67	2.62- 16.79	5.19
One Month 1977	(10)	2,491	1,085- 7,869	2,117	12.0	4.87- 29.65	7.65
Two Months 1977	(4)	5,477	2,543- 7,836	2,540	34.53	14.87- 69.7	24.23
Three Months 1977	(2)	7,491	1,644-13,338	8,269	62.70	15.46-109.93	66.8
Four Months 1977	(2)	5,943	1,496-10,390	6,289	22.83	7.88- 37.78	21.14
1976-1977 Combined	(26)	2,987	99-13,338	3,493	18.56	2.62-109.93	23.58
<u>Benthic Substrates</u>							
<u>Altered Zone 1976-1977</u>							
Gravel Substrate	(52)	3,536	54-11,087	2,973	50.8	.56-247.49	61.6
Sand Substrate	(52)	1,797	22- 8,826	2,003	37.7	.01-186.5	45.0
<u>Unaltered Zone 1976-1977</u>							
Gravel Substrate	(20)	3,602	1,003- 9,128	2,074	65.4	16.73-158.68	45.5
Sand Substrate	(20)	4,240	178-13,272	3,521	151.2	34.49-656.98	183.4

Diptera, Trichoptera and Ephemeroptera dominated the artificial substrates, accounting for 97.2% of the total numbers and 90.4% by weight for all time intervals combined (Table 10). Trichoptera and Diptera displayed the largest fluctuations in numbers and weight while Ephemeroptera remained fairly consistent throughout the time intervals (Fig. 9). Trichoptera ranged from 14.5% occurrence by numbers and 34.2% by weight in the one month 1977 samples to 57.9% by number after the four month interval and 77.5% by weight after the three month interval. Diptera occurrence by numbers ranged from 74.4% for the one month 1977 interval to 29.8% for the four month 1977 interval.

Diptera, Trichoptera and Ephemeroptera were dominated by seven families (Table 10). Chironomidae and Simuliidae accounted for 98.1% of the total numbers and 95.3% by weight within the Diptera. Chironomidae and Simuliidae were abundant in both the benthic and drift samples. These families are herbivorous, feeding on the algae and other organic debris which accumulate on the wood. The wood substrate provides a stable substrate for reattachment (particularly for Simuliidae) of drifting organisms. Simuliidae prefer a location in swift current where they can attach and strain food from the water (Hilsenhoff 1975; Pennak 1953).

Trichoptera families, Hydropsychidae and Polycentropidae, accounted for 98% of the Trichoptera total numbers and 90.0% by weight. Hydropsychidae was the dominant invertebrate in both the benthic and drift samples so it was available for attachment to the wood substrate. Food attraction was also a factor since Hydropsychidae feed on diatoms and other algae which accumulated on the wood. Polycentropodidae is a carnivorous larvae that construct silken retreats on decaying wood, debris and

Table 10. Mean number (No./m²) and biomass (g/m²) differences in colonization rates of invertebrates by major identifiable taxa equal to or exceeding 2% of the average total collected from artificial substrates installed in Plum Creek for different time intervals from 1976-1977.

	ONE MONTH, 1976		ONE MONTH, 1977		TWO MONTH, 1977		THREE MONTH, 1977		FOUR MONTH, 1977		AVERAGE	
	No./m ²	g/m ²	No./m ²	g/m ²	No./m ²	g/m ²	No./m ²	g/m ²	No./m ²	g/m ²	No./m ²	g/m ²
EPHEMEROPTERA	71	1.18	232	1.31	413	3.50	813	6.61	522	4.97	277	2.30
	(14.3)	(17.7)	(9.3)	(10.9)	(7.5)	(10.1)	(10.9)	(10.5)	(8.8)	(21.8)	(9.3)	(12.4)
EphemereIIDae	42	.96	27	.11	86	.60	291	2.16	385	3.38	89	.86
	(8.5)	(14.4)	(1.1)	(.9)	(1.6)	(1.7)	(3.9)	(3.4)	(6.5)	(14.8)	(3.0)	(4.6)
<u>EphemereIIa</u>	42	.96	27	.11	86	.60	291	2.16	385	3.38	89	.86
	(8.5)	(14.4)	(.4)	(.9)	(1.6)	(1.7)	(3.9)	(3.4)	(6.5)	(14.8)	(3.0)	(4.6)
Baetidae	-	-	120	.47	160	1.13	266	2.31	-	-	91	.53
			(4.8)	(3.9)	(2.9)	(3.3)	(3.6)	(3.7)			(3.1)	(2.9)
<u>Baetis</u>	-	-	120	.47	160	1.13	266	2.31	-	-	91	.53
			(4.8)	(3.9)	(2.9)	(3.3)	(3.6)	(3.7)			(3.1)	(2.9)
Heptageniidae	-	-	85	.73	166	1.76	250	2.12	137	1.59	88	.84
			(3.4)	(6.1)	(3.0)	(5.1)	(3.3)	(3.4)	(2.3)	(7.0)	(3.0)	(4.5)
<u>Stenonema</u>	-	-	85	.73	166	1.76	250	2.12	137	1.59	88	.84
			(3.4)	(6.1)	(3.0)	(5.1)	(3.3)	(3.4)	(2.3)	(7.0)	(3.0)	(4.5)
TRICHOPTERA	124	2.80	361	4.10	1881	20.71	3743	48.60	3439	10.80	1019	10.19
	(25.0)	(42.0)	(14.5)	(34.2)	(34.3)	(60.0)	(50.0)	(77.5)	(57.9)	(47.3)	(34.1)	(54.9)
Hydropsycidae	108	1.11	262	3.10	1425	16.06	3396	42.40	3146	6.92	857	7.80
	(21.8)	(16.6)	(10.5)	(25.8)	(26.0)	(46.5)	(45.3)	(67.6)	(52.9)	(30.3)	(28.7)	(42.0)
Polycentropidae	5	.13	73	.45	432	3.18	318	4.88	280	3.75	142	1.37
	(1.0)	(2.0)	(2.9)	(3.8)	(7.9)	(9.2)	(4.3)	(7.8)	(4.7)	(16.4)	(4.8)	(7.4)
<u>Cyrcrinellus</u>	-	-	62	.32	296	1.75	188	2.34	205	2.71	100	.78
			(2.5)	(2.7)	(5.4)	(5.1)	(2.5)	(3.7)	(3.5)	(11.9)	(3.3)	(4.2)
DIPTERA	256	1.20	1853	4.62	3043	8.13	2761	5.55	1768	6.03	1008	4.29
	(51.6)	(18.0)	(74.4)	(38.5)	(55.6)	(23.5)	(36.9)	(8.9)	(29.8)	(26.4)	(53.8)	(23.1)
Chironomidae	66	.21	1729	4.02	2768	6.47	2568	4.56	1725	5.82	1441	3.40
	(13.3)	(3.2)	(69.4)	(33.5)	(50.5)	(18.7)	(34.3)	(7.3)	(29.0)	(25.5)	(48.2)	(18.3)
Simuliidae	188	.96	110	.56	159	.88	151	.53	-	-	136	.69
	(37.9)	(14.4)	(4.4)	(4.7)	(2.9)	(2.6)	(2.0)	(.9)			(4.6)	(3.7)
OVERALL TOTAL	496	6.67	2491	12.00	5477	34.53	7491	62.70	5943	22.83	2987	18.56
ORDER TOTAL	451	5.18	2446	10.03	5337	32.34	7317	60.80	5729	21.80	2904	16.78
	(90.9)	(77.7)	(98.2)	(83.6)	(97.4)	(93.7)	(97.7)	(96.9)	(96.4)	(95.5)	(97.2)	(90.4)
Family Total	409	3.37	2406	9.44	5196	30.08	7240	58.00	5673	21.50	2844	15.49
	(82.5)	(50.5)	(96.6)	(78.7)	(94.9)	(87.1)	(96.7)	(92.4)	(95.5)	(94.0)	(95.2)	(83.5)

() = Percentages of the total numbers and weight.

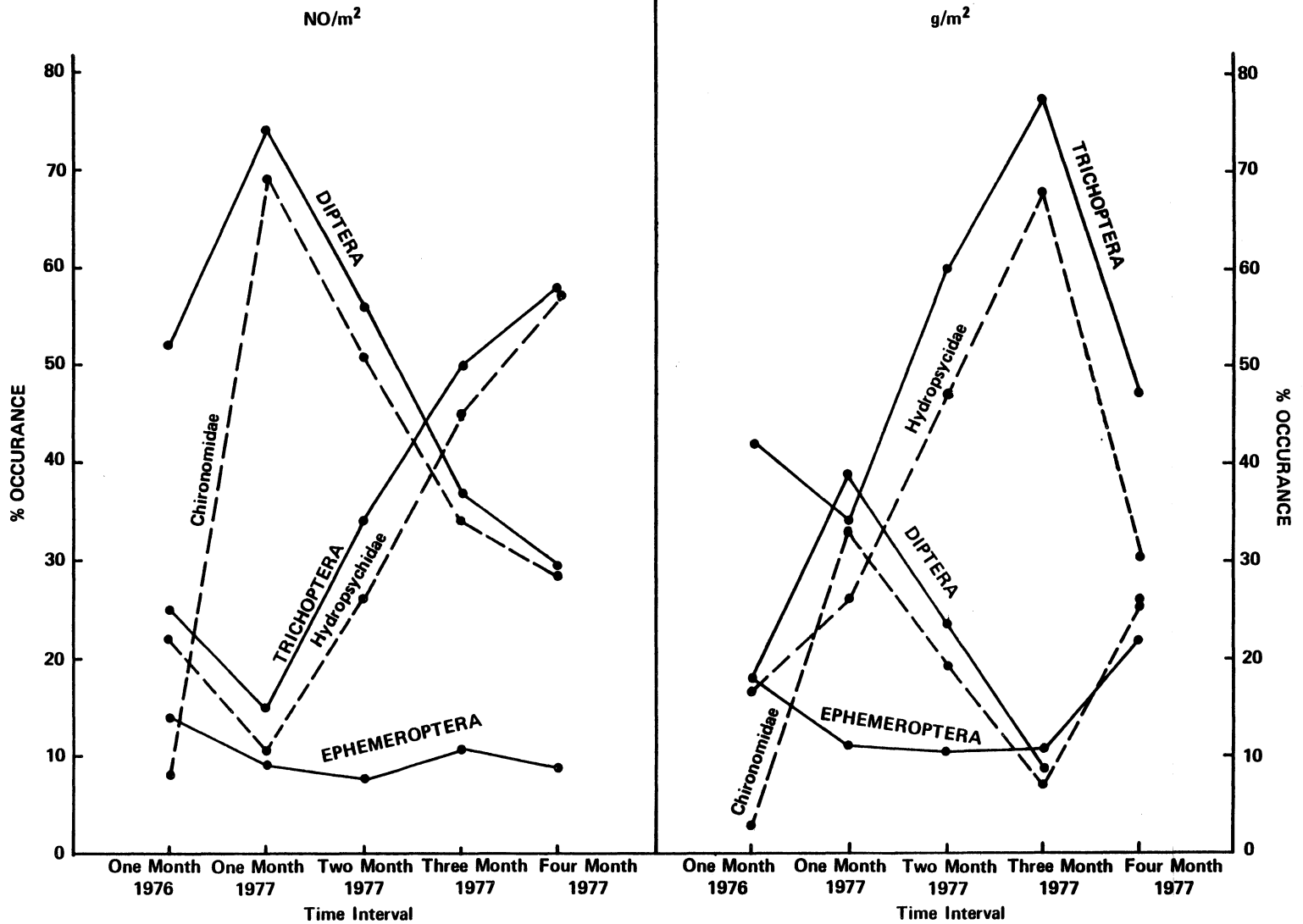


Figure 9. Invertebrate orders, Diptera, Trichoptera, Ephemeroptera, and families, Chironomidae and Hydropsychidae mean numbers and biomass percent occurrence by time interval on the artificial substrates in Plum Creek, 1976-1977.

rocks (Hilsenhoff 1975; Pennak 1953).

Ephemeroptera numbers and biomass were shared equally by the families Ephemerellidae, Baetidae and Heptageniidae. The attraction of these families to the wood substrate was probably for food and structure type. These clinging mayflies are all herbivores, browsing on algae and tissues of higher plants. They cling tightly to stones or other objects and may be found in greatest abundance in crevices or the undersides of stones (Hilsenhoff 1975; Pennak 1953).

Hydropsychidae and Chironomidae were the most abundant insect families found for all artificial substrate intervals combined and also displayed the greatest fluctuations in abundance (Fig. 9). Chironomidae dominated the one month 1977 interval with 69.4% occurrence by numbers, though only comprised 13.1% of the numbers for the one month 1976 interval. Hydropsychidae varied by weight from 16.6% occurrence in the one month 1976 samples to 67.6% occurrence for the three month 1977 sample.

Mean numbers of invertebrates found on artificial substrates were higher for the two, three and four month intervals than in 1976-1977 gravel and sand substrates for both the altered and unaltered habitat zones (Table 9). The differences between means, however, were not highly significant due to the small artificial substrate sample size (Appendix F).

The invertebrate production capabilities of wood habitat structures make them a valuable addition to the stream food base. The use of rough sawed lumber helps increase invertebrate colonization by providing a better attachment base for invertebrates and their food base.

Trout Feeding

The availability of food is a key factor in the distribution of trout in streams. Habitat alteration in Plum Creek did not appear to affect the availability of food organisms for brook and brown trout. There was no significant difference for mean number of food items per stomach between the altered and unaltered habitat zones (Table 11). The contents of the trout stomachs in the altered habitat zone, however, contained the greatest variety of taxa (Table 11). Major aquatic and terrestrial insect orders and families found in the benthic, drift and artificial substrate samples were utilized by the trout (Tables 12-13) (Appendix G).

Stomachs from the unaltered zone contained an average of 10.02 food items per stomach for all trout species combined compared to 8.86 items for the altered zone (Table 11). Brook trout contained more food items per stomach in the unaltered zone (10.78 to 7.88, $\leq .5$), while native brown trout (12.33 to 10.33) and stocked brown trout (9.66 to 5.63, $\leq .05$) contained more items per stomach from the altered zone. Seasonal fluctuations and specific feeding habits and food preferences by trout species were found in the feeding of trout in Plum Creek (Jackson 1983). Discussion of comparisons in this thesis with the benthic, drift and artificial substrates will be primarily with all trout species combined.

Trout stomachs from the altered zone contained 48 taxa compared with only 30 taxa in the unaltered zone (Table 11). Brook trout stomachs by trout species contained the highest number of taxa for both habitat zones.

Invertebrates are the most important food of stream dwelling trout, and the factors which determine their utilization are important in trout

Table 11. Mean number (\bar{X}) of food items per stomach with standard deviation (s.d.), Students t test for level of significance and number of identifiable taxa from the two habitat study zones in Plum Creek, 1976-1977. Number of stomachs analyzed in parentheses.

<u>HABITAT ZONES</u>	<u>BROOK TROUT</u>	<u>BROWN TROUT</u>	<u>STOCKED BROWN TROUT</u>	<u>ALL SPECIES COMBINED</u>
<u>Mean Number Food Items/Stomach</u>				
ALTERED \bar{X}	7.88 (247)	12.33 (58)	9.66 (38)	8.83 (343)
s.d.	8.40	12.90	5.45	9.19
UNALTERED \bar{X}	10.78 (40)	10.33 (15)	5.63 (8)	10.02 (63)
s.d.	22.70	5.11	2.62	18.27
LEVEL OF SIGNIFICANCE P<	.50	-	.05	-
<u>Total Number of Taxa</u>				
ALTERED	46	38	34	48
UNALTERED	27	23	15	30

feeding ecology. It is generally accepted that bottom and drift organisms are consumed by trout in proportion to their availability (Needham 1930; Wiseman 1951). Chi Square (χ^2) was used to test the following hypothesis: The percent occurrence of major aquatic insect taxa from the benthic, drift and artificial substrate samples are not statistically different than those taxa percentages found in the trout stomachs (Table 12) (Appendix H). Assuming we reject this hypothesis if $P < .05$, then the hypothesis was accepted by habitat zone and invertebrate sample for the following percentages:

	<u>Gravel Substrate</u>	<u>Sand Substrate</u>	<u>Gravel, Sand Drift</u>	<u>Gravel, Sand Combined</u>	<u>Artificial Substrate</u>
<u>ORDERS COMBINED</u>					
Altered Zone	0.0	62.5	87.5	50.0	50.0
Unaltered Zone	37.5	25.0	50.0	37.5	
<u>FAMILIES COMBINED</u>					
Altered Zone	0.0	12.5	75.0	29.2	50.0
Unaltered Zone	37.5	12.5	37.5	29.2	

Benthic invertebrate composition by substrate type was statistically similar to trout feeding preferences (Appendix H). Trout stomach contents revealed a utilization of dominant benthic invertebrates of both habitat zones (Table 12). Trichoptera was the most consistent and abundant food item for all species combined in the altered zone, averaging 43.2% occurrence by numbers and 40.9% by weight. In the unaltered zone Trichoptera accounted for 27.6% by numbers and 27.1% by weight for all trout species combined. Hydropsychidae and Gomphidae accounted for 36.4% by numbers and 48.3% by weight in the altered zone and 36.0% by numbers and 49.0% by weight in the unaltered zone for all trout species combined.

Table 12. Benthic, drift and artificial substrate major aquatic insect orders and families percent occurrence and their corresponding percentages in the stomachs of trout species collected in the altered and unaltered habitat zones, Plum Creek, 1976-1977.

	<u>Benthic Gravel Substrate</u>		<u>Benthic Sand Substrate</u>		<u>Drift</u>		<u>Artificial Substrate</u>		<u>Brook Trout</u>		<u>Brown Trout</u>		<u>Stocked Brown Trout</u>		<u>All Trout Species Combined</u>	
	<u>NO.</u>	<u>WT.</u>	<u>NO.</u>	<u>WT.</u>	<u>NO.</u>	<u>WT.</u>	<u>NO.</u>	<u>WT.</u>	<u>NO.</u>	<u>WT.</u>	<u>NO.</u>	<u>WT.</u>	<u>NO.</u>	<u>WT.</u>	<u>NO.</u>	<u>WT.</u>
<u>ALTERED ZONE</u>																
ODONATA	2.3	19.0	3.3	25.2	3.5	47.0	.2	2.1	14.9	26.7	17.4	30.3	19.3	32.0	16.1	28.1
Gomphidae	2.2	18.1	2.5	14.5	3.1	45.6	.04	.2	14.5	26.0	17.0	29.7	19.0	31.5	15.7	27.5
TRICHOPTERA	38.9	53.9	9.3	8.7	13.5	17.5	16.0	36.9	45.4	44.2	41.6	37.8	36.2	31.6	43.2	40.9
Hydropsychidae	34.8	50.2	6.9	5.8	7.4	10.9	12.1	23.1	24.6	25.2	13.5	13.4	13.6	12.8	20.7	20.8
DIPTERA	47.7	21.3	57.1	22.7	60.7	12.8	71.0	32.3	16.7	6.5	14.5	5.6	8.3	3.4	15.1	5.9
Chironomidae	35.8	14.8	50.2	13.1	19.7	3.2	61.4	24.2	6.4	1.6	4.1	2.4	2.5	.6	5.3	1.3
Simuliidae	5.6	2.9	1.9	.5	18.8	1.9	9.1	7.7	7.4	2.3	6.4	2.0	3.0	1.0	6.7	2.1
AQUATIC ORDER TOTAL	88.9	94.2	69.7	56.6	77.7	77.3	87.2	71.3	77.0	77.4	73.5	73.7	63.8	67.0	74.4	74.9
Family Total	78.4	86.0	61.5	33.9	49.0	61.6	82.6	55.2	52.9	55.1	41.0	47.5	38.1	45.9	48.4	51.7
<u>UNALTERED ZONE</u>																
ODONATA	2.0	17.3	1.8	9.4	1.6	26.1			16.6	33.2	18.1	26.2	11.2	14.4	16.6	29.3
Gomphidae	2.0	17.3	1.5	6.5	1.5	12.1			16.6	33.2	17.4	25.3	11.2	14.4	16.4	29.0
TRICHOPTERA	44.6	34.8	7.3	6.4	7.3	15.4			23.7	27.0	34.8	27.3	39.3	26.7	27.6	27.1
Hydropsychidae	35.0	25.1	5.0	2.7	5.1	6.6			17.8	20.6	25.8	21.4	14.9	11.5	19.6	20.0
DIPTERA	36.2	26.6	45.4	11.3	66.8	14.2			46.3	15.6	7.2	1.9	9.0	1.6	34.2	10.2
Chironomidae	23.3	3.7	38.2	5.0	28.6	1.5			3.7	1.1	2.6	.5	2.3	.4	3.3	.9
Simuliidae	3.6	1.4	4.2	.8	9.2	.7			41.2	12.9	3.9	1.1	6.7	1.2	29.7	8.2
AQUATIC ORDER TOTAL	82.8	78.7	54.5	27.1	75.7	55.7			86.6	75.8	60.1	55.4	59.5	42.7	78.4	66.6
Family Total	63.9	47.5	48.9	15.0	44.4	20.9			79.3	67.8	49.7	48.3	35.1	27.5	69.0	59.1

Hypothesis acceptance for gravel substrate by individual orders and families in both habitat zones was higher than sand substrate. Hydro-
psychidae and Gomphidae, dominant trout stomach items, also dominated
gravel substrates with 37.0% by numbers in both habitat zones and 68.3%
and 42.4% by weight in the altered and unaltered zones, respectively.
Sand substrate showed little similarity to trout stomach contents as
Hydropsychidae and Gomphidae only occurred 9.4% by numbers and 20.3% by
weight in the altered zone and 6.5% by numbers and 9.2% by weight in the
unaltered zone. Hydropsychidae and Gomphidae only occurred 9.4% by
numbers and 20.3% by weight in the altered zone and 6.5% by numbers and
9.2% by weight in the unaltered zone.

Altered zone comparisons between substrate types and trout food
preferences were not significantly different from the unaltered zone
substrate types. The 10% increase in gravel substrate and subsequent
13% reduction of sand substrate caused by habitat alteration increased
trout feeding opportunities. Trout appeared to be feeding randomly in
both habitat zones.

Wiseman (1951) found bottom organisms from Diptera and Ephemeroptera
to comprise 81.0% of the numbers collected and 88.0% of the numbers
found in stomachs. He concluded that his data supported generally
accepted theory that brook trout are "opportunists" as indicated by
Needham (1930). Dineen (1951) and Tebo and Hassler (1963) also reported
that benthos are consumed by trout in proportion to their availability.
The only exception to availability they found is the tendency for larger
trout to select larger organisms.

Needham (1928) and Elliott (1965) first suggested that invertebrate

drift may be an available source of food for trout. Subsequently, Tusa (1969) and Elliott (1970) found that aquatic invertebrates were utilized by brown trout in proportion to their abundance in the drift. Similarly, Jenkins, et al. (1970) reported that rainbow trout consumed both terrestrial and aquatic invertebrates in quantities correlated to the seasonal and hourly drift. Griffith (1974) found that five insect orders comprised 97.0% of the total drift and represented an average of 92.0% of the number of organisms eaten by brook trout. He suggested a relationship between diel drift abundance and the diet of brook trout. McClain (1976) also reported that brook trout were non-selective in their utilization of drifting invertebrates and diel differences were found in their feeding ability.

Drifting organisms in Plum Creek were comparable to trout stomach contents for both habitat zones in 26.8% of the sample hypothesis analysis for individual orders and families combined. An 87.5% hypothesis acceptance in the altered zone was found for orders combined.

Diptera dominated the drift in both habitat zones, comprising 60.7% and 66.8% by numbers in the altered and unaltered zones, respectively. The most frequently occurring insect order found in the trout stomachs was Trichoptera (43.2% by numbers) in the altered zone and Diptera (34.2% by numbers) in the unaltered zone. Hydropsychidae and Gomphidae, dominant insect families by weight in the stomach contents (48.3% altered, 49.0% unaltered zones) for all species combined, also contributed substantially to drift biomass, 56.5% in the altered zone though only 18.7% in the unaltered zone.

Terrestrial insects have been found to be important in the diet of trout, comprising between one-third and one-half of the total number of

food organisms found (Needham 1930; Tebo and Hassler 1963; Benson 1953; Elliott 1967; Swift 1970; McClain 1976; Lord 1934; Ricker 1930; Clemens 1928). Streamside vegetation appears to be the most important factor affecting the availability of terrestrial invertebrates (Needham 1969).

Habitat alteration, including some vegetative manipulation in Plum Creek, did not reduce the availability of terrestrials for trout. Terrestrials, however, made up only a small percentage of the total number of drift invertebrates in both the altered and unaltered zones (Table 13) (Appendix G). Chi Square (χ^2) was used to test the following hypothesis: The proportion of terrestrials in the drift and trout stomach contents would not be statistically different. This hypothesis was accepted for both habitat zones (Table 13).

Invertebrates found on the artificial substrates were statistically comparable to trout stomach contents with 50.0% acceptance of my hypothesis for both orders and families combined (Appendix H). Diptera dominated numbers with 71.0% occurrence and Trichoptera and Diptera accounting for 36.9% and 32.3% of the biomass respectively (Table 12). Diptera, however, only comprised 15.1% by numbers and 5.9% by weight of the stomach contents for all trout species combined. Hydropsychidae demonstrated the greatest comparability, occurring 12.1% by numbers and 23.1% by weight on the artificial substrates and 20.7% by numbers and 20.8% by weight of the stomach contents for all trout species combined.

Table 13. Terrestrial percentages by numbers and weight found in the drift and trout stomach contents by habitat zones in Plum Creek 1976-1977. Chi Square (X^2) analysis of the hypothesis: The proportion of terrestrials in the drift and trout stomach contents would not be statistically different. Probability of accepting the hypothesis ($P >$).

* Probability $>.001$

<u>Habitat Zone</u>	<u>Drift</u>		<u>Brook Trout</u>			<u>Brown Trout</u>				<u>Stocked Brown Trout</u>				<u>All Trout Species Combined</u>				
	<u>No.</u>	<u>Wt.</u>	<u>No.</u>	<u>P ></u>	<u>Wt.</u>	<u>P ></u>	<u>No.</u>	<u>P ></u>	<u>Wt.</u>	<u>P ></u>	<u>No.</u>	<u>P ></u>	<u>Wt.</u>	<u>P ></u>	<u>No.</u>	<u>P ></u>	<u>Wt.</u>	<u>P ></u>
Altered	8.1	1.7	6.6	.7	3.8	.2	9.9	.7	6.3	*	13.6	.05	7.6	*	8.2	.95	4.9	.02
Unaltered	5.5	4.3	2.6	.3	1.9	.3	3.9	.5	2.7	.5	13.4	*	5.4	.7	3.5	.50	2.4	.5

CONCLUSION

The aim of habitat management on trout streams is to provide the most favorable living conditions possible for trout. Better living conditions will mean that the stream will support a greater abundance of trout through better survival, growth and perhaps through better reproduction (White and Brynildson 1967).

These objectives were physically met in Plum Creek with a decrease in surface area and sand bottom and increases in permanent overhanging bank cover and gravel substrate resulting from habitat alteration. Instream trout habitat development creates a considerable, though only temporary, physical disturbance.

The physical disturbance of habitat alteration in this study did not decrease the number of taxa in the benthic invertebrate community or drift of these invertebrates or affect their availability as food items for trout. There was an initial reduction in benthic invertebrate mean numbers and biomass, however, 17 months after habitat alteration invertebrate numbers and biomass in both gravel and sand substrates were higher in the altered zone than the unaltered zone.

Plum Lake, the source of Plum Creek, appears to have the greatest influence on the invertebrate composition found and the ability to repopulate disturbed areas. Major aquatic and terrestrial insect orders and families found in the benthic, drift and artificial substrate samples were utilized by the trout.

One of the most positive results of habitat alteration revealed by this study is the colonization of invertebrates on the wood used for trout habitat structures. Invertebrate numbers and biomass on the wood

structure were comparable with gravel and sand substrate totals in both the altered and unaltered areas. The invertebrate production capabilities of wood habitat structures makes them a valuable addition to the stream food base.

LITERATURE CITED

- Allen, K. R. 1951. The Horokiwi stream, a study of a trout population. New Zealand Dept. Fish, Bull. 10. 231 pp.
- Barber, W. E., and N. R. Kevern. 1973. Ecological factors influencing macroinvertebrate standing crop distribution. *Hydrobiologia*. 43(1-2):53-75.
- Benson, N. G. 1953. Seasonal fluctuations in the feeding of brook trout in the Pigeon River, Michigan. *Trans. Amer. Fish. Soc.* 83:76-83.
- Bordeau, P. F. 1953. A test of random versus systematic ecological sampling. *Ecol.* 34:499-512.
- Braatz, D. A. 1974. Invertebrate drift in a central Wisconsin brook trout stream. M.S. thesis, Univ. of Wis., Stevens Point. 63 pp.
- Burkhard, W. T. 1967. Effects of channelization on the trout fishery of Tomichi Creek. Colorado Game, Fish, and Parks Dept., Fed. Aid Proj. F-26-R-4. Job Completion Rept. 9 pp.
- Carufel, L. H. 1968. Post development evaluations (investigations). Completion Rept. F-7-R-9. Arizona Game and Fish Dept. 23 pp.
- Chandler, D. C. 1937. Fate of typical lake plankton in streams. *Ecol. Monog.* 7:455-479.
- Chandler, D. C. 1939. Plankton entering the Huron River from Portage and Basin Line Lake, Michigan. *Trans. Amer. Micro. Soc.* 58:24-41.
- Chaston, I. 1969. Seasonal activity and feeding patterns of brown trout (*Salmo trutta*) in a Dartmoor stream in relation to availability of food. *J. Fish Res. Bd. Can.* 26:2165-2171.
- Clemens, W. A. 1928. The food of trout from the streams of Oneida County, New York State. *Trans. Amer. Fish. Soc.* 58:183-197.
- Cooke, W. B. 1956. Colonization of artificial bare areas by micro-organisms. *Bot. Rev.* 22(9):613-638.
- Cummins, K. W. 1962. An evaluation of some techniques for the collection and analysis of benthic samples with special emphasis on lotic waters. *Amer. Mid. Nat.* 67(2):477-504.
- Cummins, K. W. 1966. A review of stream ecology with special emphasis on organism-substrate relationships, p. 2-51. In K. W. Cummins, C. A. Tryon, Jr., and R. T. Hartman (Ed.) *Organism-substrate relationships in streams*. Spec. Pub. No. 4, Pymatuning Lab. of Ecol., Univ. of Pittsburgh.

- Cushing, C. E., Jr. 1963. Filter-feeding insect distribution and planktonic food in the Montreal River. *Trans. Amer. Fish. Soc.* 92(3):216-219.
- Dendy, J. S. 1944. The fate of animals in stream drift when carried into lakes. *Ecol. Monog.* 14:333-357.
- Dimond, J. B. 1967. Evidence that drift of stream benthos is density related. *Ecol.* 48:855-857.
- Dineen, C. F. 1951. A comparative study on the food habits of Cottus bairdi and associated species of Salmonidae. *Amer. Mid. Nat.*, 46:640-645.
- Egglshaw, H. J. 1969. The distribution of benthic invertebrates on substrate in fast-flowing streams. *J. Anim. Ecol.* 38:19-33.
- Elliott, J. M. 1965. Daily fluctuations of drift invertebrates in a Dartmoor stream. *Nature.* 205:1127-1129.
- Elliott, J. M. 1967. The food of trout (Salmo trutta) in a Dartmoor stream. *J. Appl. Ecol.* 4:59-71.
- Elliott, J. M. 1970. Diel changes in invertebrate drift and the food of trout, Salmo trutta L. *J. Fish. Biol.* 2:161-165.
- Eriksen, C. H. 1966. Benthic invertebrates and some substrate-current-oxygen interrelationships, p. 98-115. In K. W. Cummins, C. A. Tryon, Jr., and R. T. Hartman (Ed.) *Organism-substrate relationships in streams.* Spec. Pub. No. 4, Univ. of Pittsburgh.
- Gard, R. 1961. Creation of trout habitat by constructing small dams. *J. Wild. Mgmt.* Vol. 25 (4), pp. 384-390.
- Greeley, J. R. 1936. Progress of stream improvement in New York State. *Trans. Amer. Fish. Soc.* 65:316-321.
- Griffith, J. S., Jr. 1974. Utilization of invertebrate drift by brook trout (Salvelinus fontinalis) and cutthroat trout (Salmo clarki) in small streams in Idaho. *Trans. Amer. Fish. Soc.* 103(3):440-447.
- Hartman, R. T., and C. L. Himes. 1961. Phytoplankton from Pymatuning Reservoir in downstream areas of the Shenango River. *Ecol.* 42: 180-183.
- Hazzard, A. S. 1937. Results of stream and lake improvement in Michigan. *Trans. Second No. Amer. Wildlife Conf.*, pp. 620-624.
- Hilsenhoff, W. L. 1975. Aquatic insects of Wisconsin, with generic keys and notes on biology, ecology and distribution. *Wis. Dept. Nat. Resour., Tech. Bull. No. 89.* 53 pp.
- Holey, M. E. 1978. Responses of invertebrate drift to streamside brush removal. M.S. thesis, Univ. of Wis., Stevens Point. 64 pp.

- Horton, D. B. 1957. The effects of stream improvement devices in a section of a Rhode Island trout stream. Rhode Island Dept. of Agric. and Conserv., Div. of Fish and Game, Fed. Aid Proj. F-10-D-2.
- Horton, P. A. 1961. The bionomics of brown trout in a Dartmoor stream. J. Anim. Ecol. 30:311-338.
- Howmiller, R. P. 1972. Effects of preservatives on weights of some common macrobenthic invertebrates. Trans. Amer. Fish. Soc. 101(4): 743-746.
- Hubbs, C. S., J. R. Greeley and C. M. Tarzwell. 1933. Methods for improvement of Michigan trout streams. Bull. Inst. for Fish. Res., No. 1. 54 pp.
- Hunt, R. L. 1971. Responses of a brook trout population to habitat development in Lawrence Creek. Wis. Dept. Nat. Resour., Tech. Bull. No. 48. 35 pp.
- Hunter, G. W. III, L. M. Thorpe and D. E. Grosvenor. 1940. An attempt to evaluate the effect of stream improvement in Connecticut. Trans. North Amer. Wildlife Conf. 5:276-291.
- Hynes, H. B. N. 1950. The food of fresh water sticklebacks, with a review of methods used in studies of the food of fishes. J. Anim. Ecol. 19:36-58.
- Hynes, H. B. N., and M. J. Coleman. 1968. A simple method of assessing the annual production of stream benthos. Limnol. and Oceanogr. 13:569-573.
- Jackson, R. R. 1983. A 1977 creel census of Plum Creek, Sayner, Wisconsin. Wis. Dep. Nat. Resour. Fish Manage. Rep. in preparation.
- Jackson, R. R. 1983. Trout feeding characteristics in Plum Creek, Sayner, Wisconsin. Wis. Dep. Nat. Resour. Fish Manage. Rep. in preparation.
- Jackson, R. R., and P. E. Miller. 1976. Effects of changes in the physical environment on benthic organisms in Plum Creek. Water 6:81. Univ. of Wis., Stevens Point. 16 pp.
- Jenkins, T. M., Jr., O. R. Feldmeth, and G. V. Elliott. 1970. Feeding of rainbow trout (Salmo gairdneri) in relation to abundance of drifting invertebrates in a mountain stream. J. Fish. Res. Bd. Can. 27:2356-2361.
- Jester, D. B., and H. J. McKirdy. 1966. Evaluation of trout stream improvement in New Mexico. 46th Annual Conference of the Western Assoc. of State Game and Fish Commissioners. July, 1966. 26 pp.
- Kennedy, H. D. 1955. Colonization of a previously barren stream section by aquatic invertebrates and trout. Prog. Fish Cult. 17(3):119-122.

- Kroger, K. L. 1974. Invertebrate drift in the Snake River, Wyoming. *Hydrobiologia*. 44:369-380.
- Leonard, J. W. 1939. Comments on the adequacy of accepted stream bottom sampling techniques. *Trans. North Amer. Wildlife Conf.* 4:288-295.
- Lord, R. F. 1934. Type of food taken throughout the year by brook trout in a single Vermont stream with special reference to winter feeding. *Trans. Amer. Fish. Soc.* 64:182-197.
- Lund, J. W. G., and J. F. Talling. 1957. Botanical limnological methods with special reference to algae. *Bot. Rev.* 23(8, 9):489-583.
- Madsen, M. J. 1938. A preliminary investigation into the results of stream improvement in the Intermountain Forest region. *Trans. 3rd. N. Amer. Wildl. Conf.*, p. 497-503.
- McClain, J. R. 1976. Food habits of brook trout in relation to the abundance of diel drift invertebrates in the Little Colorado River. M.S. thesis, Univ. of Arizona. 37 pp.
- McKirdy, H. J. 1965. Evaluation of stream improvement structures. Final rept. 2630, U.S. Forest Service, Region 3. 45 pp.
- McLay, C. L. 1968. A study of drift in the Kakanui River, New Zealand, *Aust. J. Mar. Freshwater Res.* 19:139-149.
- Minckley, W. L. 1964. Upstream movements of Gammarus in Doe Run, Meade County, Kentucky. *Ecol.* 45:195-197.
- Moffet, J. W. 1936. A quantitative study of the bottom fauna in some Utah streams variously affected by erosion. *Bull. of the Univ. of Utah. Biol. Serv. Vol. III, No. 3.* 26(9):1-32.
- Muller, K. 1954. Investigations on the organic drift in North Swedish streams. *Rep. Inst. Freshwater Res. Drottning.* 35:133-148.
- Needham, P. R. 1928. A quantitative study of the fish food supply in selected areas. In A biological survey of the Oswego River system, New York State Conservation Dept., Suppl. to 17th Annual Report, pp. 192-206.
- Needham, P. R. 1929. Quantitative studies of the fish food supply in selected areas. In A biological survey of the Erie-Niagara system. New York State Conservation Dept., Suppl. to 18th annual report, pp. 220-232.
- Needham, P. R. 1930. Studies on the seasonal food of brook trout. *Trans. Amer. Fish. Soc.* 60:73-83.
- Needham, P. R. 1935. Quantitative studies of stream bottom foods. *Trans. Amer. Fish. Soc.* 64:238-247.

- Needham, P. R. 1938. Trout streams. Comstock Publ. Co., Inc. Ithaca, New York. 233 pp.
- Needham, P. R. 1969. Trout streams. Holden Day, Inc. San Francisco. 241 pp.
- Pardue, G. B. 1973. Production response of the bluegill sunfish (Lepomis macrochirus) to added attachment surface for fish-food organisms. Trans. Americ. Fish. Soc. 102:622-626.
- Pardue, G. B., and L. A. Nielsen. 1979. Invertebrate biomass and fish production in ponds with added attachment surface. Pp. 34-37 in D. L. Johnson and R. A. Stein, editors. 1979. Response of fish to habitat structure in standing water. North Central Division Amer. Fish. Soc. Special Publ. 6.
- Pate, V. S. L. 1932. Studies on the fish food supply in selected areas. In A biological survey of the Oswegatchie and Black River systems, New York State Conserv. Dept., Suppl. to 21st Annual Report, pp. 133-149.
- Pate, V. S. L. 1933. Studies on fish food in selected areas. In A biological survey of the Upper Hudson watershed, New York State Conserv. Dept., Suppl. to 22nd Annual Report, pp. 130-156.
- Pate, V. S. L. 1934. Studies on the fish food supply in selected areas of the Raquette watershed. In A biological survey of the Raquette watershed, New York State Conserv. Dept., Suppl. to 23rd Annual Report, pp. 136-157.
- Pennak, R. W. 1953. Freshwater invertebrates of the United States. Ronald Press, New York. 769 pp.
- Pennak, R. W., and E. D. VanGerpen. 1947. Bottom fauna production and physical nature of the substrate in a northern Colorado trout stream. Ecol. 28:42-48.
- Rees, W. H. 1959. Effects of stream dredging on young silver salmon and bottom fauna. Wash. Dept. of Fish., Fish. Res. Papers 2(2): 53-65.
- Reif, C. B. 1939. The effect of stream conditions on lake plankton. Trans. Amer. Micro. Soc. 58:398-403.
- Ricker, W. E. 1930. Feeding habits of speckled trout in Ontario waters. Trans. Amer. Fish. Soc. 60:64-72.
- Shetter, D. S., O. H. Clark and A. S. Hazzard. 1946. The effects of deflectors in a section of a Michigan trout stream. Trans. Amer. Fish. Soc. 76:248-278.
- Sladeckova, A. 1962. Limnological investigation methods for the periphyton (Aufwuchs) community. Bot. Rev. 28(2):286-350.

- Smith, L. L., Jr., and J. B. Moyle. 1944. A biological survey and fishery management plan for the streams of the Lake Superior north-shore watershed. Minn. Dept. of Conserv., Div. of Game and Fish, Tech. Bull. No. 1. 228 pp.
- Stanford, J. A. 1973. A centrifuge method for determining live weights of aquatic insect larvae with a note on weight loss in preservation. *Ecol.* 54:449-451.
- Swift, M. C. 1970. A qualitative and quantitative study of trout food in Castle Lake, California. *Calif. Fish and Game.* 56(2):109-120.
- Tarzwel, C. M. 1936. Experimental evidence on the value of trout stream improvement in Michigan. *Trans. Amer. Fish. Soc.* 66: 177-187.
- Tarzwel, C. M. 1937. Factors influencing fish food and fish production in southwestern streams. *Trans. Amer. Fish. Soc.* 67:246-255.
- Tebo, L. B., Jr., and W. W. Hassler. 1963. Food of brook, brown and rainbow trout in streams in western North Carolina. *J. Elisha Mitchell Sci. Soc.* 79:44-53.
- Thorup, J. 1966. Substrate type and its value as a basis for the delimitation of bottom fauna communities in running waters, p. 59-74. In K. W. Cummins, C. A. Tryon, Jr., and R. T. Hartman (Ed.) *Organism-substrate relationships in streams.* Spec. Pub. No. 4, Pymatuning Lab. of Ecol., Univ. of Pittsburgh.
- Tusa, I. 1969. On the feeding biology of brown trout (Salmo trutta m. fairo L.) in the course of day and night. *Zool. Listy.* 18: 275-284.
- Warner, K., and I. R. Porter. 1960. Experimental improvement of a bulldozed trout stream in northern Maine. *Trans. Amer. Fish. Soc.* 89(1):59-63.
- Waters, T. F. 1961. Standing crop and drift of stream bottom organisms. *Ecol.* 42:532-537.
- Waters, T. F. 1962. Diurnal periodicity in the drift of stream invertebrates. *Ecol.* 43:316-320.
- Waters, T. F. 1964. Recolonization of denuded stream bottom areas by drift. *Trans. Amer. Fish. Soc.* 93:311-315.
- Waters, T. F. 1965. Interpretation of invertebrate drift in streams. *Ecol.* 46(3):327-334.
- Waters, T. F. 1966. Production rate, population density, and drift of a stream invertebrate. *Ecol.* 47(4):595-604.
- White, R. J. 1975. In-stream management for wild trout. Pp. 48-58 in

- W. King, ed., Wild Trout Management. Proc. Wild Trout Mgt. Symp. at Yellowstone Nat. Pk., Sept. 1974. Publ. Trout Unlimited.
- White, R. J., and O. M. Brynildson. 1967. Guidelines for management of trout stream habitat in Wisconsin. Wis. Dept. Nat. Resources, Tech. Bull. No. 39. 65 pp.
- Williams, D. D., and H. B. N. Hynes. 1976. The recolonization mechanisms of stream benthos. *Oikos*. 27(2):265-272.
- Winger, P. V. 1972. The effects of channelization and water impoundment on the macroinvertebrates in the Weber River, Summit County, Utah. Ph.D. dissertation, Brigham Young Univ. 111 pp.
- Wiseman, J. S. 1951. A quantitative analysis of foods eaten by eastern brook trout. *Wyoming Wildlife*. 15, 10:12-17.

Appendix A. Indices of relative food value assigned to each food item in the diet of trout in Plum Creek from 1976-1977.

<u>FOOD VALUE INDEX</u>		<u>FOOD VALUE INDEX</u>	
PLECOPTERA		DIPTERA	
Adult	5	Adult	1
Perlidae	4	Simuliidae	2
Nemouridae	3	Chironomidae	1
EPHEMEROPTERA		Tabanidae	3
EphemereUidae	4	Tipulidae	4
Caenidae	3	Rhagionidae	3
TRICHOPTERA		MOLLUSCA	
Adult	4	Pelecypoda	4
Hydropsycidae	4	Gastropoda	4
Brachycentridae	3	ANNELIDA	
Rhyacophilidae	3	Oligochaeta	1
Philopotamidae	3	Hirudina	2
Polycentropidae	3	NEMATODA	.05
Helicopsychidae	1	ISOPODA	3
Limnephilidae	5	DECAPODA	20
Unidentified	3	HYDRACARINA	.05
MEGALOPTERA		FISH	10
Corydalidae	4	TERRESTRIAL	
ODONATA		ANNELIDA	2
Adult	7	COLEOPTERA	3
Gomphidae	7	HEMIPTERA	3
Calopterygidae	4	HYMENOPTERA	3
HEMIPTERA		HOMOPTERA	4
Gerridae	4	ARACHNIDA	2
Nepidae	3		
Corixidae	3		
Salidae	3		
Unidentified	3		
COLEOPTERA			
Adult	3		
Elmidae	3		
Hydrophilidae	3		

Appendix B. Significance levels (*) of student t test comparisons between means for numbers and biomass of benthic invertebrates by substrate type in the altered (A) and unaltered (U) habitat zones in Plum Creek for 1976, 1977 and 1976-1977 combined.

	No./m ²					g/m ²						
	P <	.05	.1	.2	.4	.5	P <	.05	.1	.2	.4	.5
1976 A Gravel												
vs 1976 A Sand		*										
1976 U Gravel					*						*	
1976 U Sand									*			
1977 A Gravel		*						*				
1977 A Sand		*						*				
1977 A Gravel		*						*				
1977 A Sand		*						*				
1976 A Sand												
vs 1976 U Gravel				*							*	
1976 U Sand				*				*				
1977 A Gravel		*						*				
1977 A Sand		*						*				
1977 U Gravel		*						*				
1977 U Sand		*						*				
1976 U Gravel												
vs 1976 U Sand												
1977 A Gravel					*							
1977 A Sand					*							
1977 U Gravel					*							
1977 U Sand					*			*				
1976 U Sand												
vs 1977 A Gravel				*							*	
1977 A Sand				*		*						
1977 U Gravel				*								
1977 U Sand			*					*				
1977 A Gravel												
vs 1977 A Sand		*									*	
1977 U Gravel				*								*
1977 U Sand								*				
1977 A Sand												
vs 1977 U Gravel					*							
1977 U Sand		*						*				
1977 U Gravel												
vs 1977 U Sand			*					*				

Appendix B, continued.

	No./m ²					g/m ²						
	P <	<u>.05</u>	<u>.1</u>	<u>.2</u>	<u>.4</u>	<u>.5</u>	P <	<u>.05</u>	<u>.1</u>	<u>.2</u>	<u>.4</u>	<u>.5</u>
1976-1977 A Gravel												
vs 1976-1977 A Sand		*									*	
1976-1977 U Gravel												*
1976-1977 U Sand					*		*					
1976-1977 A Sand												
vs 1976-1977 U Gravel		*					*					
1976-1977 U Sand		*					*					
1976-1977 U Gravel												
vs 1976-1977 U Sand					*		*					

Appendix C. Distribution of taxa in Plum Creek by habitat zone collected from the benthic, drift, artificial substrate and trout stomach samples, 1976-1977.

	<u>BENTHIC GRAVEL</u>		<u>BENTHIC SAND</u>		<u>DRIFT</u>		<u>ARTIFICIAL SUBSTRATE</u>	<u>TROUT STOMACHS</u>		
	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Altered</u>	<u>Unaltered</u>	
<u>AQUATIC</u>										
Anthropoda										
C. Insecta										
O. Plecoptera - stoneflies	X	X	X	X	X	X	X	X	X	X
F. Perlidae	X	X		X	X	X	X	X	X	X
<u>Perlesta</u>	X	X		X	X	X	X			
<u>Acroneuria</u>					X	X				
<u>Attaneuria</u>	X	X			X		X			
<u>Paragnetina</u>	X	X			X	X	X			
F. Nemouridae	X	X	X	X		X	X		X	
<u>Nemoura</u>	X	X	X	X		X	X			
F. Perlodidae	X	X	X	X	X	X	X			
<u>Isogenoides</u>		X	X	X						
<u>Isoperla</u>	X	X	X	X	X	X	X			
F. Taeniopterygidae	X	X	X		X	X	X			
<u>Taeniopteryx</u>	X	X	X		X	X	X			
Adults					X	X			X	
O. Ephemeroptera - mayflies	X	X	X	X	X	X	X	X	X	X
F. Ephemerellidae	X	X	X	X	X	X	X	X	X	X
<u>Ephemerella</u>	X	X	X	X	X	X	X			
F. Caenidae	X	X	X	X	X	X	X	X	X	X
<u>Caenis</u>	X	X	X	X	X	X	X			
<u>Brachycercus</u>		X	X	X	X	X				
F. Baetidae	X	X	X	X	X	X	X			
<u>Baetis</u>	X	X	X	X	X	X	X			
<u>Pseudocleon</u>						X				
<u>Cleon</u>					X					
<u>Centroptilem</u>					X					

Appendix C, continued.

	<u>BENTHIC GRAVEL</u>		<u>BENTHIC SAND</u>		<u>DRIFT</u>		<u>ARTIFICIAL</u> <u>SUBSTRATE</u>	<u>TROUT STOMACHS</u>	
	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Altered</u>	<u>Unaltered</u>
F. <u>Baetiscidae</u>	X		X	X	X	X			
<u>Baetisca</u>	X		X	X	X	X			
F. <u>Heptageniidae</u>	X		X	X	X	X	X		
<u>Stenonema</u>	X		X	X	X	X	X		
F. <u>Leptophlebiidae</u>			X				X		
<u>Leptophlebia</u>			X				X		
F. <u>Ephemeridae</u>				X					
<u>Hexagenia</u>				X					
F. <u>Tricorythidae</u>	X	X	X	X	X				
<u>Tricorythodes</u>	X	X	X	X	X				
Adult			X		X	X			
0. Odonata - dragonflies	X	X	X	X	X	X	X	X	X
F. <u>Cordulegastridae</u>	X		X	X		X			
<u>Cordulegaster</u>	X		X	X		X			
F. <u>Gomphidae</u>	X	X	X	X	X	X	X	X	X
<u>Ophiogomphus</u>	X	X	X	X	X	X	X		
<u>Stylurus</u>	X	X	X	X					
F. <u>Libellulidae</u>			X	X	X		X		
<u>Ladona</u>			X		X		X		
<u>Leucorrhinia</u>			X	X					
<u>Libellula</u>			X						
F. <u>Calopterygidae</u>			X	X	X	X	X	X	
<u>Calopteryx</u>			X	X	X	X	X		
<u>Hetaerina</u>					X				
Adult								X	X

Appendix C, continued.

	<u>BENTHIC GRAVEL</u>		<u>BENTHIC SAND</u>		<u>DRIFT</u>		<u>ARTIFICIAL SUBSTRATE</u>	<u>TROUT STOMACHS</u>	
	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Altered</u>	<u>Unaltered</u>
0. Hemiptera - bugs	X	X		X	X	X	X	X	X
F. Belostomatidae - giant water bugs									
<u>Belostoma</u>							X		
<u>Belostoma</u>							X		
F. Nepidae - water scorpions					X	X	X		
<u>Nepa</u>					X	X	X		
<u>Ranatra</u>					X	X			
F. Gerridae - water striders	X	X		X	X	X		X	X
F. Mesoveliidae - water treaders									
<u>Mesovelia</u>									
<u>Mesovelia</u>									
F. Corixidae - water boatmen					X	X		X	X
<u>Sigara</u>					X	X			
<u>Hesperocorixa</u>					X	X			
F. Notonectidae - back swimmers					X	X			
F. Veliidae					X	X			
<u>Microvelia</u>					X	X			
<u>Microvelia</u>									
F. Saldidae					X	X		X	
0. Trichoptera - caddis flies	X	X	X	X	X	X	X	X	X
F. Brachycentridae	X	X	X	X	X	X	X	X	X
<u>Brachycentrus</u>	X	X	X	X	X	X	X		
<u>Micraesema</u>			X	X					
<u>Micraesema</u>									
F. Glossosomatidae	X	X	X	X	X	X		X	X
<u>Agapetus</u>	X	X	X	X	X				
<u>Oligostomis</u>			X	X					
<u>Glossosoma</u>					X	X			
F. Goeridae	X	X	X	X					
<u>Goera</u>	X	X	X	X					

Appendix C, continued.

	<u>BENTHIC GRAVEL</u>		<u>BENTHIC SAND</u>		<u>DRIFT</u>		<u>ARTIFICIAL SUBSTRATE</u>	<u>TROUT STOMACHS</u>	
	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Altered</u>	<u>Unaltered</u>
F. <u>Helicopsychidae</u>	X	X	X	X				X	X
<u>Helicopsyche</u>	X	X	X	X					
F. <u>Hydropsycidae</u>	X	X	X	X	X	X	X	X	X
F. <u>Lepidostomatidae</u>	X	X				X			
<u>Lepidostoma</u>	X	X				X			
F. <u>Leptoceridae</u>	X		X		X	X			
<u>Ceraclea</u>	X		X		X	X			
F. <u>Limnephilidae</u>	X	X	X	X	X	X	X	X	X
<u>Frenesia</u>		X	X						
<u>Glyphopsyche</u>			X	X		X			
<u>Hydatophylax</u>		X	X	X	X	X			
<u>Nemotaulius</u>			X		X	X			
<u>Neophylax</u>	X	X			X				
<u>Onocosmoecus</u>	X					X			
<u>Platycentropus</u>	X				X	X	X		
<u>Psychoglypha</u>				X					
<u>Pycnopsyche</u>	X	X	X	X	X	X	X		
<u>Apatania</u>					X		X		
<u>Pseudostenophylax</u>	X	X	X		X	X			
F. <u>Philopotamidae</u>	X	X	X		X		X	X	
<u>Chimarra</u>	X	X	X		X				
<u>Wormaldia</u>		X					X		
F. <u>Polycentropodidae</u>	X	X	X	X	X	X	X	X	
<u>Polycentropus</u>	X	X	X	X	X	X	X		
<u>Cyrinellus</u>	X	X	X				X		
<u>Neureclipsis</u>					X				
<u>Nyctiophylax</u>							X		
F. <u>Rhyacophilidae</u>	X	X	X	X	X	X	X	X	
<u>Rhyacophila</u>	X	X	X	X	X	X	X		
F. <u>Psychomyiidae</u>					X				
<u>Lype</u>					X				
Adult					X				

Appendix C, continued.

	<u>BENTHIC GRAVEL</u>		<u>BENTHIC SAND</u>		<u>DRIFT</u>		<u>ARTIFICIAL SUBSTRATE</u>	<u>TROUT STOMACHS</u>	
	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Altered</u>	<u>Unaltered</u>
O. Megaloptera	X		X	X		X	X	X	
F. Corydalidae - fishflies	X		X	X		X	X	X	
<u>Chauloides</u>	X		X	X		X	X		
O. Coleoptera - beetles	X	X	X	X	X	X	X	X	X
F. Elmidae - riffle beetles	X	X	X	X	X	X	X	X	X
<u>Dubiraphia</u>		X	X	X	X	X			
<u>Macronychus</u>	X	X	X	X	X	X	X		
<u>Optioservus</u>	X	X	X	X	X	X	X		
<u>Stenelmis</u>				X	X	X			
F. Dytiscidae - predaceous diving beetles	X		X			X			
<u>Agabus</u>	X								
<u>Hydroporus</u>			X						
<u>Liodessus</u>						X			
<u>Laccophilus</u>						X			
F. Gyrinidae - whirligig beetles			X		X	X	X		
<u>Gyrinus</u>			X		X	X	X		
F. Haliplidae - crawling water beetles		X				X			
<u>Halipius</u>		X							
<u>Brychius</u>						X			
F. Hydrophilidae - water scavenger beetles					X		X	X	X
<u>Helphorus</u>							X		
<u>Hydrobius</u>					X		X		
<u>Hydrochus</u>							X		
<u>Laccobius</u>					X				
F. Noteridae - burrowing water beetles							X		
<u>Hydrocanthus</u>							X		
Adult					X	X		X	X

Appendix C, continued.

	<u>BENTHIC GRAVEL</u>		<u>BENTHIC SAND</u>		<u>DRIFT</u>		<u>ARTIFICIAL SUBSTRATE</u>	<u>TROUT STOMACHS</u>	
	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Altered</u>	<u>Unaltered</u>
O. Diptera - flies	X	X	X	X	X	X	X	X	X
F. Ceratopogonidae - biting midges	X	X	X	X					
F. Chironomidae - midges	X	X	X	X	X	X	X	X	X
F. Empididae - dance flies	X	X	X	X	X	X	X		
F. Rhagionidae - snipe flies		X		X		X	X	X	
<u>Atherix</u>		X		X		X	X		
F. Simuliidae - black flies	X	X	X	X	X	X	X	X	X
F. Tabanidae - horse flies	X	X	X	X	X	X		X	
<u>Chrysops</u>	X	X	X	X	X	X			
F. Tipulidae - crane flies	X	X	X	X	X		X	X	X
<u>Antocha</u>	X	X	X	X	X		X		
<u>Dicranota</u>	X	X	X	X					
<u>Hexatoma</u>	X	X	X	X					
<u>Pilaria</u>		X	X						
<u>Pseudotimnophila</u>		X		X	X				
<u>Tipula</u>	X	X	X	X	X				
<u>Limonia</u>					X				
<u>Phalacrocera</u>							X		
F. Chaoboridae - phantom midges						X			
<u>Chaoborus</u>						X			
F. Dixidae					X				
<u>Dixa</u>					X				
Adult					X	X		X	X

Appendix C, continued.

	<u>BENTHIC GRAVEL</u>		<u>BENTHIC SAND</u>		<u>DRIFT</u>		<u>ARTIFICIAL SUBSTRATE</u>	<u>TROUT STOMACHS</u>	
	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Altered</u>	<u>Unaltered</u>
Mollusca	X	X	X	X	X	X	X	X	X
C. Gastropoda - snails	X	X	X	X	X	X	X	X	X
C. Pelecypoda - clams	X	X	X	X	X	X	X	X	X
C. Crustacea									
0. Amphipoda - side swimmers	X		X		X	X			
F. Gammaridae	X		X		X	X			
<u>Gammarus</u>	X		X			X			
<u>Hyalina</u>					X	X			
0. Isopoda - sowbugs	X		X	X	X		X	X	X
F. Asellidae	X		X	X	X		X	X	X
<u>Asellus</u>	X		X	X	X		X		
0. Decapoda - crayfish			X	X	X	X		X	X
0. Cladocera					X	X			
F. Leptodoridae					X	X			
<u>Leptodora</u>					X	X			
Annelida	X	X	X	X	X	X	X	X	X
C. Hirudinea - leeches		X		X				X	
C. Oligochaeta - aquatic earthworms	X	X	X	X	X	X	X	X	X
Nematoda - roundworms	X	X	X	X		X		X	X
Hydracarina - water mites	X		X			X		X	
Collembola - spring tails		X			X	X			
Aquatic Lepidoptera - moths	X	X	X	X	X	X			
Brook Lamprey			X	X					
Fish					X	X		X	X

Appendix C, continued.

	<u>BENTHIC GRAVEL</u>		<u>BENTHIC SAND</u>		<u>DRIFT</u>		<u>ARTIFICIAL SUBSTRATE</u>	<u>TROUT STOMACHS</u>	
	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Unaltered</u>	<u>Altered</u>	<u>Altered</u>	<u>Unaltered</u>
<u>TERRESTRIAL</u>									
Annelida					X			X	X
C. Insecta									
0. Coleoptera - beetles					X	X		X	X
0. Hemiptera - bugs					X	X		X	
0. Orthoptera					X	X			
0. Hymenoptera					X	X		X	X
0. Homoptera					X	X			
0. Lepidoptera					X	X			
Arachnida					X	X		X	

Appendix D. Major taxa percentages found in the benthic substrate and drift by habitat zones. Chi Square (X^2) analysis of the following hypothesis: The proportion of major insect taxa in the benthic substrates combined and drift would not be statistically different. Probability of accepting the hypothesis ($P >$).

	Benthic Gravel and Sand Combined			Benthic Gravel and Sand Combined		
	No. (%)	Drift No. (%)	$P >$	Drift No. (%)	Drift Wt. (%)	$P >$
ODONATA A	2.7	3.5	.7	21.6	44.7	*
U	1.9	1.6	.9	11.8	26.1	*
Gomphidae A	2.6	3.1	.8	19.3	45.6	*
U	1.7	1.5	.9	10.3	12.1	.7
TRICHOPTERA A	29.0	13.5	*	34.7	17.5	*
U	24.3	7.3	*	15.0	15.4	.95
Hydropsychidae A	25.4	7.4	*	31.4	10.9	*
U	18.7	5.1	*	9.5	6.6	.5
DIPTERA A	51.0	60.7	.05	22.0	12.8	.05
U	44.1	66.8	*	16.0	14.2	.7
Chironomidae A	40.8	19.7	*	14.1	3.2	.01
U	31.4	28.6	.7	4.6	1.5	.2
Simuliidae A	4.4	18.8	*	1.9	1.9	.99
U	3.9	9.2	.01	1.0	.7	.8
ORDER TOTAL A	81.7	77.7	.5	78.3	75.0	.5
U	70.3	75.7	.3	42.8	55.7	.01
Family Total A	73.2	49.0	*	66.7	61.6	.3
U	55.7	44.4	.05	25.4	20.9	.5

*Probability .001

Appendix F. Significance levels (*) of student t test comparisons between means for numbers and biomass of invertebrates on artificial substrates after time intervals of one, two, three and four months compared to benthic substrate types in the altered (A) and unaltered (U) habitat zones in Plum Creek, 1976-1977.

	<u>No./m²</u>					<u>g/m²</u>				
	<u>P < .05</u>	<u>.1</u>	<u>.2</u>	<u>.4</u>	<u>.5</u>	<u>P < .05</u>	<u>.1</u>	<u>.2</u>	<u>.4</u>	<u>.5</u>
One Month 1976										
vs. A Gravel	*					*				
A Sand	*					*				
U Gravel	*					*				
U Sand	*					*				
One Month 1977										
vs. A Gravel				*		*				
A Sand					*	*				
U Gravel				*		*				
U Sand			*			*				
Two Months 1977										
vs. A Gravel				*						*
A Sand		*								
U Gravel				*					*	
U Sand						*				
Three Months 1977										
vs. A Gravel										
A Sand										
U Gravel										
U Sand									*	
Four Months 1977										
vs. A Gravel									*	
A Sand										
U Gravel									*	
U Sand							*			
Months-Years Combined										
vs. A Gravel						*				
A Sand				*			*			
U Gravel						*				
U Sand				*		*				

Appendix G. Mean number and percentage of weight of organisms equal to or exceeding 2% of the total found in trout stomachs in the altered or unaltered habitat zones of Plum Creek (May 1976-September 1977).

	Brook Trout				Brown Trout				Stocked Brown Trout				All Species		Combined	
	Altered		Unaltered		Altered		Unaltered		Altered		Unaltered		Altered		Unaltered	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
PLECOPTERA	.15 (1.9)	(1.8)	.1 (.9)	(1.1)	.14 (1.1)	(1.0)	1.27 (12.3)	(10.2)	.16 (1.6)	(1.5)	.13 (2.3)	(1.7)	.15 (1.6)	(1.6)	.38 (3.8)	(3.9)
Perlidae	.13 (1.7)	(1.6)	.1 (.9)	(1.1)	.09 (.7)	(.7)	1.27 (12.3)	(10.2)	.11 (1.1)	(1.0)	.13 (2.3)	(1.7)	.12 (1.3)	(1.3)	.38 (3.8)	(3.9)
EPHEMEROPTERA	.29 (3.7)	(3.8)	.15 (1.4)	(1.6)	.14 (1.2)	(1.1)	.74 (7.1)	(5.4)	.26 (2.7)	(2.6)			.26 (3.0)	(3.0)	.27 (2.7)	(2.6)
Ephemerellidae	.28 (3.6)	(3.7)	.15 (1.4)	(1.6)	.12 (1.0)	(1.0)	.47 (4.5)	(3.8)	.26 (2.7)	(2.6)			.25 (2.9)	(2.9)	.21 (2.1)	(2.1)
Caenidae	.01 (.1)	(.1)			.02 (.2)	(.1)	.27 (2.6)	(1.6)					.01 (.1)	(.1)	.06 (.6)	(.5)
ODONATA	1.17 (14.9)	(26.7)	1.8 (16.6)	(33.2)	2.14 (17.4)	(30.3)	1.87 (18.1)	(26.2)	1.87 (19.3)	(32.0)	.63 (11.2)	(14.4)	1.41 (16.1)	(28.1)	1.67 (16.6)	(29.3)
Gomphidae	1.14 (14.5)	(26.0)	1.8 (16.6)	(33.2)	2.09 (17.0)	(29.7)	1.80 (17.4)	(25.3)	1.84 (19.0)	(31.5)	.63 (11.2)	(14.4)	1.38 (15.7)	(27.5)	1.65 (16.4)	(29.0)
HEMIPTERA	.11 (1.5)	(1.2)	.10 (1.0)	(.9)	.27 (2.2)	(1.8)	.2 (1.9)	(1.6)	.29 (3.0)	(2.8)			.16 (1.9)	(1.7)	.11 (1.1)	(1.0)
Gerridae	.02 (.3)	(.3)	.05 (.5)	(.5)	.05 (.4)	(.4)							.06 (.7)	(.08)	.08 (.8)	(.8)
TRICHOPTERA	3.58 (45.4)	(44.2)	2.57 (23.7)	(27.0)	5.12 (41.6)	(37.8)	3.6 (34.8)	(27.3)	3.51 (36.2)	(31.6)	2.22 (39.3)	(26.7)	3.82 (43.2)	(40.9)	2.77 (27.6)	(27.1)
Brachycentridae	.9 (11.4)	(8.8)	.08 (.7)	(.6)	1.79 (14.5)	(10.9)			1.16 (12.0)	(8.5)			1.08 (12.2)	(9.2)	.15 (.5)	(.4)
Glossosomatidae	.17 (2.2)	(1.7)	.25 (2.3)	(2.0)	.71 (5.8)	(4.3)	.2 (1.9)	(1.2)	.26 (2.7)	(1.9)	1.13 (20.0)	(11.1)	.27 (3.1)	(2.3)	.35 (3.5)	(2.7)
Helicopsychidae	.01 (.1)	(.01)	.03 (.3)	(.07)	.05 (.4)	(.1)	.33 (3.2)	(.7)	.05 (.5)	(.1)			.02 (.2)	(.05)	.10 (1.0)	(.2)

Appendix G, continued.

	Brook Trout				Brown Trout				Stocked Brown Trout				All Species Combined			
	Altered		Unaltered		Altered		Unaltered		Altered		Unaltered		Altered		Unaltered	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
ISOPODA																
Asellidae	.06 (.8)	(.6)	.08 (.7)	(.6)			.2 (1.9)	(1.2)	.03 (.3)	(.2)			.05 (.6)	(.4)	.1 (1.0)	(.5)
DECAPODA																
	.04 (.5)	(2.4)	.23 (2.1)	(12.1)	.07 (.6)	(2.8)	.47 (4.5)	(18.7)	.03 (.3)	(.2)	.38 (6.7)	(24.7)	.04 (.5)	(2.3)	.3 (3.0)	(15.3)
FISH																
	.13 (1.7)	(4.2)	.13 (1.2)	(3.4)	.31 (2.5)	(6.3)			.39 (4.0)	(9.6)	.63 (11.2)	(20.6)	.19 (2.2)	(5.4)	.16 (1.6)	(4.0)
TERRESTRIAL																
ANNELIDA	.02 (.3)	(.09)	.03 (.3)	(.07)	.07 (.6)	(.3)			.42 (4.3)	(1.4)	.25 (4.4)	(.8)	.07 (.8)	(.3)	.05 (.5)	(.1)
COLEOPTERA	.05 (.6)	(.5)	.18 (1.7)	(1.4)	.29 (2.4)	(1.8)	.13 (1.3)	(.8)	.21 (2.2)	(1.5)	.13 (2.3)	(1.2)	.11 (1.3)	(1.0)	.16 (1.6)	(1.2)
HYMENOPTERA	.37 (4.7)	(2.4)	.03 (.3)	(.1)	.55 (4.5)	(2.2)	.07 (.7)	(.3)	.37 (3.8)	(1.8)	.25 (4.4)	(1.7)	.4 (4.6)	(2.3)	.06 (.6)	(.3)
HOMOPTERA	.05 (.6)	(.6)	.03 (.3)	(.3)	.19 (1.5)	(1.5)	.2 (1.9)	(1.6)	.29 (3.0)	(2.8)	.13 (2.3)	(1.7)	.1 (1.1)	(1.1)	.08 (.8)	(.8)
AQUATIC TOTAL	7.21 (91.5)	(94.8)	10.54 (97.0)	(98.1)	10.91 (88.5)	(93.2)	9.83 (94.9)	(97.2)	8.13 (83.9)	(90.6)	4.88 (86.5)	(94.7)	7.95 (89.7)	(94.5)	9.62 (95.8)	(97.5)
TERRESTRIAL TOTAL	.49 (6.2)	(3.6)	.27 (2.5)	(1.9)	1.10 (8.9)	(5.8)	.4 (3.9)	(2.7)	1.29 (13.3)	(7.5)	.76 (13.4)	(5.4)	.68 (7.8)	(4.7)	.35 (3.5)	(2.4)
COMBINED TOTAL	7.70 (97.7)	(98.4)	10.81 (99.5)	(100.0)	12.01 (97.4)	(99.0)	10.23 (98.8)	(99.9)	9.42 (97.2)	(98.1)	5.64 (99.9)	(100.1)	8.63 (97.5)	(99.2)	9.97 (99.3)	(99.9)
OVERALL TOTAL	7.88		10.87		12.33		10.36		9.69		5.64		8.86		10.04	

Appendix G, continued.

	Brook Trout				Brown Trout				Stocked Brown Trout				All Species		Combined	
	Altered		Unaltered		Altered		Unaltered		Altered		Unaltered		Altered	Unaltered	Unaltered	Unaltered
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Hydropsychidae	1.94 (24.6)	(25.2)	1.93 (17.8)	(20.6)	1.66 (13.5)	(13.4)	2.67 (25.8)	(21.4)	1.32 (13.6)	(12.8)	.84 (14.9)	(11.5)	1.82 (20.7)	(20.8)	1.97 (19.6)	(20.0)
Limnephilidae	.5 (6.4)	(8.0)	.28 (2.6)	(3.7)	.86 (7.0)	(8.8)	.4 (3.9)	(4.0)	.63 (6.5)	(7.6)	.25 (4.4)	(4.1)	.57 (6.5)	(8.1)	.3 (3.0)	(3.8)
COLEOPTERA	.19 (2.5)	(.8)	.29 (2.7)	(2.0)	.44 (3.6)	(2.4)	.4 (3.9)	(2.1)	.42 (4.3)	(3.1)			.27 (3.0)	(2.1)	.27 (2.7)	(1.9)
Elmidae	.06 (.8)	(.5)	.18 (1.7)	(1.3)	.28 (2.3)	(1.4)	.13 (1.3)	(.5)	.34 (3.5)	(2.5)			.13 (1.5)	(1.0)	.14 (1.3)	(1.0)
Adult	.11 (1.4)	(1.0)	.08 (.7)	(.5)	.16 (1.3)	(1.0)	.27 (2.6)	(1.6)	.08 (.8)	(.6)			.12 (1.3)	(.9)	.11 (1.0)	(.8)
DIPTERA	1.3 (16.7)	(6.5)	5.03 (46.3)	(15.6)	1.78 (14.5)	(5.6)	.74 (7.2)	(1.9)	.8 (8.3)	(3.4)	.51 (9.0)	(1.6)	1.33 (15.1)	(5.9)	3.43 (34.2)	(10.2)
Chironomidae	.5 (6.4)	(1.6)	.4 (3.7)	(1.1)	.5 (4.1)	(1.0)	.27 (2.6)	(.5)	.24 (2.5)	(.6)	.13 (2.3)	(.4)	.47 (5.3)	(1.3)	.33 (3.3)	(.9)
Simuliidae	.58 (7.4)	(2.3)	4.48 (41.2)	(12.9)	.79 (6.4)	(2.0)	.4 (3.9)	(1.1)	.29 (3.0)	(1.0)	.38 (6.7)	(1.2)	.59 (6.7)	(2.1)	2.98 (29.7)	(8.2)
Tipulidae	.17 (2.2)	(2.3)	.15 (1.4)	(1.6)	.22 (1.8)	(1.8)			.16 (1.7)	(1.5)			.18 (2.1)	(2.1)	.1 (1.0)	(1.0)
MOLLUSCA	.19 (2.4)	(2.6)	.06 (.6)	(.6)	.50 (4.1)	(4.1)	.34 (3.3)	(2.6)	.37 (3.8)	(3.6)	.38 (6.7)	(5.0)	.27 (3.1)	(3.1)	.16 (1.6)	(1.7)
Gastropoda	.11 (1.4)	(1.5)	.03 (.3)	(.3)	.21 (1.7)	(1.7)	.27 (2.6)	(2.1)	.13 (1.3)	(1.3)	.13 (2.3)	(1.7)	.13 (1.5)	(1.5)	.10 (1.0)	(1.0)
Pelecypoda	.08 (1.0)	(1.1)	.03 (.3)	(.3)	.29 (2.4)	(2.4)	.07 (.7)	(.5)	.24 (2.5)	(2.3)	.25 (4.4)	(3.3)	.14 (1.6)	(1.6)	.06 (.6)	(.7)

Appendix H. Chi Square (χ^2) analysis of the hypothesis: The percent occurrence of major aquatic insect taxa from the benthic, drift and artificial substrate samples in Plum Creek, 1976-1977 are not statistically different than those taxa percentages found in the trout stomachs. Probability of accepting the hypothesis ($P >$).

*Probability $>$.001

	Brook Trout		Brown Trout		Stocked Brown Trout		All Species Combined	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
<u>ODONATA</u>								
Benthic Gravel - A	*	.05	*	.01	*	*	*	.05
- U	*	*	*	.02	*	.50	*	.01
Benthic Sand - A	*	.80	*	.30	*	.20	*	.70
- U	*	*	*	*	*	.10	*	*
Drift - A	*	*	*	*	*	*	*	*
- U	*	.10	*	.98	*	.01	*	.50
Artificial Substrate - A	*	*	*	*	*	*	*	*
<u>Gomphidae</u>								
Benthic Gravel - A	*	.05	*	.01	*	*	*	.01
- U	*	*	*	.05	*	.50	*	.50
Benthic Sand - A	*	*	*	*	*	*	*	*
- U	*	*	*	*	*	.01	*	*
Drift - A	*	*	*	*	*	*	*	*
- U	*	*	*	*	*	.50	*	*
Artificial Substrate - A	*	*	*	*	*	*	*	*
<u>TRICHOPTERA</u>								
Benthic Gravel - A	.20	.10	.70	.01	.70	*	.50	.01
- U	*	.20	.05	.20	.30	.10	*	.20
Benthic Sand - A	*	*	*	*	*	*	*	*
- U	*	*	*	*	*	*	*	*
Drift - A	*	*	*	*	*	*	*	*
- U	*	.01	*	*	*	.01	*	.01
Artificial Substrate - A	*	.20	*	.90	*	.30	*	.50
<u>Hydropsychidae</u>								
Benthic Gravel - A	.05	*	*	*	*	*	.01	*
- U	*	.30	.10	.70	*	.01	.01	.30
Benthic Sand - A	*	*	.01	.01	.01	.01	*	*
- U	*	*	*	*	*	*	*	*
Drift - A	*	*	.05	.50	.05	.70	*	.01
- U	*	*	*	*	*	.05	*	*
Artificial Substrate - A	*	.70	.70	.05	.70	.02	.01	.70

Appendix H, continued.

	Brook Trout		Brown Trout		Stocked Brown Trout		All Species Combined	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
<u>DIPTERA</u>								
Benthic Gravel - A	*	*	*	*	*	*	*	*
- U	.05	.02	*	*	*	*	.70	*
Benthic Sand - A	*	*	*	*	*	*	*	*
- U	.90	.20	*	*	*	*	.05	.80
Drift - A	*	.10	*	.05	*	.01	*	.05
- U	*	.70	*	*	*	*	*	.30
Artificial Substrate - A	*	*	*	*	*	*	*	*
<u>Chironomidae</u>								
Benthic Gravel - A	*	*	*	*	*	*	*	*
- U	*	.20	*	.10	*	.10	*	.20
Benthic Sand - A	*	*	*	.01	*	*	*	*
- U	*	.10	*	.05	*	.05	*	.10
Drift - A	*	.50	*	.70	*	.20	*	.30
- U	*	.80	*	.50	*	.50	*	.70
Artificial Substrate - A	*	*	*	*	*	*	*	*
<u>Simuliidae</u>								
Benthic Gravel - A	.50	.80	.80	.70	.30	.30	.70	.70
- U	*	*	.90	.90	.10	.90	*	*
Benthic Sand - A	*	.02	*	.05	.50	.70	*	.05
- U	*	*	.90	.80	.30	.70	*	*
Drift - A	.01	.80	.01	.95	*	.70	.01	.90
- U	*	*	.10	.70	.50	.70	*	*
Artificial Substrate - A	.70	.05	.50	.05	.05	.02	.50	.05
<u>AQUATIC ORDER TOTAL</u>								
Benthic Gravel - A	*	*	*	*	*	*	*	*
- U	.50	.50	*	*	*	*	.30	.01
Benthic Sand - A	.20	*	.50	*	.20	.05	.50	*
- U	*	*	.30	*	.50	*	*	*
Drift - A	.90	.70	.50	.80	*	.10	.50	.99
- U	.02	*	*	.98	*	.01	.70	.05
Artificial Substrate - A	.01	.20	*	.70	*	.50	*	.50
<u>Aquatic Family Total</u>								
Benthic Gravel - A	*	*	*	*	*	*	*	*
- U	.01	*	.01	.90	*	*	.30	.05
Benthic Sand - A	.10	*	*	.01	*	.02	.01	*
- U	*	*	.90	*	.01	*	*	*
Drift - A	.50	.20	.30	.01	.05	.01	.90	.05
- U	*	*	.30	*	.10	.20	*	*
Artificial Substrate - A	*	.99	*	.20	*	.10	*	.50