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The Benthic Fauna in Four Small Southern Appalachian Streams

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ABSTRACT: Monthly quantitative samples of benthic organisms were collected from streams in four different watersheds from August 1968 through July 1969. Each of the watersheds supports one of the following types of vegetation: old-field succession, hardwood forest, white pine forest with a few hardwoods, coppice forest. The kinds of organisms in the four streams were generally similar but their relative importance varied significantly. A Duncan's multiple-range test showed significant differences in the numbers of most taxa among the watersheds. The old-field stream had the greatest abundance while the coppice stream had the greatest standing crop biomass. The white pine stream had lowest standing crops of both numbers and biomass. Most of the differences among watersheds were attributed to different inputs of allochthonous detritus.

INTRODUCTION

In recent years the subject of distribution and abundance of aquatic invertebrates has received much attention. Harrod (1964) demonstrated that certain aquatic plant and animal species are commonly associated with one another. The importance of detritus to aquatic insect distribution was shown by Egglishaw (1964) in his studies on British streams. Ross (1963) stated that many caddis fly taxa are associated with the eastern temperate deciduous forest, others with montane coniferous forest, and still others with other biomes. He described conditions which a deciduous forest imposes on a stream including dense shade and lower stream-bank temperatures in summer, only slight shade in colder seasons, heavy autumnal leaf-fall into the stream which possibly serves as food for invertebrates, and a low volume of soil erosion.

Certain terrestrial communities within these biomes also influence the distribution and abundance of aquatic invertebrates. Minshall (1967) found allochthonous leaf material to be by far the most important food source in Morgan Creek in Kentucky. Minshall (1968) attributes low species diversity and total numbers to removal of forest cover. Egglishaw and MacKay (1967) report that streams in land devoid of deciduous trees were chemically poorer and had less allochthonous plant material than streams with deciduous trees on the bank. The density of bottom fauna was greater in the latter.

The effect of vegetational shading and direct illumination on the distribution of fauna in African mountain streams was studied by Hughes (1966). He found that, although distribution of certain species was influenced, the population density was minimally affected and there was no overall effect on any group or population.

Stern and Stern (1969) found the deciduous forest surrounding a Tennessee cold springbrook had the greatest effect on the abundance and species composition of the fauna. The purpose of the present study was to compare benthic fauna in small mountain streams originating in and flowing through four different plant communities.

STUDY AREA

The U. S. Forest Service in 1934 established the Coweeta Hydrologic Laboratory in the southern Appalachians of western North Carolina.

Four watersheds were selected within an area of less than 1 sq mile. They were Old field, Hardwood, White pine, and Coppice. The first three faced NW and drained into Ball Creek. The latter faced E and drained into Shope Fork.

In the Old field watershed, stream-bank vegetation growing up to 5 m elevation above the flowing channel was removed by clear-cutting (12% of the watershed area) in 1941. Regrowth was allowed until 1958 when the forest was clear-cut and converted over a 3-year period to Kentucky 31 fescue. The conversion was accompanied by heavy application of lime and NPK, and in March 1965 the grass was refertilized with NPK. By use of Atrazine and Paraquat in 1966 and 1967 the grass cover was killed and maintained virtually free of vegetation except for a narrow (3 m) band along the stream. Since April 1968, vegetation on the watershed has been allowed to revert naturally toward a hardwood forest.

The Hardwood watershed vegetation had not been disturbed since the laboratory was established. *Liriodendron tulipifera* L., *Quercus rubra* L., *Carya* spp., *Taxus canadensis* (L.) Carr. and *Rhododendron* spp. were predominant along the stream margins. On the slopes, *Quercus* spp., *Carya* spp., *Rhododendron* spp., *Kalmia latifolia* L., *Acer rubrum* L., *Nyssa sylvatica* L., *Oxydendrum arboreum* (L.) DC. and *Cornus florida* L. were the most common plant species.

In 1942, all forest and shrub vegetation on the White pine watershed was cut but not removed. From 1943 to 1955, a low herbaceous and shrub cover developed and was maintained by annual clear-cuttings. In 1956, white pines (*Pinus strobus* L.) were planted. Despite attempts to control hardwood regrowth by cutting, a dense growth of *Liriodendron tulipifera* L., ferns, *Rubus occidentalis* L. and *Rhododendron* spp. developed along the stream.

During 1939 and 1940, all woody vegetation on the Coppice watershed was cut and left in place. A coppice forest was allowed to regrow, and a similar cut was made in 1962. The woody vegetation in this watershed included *Liriodendron tulipifera* L., *Quercus rubra* L., *Carya* spp., *Taxus canadensis* (L.) Carr., *Rhododendron* spp., *Kalmia latifolia* L., *Acer rubrum* L., *Nyssa sylvatica* L., *Oxydendrum arboreum* (L.) DC and *Cornus florida* L.

The substrate in the four watersheds consisted of sand and flat granite rocks to 25 cm in diam. The rocks in the Old field stream were generally covered with more sand than those in the other watersheds. The Old field stream flowed over a large granite outcrop in one area which was intermittently barren or covered with moss. There were many small barren outcrops in the Coppice stream. At the base of each waterfall formed by these outcrops was a pool with a sand bottom. Some of these waterfalls approached 2 m in height.

The streams were about ½ m wide in the sampling area but occasionally their width approached 2 m. Water depth ranged from less than 3 cm in areas where the stream bed was wide to about 15 cm in narrow areas.

METHODS

The lower portion of each stream was divided longitudinally into four sections. Due to the irregular relief of the area, the stream beds were not measured precisely but were measured approximately by paces. Above approximately 400 paces, sampling was impractical because the stream bed was narrow and filled with debris.

A stratified random sampling technique was used. Each month one number was selected from a table of random numbers and used as an index for sampling sites along the streams. For example, if 35 was the number chosen, then samples were collected at 35, 135, 235 and 335 paces from the weir site. The same set of numbers was used on each watershed. Sampling began at the weir and proceeded toward the source so that no substrate was disturbed before it was sampled. Thus one sample was collected from each 100-pace section of each stream monthly between 12 August 1968 and 18 July 1969. A surber sampler (Usinger, 1963) with a nylon mesh of 43 threads per inch was used for sampling. The sampler was placed in the deepest part of the stream at each location and the substrate within the sampler was disturbed by hand. Attached plants and animals were removed from large rocks with forceps and allowed to wash into the net. The sampler was removed from the stream when it appeared that all detritus and benthic organisms had been washed into the net. Samples were then transferred to a plastic bag, stored in crushed ice and returned to the lab where they were processed within 24 hr. Each sample was washed in a sieve of 10 meshes/cm and the retained portion was placed in a white enamel tray where the organisms and detritus were picked out by hand. Ash-free dry weights were obtained according to the method used by Nelson and Scott (1962).

Dissolved oxygen, *p*H and temperatures were measured in the four streams each month. The measurements were taken immediately above the weir ponds. Stream temperature and dissolved oxygen data were obtained with a YSI oxygen-temperature probe, and *p*H was determined with a Hellige kit. Turbidity and alkalinity analyses were conducted using Hach reagents and a Bausch and Lomb "Spectronic 20" spectrophotometer. Conductivity was measured with a Hellige conductivity meter.

RESULTS AND DISCUSSION

Dissolved substances.—Very small quantities of dissolved minerals were found in the water at Coweeta (Tables 1 and 2). Lowest values were recorded in the Hardwood stream and highest values were in the Old field stream. The high P concentrations were attributed to the application of NPK between 1958 and 1965. The Old field stream was most turbid and the Hardwood stream, least turbid. The low turbidity, conductivity and alkalinity values indicate the nature of the Coweeta streams. The *p*H was generally constant, reflecting the chemical stability of these streams.

TABLE 1.—Physical features of four streams at the Coweeta Hydrologic Laboratory

Watershed	Old field	Hardwood
Area (ha)	9.1	12.8
Elevation (m)	700-900	727-990
Mean annual discharge (ft^3/mi^2)	2.60	2.79
Temperature (C)		
maximum (August)	18.5	17.5
minimum (December)	5.5	2.0
Turbidity (jackson units)		
maximum	26.0	12.0
minimum	1.0	0.0
Dissolved oxygen (ppm)		
maximum	10.0	13.8
minimum	8.0	8.0

TABLE 1.—(continued)

Watershed	White pine	Coppice
Area (ha)	13.9	16.6
Elevation (m)	734-1014	717-900
Mean annual discharge (ft^3/mi^2)	2.04	2.69
Temperature (C)		
maximum (August)	16.0	16.0
minimum (December)	2.0	5.2
Turbidity (jackson units)		
maximum	12.0	20.0
minimum	0.0	6.0
Dissolved oxygen (ppm)		
maximum	12.0	10.0
minimum	8.8	7.2

TABLE 2.—Chemical features of four streams at the Coweeta Hydrologic Laboratory

Watershed		Old field	Hardwood	White pine	Coppice
Conductivity (μmho)	max.	17.6	14.0	11.0	10.3
	min.	12.0	11.2	10.5	8.7
Alkalinity (ppm)		10.0	10.0	10.0	10.0
*p*H		6.7	6.8	6.9	6.7
Total phosphate (μg/l)		9.84	7.49	7.39	4.05
Ca (ppm)*		1.077	.649	.516	.470
Mg (ppm)*		.648	.289	.213	.252
K (ppm)*		.616	.480	.446	.431
Na (ppm)*		1.125	.913	.763	.639

* Swank and Elwood, 1971

Dissolved oxygen values increased in all the streams as solubility of the gas increased during the winter months. No consistent differences were noted among the streams. The lowest values were recorded in August and the highest in December.

Temperatures.—The Old field stream was warmer than the others in every month except January. This was attributed to two factors: the absence of shade and the time the readings were taken, which was about 2 PM. Swift and Messer (1971) report increases of up to 8 C where forest trees and understory vegetation were completely cut. Even in winter, the Hardwood stream was heavily shaded by dense *Rhododendron* growths and the White pine stream was heavily shaded throughout the year. These two streams consistently had the lowest temperatures. Temperatures in all streams were highest in August and lowest in December. It should be emphasized that the temperatures in Table 1 are not means, but were recorded at the time of sample collection.

Detritus.—The standing crops of detritus in Coweeta streams are summarized in Table 3. On the Old field stream the source of detritus was primarily grasses and grass roots. Mosses were present on wet rock outcrops, but their biomass was significant only in warmer months when there was little detritus contributed by grasses. Sparse growths of *Rhododendron* spp., *Rubus occidentalis* L. and other shrubs also contributed to detritus.

Detritus in the Hardwood stream consisted mainly of leaves from deciduous trees and *Rhododendron*. *Rhododendron* leaves comprised almost half the detritus, and chestnut oak accounted for a large portion of the remainder.

In the White pine stream detritus was composed of both deciduous leaves and pine needles. Dead needles remain in the trees and contribute detritus to the stream all year. Some grasses, *Rhododendron* and other littoral, woody growth also contributed to detritus.

The source of detritus in the Coppice stream was primarily deciduous leaves mixed with some *Rhododendron*. Sparse growths of grasses along the stream banks also contributed to detritus accumulation. In samples taken from granite outcrops, most of the vegetable material was moss and very few recognizable leaf fragments were present.

Bottom fauna.—Since it was difficult to quantify the sizes of these small streams and since the turnover time for all the organisms was not similar, a relative importance value (Ball *et al.*, 1969) rather than

TABLE 3.—Maxima, minima and monthly averages (g/m^2) of detritus removed from Coweeta streams

Watershed	Old field	Hardwood	White pine	Coppice
Maximum	172.2 (Feb.)	223.7 (Nov.)	117.3 (Sept.)	262.0 (Nov.)
Minimum	21.6 (June)	34.9 (July)	37.5 (June)	11.9 (Apr.)
Average	74.6	110.2	70.9	109.9

absolute number was used for comparisons. This value is the product of the per cent by weight and per cent by number for each group of insects (Table 4).

Homogeneity of total numbers among watersheds was tested for each taxon using a Duncan multiple-range test (Table 5). Non-insects were not included. The monthly mean standing crops of numbers and biomass (ash-free dry weights) for the 16 most important organisms are presented in Table 6.

The importance values for each species were averaged for the four watersheds, and the 16 most important organisms were included for discussion. Four "minor" organisms which exhibited marked differ-

TABLE 4.—Rank by relative importance of benthic organisms collected from Coweeta watersheds from August 1968 to July 1969. Adult forms are marked (A)

Organism	Old field	Hard-wood	White pine	Coppice
Collembola	35	20	12	26
Ephemeroptera				
Ephemera sp.	53	....	....	....
Stenonema spp.	18	7	8	11
Epeorus sp.	25	27	25	25
Isonychia sp.	29	49	38	46
Paraleptophlebia sp.	20	6	13	15
Ephemerella spp.	7	28	5	10
Baetis sp.	16	40	19	18
Odonata				
Cordulegaster erroneus Hagen	50	31	30	48
Lanthus albistylus Hagen	11	19	3	9
Plecoptera				
Peltoperla maria Needham	26	1	1	1
Nemoura sp.	17	26	35	17
Leuctra sp.	38	29	20	29
Acroneuria arida Hagen	46	23	24	31
Isogenus (Yugus) bulbosus Frison	28	5	17	5
Alloperla sp.	37	17	18	13
Coleoptera				
Promoresia tardella Fall (A)	53	....	....	48
P. tardella Fall	52	....	....	....
Limnius latiusculus Le Conte (A)	8	12	14	28
L. latiusculus Le Conte	22	36	23	32
Optioservus immunis Fall (A)	9	16	27	35
O. immunis Fall	3	9	2	30
Ectopria sp.	13	38	21	21
Anchytarsus bicolor (Melsh.)	10	39	26	48
Trichoptera				
Rhyacophila spp.	5	14	15	19
Chimarra sp.	54	....	47	49
Sortosa sp.	....	52	53	....
Wormaldia sp.	27	33	43	27
Lype diversa (Banks)	30	13	22	33
Polycentropus sp.	....	52	....	....

ences in distribution and habitat are also included. In the following comments the organisms appear in the order of their combined importance values for the four streams.

Peltoperla maria Needham (Plecoptera: Peltoperlidae) was the most important animal in three of the four watersheds; in the Old field stream, however, it ranked 26th. Greatest numbers of *P. maria* occurred in the Hardwood stream. *P. maria* contributed about 1/10 of the total biomass in the Hardwood stream and 1/20 of the total biomass in the Coppice stream. Although numbers were much lower than in the preceding two streams, *P. maria* contributed about 1/20 of the biomass in the White pine stream. In the Old field stream this insect

TABLE 4.—(continued)

wood pine Coppice	Old field	Hardwood	White pine	Coppice
Diplectrona modesta Banks	4	3	6	4
Parapsyche cardis Ross	14	10	9	7
Ochrotrichia sp.	21	....	....	47
Pycnopsyche guttifer (Walker) and *P. scabripennis* (Rambur)	31	25	36	20
Pycnopsyche gentilis (McLachlan)	51	43	53	....
Neophylax sp.	23	41	37	14
Oecetis sp.	....	....	53	40
Lepidostoma sp.	34	37	31	48
Pseudogoera singularis Carpenter	32	34	40	22
Sericostoma pele Ross	44	18	28	37
Diptera				
Tipula spp.	6	11	7	2
Eriocera spp.	1	8	11	3
Pedicia sp.	39	24	33	23
Geronomyia sp.	51	52	50	....
Antocha saxicola O. S.	53	35	32	40
Limnophila sp.	51	52	51	47
Dicranota sp.	40	22	34	24
Pseudolimnophila sp.	36	50	42	....
Unidentified Tipulid species	48	4	48	39
Protoplasa fitchii (O.S)	53	53	....	....
Blephariceridae	57	51	53	....
Psychodidae	51	52	51	47
Telmatoscopus sp.	49	53	41	43
Dixa sp.	43	44	49	36
Simulium sp.	24	48	52	44
Chironomidae	2	2	4	6
Zavralia sp.	33	52	....	47
Ceratopogonidae	19	30	29	16
Tabanus sp.	53	....	....	....
Dolichopodidae	....	42	46	49
Empidae	41	50	44	45
Chelifera sp.	53	45	53	42
Non-insects				
Annelida	49	32	39	34
Decapoda (*Cambarus b. bartoni*)	12	21	10	8
Desmognathus spp.	15	15	16	12
Eurycea bislineata wilderae Dunn	47	....	....	38

comprised only 1/500 of the total biomass. This emphasizes the fact that the Pine and Old field streams supported less *P. maria* biomass due to less hardwood leaf input. Peaks in abundance of *P. maria* were positively correlated with peaks in detritus input.

The Chironomidae were most abundant in the Old field stream. Few were collected in bare rocky areas. Species of Chironomidae collected included Diamesinae: *Diamesia nivoriundia* (Fitch); Chironominae: *Chironomus fulvipilus* (Rempel), *Zavralia* sp.; Tanypodinae: *Conchapelopia* sp.; Orthocladinae: *Metriocnemus lundbecki* Johannsen, *Brillia sera* Roback, *Orthocladius* sp., *Nanocladius* spp., *Pseudorthocladius* nr. *curtistylus* Goetghebuer, and *Pseudorthocladius* sp. The chironomids are included collectively rather than separately because of the similarity of their feeding habits and the difficulty of sorting out individual species. *Conchapelopia* sp. was the only predator collected.

Diplectrona modesta Banks was reported by Ross (1944) to feed on plankton and sessile diatoms. Bacteria and fine detritus may also be a food source (Hynes, 1970). In all watersheds except the White pine, the abundance of this filter feeder was inversely related to the amount of detritus collected. Filter feeders probably prefer areas of little detritus accumulation where they are exposed to optimum current.

Tipula had its greatest importance in the Coppice stream where it comprised about 1/3 of the total biomass. Specimens were principal-

TABLE 5.—Results of Duncan's multiple-range test on total number of organisms collected. Homogeneity exists between the streams to the right of each species and the one at the top of the column. O = Old field, H = Hardwood, P = Pine, C = Coppice

	O	H	P	C
Podura aquatica	C	P, C	H	O, H
Baetis sp.	C	P	H	O
Ephemerella spp.	P, C	"no others"	O, C	P, O
Paraleptophlebia sp.	P, C	"no others"	O, C	P, O
Stenonema spp.	C	"no others"	C	O, P
Peltoperla maria	"no others"	P, C	H, C	H, P
Nemoura sp.	H	O, H, P	H, C	H, P
Leuctra sp.	H, C	O, H, P	H, C	O, H, P
Optioservus immunis (Adult)	"no others"	C	"no others"	H
Optioservus immunis (Larvae)	"no others"	C	"no others"	H
Limnius latiusculus (Adult)	"no others"	H, C	H	H
Ectopria sp.	"no others"	P, C	H, C	H, P
Anchytarus bicolor	"no others"	P, C	H, C	H, P
Ochrotrichia sp.	"no others"	P, C	H, C	H, P
Parapsyche cardis	"no others"	P, C	H, C	H, P
Diplectrona modesta	H	O	C	P
Sericostoma pele	P, C	"no others"	O, C	O, P
Rhyacophila	H, C	O, P, C	H, C	O, H, P
Tipula spp.	H, P	O. P	O, H	"no others"
Ceratopogonidae	H	O, P, C	H, C	H, P
Chironomidae	"no others"	P, C	H	H

TABLE 6.—Average monthly standing crops/m² and ash free dry wt/m² for four streams, Coweeta Hydrologic Lab, Macon Co., N.C.

Organism	Old field		Hardwood		White pine		Coppice	
	No.	G	No.	G	No.	G	No.	G
Cambarus	4.6	.788	2.0	.104	4.2	.100	3.2	1.110
Ephemerella	71.6	.029	10.1	.002	43.0	.009	38.6	.008
Stenonema	8.7	.010	37.2	.021	19.4	.016	13.0	.015
Lanthus	7.4	.130	3.4	.029	11.0	.056	6.5	.042
Peltoperla	3.5	.004	151.1	.104	108.4	.031	143.8	.155
Isogenus	9.4	.002	18.2	.058	20.4	.002	41.4	.025
Paraleptophlebia	23.8	.002	92.5	.009	25.2	.005	22.1	.004
Rhyacophila	22.4	.011	15.6	.016	11.5	.006	20.6	.002
Parapsyche	11.3	.030	6.1	.107	19.1	.014	17.2	.044
Diplectrona	104.6	.052	88.5	.066	24.6	.017	81.5	.027
Optioservus (larva)	167.0	.033	2.7	.001	71.5	.014	6.6	.001
Limnius (adult)	71.6	.007	23.1	.002	35.2	.004	8.6	.001
Tipula	8.5	.128	3.9	.117	3.3	.058	24.0	1.080
Eriocera	82.3	.037	49.6	.015	20.7	.015	40.1	.020
Chironomidae	218.7	.002	93.8	.007	64.7	.008	109.3	.010
Desmognathus	4.9	.195	4.2	.347	4.4	.177	5.9	.104
Total of top 16	820.3	1.460	602.0	1.005	486.6	.532	582.4	2.648
Total of all others	394.0	.177	202.3	.066	229.7	.056	200.7	.100
Combined total	1214.3	1.637	804.3	1.071	716.3	.588	783.1	2.748

ly found in leaf-filled pools at the bases of small waterfalls. In the laboratory they fed on deciduous leaves. Egglishaw and MacKay (1967) reported that densities of *Tipula* species were greatest in the pool areas of the streams they studied. This genus was responsible for about 1/10 of the biomass in the Hardwood and Pine streams and about 1/14 of the biomass in the Old field stream. *Tipula abdominalis* (Say) and *T. ignoblis* Loew were collected.

Eriocera longicornis (Walker), *E. spinosa* (Osten Sacken) and *E. fultonensis* (Alexander) were collected. They were found in predominantly sandy areas of the streams. Gut analysis indicated that larger individuals were omnivores while the smaller ones were detritivores. The genus showed greatest numbers and biomass in the Old field stream. Their distribution appears to be influenced somewhat by the abundance of a sandy substrate but feeding relationships may be the determining factor. More work is needed on the feeding habits of this genus.

The abundance of the filter feeder *Parapsyche cardis* Ross, like *Diplectrona modesta*, was inversely related to amounts of detritus. *P. cardis* was more important in the Coppice stream than in the other streams. Although the discharges of the four Coweeta streams were similar, the abundance of small waterfalls in the Coppice stream made available more suitable habitats than were present in the other streams. These waterfalls produced increased currents, and Eddington (1968) has shown that caddis larvae construct their nets in currents where they are most efficient. *P. cardis* was least important in the White pine stream which also had the lowest discharge.

The importance value of the predator, *Lanthus albistylus* Hagen, was much greater in the White pine stream than in the other three streams. The larvae of *Optioservus immunis* Fall were next in importance. In the Red Cedar River, Elmidae larvae and adults were common on all bottom types and ranked second in importance for that study (Ball *et al.*, 1969). The adult elmid, *Limnius latiusculus* Le Conte, ranked 15th in the four Coweeta streams combined. Adults of *O. immunis* were slightly less important. Actual abundance was greatest in the Old field stream where there were minute grains of charcoal which were the same size and color as the elmid adults. The immature elmids had alternate bands of light and dark brown, a pattern which might resemble sand. Both of the above patterns possibly protect them from their predators, *i.e.*, salamanders and predaceous insects.

Stenonema spp. were observed to feed on hardwood leaves which comprised most of the detritus in the Hardwood stream where they were most abundant.

Cambarus bartoni bartoni Fabricius (Decapoda) was the most important in the Coppice stream. Crayfish accounted for about 1/2 of the biomass in the Old field stream, 1/10 of the biomass in the Hardwood stream, 1/6 of the biomass in the White pine stream and 1/3 in the Coppice stream where they were abundant in pools.

Ephemerella spp. were homogeneously distributed among the White pine, Old field and Coppice streams. According to Percival and Whitehead (1929), mosses and algae are the main food of this genus. The genus was least important in the heavily shaded Hardwood stream where very little moss and algae occurred. The most abundant species was *E. funeralis.*

Rhyacophila torva Hagen, *R. nigrita* Banks, *R. carolina* Banks, *R. minora* Banks, *R. glaberrima* Ulmer and *R. fuscula* Walker were collected on the mats of moss which grew on rock outcrops in the streams. Ross (1944) observed that *Rhyacophila* fed upon chironomid larvae. While their seasonal abundance was not positively correlated with *Rhyacophila* in our samples, both had their greatest importance value in the Old field stream. In a study of the feeding habits of seven western North American species of *Rhyacophila,* Thut (1969) found that five were carnivores, one omnivorous and one herbivorous. Chironomidae were the most numerous animals in the gut although Copepoda, Acari and others were also important.

Paraleptophlebia sp. was most important in the Hardwood stream and then in the White pine and Coppice streams, respectively. They were found in the habitat described by Day (1963): "They may be found in any part of the stream with a moderate or slow current but the preferred location is in slowly running shoal water 1/4 to 12 inches deep where the nymphs concentrate in deposits of decaying leaves, bark and wood."

Isogenus (Yugus) bulbosus Frison was most important in the Coppice and Hardwood streams where it possibly fed on insects and/or deciduous leaves which collected on debris and in the pools. According to Richardson and Gaufin (1971), *I. elongatus* is usually carnivorous but under certain conditions exists entirely on detritus. They found its diet to be 64.9% animal and 31.2% plant material.

The salamander species *Desmognathus ochrophaeus* Cope, *D. fuscus* Green, *D. monticola* Dunn and *D. quadramaculatus* Holbrook were found in the four streams. Gut analysis revealed that they are predaceous on all other animals in these streams. The Hardwood stream supported the greatest salamander biomass (Table 6), and the Coppice stream, although it supported the greatest animal biomass, had the lowest biomass of salamanders. It is hoped that more detailed gut analyses will help explain this situation.

Although their importance values were small, the four following insects should be included in the discussion because of their abundance in the Old field stream. *Anchytarsus bicolor* (Melsh.) (Ptilodactylidae: Coleoptera) was most abundant in shallow samples containing much grass and grass roots. According to Leech and Chandler (1963), their staple diet consists of roots of grasses and leaf mold. Grasses were more dense in the channel of the Old field stream than in any of the other streams.

Another insect showing a peculiar distribution in the Old field stream was *Ochrotrichia* sp. (Trichoptera: Hydroptilidae). Collections were usually recorded from moss-covered granite outcrops.

Percival and Whitehead (1929) collected more hydroptilids from moss on stones than on other substances and reported their food to be algae and diatoms. Hughes (1966) found that hydroptilids were more abundant in open areas of streams than shaded areas. He also stated that Trichoptera were often limited by availability of case-making materials. Bank cutting and channel degradation in the Old field stream could have provided a greater amount of suitable sand grains than was available in the other streams. The moss outcrops, however, are suspected to be the central factor influencing the distribution of *Ochrotrichia*. Nielsen (1948) reported that larval mouthparts of hydroptilids are modified for piercing and sucking the cells of filamentous algae or scooping up diatoms.

A small chironomid, *Zavralia* sp., was collected most frequently in the Old field stream. It built a minute case about 5 mm long similar to cases of the caddis fly family Odontoceridae. Its distribution may have been influenced by the availability of suitable sized grains of sand for its case.

The distribution of the water penny, *Ectopria* sp., seems to be affected by the amount of sunlight reaching the stream. According to Duncan's test, the numbers of *Ectopria* in the Old field stream were significantly greater than in the others. This organism was least important in the heavily shaded Hardwood stream. In the Old field stream they were most frequently collected on algae-covered stones. Pennak (1953) reports that algae are the chief food of this genus.

SUMMARY AND CONCLUSIONS

All Coweeta streams had low concentrations of dissolved substances and were similar chemically. An exception was the higher P concentration in the Old field stream, which was attributed to the application of fertilizer to the watershed. Due to low temperatures all streams had high dissolved oxygen.

The vegetation on each watershed is possibly the main factor affecting species composition in the streams although flow rate, gradient and substrate also influence distribution. Allochthonous detritus was the main source of energy for the primary consumers since there were sparse aquatic macrophytes and probably little aquatic primary production.

Most of the differences in the fauna of the four watersheds can be explained by the availability of food and/or case-making materials, both of which are directly or indirectly controlled by vegetation. The biomass/unit area in Coweeta streams agrees with results from several other aquatic environments (MacKay and Kalff, 1969), although our numbers were lower.

Most genera occurred in all four streams but their importance varied from stream to stream. The results of Duncan's multiple-range test performed on total numbers of individuals in each insect category showed that the Old field stream was least like the other three. The most important organism was *Peltoperla maria* followed by

Chironomidae, *Diplectrona modesta* and *Tipula* spp. As would be expected, most of the important animals were herbivores and only a few, such as *Lanthus* and *Desmognathus*, were carnivores. The standing crops of detritivores increased and decreased at roughly the same times as did detritus. Filter feeders such as *Diplectrona* and *Parapsyche* showed an inverse relation to detritus.

Although it was not quantified in this study, the influence of fine detritus upon insect distribution should not be overlooked. Fine detritus, and its associated fungal and bacterial community, is probably essential to the diets of many smaller organisms such as the Elmidae, some Chironomidae and some filter feeders (Hynes, 1970). The amount of fine detritus in the water is controlled more by detritivores than by stream flow. Kilmer and Cummins (1971) estimated that only 5% of leached large particulate organic matter was broken into fine detritus by the stream's mechanical action.

Several workers have reported low diversity and total numbers in streams flowing through land devoid of deciduous trees (Minshall, 1968; Egglishaw and MacKay, 1967). This was not the case in the Old field stream where we found high numbers of individuals and species. Although some detritus feeders such as *Peltoperla maria* were unimportant in the Old field stream, others such as *Cambarus b. bartoni* were abundant. Perhaps the prolific input of grass detritus into this stream was utilized by crayfish in lieu of the hardwood leaf detritus of the other streams. Slightly higher water temperatures caused by clear-cutting could also have influenced the abundance of organisms in this stream (Swift and Messer, 1971).

The abundance of *Rhododendron* leaves may explain why the Hardwood stream supported only about 1/3 as much animal biomass as the Coppice stream. Both streams had about the same amount of leaf detritus, but the proportion of *Rhododendron* leaves was much less in the Coppice stream. Wallace *et al.* (1970) showed that *Rhododendron* leaves were not a preferred food of an herbivorous stonefly. *Rhododendron* leaves appeared resistant to decay and subject to little feeding by invertebrates since intact leaves were found throughout the year.

The White pine stream supported only 1/5 to about 1/2 as much animal biomass as the other streams. In laboratory experiments (Wallace *et al.*, 1970), pine needles were not a preferred food of *Peltoperla* nymphs. About half the detritus in the Pine stream was pine needles and the rest was contributed by littoral hardwood growth, much of which was *Rhododendron*. The scarcity of palatable detritus partially explains the lower number of insects there. These results indicate that forest monoculture practices involving pine watersheds may seriously affect secondary production of aquatic invertebrates.

The Coppice stream had from two to five times as much animal biomass as the other streams. This was probably due to its larger drainage basin and the composition of leaf detritus which contained less *Rhododendron* than the Hardwood stream. The greater number of small, detritus-filled pools in the Coppice stream resulted in more extensive favorable habitats for *Tipula, Peltoperla* and *Cambarus*. Above these pools were small waterfalls where *Parapsyche* occurred in the swift current.

Other differences in distribution will, hopefully, be explained as additional gut analyses are made and as the influence of allochthonous detritus and other foreign substances on water quality are more clearly understood. The role of fungi and bacteria in the aquatic system must be elucidated before we can understand completely the interactions between organisms and detrital food sources.

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