CHANGES IN THE INVERTEBRATE POPULATIONS, FISH POPULATIONS, AND WATER CHEMISTRY OF A SMALL STREAM ABOVE AND BELOW TWO IMPOUNDMENTS

by

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INTRODUCTION

Impoundments cause many alterations in a lotic environment. The most obvious alteration is the creation of a lentic situation behind the dam; however, there may be other less visible alterations downstream.

The effects of large mainstream reservoirs on their water supplies have been well documented. Important downstream effects are alteration of flow patterns (Neel, 1963), reduction of turbidity (Churchill, 1958; Neel, 1963; Morris, et al, 1968; Soltero, et al, 1973), changes in temperature regime (Pfitzer, 1954; Neel, 1963; Spence and Hynes, 1971a, Lehmkuhl, 1972), increased growth of attached algae (Neel, 1973), changes in chemical characteristics of the water (Dendy and Stroud, 1949; Spence and Hynes, 1971a; Lehmkuhl, 1972; Soltero, et al, 1973), and changes in species composition and diversity of invertebrates and fish (Bacon, et al, 1968; Isom, 1968; Morris, et al, 1968; Spence and Hynes, 1971a, 1971b; Ward, 1974).

Changes in species composition and diversity are often related to chemical and physical changes. Dendy and Stroud (1949) noted that the warmwater habitat below Fontana Reservoir, Tennessee, was changed to one capable of supporting trout following impoundment. Disappearance of many cyprinid species and changes in benthic populations have been attributed to reduction of water temperature below reservoirs (Pfitzer, 1954; Spence and Hynes, 1971a; Lehmkuhl, 1972).

Though the impact of large impoundments on downstream areas has been well documented, little is known about the impact of reservoirs on small streams. Small streams are an important resource since many function as spawning and nursery areas for fish. Other streams contain unique faunas. Recognition of the importance of small streams and the limited data base on reservoir impacts has caused the Soil Conservation Service to critically evaluate its construction activities. However, ponds will continue to be built by other parties.

The impacts of small impoundments on streams may be placed into one of three categories; impacts on energy dynamics, impacts on physio-chemical dynamics, and material impacts (addition of substances not associates with normal stream metabolism). Additionally, ponds may serve as foci of introduction of exotic species, and block movements of native species.

Energy Impacts

Ponds provide sources of photosynthetic activity and energy input not normally found in streams. A pond may output more energy than it traps from upstream sources, and act as an allochthonous energy source for the stream below. Conversely, a pond may create an energy sink if the intake of transported energy exceeds the energy output.

Aquatic communities below an energy exporting pond should show increased benthic population densities and biomass. Conversely, the reduction in energy below an energy sink pond should result in reduced benthos density and biomass. Fish populations may not be significantly affected by energy output if the energy reduction is seasonal. However, under long term energy reductions fish populations may be reduced and species composition shifted toward more efficient forms.

Physiochemical Impacts

Factors such as temperature, nutrient load, and flow patterns may be modified below small impoundments. Temperature may be increased downstream and increased temperature below the pond will cause reduced oxygen concentrations which may result in alteration of the aquatic communities. Nutrients may be reduced below the pond during seasons of high photosynthetic activity, and be unaffected or increased during non production seasons. Alteration of nutrient loads will alter periphyton production and the population and biomass of grazing aquatic species dependent on periphyton.

Material Impacts

Ponds may output various forms of suspended or dissolved material that will cause alterations within the stream communities. Material with high BOD may severely reduce oxygen and eliminate sensitive organisms, and flocculent materials may cause smothering. Other noxious or toxic materials may also be output. Material impacts may be dependent upon the location of the outlet structure.

The following study was undertaken to evaluate the effects of small (less than 4 hectares) impoundments on small (less than 0.3 cubic meters per second flow) receiving streams. Major objectives were:

1. To determine seasonal changes in chemical parameters above and below two small, top-water release, impoundments.
2. To determine seasonal changes in population size, species composition, and structure of benthic communities above and below two small, top-water release, impoundments.

3. To determine seasonal changes in population size, and species composition of fish populations above and below two small, top-water release, impoundments.
4. To determine seasonal changes in the species composition and quantity of drift above and below two small, top-water release impoundments.

The hypothesis tested was that these factors were not different above and below the ponds.

STUDY AREA

A small, first order, tributary of Mill Creek on the Reynolds Homestead Research Center, 1.2 kilometers north of Critz, Patrick County, Virginia, was selected as the location of the study. The drainage basin (Figure 1) ranged in elevation from 591 meters to 310 meters and encompassed 432 hectares. The stream was intermittent until reaching an elevation of 329 meters. The permanent section was 1.8 kilometers in length. The upper 800 meters flowed through mixed decidious forest. The 1000 meters of stream traversing the Reynolds Homestead flowed through brush thickets at the boundary of cleared fields and hardwood forest.

Two 0.2 ha. ponds were constructed adjacent to the stream in 1974. Water was diverted from the stream into individual water supplies for each pond. Each pond discharged independently to the original stream through a surface draw standpipe. Downstream sampling sites were located downstream of the second outlet.

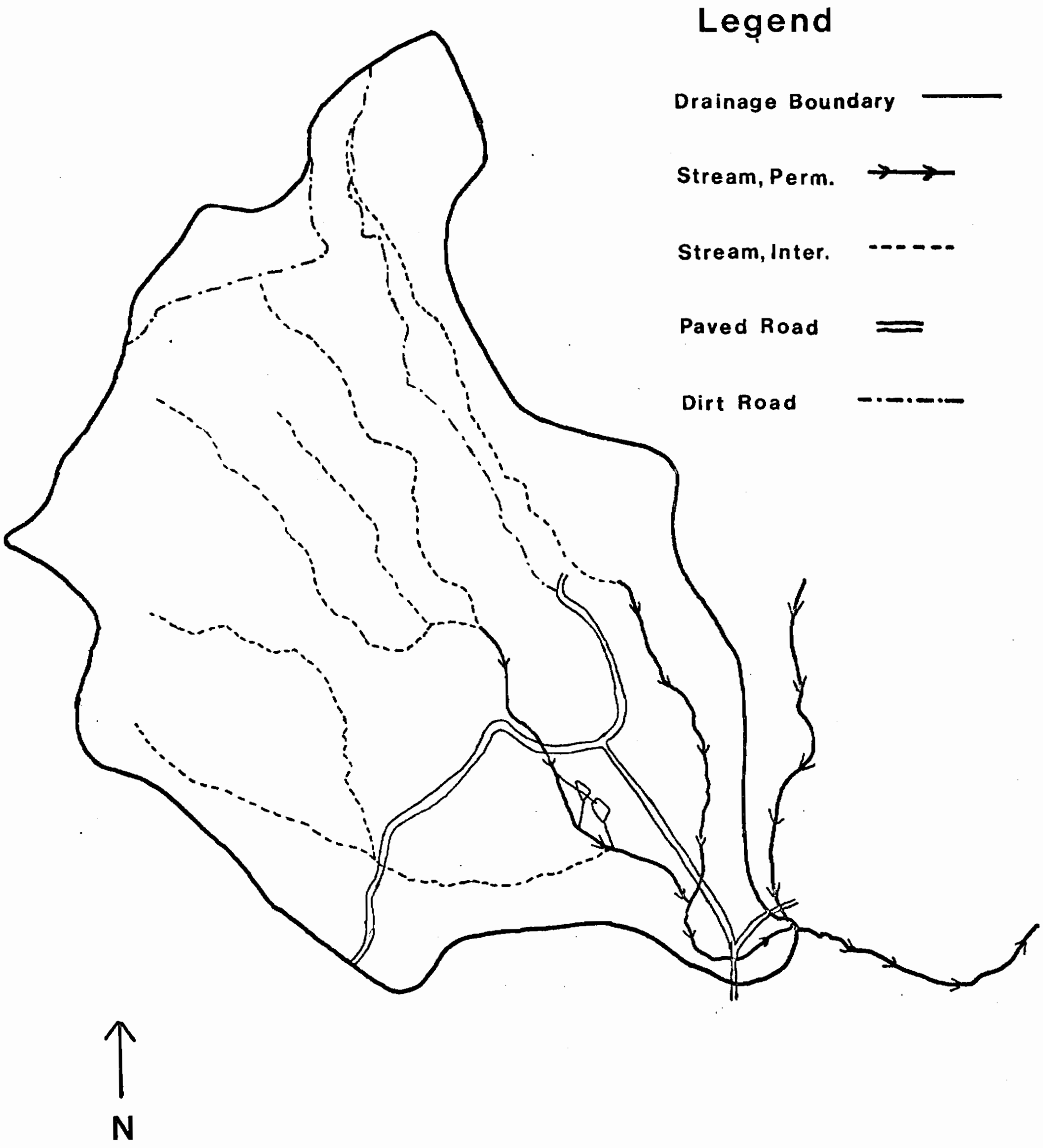

Figure 1. Drainage basin and pond location on a tributary stream of Mill Creek, Patrick County, Virginia

MATERIALS AND METHODS

Benthos

Benthic macroinvertebrates were sampled quarterly in September, 1975, January, April, and July, 1976 with a one-third square meter modified Hess sampler and three sixty second depletion runs (Carle, 1976) (sampling locations were matched by substrate and flow). Samples were preserved with 40 percent isopropyl alcohol, then separated and identified. Individual taxa were counted for each depletion run and population estimates made using a depletion estimator (Carle, 1976). Individual taxa were placed in a Buchner funnel suction apparatus to remove excess fluid. Taxa were weighed to the nearest 0.1 milligram on tared glasine power paper. Average weight per organism was calculated, and biomass estimates made by multiplying weight per organism by the estimated population.

Fish

Fish populations were sampled quarterly in September, 1975, January, April, and July, 1976 in three contiguous sections above and three below the ponds. Sections were blocked at each end prior to sampling and fish were collected by electrofishing (230 volts DC) three depletion runs in each section. Fish from each run were field identified to species, counted, and batch weighed by species. Population estimates and biomass of each fish species were computed as with the benthos.

Drift

Twenty-four hour samples of invertebrate drift were collected quarterly in September, 1975, January, April, and July, 1976 above and below the ponds. Drift sampling locations were downstream of benthic sampling sites. Nets were 15 cm X 15 cm X 145 cm in size and constructed of 452 mesh Nitex (approximate opening 452μ). Samples were preserved in 40 percent isopropyl alcohol, separated, identified, counted, and weighed. Drift rates were computed as number of organisms per 100 cubic meters of flow sampled.

Water Chemistry

Monthly water samples were collected in acid washed plastic containers for alkalinity, hardness, nitrate, pH, total phosphate, filterable orthophosphate, total and dissolved solid analyses. Total organic carbon samples were collected in 300 ml BOD bottles and preserved with 1.5 ml concentrated HCl.

Dissolved oxygen samples were collected in 300 ml BOD bottles and analyzed with the azide modification of the Winkler technique. Nitrates were analyzed by the cadmium reduction method. The persulfate digestion method was used in total phosphate analysis. Phosphate concentrations were measured for both phosphate analyses by the ascorbic acid method. Hardness was determined by EDTA titration. A Corning Model 12 Research pH Meter was used to measure pH. Solids were dried at 105°C for 24 hours and weighed to the nearest milligram. All analyses were performed as in Standard Methods (APHA, 1971).

Statistical Analysis

Physiochemical factors were tested by the Wilcoxon signed rank test for paired data (Hollander and Wolfe, 1973). The data was divided into two six month periods, the production season, April through September, and the non production season, October through March, for certain factors. All tests were one tailed in the direction indicated in the results, and decisions were made at the $\alpha = .1$ level.

Populations for each fish species were tested with a modified Friedmans test with two treatments and multiple observations per cell for a directional hypothesis (Pirie, personal communications). Locations, above or below the ponds, were the treatments, and the data were blocked by season. Population estimates from a 50 meter section for each species were the observations. The calculated statistic is approximated by the normal distribution. All decisions were made at the $\alpha = .1$ level.

Population estimates of selected invertebrate species were analyzed with a 4X2 contingency table to determine the significance of the interaction between season and location.

RESULTS

Physiochemical Parameters

Temperature was significantly higher (signed rank test, α = .009, n = 11, T^+ = 58.5) (mean temperature difference 2°C) below the ponds (Table 1, Figure 2). The largest difference (4.5°C) occurred in February. This difference was probably attributable to a short period of exceptionally warm weather, 20°C+ temperatures, that occurred in that month. However, during three winter months, December, January, and March, temperatures were lower below the ponds.

Dissolved oxygen was also significantly lower (signed rank test, $.007 < \alpha < .01$, n = 10, T^+ = 50.5) below the ponds (Table 1, Figure 3). The percent saturation above the ponds averaged 98 percent, whereas, the percent saturation averaged 97 percent below the ponds. However, in November and December, concurrent with leaf fall, saturation dropped to 88 percent and 82 percent above the ponds and 86 percent and 80 percent below the ponds respectively. The differences in monthly percent saturation above and below the ponds were not statistically significant (signed rank test α = .5, n = 12, T^+ = 39).

Organic carbon was significantly lower below the ponds (signed rank test, α = .031, n = 5, T^+ = 15) during the production season, but unaffected during the nonproduction season (signed rank test, α = .5, n = 5, T^+ = 7) (Table 1, Figure 4).

Total solids were higher (signed rank test, $0.74 < \alpha < .084$, n = 11, T^+ = 49.5) below the ponds over the entire year (Table 1, Figure 5).

The monthly solid load was composed almost entirely of dissolved solids (Table 1, Figure 6). Suspended solids averaged 21 mg/l above the ponds and 18 mg/l below the ponds. These differences were not statistically significant (signed rank test, α = .5, n = 12, T^+ = 39).

Nitrates were significantly higher below the ponds (signed rank test, α = .016, n = 6, T^+ = 21) during the nonproduction season, but were not significantly different (signed rank test, α = .125, n = 3, T^+ = 6) during the production season (Table 1, Figure 7). No significant difference (signed rank test, α = .5, n = 6, T^+ = 10.5) was found between orthophosphate concentrations above and below the ponds during the nonproduction season. Orthophosphate concentrations were significantly lower (signed rank test, α = .031, n = 5, T^+ = 15) below the ponds during the production season (Table 1, Figure 8). Total phosphate concentrations were not significantly different (signed rank test, α = .5, n = 6, T^+ = 10.5) above and below the ponds during the production season (Table 1, Figure 9). Significantly higher total phosphate concentrations (signed rank test, α = .016, n = 6, T^+ = 21) were recorded below the ponds during the nonproduction season.

Hardness was significantly higher (signed rank test, α = .01, n = 9, T^+ = 42) below the ponds (Table 1, Figure 10). Alkalinities tended to be higher below the ponds; however, these differences were not statistically significant (signed rank test, α = .138, n = 10, T^+ = 39) (Table 1, Figure 11). Stream discharge was approximately doubled over upstream flows below the ponds (Table 1, Figure 12). No surface source could be located indicating ground water addition.

Table 1. Mean and range of physiochemical factors above and below two small ponds on a tributary to Mill Creek, Patrick County, Virginia.

	ABOVE PONDS		BELOW PONDS	
Factor	Mean	Range	Mean	Range
Temperature °C	14.3	5.5-21.0	15.6	5.0-22.5
Dissolved Oxygen	9.8	8.3-11.4	9.3	7.9-11.8
Total Organic Carbon[1]	2.0	0.4-4.5	2.0	0.1-3.5
Total Solids[1]	148	5-1065	170	15-1190
Dissolved Solids[1]	128	0-1065	177	10-1100
NO_3[1]	0.02	0.002-0.0075	0.04	0.02-0.082
Ortho-PO_4[1]	0.016	0.005-0.036	0.013	0-0.036
Total-PO_4[1]	0.09	0.008-0.18	0.10	0.04-0.21
Hardness[2]	20.9	16-27	25.8	20.5-32
Alkalinity[2]	11.6	0-21	13.4	0-19.5
Discharge[3]	0.016	0.006-0.020	0.031	0.010-0.050
pH	6.79	6.1-7.21	6.76	6.0-7.70

[1] milligrams per liter

[2] milligrams per liter $CaCO_3$

[3] cubic meters per second

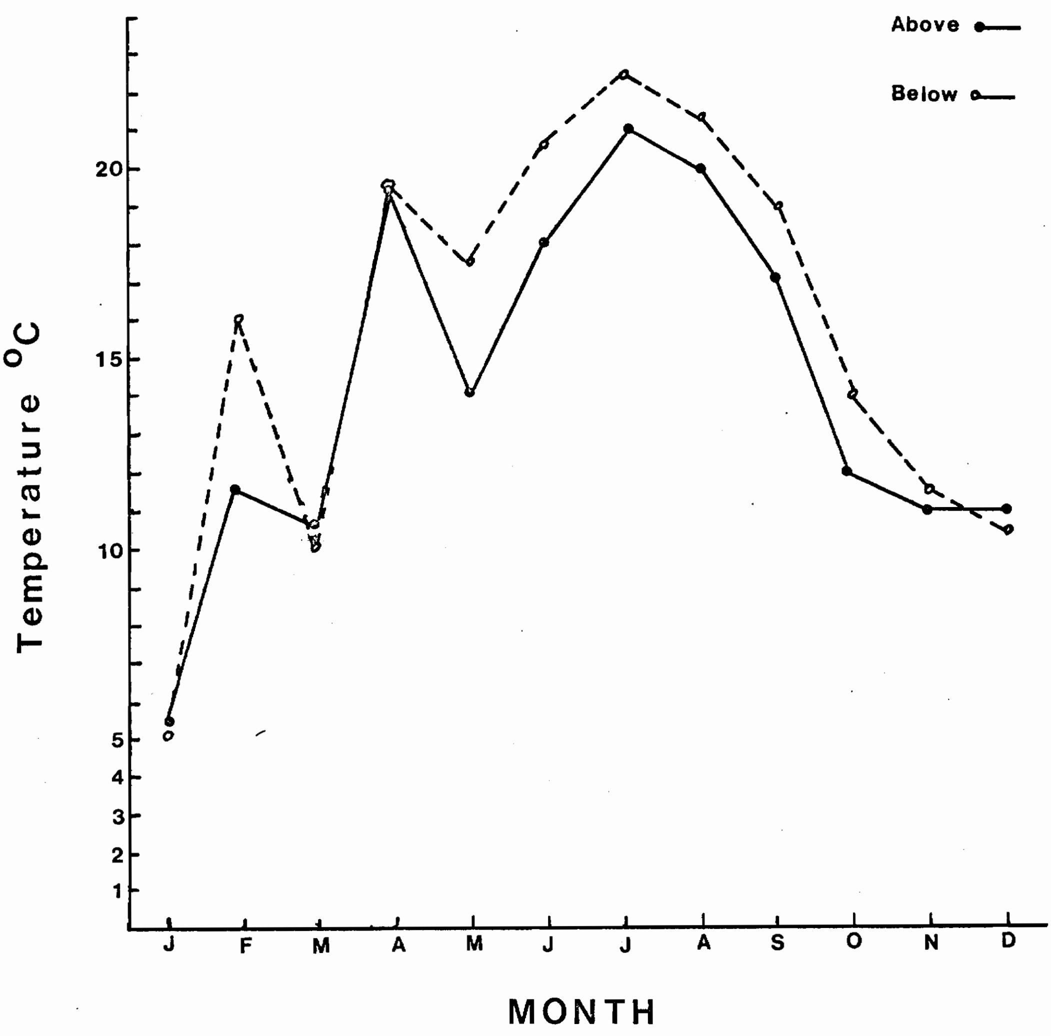

Figure 2. Monthly temperatures recorded above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia

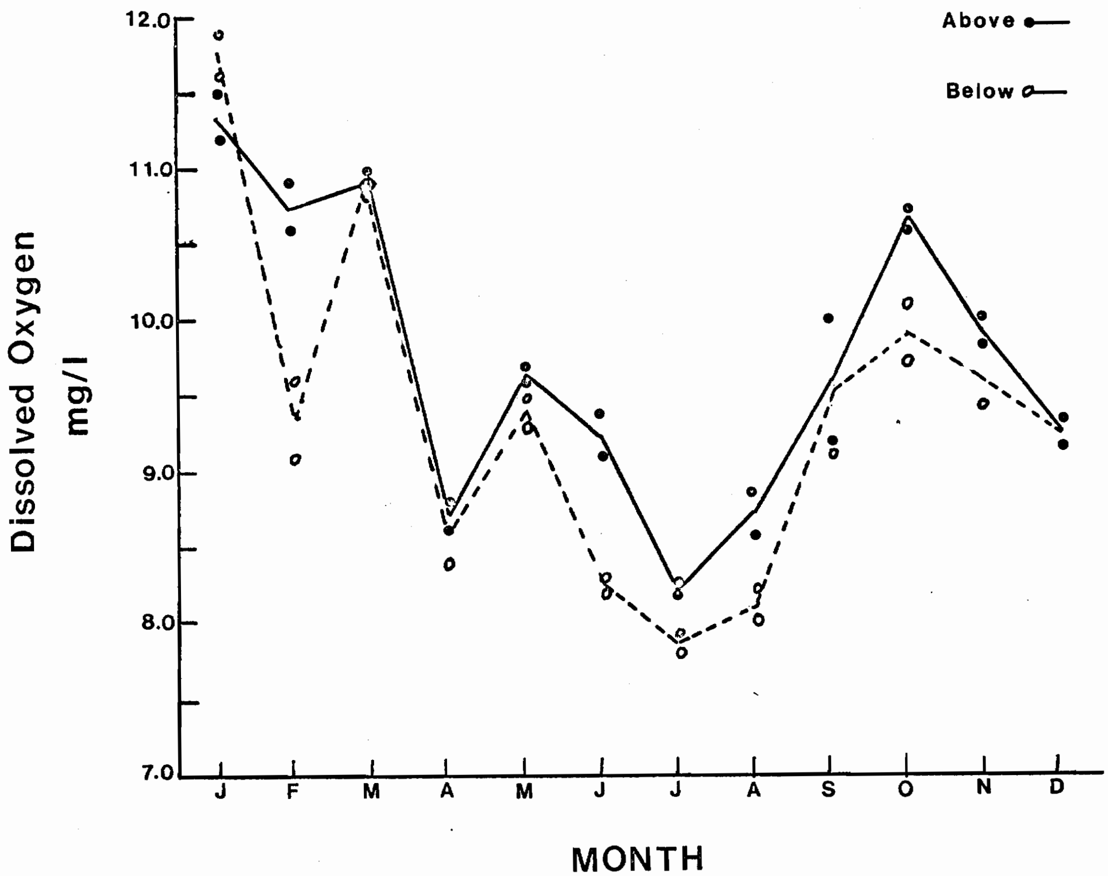

Figure 3. Monthly dissolved oxygen concentrations recorded above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia

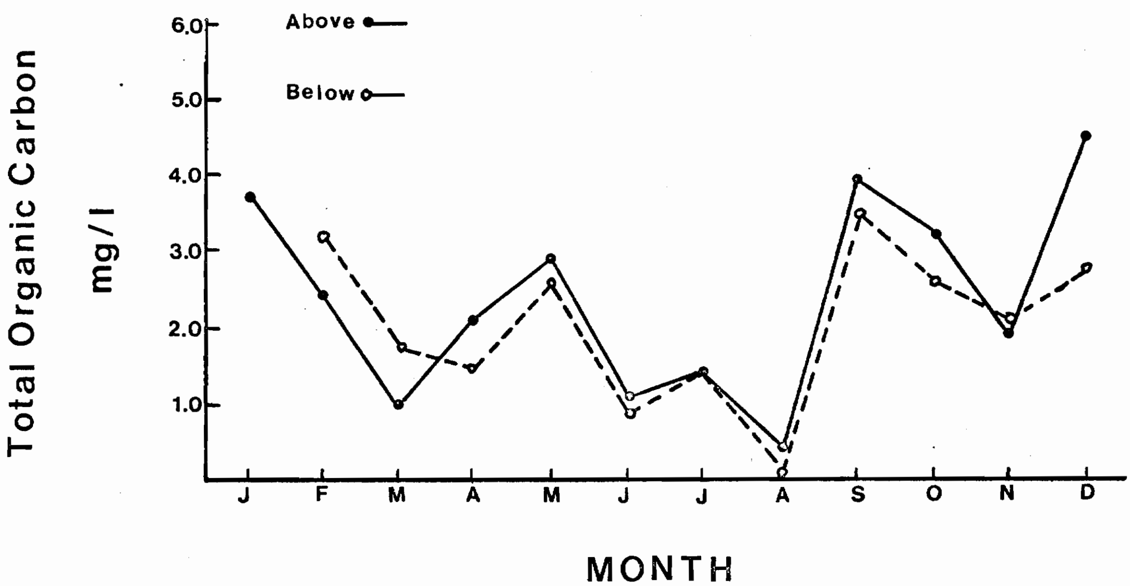

Figure 4. Monthly total organic carbon concentrations recorded above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia. Sample from January below the ponds was lost.

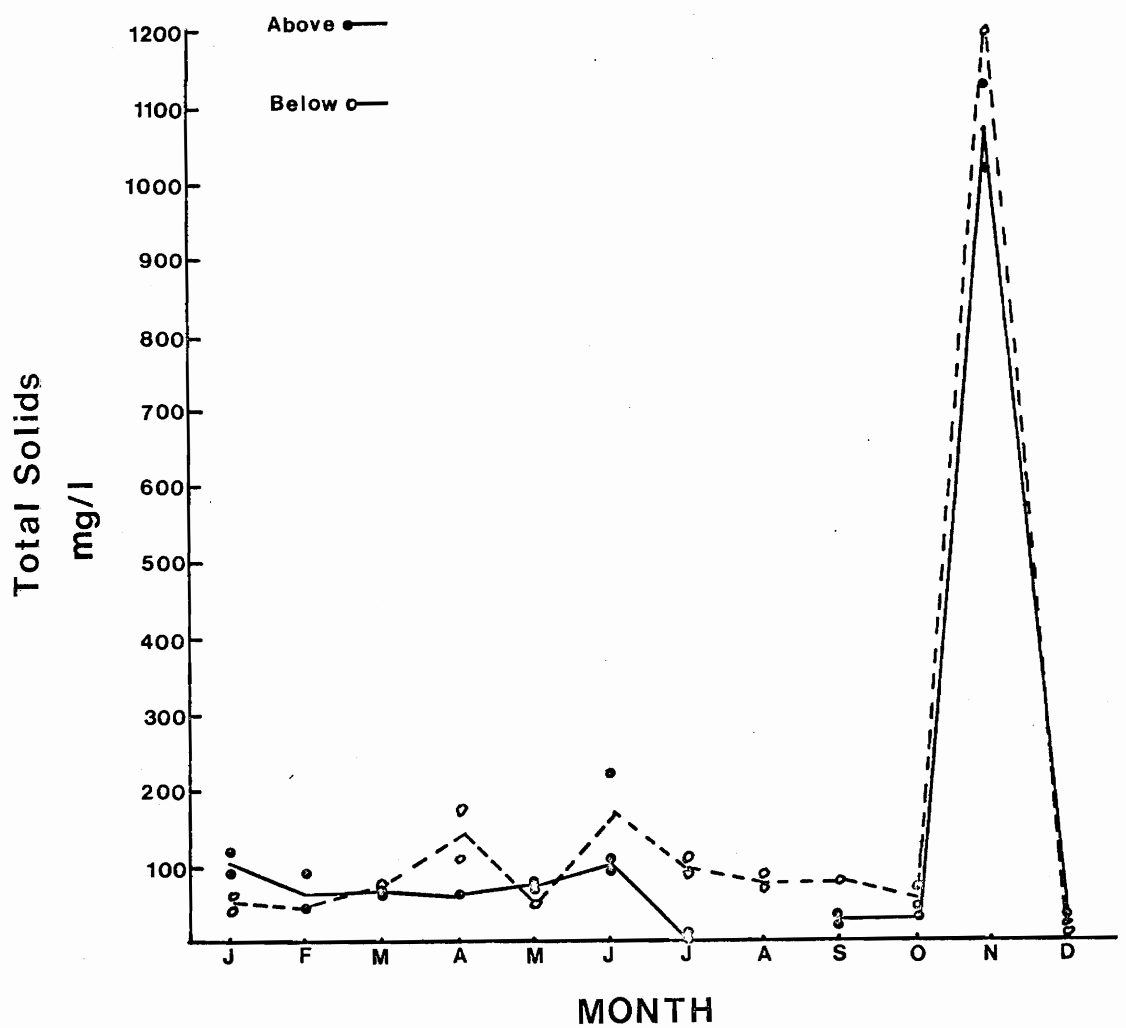

Figure 5. Monthly total solid load recorded above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia.

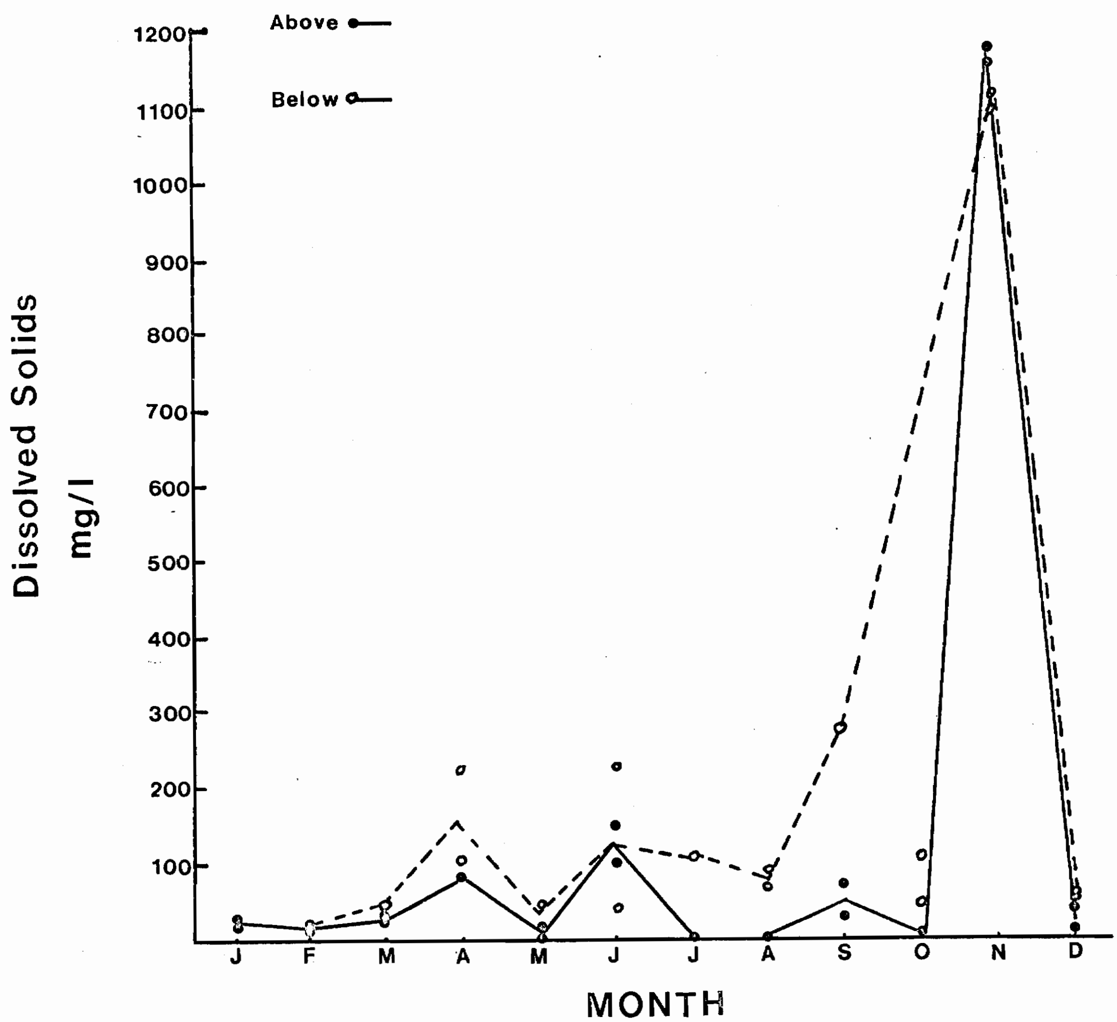

Figure 6. Monthly dissolved solid load recorded above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia

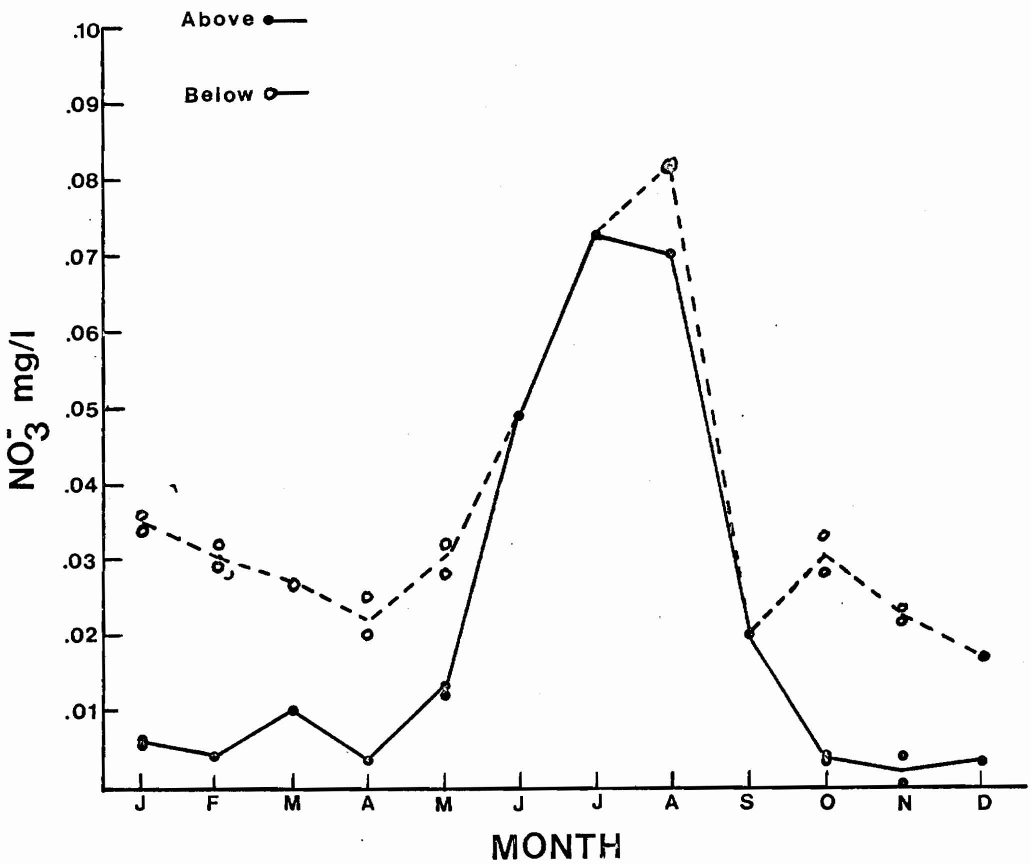

Figure 7. Monthly nitrate concentrations recorded above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia

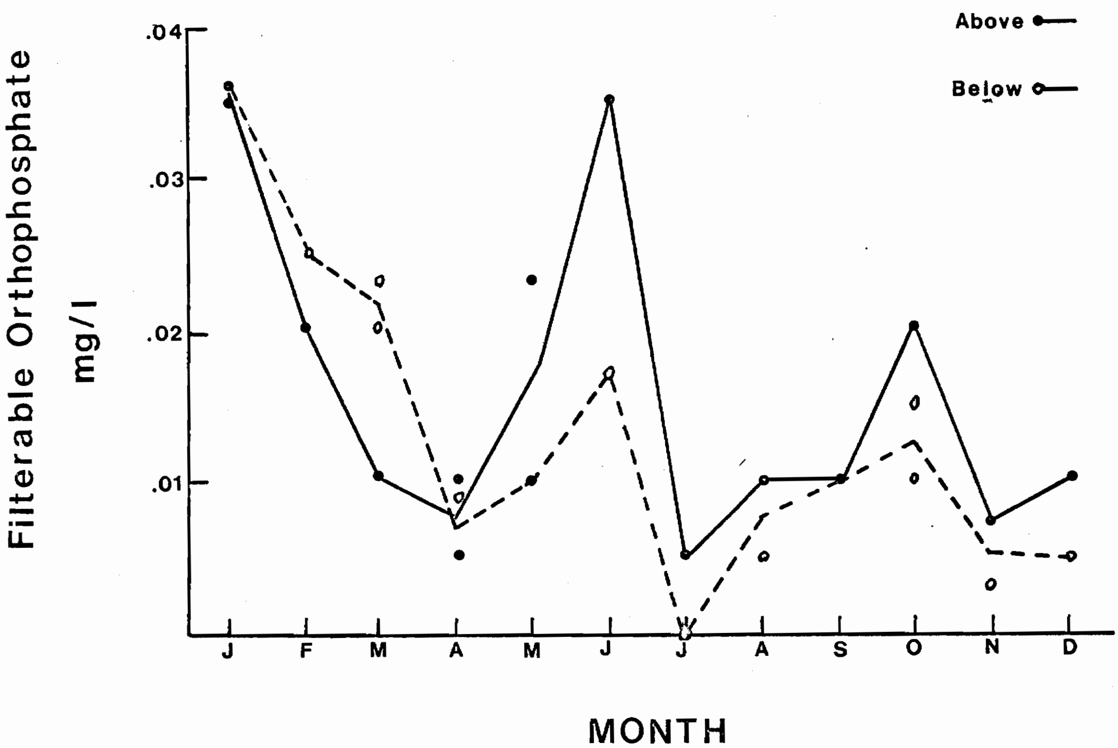

Figure 8. Monthly filterable orthophosphate concentrations recorded above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia

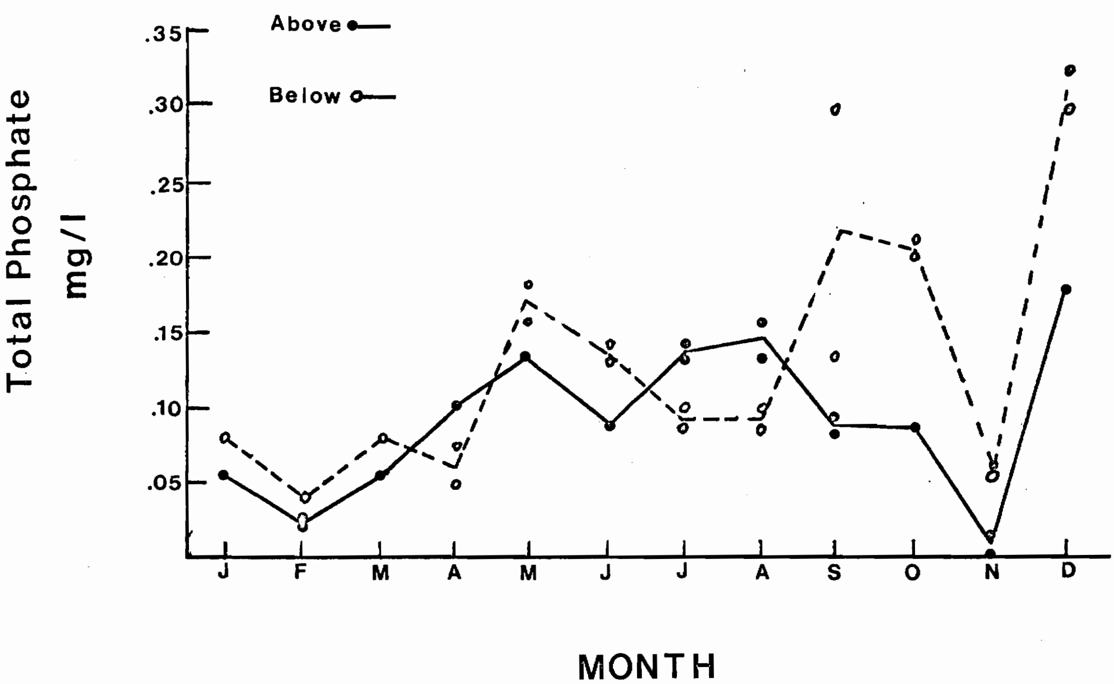

Figure 9. Monthly total phosphate concentrations recorded above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia

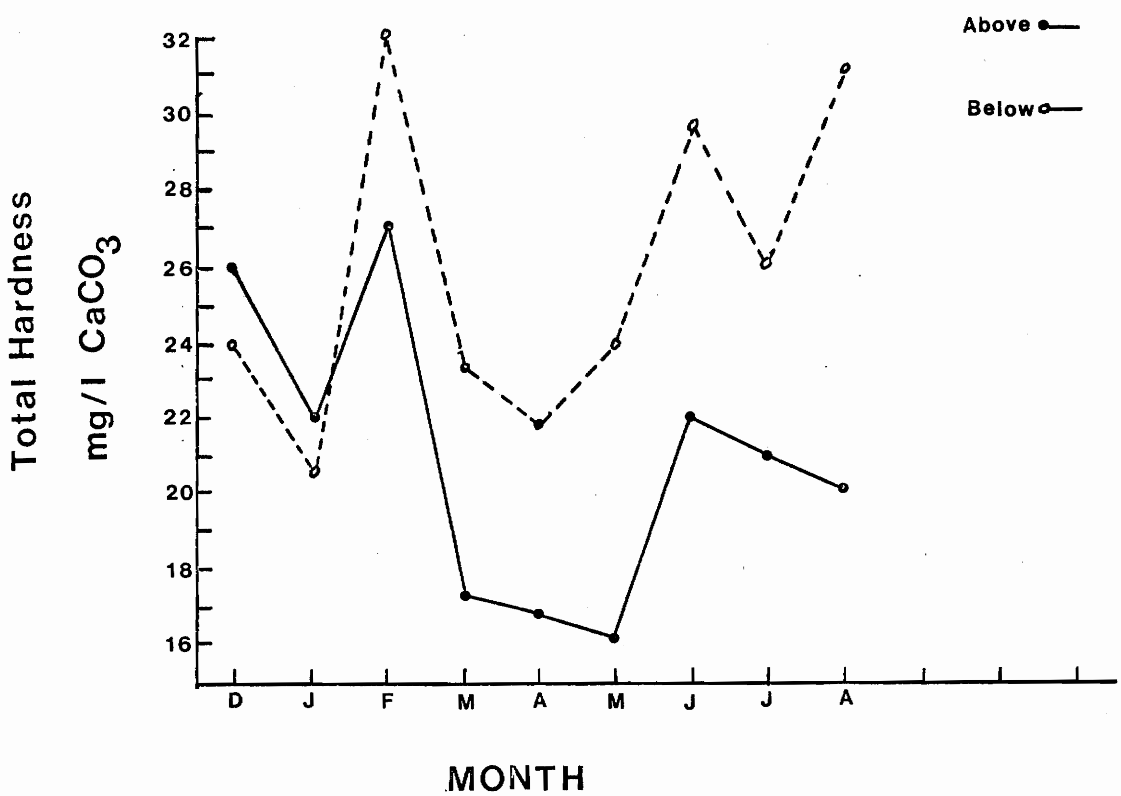

Figure 10. Monthly total hardness recorded above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia. Hardness was not recorded in September, October, or November.

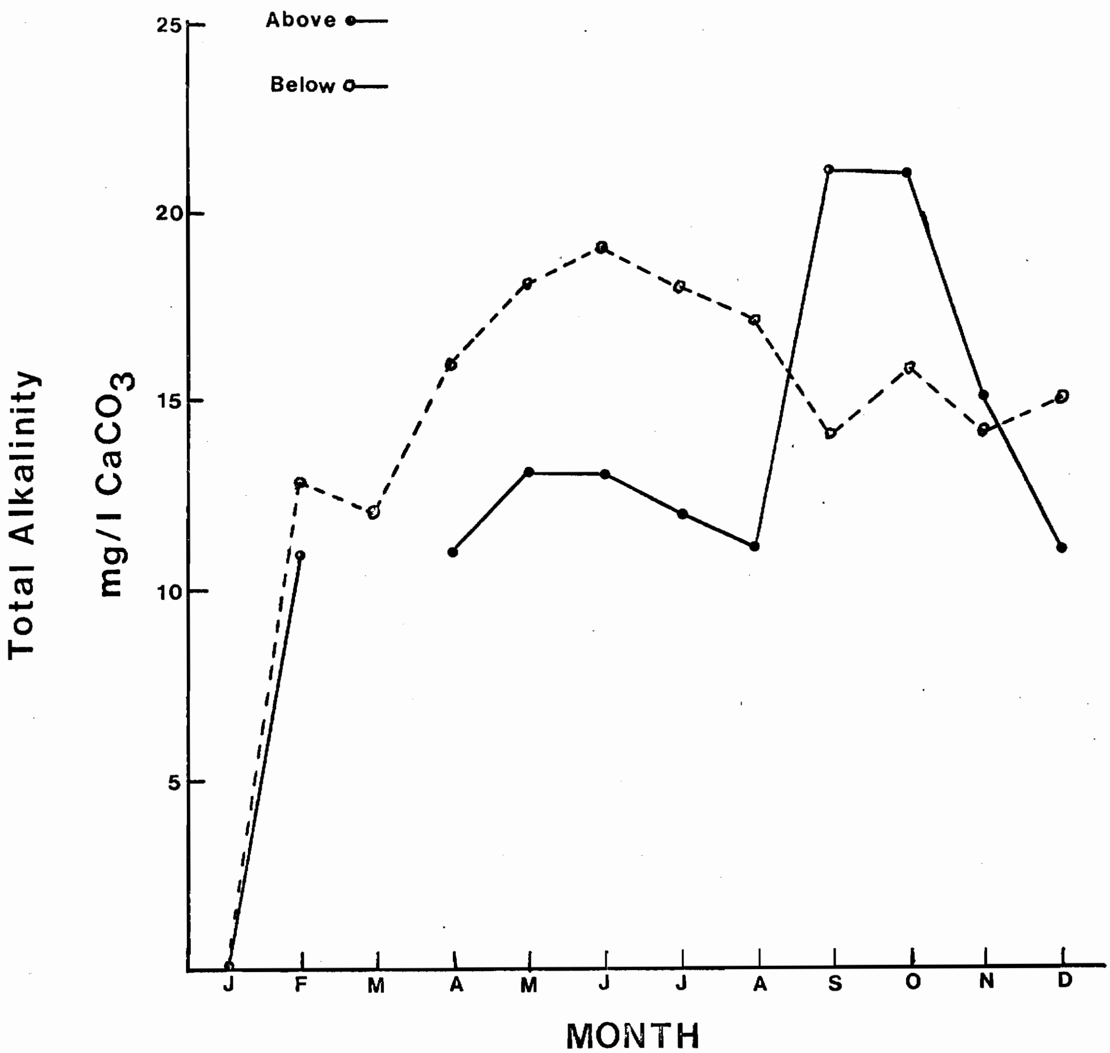

Figure 11. Monthly alkalinity recorded above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia. January sample above the ponds was contaminated.

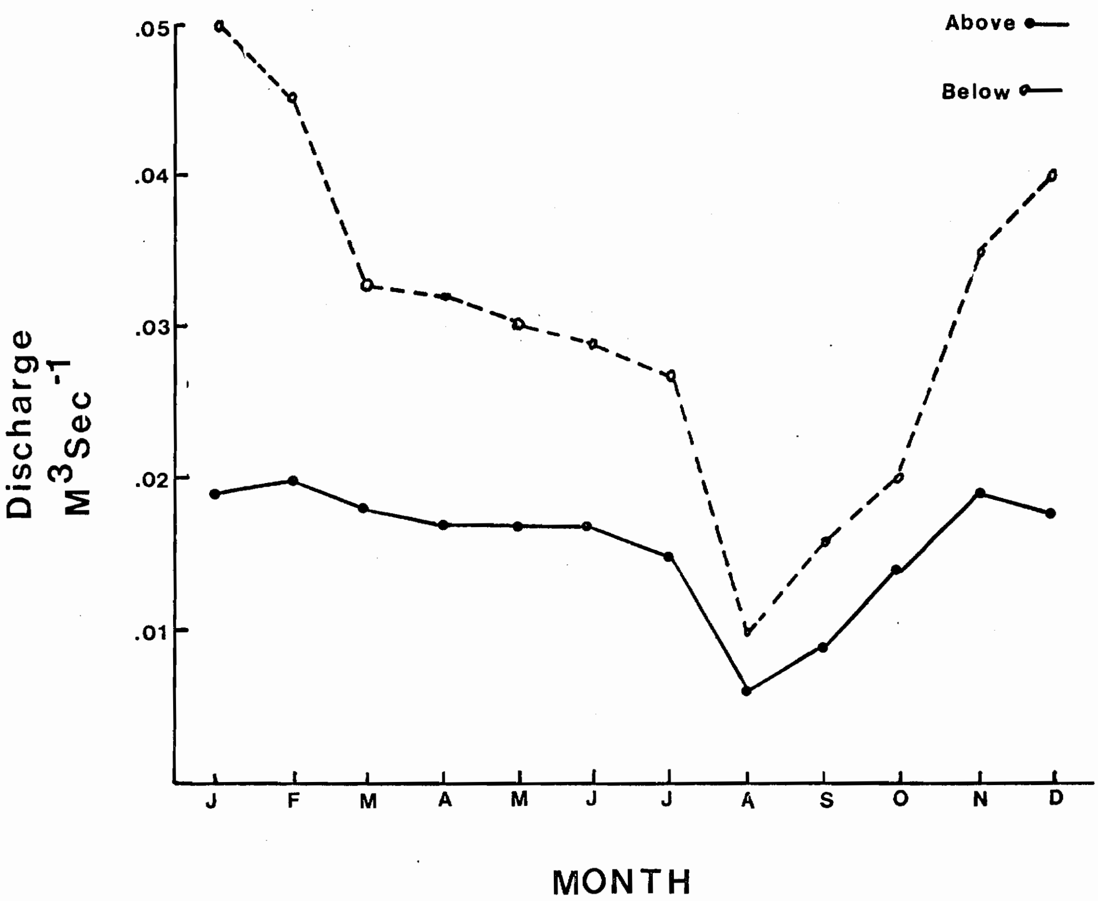

Figure 12. Monthly discharge recorded above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia

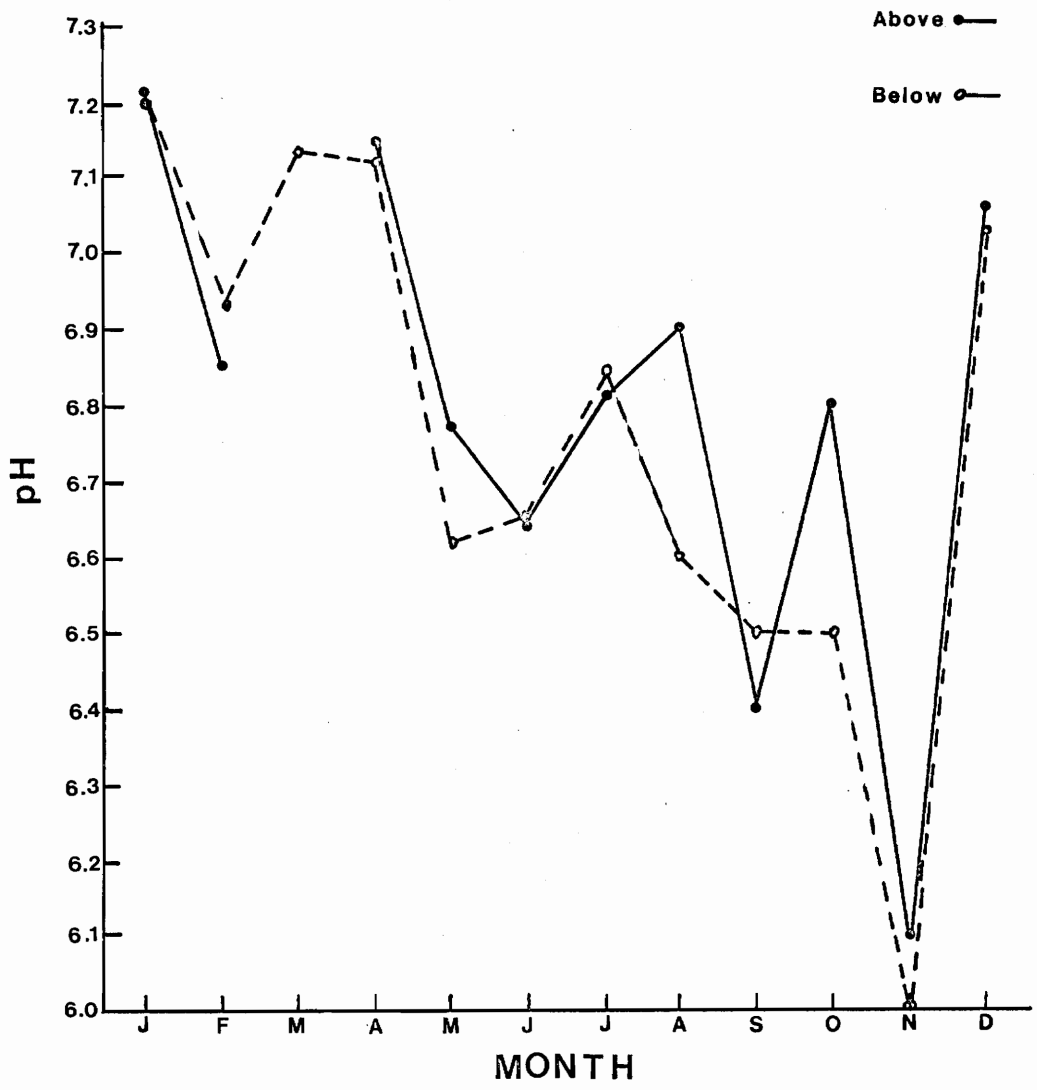

Figure 13. Monthly pH recorded above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia. January sample above the ponds was contaminated.

Wide monthly fluctuations above and below the ponds were observed in pH (Table 1, Figure 13). These fluctuations appeared to be a result of equipment malfunction and pH differences were not tested statistically.

Benthos and Drift

Benthic invertebrate populations showed small changes in species composition. Composition by major orders is shown in Figure 14. Twenty-eight invertebrate were judged to have sufficient population estimates in all seasons to be tested statistically. Twenty-six taxa had significant season-station interactions in numbers ($\alpha = .05$).

Total benthic macroinvertebrate population densities were higher below the ponds in September and July (Table 2). However, in January and April, population densities were lower below the ponds (Table 2).

The largest difference in numbers below the ponds in September occurred in *Cheumatopsyche* sp. larvae (180 more individuals below than above the ponds), *Optioservus* sp. larvae (111 more individuals below than above the ponds), *Oulimnius latiusculus* adults (109 more individuals below than above the ponds), and Chironominae larvae (98 more individuals below than above the ponds) (Appendix Table II). *Oulimnius latiusculus* adults (443 more individuals below than above the ponds), *Cheumatopsyche* sp. larvae (411 more individuals below than above the ponds), Gastropoda (316 more individuals below than above the ponds), *Agapetus* sp. larvae (253 more individuals below than above the ponds), Chironominae larvae (242 more individuals below than above the ponds), and *Hydropsyche* sp. larvae (173 more individuals below than above the ponds) were mostly

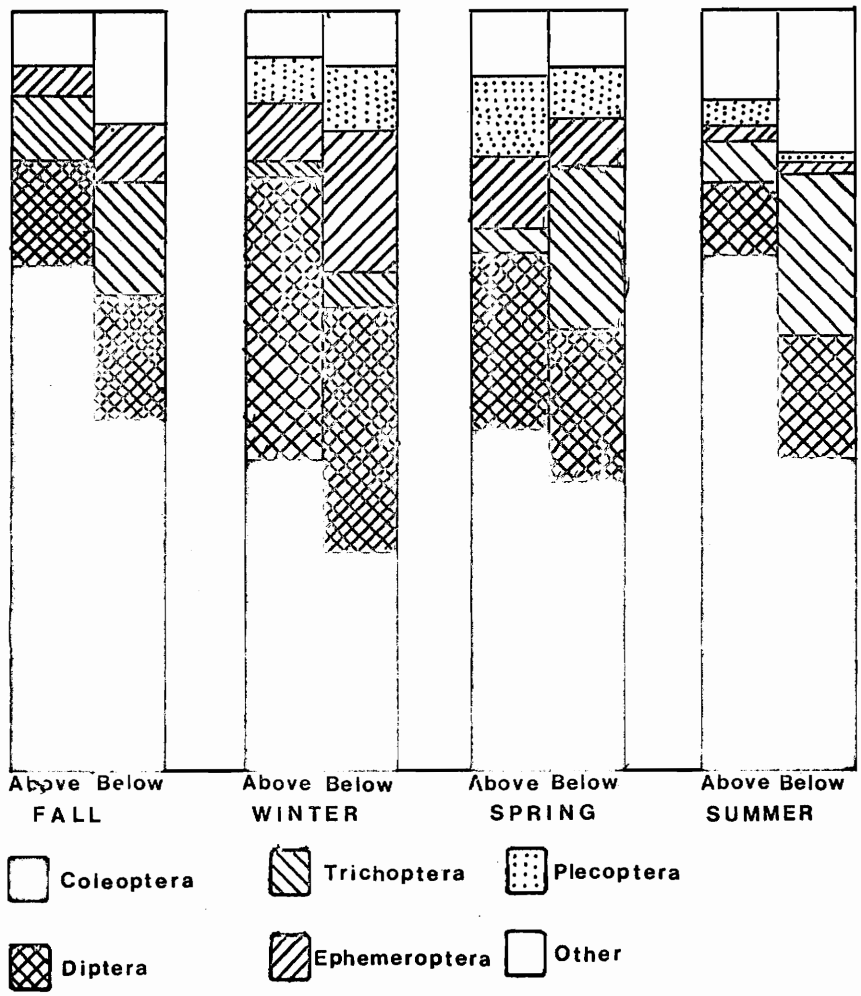

Figure 14. Composition of major orders of estimated benthic invertebrate populations above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia

Table 2. Total estimated density of benthic invertebrate populations (all taxa estimates pooled) per 0.33 $meter^2$ above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia.

SEASON	ABOVE	BELOW
October 1, 1975	950	1161
January 16, 1976	1070	322
April 30, 1976	2209	1869
July 14, 1976	2786	4189

responsible for the higher numbers below the ponds in July (Appendix Table II).

The organisms responsible for the major portion of the lower numbers in January below the ponds were Chironominae larvae (172 fewer individuals below than above the ponds), Optioservus sp. larvae (118 fewer individuals below than above the ponds), Helichus sp. larvae (75 fewer individuals below than above the ponds), Oulimnius latiusculus adults (73 fewer individuals below than above the ponds), and Orthocladinae larvae (65 fewer individuals below than above the ponds) (Appendix Table II). Chironominae larvae (304 fewer individuals below than above the ponds), Optioservus sp. larvae (113 fewer individuals below than above the ponds), Acari (112 fewer individuals below than above the ponds), Ephemerella sp.(102 fewer individuals below than above the ponds), and Helichus sp. larvae (98 fewer individuals below than above the ponds) constituted most of the decrease in numbers below the ponds in April (Appendix Table II).

Numbers in all ecological groups (based upon a classification by feeding mechanisms by Cummins 1973, Table 3) were higher below the ponds in September (Table 4). Suspension feeders, predators, deposit collectors, and unclassified organisms also had higher percent composition below the ponds. Shredders and scrapers had lower percent composition below the ponds.

Numbers in all groups except shredders were higher downstream in July (Table 5). Percent composition was higher below the ponds for

Table 3. Ecological groupings[1] based upon feeding mechanisms of benthic invertebrate taxa collected above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia.

Suspension Feeders

Ameletus sp.
Isonychia sp.
Sortosa sp.
Wormaldia sp.
Psychomyiidae young instar
Polycentropus sp.
Diplectrona sp. larvae
Hydropsyche sp. larvae
Cheumatopsyche sp. larvae
Oecetis sp.
Simulium sp. larvae

Deposit Collectors

Ephemera sp.
Baetisca carolina
Baetis sp.
Pseudocloeon sp.

Predators

Cordulegaster sp.
Gomphidae (*Lanthus* young instar)
Hagenius sp.
Boyeria sp.
Hetaerina sp.
Isoperla sp.
Nigronia serricornus
Rhyacophila sp.
Dineutus sp.
Tanypodinae
Palpomyia sp.
Hemerodromia sp.

Unclassified

Hydra americana
planeria
Nematoda
Oligocheata
Cladocera

Unclassified (continued)

Copepoda
Ostracoda
Cambarus sp.
Acari
Psychoda sp. B
Dixa sp.
Simulium sp. pupae
Orthodadinae L&P
Chironominae L&P
Palpomyia sp. pupae
Dolichopodidae
Hemerodromia sp.
Muscidae
Pelecypoda

Shredders

Peltoperla sp.
Nemoura sp.
Leuctra sp.
Allocapnia sp.
Limnephilidae young instar
Neophylax sp.
Pycnopsyche sp.
Lepidostomatidae
Tipula sp.
Antocha sp.
Dicranota sp.
Pseudolimnophila sp.
Eriocera sp.
Protoplasa fitchii

Scrapers

Brachyptera sp.
Epeorus sp.
Stenonema sp.
Ephemerella sp.
Paraleptophlebia sp.
Caenis sp.
Centroptilum sp.

Table 3. Ecological groupings[1] based upon feeding mechanisms of benthic invertebrate taxa collected above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia (continued).

<u>Scrapers</u> (continued)

<u>Glossosoma</u> sp.
<u>Agapetus</u> sp.
<u>Psilotreta</u> sp.
<u>Helichus</u> sp.
<u>Oulimnius</u> sp.
<u>Stenelmis</u> sp.
<u>Macronychus</u> sp.
<u>Gonielmis</u> sp.
<u>Optioservus</u> sp.
<u>Ectopria</u> sp.
<u>Psephenus</u> sp.
<u>Atrichopogon</u> sp.
<u>Tabanus</u> sp.
Gastropoda

[1]Classification of organisms generally follows Cummins, 1973 with additions from Hynes, 1972; Bay, 1974; Minckney, 1961.

Table 4. Numbers and percent composition by ecological groups of benthic invertebrates captured in October, 1975 above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia.

GROUP	ABOVE		BELOW	
	Number	Percent	Number	Percent
Suspension feeders	118	12.4	290	16.5
Shredders	17	1.8	26	1.5
Scrapers	651	68.5	979	55.6
Predators	15	1.6	33	1.9
Deposit Collectors	12	1.3	63	3.6
Unclassified	137	14.2	370	21.0

suspension feeders, predators, deposit collectors, and unclassified organisms. Shredders and scrapers both had lower percent composition below the ponds.

All ecological groups had lower numbers below the ponds in January (Table 6). Deposit collectors, scrapers, and unclassified organisms also had lower percent composition below the ponds but all other groups had higher percent composition.

In April, the numbers of suspension feeders, predators, and deposit collectors were higher while numbers of shredders, scrapers, and unclassified organisms were lower below the ponds (Table 7). Percent composition was higher for suspension feeders, predators, deposit collectors, and scrapers, and lower for shredders and unclassified organisms below the ponds.

Total biomass of benthic macroinvertebrates was higher in all sampling periods below the ponds (Table 8). However, in two sampling periods *Tipula abdominalis* occurred in low numbers but large biomass. In January, *T. abdominalis* was 0.49 percent of the estimated population by numbers, but 87.25 percent of the estimated biomass below the ponds and in April. *T. abdominalis* was 0.11 percent of the estimated population below the ponds, but 51.74 percent of the estimated biomass. Exclusion of *T. abdominalis* from January and April data below the ponds showed lower biomass downstream in those two seasons.

The taxa accounting for the major portion of the downstream biomass increase in September were *Cheumatopsyche* sp. larvae (190.7 mg greater biomass below than above the ponds), *Baetisca carolina* (48.4 mg

Table 5. Numbers and percent composition by ecological group of benthic invertebrates captured in July, 1976 above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia.

GROUP	ABOVE		BELOW	
	Number	Percent	Number	Percent
Suspension feeders	129	4.6	695	16.6
Shredders	109	3.9	95	2.3
Scrapers	1968	70.6	2524	60.3
Predators	29	1.0	182	4.3
Deposit Collectors	6	0.2	35	0.8
Unclassified	545	19.6	658	15.7

Table 6. Numbers and percent composition by ecological group of benthic invertebrates captured in January, 1976 above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia.

GROUP	ABOVE		BELOW	
	Number	Percent	Number	Percent
Suspension feeders	41	3.8	29	9.0
Shredders	72	6.7	28	8.6
Scrapers	532	49.7	153	47.5
Predators	17	1.5	9	2.7
Deposit collectors	5	.5	0	0
Unclassified	403	37.7	121	37.6

Table 7. Numbers and percent composition by ecological group of benthic invertebrates captured in April, 1976 above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia.

GROUP	ABOVE		BELOW	
	Number	Percent	Number	Percent
Suspension feeders	56	2.5	123	6.6
Shredders	249	11.3	96	5.1
Scrapers	1152	52.2	1115	59.7
Predators	74	3.3	82	4.4
Deposit collectors	42	1.9	70	3.7
Unclassified	636	28.8	383	20.5

Table 8. Total estimated biomass of benthic invertebrates (all taxa estimates pooled) per 0.33 $meter^2$ above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia.

SEASON	ABOVE	BELOW
Fall - October 1, 1975	454.2 mg	814.0 mg
Winter - January 14, 1976	551.9 mg	1841.2 mg[1]
Spring - April 30, 1976	2231.9 mg	2266.1 mg[2]
Summer - July 14, 1976	1083.3 mg	3572.6 mg

[1]Biomass without *Tipula abdominalis* 222.9 mg

[2]Biomass without *Tipula abdominalis* 1093.7 mg

greater biomass below than above the ponds), Hydropsyche sp. larvae (48.1 mg greater biomass below than above the ponds), and Chironominae larvae (26.4 mg greater biomass below than above the ponds) (Appendix Table II). In July, Hydropsyche sp. larvae (763.5 mg greater biomass below than above the ponds), Cheumatopsche sp. larvae (483.5 mg greater biomass below than above the ponds), Gastropoda (377.7 mg greater biomass below than above the ponds), Optioservus sp. adults (235.6 mg greater biomass below than above the ponds) had the largest increases in biomass below the ponds.

The organisms having the largest decreases in biomass below the ponds in January were Optioservus sp. adults (57.1 mg lower biomass below than above the ponds), Brachyptera sp. (55.7 mg lower biomass below than above the ponds), Simulium vittatum pupae (46.4 mg lower biomass below than above the ponds), Tipula sp. larvae (33.5 mg lower biomass below than above the ponds), and Oulimnius latiusculus adults (32.0 mg lower biomass below than above the ponds) (Appendix Table II). Tipula abdominalis occurred only below the ponds and had a biomass of 1608.3 mg in January. Ephemerella sp. (565.0 mg lower biomass below than above the ponds), Pseudolimnophila sp. larvae (233.3 mg lower biomass below than above the ponds), Epeorus humeralis (202.4 mg lower biomass below than above the ponds), Stenonema sp. (175.8 mg lower biomass below than above the ponds), Peltoperla sp. (168.8 mg lower biomass below than above the ponds), and Cheumatopsyche sp. larvae (124.4 mg lower biomass below than above the ponds) were the bulk of the downstream biomass decrease in April (Appendix II). Tipula abdominalis was captured only below the ponds in April and had a biomass of 1172.4 mg.

Biomass of suspension feeders, scrapers, deposit collectors, and unclassified taxa was higher below the ponds in September, while biomass of shredders was lower below the ponds (Table 9). Shredders had lower biomass below the ponds in July, while all other ecological groups had higher biomass below the ponds (Table 10). Biomass in all groups was lower in January below the ponds with the exception of the shredder T. abdominalis (Table 11). Including T. abdominalis with the shredders resulted in increased biomass of shredders below the ponds. Predator and deposit collector biomass was higher below the ponds in April (Table 12). Shredders had higher biomass in April below the ponds with the inclusion of T. abdominalis.

Total drift rates exclusive of zooplankton were lower below the ponds in April, July, and September (Table 13) as were drift rates for most taxa (Appendix Table III). Total drift rates and drift rates for most taxa were higher in January below the ponds.

Fish

Seven species of fish were collected in the stream. Five species, mountain redbelly dace, Phoxinus oreas, rosyside dace, Clinostomus funduloides, creek chub, Semotilis atromaculatus, bluehead chub, Nocomis leptocephalus, and fantail darter, Etheostoma flabellare, were native to the stream. Bluegill, Lepomis macrochirus, and fathead minnow, Pimephales promelas, were introduced into the ponds and escaped to the stream.

Table 9. Biomass by ecological group of invertebrates captured in October, 1975 above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia.

GROUP	UPSTREAM BIOMASS	DOWNSTREAM BIOMASS
Suspension feeders	124.0 mg	314.4 mg
Shredders	29.9 mg	15.6 mg
Scrapers	271.6 mg	395.7 mg
Predators	9.4 mg	8.6 mg
Deposit collectors	3.8 mg	57.4 mg
Unclassified	15.6 mg	46.6 mg

Table 10. Biomass by ecological group of invertebrates captured in July, 1976 above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia.

GROUP	UPSTREAM BIOMASS	DOWNSTREAM BIOMASS
Suspension feeders	126.5 mg	1290.9 mg
Shredders	574.3 mg	546.0 mg
Scrapers	339.3 mg	1356.9 mg
Predators	2.2 mg	267.1 mg
Deposit collectors	0.5 mg	6.3 mg
Unclassified	32.3 mg	105.4 mg

Table 11. Biomass by ecological group of invertebrates captured in January, 1976 above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia.

GROUP	UPSTREAM BIOMASS	DOWNSTREAM BIOMASS
Suspension feeders	103.0 mg	58.8 mg
Shredders	159.6 mg	95.5 mg[1]
Scrapers	218.3 mg	79.4 mg
Predators	1.7 mg	0.9 mg
Deposit collectors	5.7 mg	0.2 mg
Unclassified	63.7 mg	2.9 mg

[1]Excluding *Tipula abdominalis*

Table 12. Biomass by ecological group of invertebrates collected in April, 1976 above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia.

GROUP	UPSTREAM BIOMASS	DOWNSTREAM BIOMASS
Suspension feeders	230.2 mg	96.4 mg
Shredders	441.6 mg	30.9 mg[1]
Scrapers	1383.0 mg	797.3 mg
Predators	30.6 mg	81.2 mg
Deposit collectors	32.8 mg	52.5 mg
Unclassified	113.7 mg	35.5 mg

[1]Excluding *Tipula abdominalis*

Table 13. Total drift rates by season excluding zooplankton per 100 cubic meters flow above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia.

SEASON	ABOVE	BELOW
October 1, 1975	336.9	91.7
January 15, 1976	56.2	121.8
April 22, 1976	372.4	42.4
July 14, 1976	176.1	85.4

Three species, mountain redbelly dace, rosyside dace, and fantail darter, were found both above and below the ponds during all sampling periods (Table 14). Bluegill and fathead minnow were found only below the ponds.

Creek chubs tended to be found above the ponds and bluehead chub below the ponds (Table 14). Very few of either species were found at the reciprocal location (Table 15).

Total estimated numbers of fish were lower below the ponds in all sampling periods except January (Table 15). Rosyside dace, the dominant fish species above the ponds, had significantly lower numbers below the ponds (modified Friedman's test, $\alpha = .004$, $S = 2.65$), whereas, mountain redbelly dace and fantail darter had higher numbers below the ponds, modified Friedman's test, $.06<\alpha<.07$, $S = 1.52$, and $\alpha = .015$, $S = 2.17$ respectively (Table 15). Combined populations of creek chub and bluehead chub also had higher numbers below the ponds (modified Friedman's test, $\alpha<.001$, 3.28) (Table 15).

Total fish biomass was higher below the ponds in all sampling periods (Table 16). Rosyside dace biomass was lower below the ponds (Table 16), but this decrease was offset by higher biomass of mountain redbelly dace, fantail darter and combined biomass of creek chub and bluehead chub.

Table 14. Seasonal distributions of fish species captured above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia. A + indicates that the species was captured at the location during that sampling period.

SEASON	LOCATION	SPECIES						
		P. oreas	*C. funduloides*	*S. atromaculatus*	*N. leptocephalus*	*P. promelas*	*E. flabellare*	*L. macrochirus*
Fall	Above	+	+	+	+		+	
	Below	+	+		+		+	+
Winter	Above	+	+	+			+	
	Below	+	+		+	+	+	+
Spring	Above	+	+	+	+		+	
	Below	+	+	+	+		+	+
Summer	Above	+	+	+			+	
	Below	+	+	+	+	+	+	+

Table 15. Seasonal estimated populations per 150 meters for each fish species (50 meter estimates corrected to 1 meter^3 sec^{-1} flow and pooled for each location) above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia.

SPECIES	SEASON							
	October		January		April		July	
	Above	Below	Above	Below	Above	Below	Above	Below
Phoxinus oreas	313	1161	438	903	563	1194	1063	3387
Clinostomus funduloides	12125	2387	2938	2613	8938	2548	14938	2579
Semotilis atromaculatus	125	0	750	0	2188	548	1063	516
Nocomis leptocephalus	63	1387	0	1817	63	2484	0	2452
Pimephales promelas	0	0	0	129	0	0	0	65
Etheostoma flabellare	2938	3355	2750	3741	3625	5548	2500	2968
Lepomis macrochirus	0	65	0	129	0	258	0	226
TOTAL	15564	8355	6876	9203	15377	12580	19564	12193

Table 16. Seasonal estimated biomass in milligrams per 150 meters for each fish species (50 meter estimates corrected to 1 $meter^3$ sec^{-1} flow and pooled for each location) above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia.

SPECIES	SEASON							
	Fall		Winter		Spring		Summer	
	Above	Below	Above	Below	Above	Below	Above	Below
Phoxinus oreas	467.5	1361.3	743.8	1583.9	218.8	2029.0	887.5	3512.9
Clinostomus funduloides	14000.0	5590.3	4093.8	7477.4	13312.5	6451.6	19618.8	4625.8
Semotilis atromaculatus	1875.0	-	4825.0	0	8118.8	2241.9	5693.8	1819.4
Nocomis leptocephalus	293.8	14271.0	-	17077.4	1100.0	25477.4	-	13016.1
Pimephales promelas	-	-	-	71.0	-	-	-	135.5
Etheostoma flabellare	3481.3	5510.0	5568.8	8206.5	4787.5	7145.2	2525.0	3345.2
Lepomis macrochirus	-	227.6	-	1996.8	-	3841.9	-	2341.9
TOTAL	20117.6	26955.2	15231.4	36413.0	27537.6	47187.0	28725.1	28796.8

DISCUSSION

The higher hardness observed below the ponds may have resulted from solution of substances within the ponds, solution of substances during subsurface return flow from the ponds, addition of ground water, or inflow of a tributary stream or spring. The increased discharge downstream and lack of discernable surface source indicated addition of groundwater below the ponds. The higher hardness below the ponds probably resulted from that source.

Alkalinity was largely unaffected by the ponds. Any alkalinity increases that may have resulted from photosynthetic uptake of free CO_2 within the ponds would have been lost by return of CO_2 to equilibrium concentration in the turbulent outflow from the ponds (Gameson, 1954; Hynes, 1972).

The ponds acted as heat exporters during most of the year. There were, however, lower temperatures below the ponds during winter. Decreased dissolved oxygen below the ponds appeared to be a result of these temperature changes. A reduction in oxygen saturation indicative of the input of an oxygen demanding material below the ponds was not observed. The lack of organic carbon input below the ponds also confirmed the probable lack of significant oxygen demand.

The observed temperature and dissolved oxygen concentrations appeared to be with the tolerance of most invertebrate species (Surber and Bessey, 1974; Nebeker, 1972; Gaufin, 1973); however, the amplitude of the seasonal fluctuations of these factors appeared to be increased below the ponds (Figures 2 and 3). Alterations in competitive and behavioral interactions within the benthic communities caused by these minor changes in water quality may have caused the small changes in species composition observed. However, these alterations in water quality cannot account for the radical changes in population densities and biomass of invertebrates and fish.

Limited nutrient trapping appeared to occur during the production season; whereas, limited nutrient export occurred in the nonproduction season. Periphyton was not sampled and no statement can be made concerning the alterations nutrient trapping or export may have caused in periphyton densities.

Changes in periphyton densities caused by changes in nutrient dynamics should be directly reflected in populations of periphyton grazers (scrapers). However, population densities and biomass of scrapers were lower below the ponds in January and April when nutrient export may have occurred. Conversely, nutrient trapping probably occurred in July and September, but scraper population densities were higher below than above the ponds in July and September.

The discrepancy between observed and expected benthic population reactions may have resulted from utilization of alternate food sources by benthic organisms. This hypothesis is difficult to evaluate because there is considerable ambiguity concerning the feeding habits of most aquatic invertebrates (Cummins, 1973). Many of the taxa considered as scrapers may rely heavily on detritus in addition to periphyton during parts of the year or parts of their life cycle. This polyphagy would probably mask differences caused by periphyton changes. Secondly, nutrient export occurred during winter when solar insolation would have limited periphyton production regardless of the nutrient load. Finally, the changes in nutrient dynamics may not have been sufficient to alter periphyton production.

The ponds appeared to act as energy exporters in some seasons and as energy sinks in others. Seasonal changes in downstream benthic populations appeared to be tied to changes in photosynthetic activity within the ponds and output of organic material from the ponds.

Increased benthic density and biomass below the ponds during summer indicated increased available energy below the ponds. The high zooplankton drift rates below the ponds in September were indicative of the energy output of the ponds.

The ponds appeared to be acting as energy sinks in January. Decreased benthic population densities and biomass in all ecological groups were indicative of decreased available energy below the ponds during this period. The energy lost within the ponds from intercepted downstream transport of organic material apparently was greater than the energy contained in the output of organic matter from the ponds and any increased periphyton production derived from nutrient export.

April appeared to be a transition period from less to greater available energy below the ponds. Zooplankton drift below the ponds was high, indicating increased energy output from the ponds. Benthic population densities and biomass above and below the ponds were similar, albiet somewhat smaller downstream. Higher available energy below the ponds during summer resulted in increased density and biomass of benthic invertebrates; however, benthic population reaction appeared to lag behind changes in energy.

Drift rates above and below the ponds may provide additional evidence that these community alterations were energy related. Waters (1966) extended Müller's (1954) hypothesis of the density dependent nature of drift, and treated drift as an agent of population regulation functionally dependent upon the production rate at or above the carrying capacity of the stream bottom. Hildebrand (1974) and Otto (1976) could find no dependency between drift and other downstream movements and benthic density, but suggested that carrying capacity for benthic invertebrates may be related to quantity and quality of available food.

There was no dependency between drift and benthic density observed in the study as evidenced by higher drift rates from lower population densities at various seasons (Tables 2 and 13). The lower drift rates below the ponds in July and September, in spite of higher benthic densities, may indicate increased carrying capacity due to greater energy availability. Likewise, the higher drift rates below the ponds in January may have resulted from reduced energy during that season.

The increased energy did not appear to be available to all ecological groups. Suspension feeders, and deposit collectors appeared to be able to use the energy efficiently. Scraper populations did not respond as much, and the energy appeared to be unavailable to shredders.

The increased available energy downstream was reflected in fish populations. There was a general increase in numbers and biomass of all fish except rosyside dace below the ponds. Seasonal fluctuations in energy below the ponds were not evident in fish populations. Fish can draw upon energy stores in the body to compensate for short term energy shortages.

The responses of rosyside dace, creek chub, and bluehead chub may have resulted from competitive interactions. Redside dace feeds primarily upon terrestrial insects (Trautman, 1957), and rosyside dace may have similar food habits. Terrestrial insect availability probably would be unaltered below the ponds. The increased food supply for aquatic feeding forms below the ponds over much of the year versus the constant or decreased supply for terrestrial feeders may have placed rosyside dace at a competitive disadvantage.

The food habits and other requirements of creek chub and bluehead chub are similar (Lachner and Jenkins, 1971; Scott and Crossman, 1973; Pflieger, 1975). Pflieger (1975) believes that creek chub is restricted to head water streams because it is a poor competitor in more diverse faunas. The increased available energy below the ponds may have provided bluehead chub with a competitive advantage over creek chub.

Similar competitive interactions may also have accounted for some of the species composition differences in the benthic communities.

Blockage of fish movements did not appear to be a major impact in the system. Sufficient spawning areas for all species appeared to be available above and below the ponds. However, if creek chub or bluehead chub was restricted to certain areas for spawning, blockage of upstream or downstream movements could account for the dichotomy in their distribution.

The introduction of fathead minnow and bluegill indicated a possible major impact. The significance of these introductions in this system could not be evaluated; but, the introduction of a highly competitive species in some systems could disrupt the competitive balance.

This study concerned itself with downstream impacts primarily; however, impoundments may impact upstream fish communities (Earman, 1973). Headwater streams probably act as islands for many fish populations (Echelle, et al, 1975; Echelle and Schnell, 1976), and the establishment of an impoundment may accelerate invasion of more lacustrine species and cause depletion or extinction of locally adapted faunas. The inlet system in the ponds studies precluded such upstream impacts; however, in systems where the stream directly feeds the ponds, such impacts may be of greater importance.

CONCLUSIONS

The major impacts associated with the ponds appeared to be alteration of energy dynamics. The alterations were seasonally dependent, and may have resulted from interception of larger particle organic matter being transported downstream and its replacement by finer organic matter. The alterations manifested themselves in changes in numbers and biomass of benthic macroinvertebrates and fish, and changes in drift patterns below the ponds. The energy dynamics alterations may have also influenced competitive interactions among benthic organisms and fish.

The direct influence of physiochemical alterations appeared to be masked by energy related alterations; however, alterations in physiochemical factors may have caused minimal changes in species composition in aquatic communities below the ponds.

Material impacts in the system studied appeared to be negligible; however, Young (unpublished data) found significant impacts associated with the introduction of a floc of iron and iron bacteria below a bottom release impoundment. Material impacts may be of major importance in bottom release systems.

The ponds appeared to cause a general increase in stream productivity downstream. However, increased amplitude in seasonal fluctuations of physiochemical factors combined with seasonal fluctuations in energy below the ponds appeared to produce a more fluctuating environment below the ponds leading to reduced stability in downstream communities.

The impacts evidenced in this study do not appear to be as drastic as those reported in larger systems. There were no large scale alterations in species composition or reductions in number of taxa present below the ponds. In systems containing rare species or with uniquely adapted faunas, the less stable environmental conditions, possible introduction of exotic species, and the possible disruption of competitive balance with the system may cause major impacts. These possible impacts should be dealt with in the design and planning of small pond construction.

LITERATURE CITED

American Public Health Association. 1971. Standard methods for the examination of water and wastewater. 13th ed. New York. 874pp.

Bacon, E. J., S. H. Newton, R. J. Kilambi, and C. E. Hoffman. 1969. Changes in the ichthyofauna in the Beaver Reservoir tailwater. Proc. 22nd Ann. Conf., Southeastern Assoc. of Game and Fish Commrs. pp245-248.

Bay, E. C. 1974. Predator-prey relationships among aquatic insects. Ann. Rev. Entomol. 19:441-453.

Carle, F. L. 1976. An evaluation of the removal method for estimating benthic populations and diversity. M. S. Thesis, Virginia Polytechnic Institute and State Univ. 110pp.

Churchill, M. A. 1958. Effects of storage impoundments on water quality. Trans. Amer. Soc. Civil Engr. 123:419-464.

Cummins, K. W. 1973. Tropic relations of aquatic insects. Ann. Rev. Entomol. 18:183-206.

Dendy, J. S., and R. H. Stroud. 1949. The dominating influence of Fontana Reservoir on temperature and dissolved oxygen in the Little Tennessee River and its impoundments. J. Tenn. Acad. Sci. 24:41-51.

Earman, D. C. 1973. Upstream changes in fish populations following impoundment of Sagehen Creek, California. Trans. Amer. Fish. Soc. 102:626-629.

Echelle, A. A., A. F. Echelle, M. H. Smith and L. G. Hill. 1975. Analysis of genic continuity in a headwater fish, Etheostoma radiosum (Percidae). Copeia, 1975:197-204.

Echelle, A. A., and G. D. Schnell. 1976. Factor analysis of species associations among fishes of the Kiamichi River, Oklahoma. Trans. Amer. Fish. Soc. 105:71-31.

Gameson, A. L. H. 1957. Weirs and the aeration of rivers. J. Inst. Wat. Engrs. 11:447-490.

Gaufin, A. R. 1973. Water quality requirements of aquatic insects. Office of Research and Development, U. S. Environmental Protection Agency, Washington, D. C. 89pp.

Hildebrand, S. G. 1974. The relation of draft to benthos density and food level in an artificial stream. Limn. and Oceano. 19:951-957.

Hollander, M., and D. A. Wolfe. 1973. Nonparametric Statistical Methods. John Wiley and Sons, Inc., New York. 503pp.

Hynes, H. B. N. 1972. The ecology of running waters. Univ. of Toronto Press, Toronto. 553pp.

Isom, B. G. 1971. Effects of storage and mainstream reservoirs on benthic macroinvertebrates in the Tennessee Valley, pp. 179-191. In: G. E. Hall ed., Reservoir Fisheries and Limnology. Amer. Fish. Soc., Washington, D. C.

Lachner, E. A., and R. E. Jenkins. 1971. Systematics, Distribution and evolution of the chub genus Nocomis Girard (Pices, Cyprinidae) of the eastern United States, with description of new species. Smithson. Contrib. to Zool. No. 85. 97pp.

Lehmkuhl, D. M. 1972. Changes in thermal regime as a cause of reduction of benthic fauna downstream of a reservoir. J. Fish. Res. Bd. Canada 29:1329-1332.

Minckley, W. L. 1963. The ecology of a spring stream Doe Run, Meade County, Kentucky. Wild. Monogr. No. 11. 124pp.

Morris, L. A., R. N. Langemeier, T. R. Russell, and A. Witt, Jr. 1968. Effects of a main stem impoundment and channelization upon the limnology of the Missouri River, Nebraska. Trans. Amer. Fish. Soc. 97:300-388.

Müller, K. 1954. Investigations on the organic draft in North Swedish streams. Rep. Inst. Freshwater Res., Drottningholm 35:133-148.

Nebeker, A. V. 1972. Effect of low oxygen concentration on survival and emergence of aquatic insects. Trans. Amer. Fish. Soc. 101:675-679.

Neel, J. K. 1963. The impact of reservoirs, pp. 575-593. In: D. G. Frey ed., Limnology in North America. Univ. of Wisconsin Press, Madison.

Otto, C. 1976. Factors affecting the drift of Potomophylax cingulatus (Trichoptera) larvae. Oikos 27:93-100.

Pfitzer, D. W. 1954. Investigations of water below storage reservoirs in Tennessee. Trans. 19th North Amer. Wildl. Conf. pp.271-282.

Pfleger, W. L. 1975. The fishes of Missouri. Missouri Dept. Conservation. 343pp.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Bull. 184, Fish.Res. Bd. Canada, Ottawa 966pp.

Soltero, R. A., J. C. Wright, and R. A. Horpestad. 1973. Effects of impoundment on the water quality of the Bighorn River. Wat. Res. 5:343-354.

Spence, J. A., and H. B. N. Hynes. 1971a. Differences in benthos upstream and downstream of an impoundment. J. Fish. Res. Bd. Canada 28:35-43.

______, and ______. 1971b. Differences in fish populations upstream and downstream of a mainstream impoundment. J. Fish, Res. Bd. Canada 28:45-46.

Surber, E. W., and W. E. Bessey. 1974. Minimum oxygen levels survived by stream invertebrates. Bul. 81, Virginia Water Res. Center, Virginia Polytechnic Institute and State University, Blacksburg. 52pp.

Ward, J. V. 1974. A temperature-stressed ecosystem below a hypolimnion release mountain reservoir. Arch. Hydrobiol. 74: 247-275.

Waters, T. F. 1966. Production rate, population density, and drift of a stream invertebrate. Ecology 47:595-604.

APPENDIX

Appendix Table I. Invertebrate taxa collected in benthic and drift samples from October 1, 1975 to July 14, 1976 above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia.

Hydroidea
- *Hydra americana*

Turbellaria (planeria)
Nematoda
Oligocheata (Naididae mostly)
Cladocera
Copepoda
Ostracoda
Isopoda
- *Asselus militarilis*

Decapoda
- *Cambarus* sp.

Acari
Insecta
- Collembola
- Ephemeroptera
  - Ephemeridae
    - *Ephemera* sp.
    - *Hexagenia mingo*?
  - Heptageniidae
    - *Stenonema* sp.
    - *S. rubrum*
    - *Epeorus* sp.
    - *E. humeralis*
    - *E. fradator*
    - *E. fragilis*
  - Siphlonuridae
    - *Ameletus lineatus*
    - *Isonychia* sp.
    - *I. sadleri*
    - *I. thalia*?
  - Leptophlebiidae
    - *Leptophlebia* sp.
    - *Paraleptophlebia* sp.
    - *Habrophlebia* sp.
  - Baetiscidae
    - *Baetisca carolina*
  - Ephemerellidae
    - *Ephemerella* sp.
    - *E. simplex*
    - *E. dorothea*
    - *E. aestiva*

Appendix Table I. Invertebrate taxa collected in benthic and drift samples from October 1, 1975 to July 14, 1976 above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia (continued).

E. funeralis
Caenidae
Caenis sp.
Baetidae
Baetis sp.
Centroptilum sp.
Pseudocloeon sp.
P. dubium
Odanata
Cordulegasteridae
Cordulegaster sp.
Gomphidae
Lanthus sp.? young instar
Hagenius sp.
Aeshnidae
Boyeria sp.
Libellulidae
Erythemis sp.
Agrionidae
Agrion sp.
Hetaerina sp.
Plecoptera
Peltoperlidae
Peltoperla sp.
Nemouridae
Nemoura sp.
Leuctridae
Leuctra sp.
Capniidae
Allocapnia sp.
Taeniopterygidae
Brachyptera sp.
Perlodidae
Isogenus sp.
Isoperla sp.
Chloroperlidae
young instar
Perlidae
Perlesta sp.
Megaloptera
Corydalidae
Nigronia serricornus

Appendix Table I. Invertebrate taxa collected in benthic and drift samples from October 1, 1975 to July 14, 1976 above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia (continued).

Trichoptera
- Rhyacophilidae
  - *Rhyacophila* sp.
- Glossosomidae
  - *Glossosoma* sp.
  - *Agapetus* sp.
- Philopotamidae
  - *Wormaldia* sp.
  - *Sortosa* sp.
- Psychomyiidae
  - *Polycentropus* sp.
- Hydropsychidae
  - *Diplectrona* sp.
  - *Cheumatopsyche* sp.
  - *Hydropsyche* sp.
- Limnephilidae
  - *Neophylax* sp.
  - *Pycnopsyche* sp.
- Odontoceridae
  - *Psilotreta* sp.
- Lepidostomatidae
  - young instar

Coleoptera
- Gyrinidae
  - *Dineutus* sp.
- Dryopidae
  - *Helichus* sp.
- Elmidae
  - *Stenelmis* sp.
  - *Macronychus glabratus*
  - *Oulimnius latiusculus*
  - *Gonielmis dietrichi*
  - *Optioservus* sp.
- Psephenidae
  - *Ectopria* sp.
  - *Psephenus* sp.

Diptera
- Tipulidae
  - *Tipula* sp.
  - *T. abdominalis*
  - *Antocha* sp.
  - *Dicranota* sp.
  - *Pseudolimnophila* sp.

Appendix Table I. Invertebrate taxa collected in benthic and drift samples from October 1, 1975 to July 14, 1976 above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia (continued).

Eriocera sp.
E. cinecera?
E. Fultonensis?
Tanyderidae
Protoplasa fitchii
Psychodidae
Psychoda sp.
Culicidae
Chaoborus punctipennis?
Dixidae
Dixa sp.
Simuliidae
Simulium sp.
S. sp. A (Johannsen)
S. vittatum
S. venustum
Chironomidae
Tanypodinae
Orthodadinae
Chironominae
Ceratopogonidae
Atrichopogon websteri?
Palpomyia?
Stratiomyidae
Tabanidae
Tabanus sp.
Empididae
Hemerodromia sp.
Muscidae
Gastropoda
Ancylidae
Ferrissia sp.
Snails
Pelecypoda

Appendix Table II. Population density and biomass in milligrams of benthic invertebrate taxa per 0.33 meter^2 by seasons above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia.

TAXA	DENSITY Above	DENSITY Below	BIOMASS Above	BIOMASS Below
Hydra americana				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	0	66	0	1.5
Planeria				
October, 1975	0	2	0	0.4
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	0	0	0	0
Nematoda				
October, 1975	8	15	T	0.6
January, 1976	10	3	0.3	0.4
April, 1976	5	7	T	0.5
July, 1976	14	56	5.8	0.2
Oligocheata				
October, 1975	30	29	5.6	1.4
January, 1976	30	15	1.9	0.6
April, 1976	33	62	1.4	0.4
July, 1976	60	130	3.7	15.2
Ostracoda				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	0	15	0	0.6

Appendix Table II. Population density and biomass in milligrams of benthic invertebrate taxa per 0.33 meter^2 by seasons above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia. (continued).

TAXA	DENSITY Above	DENSITY Below	BIOMASS Above	BIOMASS Below
Cambarus sp.				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	1	0	86.0	0
July, 1976	0	0	0	0
Acari				
October, 1975	11	56	1.0	4.3
January, 1976	10	2	0.6	0.4
April, 1976	136	24	6.2	0.5
July, 1976	219	202	6.9	9.2
Collembola				
October, 1975	1	2	T	T
January, 1976	0	1	0	0.2
April, 1976	1	1	T	T
July, 1976	1	0	T	0
Ephemera				
October, 1975	0	1	0	6.3
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	2	1	0.1	4.7
Stenonema sp.				
October, 1975	17	58	32.6	35.1
January, 1976	2	1	3.3	0.2
April, 1976	29	4	180.2	4.5
July, 1976	42	40	51.9	7.7

Appendix Table II. Population density and biomass in milligrams of benthic invertebrate taxa per 0.33 meter^2 by seasons above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia (continued).

TAXA	DENSITY Above	DENSITY Below	BIOMASS Above	BIOMASS Below
Epeorus sp.				
October, 1975	0	0	0	0
January, 1976	5	0	2.8	0
April, 1976	2	0	13.0	0
July, 1976	2	1	0.1	T
E. humeralis				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	18	0	202.4	0
July, 1976	0	0	0	0
E. fradator				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	1	0	4.5	0
July, 1976	0	0	0	0
Ameletus lineatus				
October, 1975	0	0	0	0
January, 1976	1	0	11.0	0
April, 1976	0	0	0	0
July, 1976	0	0	0	0
Isonychia sadleri				
October, 1975	10	1	22.9	0.7
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	0	0	0	0

Appendix Table II. Population density and biomass in milligrams of benthic invertebrate taxa per 0.33 meter^2 by seasons above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia (continued).

TAXA	DENSITY Above	DENSITY Below	BIOMASS Above	BIOMASS Below
I. thalia				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	2	0	1.0
July, 1976	2	1	0.1	T
Paraleptophlebia sp.				
October, 1975	1	0	0.1	0
January, 1976	1	0	T	0
April, 1976	0	0	0	0
July, 1976	0	0	0	0
Baetisca carolina				
October, 1975	6	57	1.8	50.2
January, 1976	5	0	5.7	0
April, 1976	1	1	10.4	26.1
July, 1976	1	28	T	5.3
Ephemerella sp.				
October, 1975	1	18	T	0.9
January, 1976	64	58	27.7	40.3
April, 1976	102	0	565.0	0
July, 1976	1	5	T	T
E. simplex				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	3	1	4.8	0.5
July, 1976	0	0	0	0

Appendix Table II. Population density and biomass in milligrams of benthic invertebrate taxa per 0.33 meter^2 by seasons above and below two small ponds on a tributary stream of Mill Creek, Patrick County Virginia (continued).

TAXA	DENSITY		BIOMASS	
	Above	Below	Above	Below
E. dorothea				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	9	44	50.5	178.4
July, 1976	0	0	0	0
E. aestiva				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	1	0	0.1	0
Baetis sp.				
October, 1975	1	5	0.1	0.9
January, 1976	0	0	0	0
April, 1976	0	22	0	10.7
July, 1976	4	4	0.4	0.8
Centroptilum sp.				
October, 1975	1	0	0.1	0
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	0	0	0	0
Pseudocloeon sp.				
October, 1975	5	0	1.9	0
January, 1976	0	1	0	0.2
April, 1976	34	43	18.6	14.1
July, 1976	1	2	0.4	0.8

Appendix Table II. Population density and biomass in milligrams of benthic invertebrate taxa per 0.33 meter^2 by seasons above and below two small ponds on a tributary stream of Mill Creek, Patrick County Virginia (continued).

TAXA	DENSITY Above	DENSITY Below	BIOMASS Above	BIOMASS Below
P. dubium				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	7	4	3.9	1.7
July, 1976	0	0	0	0
Cordulegaster sp.				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	0	1	0	193.3
Lanthus? young instar				
October, 1975	3	8	2.1	5.1
January, 1976	4	0	0.7	0
April, 1976	7	3	0.6	0.4
July, 1976	2	6	0.6	12.1
Hagenius sp.				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	1	1	0.2	3.2
Boyeria sp.				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	1	0	0.3
July, 1976	0	1	0	4.7

Appendix Table II. Population density and biomass in milligrams of benthic invertebrate taxa per 0.33 meter^2 by seasons above and below two small ponds on a tributary stream of Mill Creek, Patrick County Virginia (continued).

TAXA	DENSITY		BIOMASS	
	Above	Below	Above	Below
Hetaerina sp.				
October, 1975	0	1	0	0.1
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	0	3	0	0.2
Peltoperla sp.				
October, 1975	9	14	26.2	3.1
January, 1976	1	1	T	8.4
April, 1976	108	39	175.9	7.0
July, 1976	10	6	10.4	9.2
Nemoura sp.				
October, 1975	2	0	T	0
January, 1976	23	17	21.0	13.9
April, 1976	3	1	0.2	T
July, 1976	23	11	1.4	3.0
Leuctra sp.				
October, 1975	3	3	0.5	0.7
January, 1976	19	3	1.7	T
April, 1976	106	45	3.5	4.5
July, 1976	70	45	18.9	16.4
Allocapnia sp.				
October, 1975	0	0	0	0
January, 1976	0	1	0	0.5
April, 1976	0	0	0	0
July, 1976	0	0	0	0

Appendix Table II. Population density and biomass in milligrams of benthic invertebrate taxa per 0.33 meter^2 by seasons above and below two small ponds on a tributary stream of Mill Creek, Patrick County Virginia (continued).

TAXA	DENSITY		BIOMASS	
	Above	Below	Above	Below
Brachyptera sp.				
October, 1975	0	0	0	0
January, 1976	17	4	76.2	20.5
April, 1976	0	0	0	0
July, 1976	0	0	0	0
Perlodidae young instar				
October, 1975	0	0	0	0
January, 1976	2	0	T	0
April, 1976	1	0	T	0
July, 1976	0	0	0	0
Isoperla sp.				
October, 1975	0	2	0	0.2
January, 1976	0	0	0	0
April, 1976	30	43	26.0	76.0
July, 1976	0	2	0	1.8
Perlidae young instar				
October, 1975	0	0	0	0
January, 1976	0	1	0	T
April, 1976	1	0	T	0
July, 1976	0	0	0	0
Nigronia serricornus				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	3	0	0.3	0

Appendix Table II. Population density and biomass in milligrams of benthic invertebrate taxa per 0.33 meter^2 by seasons above and below two small ponds on a tributary stream of Mill Creek, Patrick County Virginia (continued).

TAXA	DENSITY		BIOMASS	
	Above	Below	Above	Below
<u>Rhyacophila</u> sp.				
October, 1975	6	0	6.8	0
January, 1976	0	0	0	0
April, 1976	1	0	T	0
July, 1976	0	1	0	0.3
<u>Glossosoma</u> sp.				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	1	0	0.9	0
<u>Glossosoma</u> sp. pupae				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	2	0	6.9	0
<u>Agapetus</u> sp.				
October, 1975	0	1	0	T
January, 1976	1	1	T	0.2
April, 1976	12	341	7.2	223.3
July, 1976	16	269	16.3	118.0
<u>Agapetus</u> sp. pupae				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	0	4	0	13.6

Appendix Table II. Population density and biomass in milligrams of benthic invertebrate taxa per 0.33 meter^2 by seasons above and below two small ponds on a tributary stream of Mill Creek, Patrick County Virginia (continued).

TAXA	DENSITY Above	DENSITY Below	BIOMASS Above	BIOMASS Below
Wormaldia sp.				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	2	0	0.3	0
July, 1976	0	0	0	0
Sortosa sp.				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	1	0	0.3	0
Polycentropus sp.				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	3	0	0.6	0
July, 1976	1	0	T	0
Diplectrona sp.				
October, 1975	36	34	48.2	36.4
January, 1976	6	0	39.7	0
April, 1976	5	0	58.1	0
July, 1976	64	49	92.6	12.8
Diplectrona sp. pupae				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	0	1	0	5.3

Appendix Table II. Population density and biomass in milligrams of benthic invertebrate taxa per 0.33 meter^2 by seasons above and below two small ponds on a tributary stream of Mill Creek, Patrick County Virginia (continued).

TAXA	DENSITY		BIOMASS	
	Above	Below	Above	Below
<u>Cheumatopsyche</u> sp.				
October, 1975	34	214	27.9	218.6
January, 1976	15	13	20.3	33.5
April, 1976	47	29	171.4	47.0
July, 1976	59	470	92.6	514.8
<u>Cheumatopsyche</u> sp. pupae				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	1	0	T	0
July, 1976	0	9	0	38.2
<u>Hydropsyche</u> sp.				
October, 1975	2	12	1.3	49.4
January, 1976	0	1	0	14.7
April, 1976	0	0	0	0
July, 1976	0	173	0	763.3
<u>Hydropsyche</u> sp. pupae				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	1	0	T	0
July, 1976	0	0	0	0
Limnephilidae young instar				
October, 1975	0	0	0	0
January, 1976	1	1	T	T
April, 1976	0	0	0	0
July, 1976	0	0	0	0

Appendix Table II. Population density and biomass in milligrams of benthic invertebrate taxa per 0.33 meter^2 by seasons above and below two small ponds on a tributary stream of Mill Creek, Patrick County Virginia (continued).

TAXA	DENSITY		BIOMASS	
	Above	Below	Above	Below
Neophylax sp.				
October, 1975	0	0	0	0
January, 1976	3	1	14.1	3.0
April, 1976	2	0	18.6	0
July, 1976	0	0	0	0
Psilotreta sp.				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	2	0	1.6	0
Dineutus sp.				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	0	5	0	36.2
Helichus sp. larvae				
October, 1975	46	72	15.2	42.8
January, 1976	79	4	39.7	9.8
April, 1976	116	18	75.2	52.6
July, 1976	49	22	79.6	142.2
Helichus sp. adult				
October, 1975	3	0	36.5	0
January, 1976	1	0	7.2	0
April, 1976	0	0	0	0
July, 1976	0	1	0	6.8

Appendix Table II. Population density and biomass in milligrams of benthic invertebrate taxa per 0.33 meter^2 by seasons above and below two small ponds on a tributary stream of Mill Creek, Patrick County Virginia (continued).

TAXA	DENSITY Above	DENSITY Below	BIOMASS Above	BIOMASS Below
Stenelmis sp. larvae				
October, 1975	0	3	0	0.2
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	1	2	T	0.2
Stenelmis sp. adult				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	1	0	9.0	0
July, 1976	0	3	0	6.4
Macronychus glabratus adult				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	0	1	0	1.2
Oulimnius latiusculus larvae				
October, 1975	89	106	4.2	6.2
January, 1976	49	5	3.5	0.5
April, 1976	144	142	17.2	22.7
July, 1976	319	217	11.9	16.9
Oulimnius latiusculus adult				
October, 1975	160	269	33.1	53.1
January, 1976	99	26	36.9	4.9
April, 1976	354	365	79.9	76.7
July, 1976	164	607	36.2	129.8

Appendix Table II. Population density and biomass in milligrams of benthic invertebrate taxa per 0.33 meter^2 by seasons above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia (continued).

TAXA	DENSITY Above	DENSITY Below	BIOMASS Above	BIOMASS Below
Gonielmis dietrichi adult				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	0	2	0	0.8
Optioservus sp. larvae				
October, 1975	233	344	14.2	51.9
January, 1976	160	42	22.2	7.5
April, 1976	272	159	50.6	70.4
July, 1976	1330	835	115.0	289.4
Optioservus sp. adult				
October, 1975	99	72	135.4	96.5
January, 1976	52	10	67.9	10.8
April, 1976	89	20	114.3	30.8
July, 1976	15	164	19.6	225.2
Optioservus sp. pupae				
October, 1975	0	1	0	T
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	1	1	T	T
Ectopria sp.				
October, 1975	1	1	0.2	0.5
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	3	9	3.2	15.7

Appendix Table II. Population density and biomass in milligrams of benthic invertebrate taxa per 0.33 $meter^2$ by seasons above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia (continued).

TAXA	DENSITY		BIOMASS	
	Above	Below	Above	Below
Psephenus sp.				
October, 1975	0	1	0	T
January, 1976	1	0	0.4	0
April, 1976	2	0	2.5	0
July, 1976	2	4	3.1	12.3
Tipula sp.				
October, 1975	1	5	2.8	11.1
January, 1976	2	1	44.3	10.5
April, 1976	0	0	0	0
July, 1976	1	1	30.5	131.7
T. abdominalis				
October, 1975	0	0	0	0
January, 1976	0	2	0	1608.3
April, 1976	0	2	0	1172.4
July, 1976	1	1	518.9	368.1
Antocha sp.				
October, 1975	0	0	0	0
January, 1976	3	0	0.5	0
April, 1976	1	0	0.6	0
July, 1976	1	16	0.2	6.3
Antocha sp. pupae				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	0	1	0	0.5

Appendix Table II. Population density and biomass in milligrams of benthic invertebrate taxa per 0.33 meter^2 by seasons above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia (continued).

TAXA	DENSITY Above	DENSITY Below	BIOMASS Above	BIOMASS Below
Dicranota sp.				
October, 1975	0	2	0	3.1
January, 1976	9	1	1.4	0.4
April, 1976	6	7	9.6	4.5
July, 1976	1	9	0.9	10.8
Pseudolimnophila sp.				
October, 1975	2	1	0.4	0.1
January, 1976	11	0	0.5	0
April, 1976	22	0	233.3	0
July, 1976	0	0	0	0
Eriocera sp.				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	0	5	0	0.3
E. cinecera?				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	1	0	4.7
July, 1976	0	0	0	0
E. fultonensis				
October, 1975	0	3	0	0.7
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	0	0	0	0

Appendix Table II. Population density and biomass in milligrams of benthic invertebrate taxa per 0.33 meter^2 by seasons above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia (continued).

TAXA	DENSITY		BIOMASS	
	Above	Below	Above	Below
Protoplasa fitchii				
October, 1975	0	1	0	0.5
January, 1976	0	1	0	T
April, 1976	0	1	0	10.3
July, 1976	0	1	0	0.3
Psychoda sp.				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	1	0	0.4
July, 1976	0	0	0	0
Dixa sp.				
October, 1975	0	2	0	0.5
January, 1976	0	0	0	0
April, 1976	1	1	T	T
July, 1976	0	0	0	0
Simulium sp. larvae				
October, 1975	36	29	23.7	9.3
January, 1976	19	15	32.1	6.7
April, 1976	1	92	T	48.4
July, 1976	2	2	1.0	T
S. sp. A (Johannsen) pupae				
October, 1975	0	0	0	0
January, 1976	9	0	2.5	0
April, 1976	0	0	0	0
July, 1976	0	0	0	0

Appendix Table II. Population density and biomass in milligrams of benthic invertebrate taxa per 0.33 meter^2 by seasons above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia (continued).

TAXA	DENSITY		BIOMASS	
	Above	Below	Above	Below
S. vittatum pupae				
October, 1975	0	0	0	0
January, 1976	19	0	46.4	0
April, 1976	0	0	0	0
July, 1976	0	0	0	0
S. venustum pupae				
October, 1975	2	0	1.1	0
January, 1976	0	0	0	0
April, 1976	1	0	0.5	0
July, 1976	0	0	0	0
Tanypodinae larvae				
October, 1975	0	2	0	0.8
January, 1976	3	1	T	T
April, 1976	4	4	0.6	1.1
July, 1976	5	28	0.5	4.3
Orthodadinae				
October, 1975	34	48	5.4	-
January, 1976	86	21	9.2	0.9
April, 1976	55	141	2.8	17.4
July, 1976	69	123	4.2	3.3
Orthodadinae pupae				
October, 1975	1	13	T	2.6
January, 1976	1	0	T	0
April, 1976	5	0	1.1	0
July, 1976	0	3	0	T

- = biomass data not obtained

Appendix Table II. Population density and biomass in milligrams of benthic invertebrate taxa per 0.33 meter^2 by seasons above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia (continued).

TAXA	DENSITY		BIOMASS	
	Above	Below	Above	Below
Chironominae				
October, 1975	48	146	2.0	28.4
January, 1976	226	54	2.7	0.3
April, 1976	383	79	14.5	9.5
July, 1976	155	379	2.6	11.9
Chironominae pupae				
October, 1975	2	16	0.5	3.2
January, 1976	1	0	0.2	0
April, 1976	3	19	0.3	3.7
July, 1976	18	6	1.7	1.1
Atrichopogon websteri?				
October, 1975	0	1	0	T
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	0	1	0	T
Palpomyia sp.				
October, 1975	4	8	0.3	0.5
January, 1976	7	1	0.9	T
April, 1976	15	29	0.8	3.1
July, 1976	7	17	0.3	0.3
Palpomyia sp. pupae				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	1	0	T
July, 1976	0	1	0	T

Appendix Table II. Population density and biomass in milligrams of benthic invertebrate taxa per 0.33 meter^2 by seasons above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia (continued).

TAXA	DENSITY		BIOMASS	
	Above	Below	Above	Below
Tabanus sp.				
October, 1975	0	4	0	107.8
January, 1976	1	1	6.8	4.4
April, 1976	1	0	6.7	0
July, 1976	0	1	0	14.4
Dolichopodidae				
October, 1975	0	1	0	0.1
January, 1976	0	0	0	0
April, 1976	1	0	0.2	0
July, 1976	0	0	0	0
Hemerodromia sp.				
October, 1975	2	13	0.2	1.7
January, 1976	3	7	T	0.9
April, 1976	17	2	2.8	0.2
July, 1976	11	126	0.4	11.0
Hemerodromia sp. pupae				
October, 1975	0	1	0	0.4
January, 1976	0	0	0	0
April, 1976	1	3	0.3	1.2
July, 1976	0	5	0	2.4
Muscidae				
October, 1975	0	0	0	0
January, 1976	0	0	0	0
April, 1976	0	2	0	T
July, 1976	0	0	0	0

Appendix Table II. Population density and biomass in milligrams of benthic invertebrate taxa per 0.33 meter^2 by seasons above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia (continued).

TAXA	DENSITY Above	DENSITY Below	BIOMASS Above	BIOMASS Below
Ferrissia sp.				
October, 1975	0	1	0	0.4
January, 1976	0	0	0	0
April, 1976	0	0	0	0
July, 1976	0	4	0	0.8
Snails				
October, 1975	0	58	0	-
January, 1976	0	1	0	0.2
April, 1976	0	22	0	137.5
July, 1976	22	338	1.4	339.2
Pelecypoda				
October, 1975	0	8	0	4.7
January, 1976	3	1	0.1	0.2
April, 1976	2	8	0.4	2.3
July, 1976	2	22	0.4	2.7

T < 0.1 mg

- = biomass data not obtained

Appendix Table III. Drift rates of invertebrate taxa in number per 100 cubic meters flow sampled by season above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia.

TAXA	OCTOBER		JANUARY		APRIL		JULY	
	Above	Below	Above	Below	Above	Below	Above	Below
Hydra americana	0	0	0	2.58	0	0	0	33.17
Nematoda	0	0	0	0	0	0	0.52	0
Oligocheata	0.73	4.65	0.15	1.38	4.58	1.32	4.19	0.54
Cladocera	0	112.86	0	0	0	0.48	0	0
Copepoda	17.45	55.85	1.35	0.86	3.27	69.53	0	0
Asselus militarilis	0	0.29	0	0.17	0.65	0	0	0
Acari	8.00	0	1.05	4.48	18.32	0	3.66	1.43
Collembola	0	0	24.97	65.62	7.20	1.80	0.52	0
Ephemera sp.	0	0.29	0	0.52	1.31	0	1.05	0
Hexagenia mingo?	0	0	0	0.52	1.31	0.12	0	0
Stenonema sp.	6.54	0.29	1.05	1.89	13.09	1.68	3.66	0.72
Epeorus sp.	0	0	0.15	0	0.65	0	0	0
E. humeralis	0.73	0	0	0	0	0	0	0
Ameletus lineatus	0	0	0.45	0.34	0	0	0	0
Isonychia sadleri	0	0	0.90	0.17	2.62	0	0	0
I. thalia?	8.00	0	0	0	0	0	0	0
Leptophlebia sp.	0	0	0.15	0	0	0	0	0
Paraleptophlebia	0	0.29	0.30	1.03	15.05	0.12	2.09	0
Habrophlebia	0	0	0	0	1.96	0	0	0
Baetisca carolina	28.36	2.04	0.15	0.86	7.85	0	0.52	0
Ephemerella sp.	0	0.87	0	0	0	0	0	0.18
E. simplex	0	0	0.15	0	5.89	0.24	0	0
E. dorothea	0	0	4.66	7.41	7.85	1.08	0	0
E. aestiva	7.27	0	0	0.52	3.27	0	6.28	0.18
E. funeralis	0	0	0	0	0.65	0.12	0	0

Appendix Table III. Drift rate of invertebrate taxa in number per 100 cubic meters flow sampled by season above and below two small ponds on a tributary stream of Mill Creek, Patrick County, Virginia (continued).

TAXA	OCTOBER		JANUARY		APRIL		JULY	
	Above	Below	Above	Below	Above	Below	Above	Below
Hydropsyche sp.	0	0	0	0	0	0	1.05	0.18
Limnephilidae young instar	7.27	4.36	0.15	0	0	0	0	0
Neophylax sp.	0	0	0	0	0.52	0	0	0
Pycnopsyche sp.	0	0	1.05	1.03	0.65	0	0	0
Oecetis sp.	0	0.29	0	0	0.65	0	0	0
Lepidostomatidae young instar	0	0	0	0	1.31	0	0	0
Dineutus sp.	0	0	0	0	0	0	0	0.18
Helichus sp. larvae	0.73	0.29	0	0	0.65	0	0.52	0
Helichus sp. adult	2.18	0.29	0	0.17	7.85	0.12	1.57	0
Macronychus glabratus larvae	0	0.29	0	0.17	0	0	0	0.18
Oulimnius latiusculus larvae	2.18	0.58	0	0	2.62	0.12	4.71	0
O. latiusculus adults	10.18	5.82	0.45	1.21	15.05	0	10.47	0.54
Gonielmis dietrichi	0	0	0	0	0	0	0.52	0
Optioservus sp. larvae	25.45	1.16	0.15	1.55	1.31	0.24	11.52	2.51
Optioservus sp. adults	0.73	0.58	0	0.34	3.93	0	1.57	0.18
Ectopria sp.	0	0.29	0	0	0	0	0	0
Psephenus sp.	0	0.29	0	0	0	0	0	0
Tipula sp.	0	0.58	0	0	0	0	0	0
T. abdominalis	15.27	0.87	0	0	0	0.12	0	0
Antocha	1.45	0	0	0	0.65	0	0	0
Dicranota sp.	0	0	0	0.17	0.65	0	0	0.18
Protoplasa fitchii	0	0	0	0	0	0.12	0	0
Psychoda sp.	0	0.29	0	0	0	0	0	0
Chaoborus punctipennis	0	0.29	0	0.17	0	0	0	0
Dixa sp.	1.45	0	1.81	0.69	12.43	0	0.52	0

Species composition of benthic invertebrate populations was similar above and below the ponds. Numbers and biomass benthic invertebrates were higher below the ponds in summer and fall, lower in winter, and similar in spring. Total drift rates were higher below the ponds in winter and lower in all other seasons.

Population densities and biomass for most species were higher below the ponds. *Clinostomus funduloides* was reduced in numbers and biomass. *Semotilis atromaculatus* and *Nocomis leptocephalus* were dichotomus in distribution, *Semotilis* found above the ponds and *Nocomis* below the ponds. *Pimephales promelas* and *Lepomis macrochirus* were introduced to the system below the ponds.