Aquatic Macroinvertebrates of the Upper French Broad River Basin

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ABSTRACT.— The aquatic macroinvertebrates of the Upper French Broad River were sampled over a two-year period beginning in May 1977. The information gathered in this study, along with additional data for other select tributary streams, were combined to generate a list of 267 invertebrate taxa. The faunas of the French Broad River and tributaries are compared to those of other rivers and streams of the southern Appalachians to define "normal" faunal characteristics of lotic systems in this geographic area. Information is presented on taxa richness and abundance for the six major taxonomic groups. Temporal and spatial changes in the benthic macroinvertebrate communities were associated with changes in flow rates, watershed sizes, average temperatures, canopies, substrate characteristics, and gradients.

INTRODUCTION

A chronicle of the French Broad River by Dykeman (1955) referred to the river as "the classic example of an Appalachian River". Dykeman presented the French Broad as a study of paradoxes: allure and despair, problems and promises. These paradoxes are especially evident today as we consider the inevitable growth and development of the upper French Broad River basin in North Carolina, balanced against the assimilative capacity of the river. Can the river continue to absorb perturbations and remain a valuable natural resource?

Water quality records for the French Broad River in Transylvania County are of little help in answering this question. A water quality monitoring site is located in Rosman, North Carolina, and is maintained by the Division of Environmental Management. The water quality is described as very good, with few stream contraventions recorded (N.C. Department of Natural Resources and Community Development 1976). This site is also monitored by the United States Geological Survey, and continuous stream flow records have been collected since 1955. The average stream discharge at Rosman, located just below the confluence of the North and West Forks, is 242 cfs (6.85 m^3/sec) and the average rainfall there is 122.9 cm/year (United States Geological Survey 1979). Average flow of the river during the period of the study herein reported can be seen in Figure 1. The watershed above Rosman is

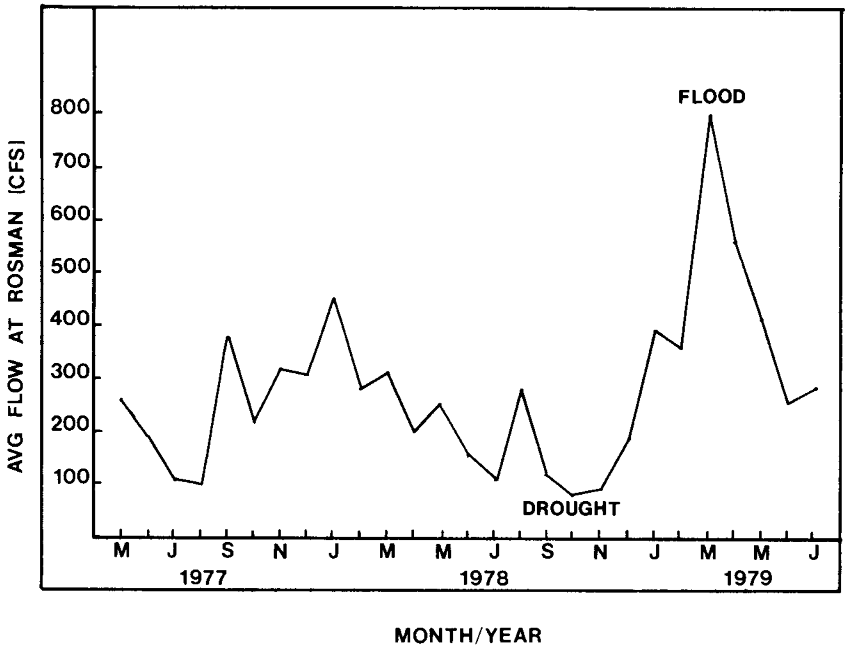

Fig. 1. Average flow of the French Broad River at Rosman, North Carolina, May 1977-July 1979.

approximately 104 km^2, generally ranges from 610 to 1524 m elevation, and consists primarily of forest and farm land. A cursory inspection of topographic maps reveals that much of the watershed lies in the Pisgah National Forest. The East Fork of the French Broad joins the mainstem below Rosman.

This paper describes the composition of the aquatic macroinvertebrate fauna of the Upper French Broad River (Transylvania County) and selected tributaries. This fauna is then compared to that of several other Appalachian streams and rivers to define "normal" faunal characteristics of lotic systems in the geographic area. Water quality is dependent upon watershed characteristics (Lotspeich 1980), and the nature of the aquatic community is shown to be similarly dependent upon these characteristics. Therefore, faunal characteristics can be used as baseline information, along with water quality records, to describe the current environmental quality of the watershed and indicate how this may change with growth and development.

MATERIALS AND METHODS

Monitoring Stations

Biological monitoring stations were established along an 11 km section of the French Broad River in Transylvania County (Fig. 2). Two stations were selected above Rosman to serve as examples of "Upper River-Montane" (UR) stations, areas of nearly complete canopy cover and higher gradient. Below Rosman the river begins to meander through a fairly large floodplain. Two stations were selected in this area to serve as examples of "Upper River-Lowland" (LR) stations, areas with little canopy cover and lower gradient. The two upper river stations are French Broad 1 and 2. French Broad 1 (FB-1) was located on the West Fork above the US 64 bridge, while French Broad 2 (FB-2) was located on the North Fork at the bridge over state rural road (SRR) 1322. The two lower river stations are French Broad 3 and 4; FB-3 was located at SRR 1129 and FB-4 at SRR 1331.

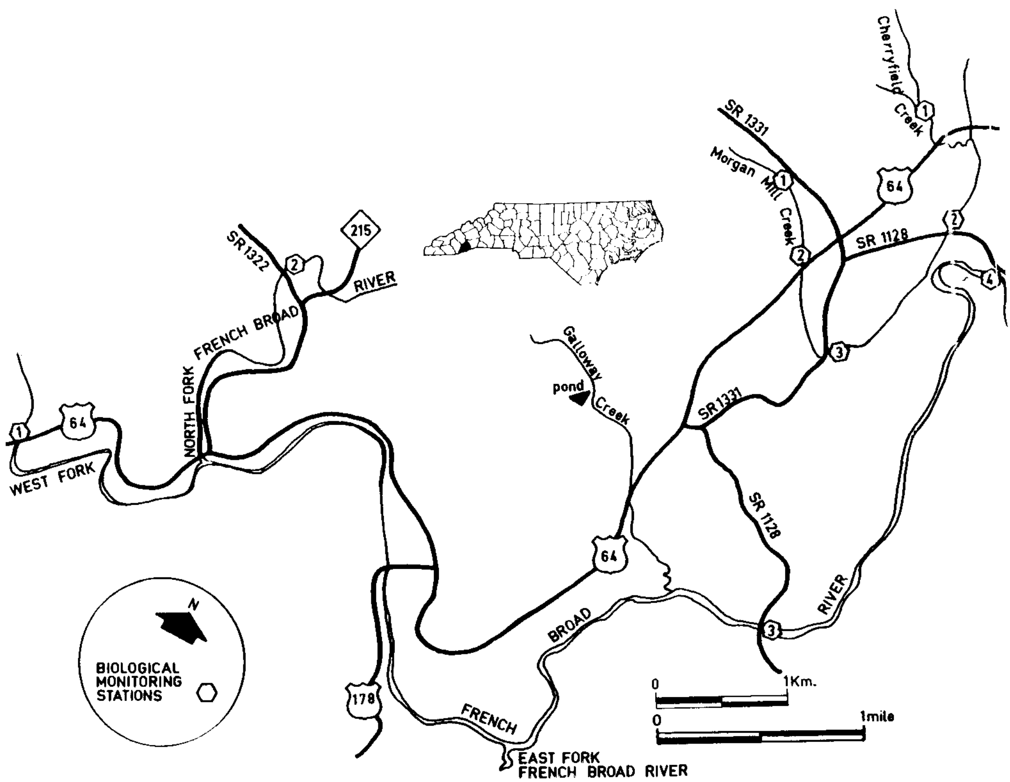

Fig. 2. Biological monitoring stations: French Broad River, Morgan Mill Creek, and Cherryfield Creek.

In addition to the four river stations, five tributary stations were located on Cherryfield and Morgan Mill creeks, which are second order streams. Two stations were established on Cherryfield Creek: a control 0.1 km above US 64 along SRR 1332, and a downstream station 1.0 km below US 64 along SRR 1331. Three stations were located on Morgan Mill Creek: a control 0.6 km above US 64 along SRR 1331, another immediately below US 64, and a third at the SRR 1331 bridge. Cherryfield and Morgan Mill creeks converge before flowing into the French Broad near river mile 212. The Cherryfield Creek watershed is 7.04 km^2 while the Morgan Mill Creek watershed is 2.93 km^2.

Collection Methods

Samples were collected using the "kick net" method. The net was positioned upright on the streambed while an upstream area of approximately 1 m^2 was physically disrupted. This technique is less quantitative than others but may be used across a wide range of habitats. White and Fox (1980) found that the kick technique was superior to other methods by providing the largest number of species per unit time. The kick net was constructed of window screening with 1 mm openings; smaller mesh is available, but has a tendency to clog with organic debris and silt, causing some flow to be diverted around the net. We had success collecting even very small Chironomidae using this method. The samples were then rinsed into a wash bucket (brass wire cloth mesh No. 30), placed in quart freezer containers, and preserved in ethanol. Two samples were collected from each stream station and three from each river station.

Little time could be devoted to qualitative collections (pools, bank sweeps, and others), as this study was being conducted to determine the probable effects of road construction on stream and river fauna of this geographic area. Therefore, samples were collected from habitats that normally would produce the most diverse fauna. Ten collections were made from the river stations over a twenty-five month period (June 1977-July 1979). Nine collections were made from the tributary stations over a twenty-two month period (February 1978-December 1979). Collection dates and locations were chosen to coincide with construction activities.

A list of taxonomic references used in our identifications is available from the authors.

RESULTS AND DISCUSSION

Taxa Richness: Rivers

Total taxa richness from the four French Broad River stations was 221. Five other surveys conducted on Appalachian mountain river systems were selected for comparison. They were conducted above most potential pollution sources and were therefore assumed to be relatively undisturbed enough to serve as controls. None produced as many total taxa as our study, and the lower taxa richness (Table 1) is attributable to less frequent sampling and/or less precise taxonomy. Collection methodology was designed, in each survey, to produce the most diverse fauna.

Table 2 presents average taxa richness (per collection) for six reference sites on Appalachian mountain rivers. The level of taxonomic resolution accounts for at least some variability between surveys. For example, Starnes (1976) identified chironomids only to family in her survey of the Little Pigeon River, while in our survey we identified 74 taxa

Table 1. Total taxa richness (S) comparisons for six Appalachian river studies.

	S	# Collections	# Station	Method	Reference
French Broad River, NC	221 (177)[1]	7	4	Kick net	This paper
Mills River (MR-1, MR-2), NC	131	4	2	Kick net	Lenat et al. (1979)
North Toe River (NT-1), NC	113	6	2	Kick net	Lenat et al. (1979)
French Broad River (FB), NC	106	1	4	Assorted	Harned (1977)
Shenandoah River (SH), VA	111	summary	1	Kick net	Seagle & Hendricks (1978)
Little Pigeon River (LPR), TN	71	12	1	Surber	Starnes (1976)

[1] Stations FB-1 and FB-2, upper river-montane only.

Table 2. Average taxa richness comparisons by taxonomic group for four Appalachian river studies. Abbreviations as in Table 1.

	Station					
Order	FB-1	FB-2	MR-1	MR-2	NT-1	LPR
Ephemeroptera	18.4	15.6	11.6	14.2	10.3	9.0
Plecoptera	7.6	3.9	5.8	7.4	5.6	4.3
Trichoptera	11.7	8.1	9.0	13.6	6.3	6.0
Diptera	25.4	18.7	15.0	22.0	11.6	5.2[1]
Coleoptera	5.9	2.6	3.0	3.8	2.1	1.8
Other	4.7	10.9	3.1	5.6	4.4	3.2
Totals	73.7	52.3	47.5	66.6	40.3	29.6

[1] Chironomids identified only to family level.

within the family Chironomidae. Because several of the surveys listed in Table 1 were conducted by our group, reduction in taxa richness between these surveys cannot be accounted for by differences in collection and taxonomic techniques. For example, the low average taxa richness in the Trichoptera for the North Toe River cannot be accounted for taxonomically.

ABUNDANCE (PERCENT OF TOTAL ABUNDANCE): RIVERS

Table 3 summarizes average community composition by taxonomic order (as percent of total abundance) for several Appalachian mountain control stations. Differences within watersheds are small for both the French Broad and Mills rivers. However, large differences exist between watersheds, and much of the variability can be attributed to watershed characteristics.

Average annual water temperature is higher for the French Broad (12.8° C) than for the Mills River (11.3° C) (N.C. Department of Natural Resources and Community Development 1977). The cooler water temperature of the Mills River might favor the development of the Plecoptera community observed there (Baumann 1979). Also, several of the dominant Plecoptera genera in the Mills River are chironomid predators, which may account for the low percentage of Diptera in this area. Average annual water temperature of the North Toe River also is high (14.0° C) and might limit Plecoptera.

The highest percent abundance for Trichoptera was noted for the North Toe River, and is related to watershed size. The North Toe watershed (193 km^2) is substantially larger than either the French Broad (97 km^2) or Mills River (43 km^2) watersheds. Larger drainage areas result in increased flow (Edington 1968) and increased amount of fine particulate organic matter (Wallace 1975). These variables influence the distribution of hydropsychid Trichoptera (Gordon and Wallace 1975) because of the net building and filter feeding habits of this group. The North Toe River at the sampling site is dominated by hydropsychid

Table 3. Average percent community composition comparisons by taxonomic order for four Appalachian mountain river studies. Abbreviations as in Table 1.

Order	FB-1	FB-2	MR-1	MR-2	NT-1	LPR
Ephemeroptera	40	46	39	37	40	20
Plecoptera	4	4	16	10	7	6
Trichoptera	16	12	18	26	35	22
Diptera	33	28	20	18	11	44
Coleoptera	5	3	5	5	6	4
Other	2	7	2	4	1	4

caddisflies, as are many other riverine systems with large watersheds (Ross 1944; Rhame and Stewart 1976). Anderson (1976) said that hydropsychids are "particularly" characteristic of large rivers.

TAXA RICHNESS: STREAMS

The total number of taxa for the two French Broad tributaries (5 stations) was 199 (Table 4). Surveys conducted by the Division of Environmental Management in the seven other Appalachian streams shown in Table 4 did not record as many taxa, but this may simply reflect the far fewer samples collected. It has long been known that taxa richness is a logarithmic function of collection area (Gleason 1922). A larger number of samples increases collection efficiency, hence produces greater taxa richness.

Average taxa richness per collection for the taxonomic orders is presented in Table 5. This table also includes information from the seven other mountain stream surveys listed in Table 4.

ABUNDANCE (PERCENT OF TOTAL ABUNDANCE): STREAMS

Table 6 gives abundance (as a percent of total abundance) for taxonomic orders. As before, we include comparisons from other presumably unstressed Appalachian streams. We have also been able to include data from Tebo and Hassler (1961), Talak (1977), and Dysart et al.

Table 4. Total taxa richness (S) comparisons for nine Appalachian stream studies.

Stream	S	# Collections	# Stations	Methods	Reference
Cherryfield (CF) and Morgan Mill (MM) Creeks	199	90	5	Kick net	This paper
Dark Ridge Creek (DR-1)	152	30	3	Kick net	Penrose et al. (1980)
Threemile Creek (TM-1)	103	12	1	Kick net	Lenat et al. (1979)
Brushy Creek (BR-1)	102	12	1	Kick net	Lenat et al. (1979)
Cox Creek (Cox-1)	124	9	3	Kick net	Penrose et al. (1980)
Tributary to Beech Creek (BC-1)	68	8	1	Kick net	Lenat et al. (1979)
Prices Creek (PC-1)	81	8	1	Kick net	Penrose et al. (1980)
Blankenship Creek (BL-1)	91	8	1	Kick net	Penrose et al. (1980)
Sweeten Creek (SW-1)	73	8	1	Kick net	Lenat et al. (1979)

Table 5. Average taxa richness comparisons by taxonomic order for ten Appalachian reference stream sites. Abbreviations as in Table 4.

Order	CF-1	MM-1	DR-1	TM-1	BR-1	Cox-1	BC-1	PC-1	BL-1	SW-1	Avg.
Ephemeroptera	12.2	10.6	12.0	11.0	8.3	6.6	7.8	8.8	9.6	6.7	9.4
Plecoptera	7.1	8.4	7.4	4.0	5.3	5.6	8.3	6.2	5.2	6.3	6.4
Trichoptera	9.4	8.7	9.8	5.0	7.3	5.7	8.0	6.2	9.0	7.3	7.6
Diptera	17.6	20.0	16.2	13.3	14.3	10.9	11.8	11.0	14.4	12.0	14.2
Coleoptera	3.4	3.4	2.6	1.7	1.2	3.2	2.0	2.8	2.2	3.3	2.6
Other	3.7	5.0	2.8	3.0	5.3	5.9	6.3	2.5	3.6	5.4	4.4
Totals	53.4	56.1	50.8	38.0	41.8	37.9	44.2	37.5	44.0	41.0	44.6

Table 6. Average percent community composition by taxonomic order for thirteen Appalachian mountain reference stream sites. Abbreviations as in Table 4.

	Station												
Order	SW-1	BR-1	BC-1	PC-1	BL-1	Cox-1	MM-1	CF-1	TM-1	DR-1	Tebo & Hassler 1961	Talak 1977	Dysart et al. 1973
Ephemeroptera	18	37	35	61	62	60	26	45	28	47	30	71	43
Plecoptera	30	28	16	17	11	8	14	7	18	13	15	8	13
Trichoptera	27	14	29	11	14	12	18	15	34	14	22	12	11
Diptera	15	16	12	7	11	13	23	13	16	15	21	6	17
Coleoptera	4	2	3	3	3	6	16	17	1	5	10	1	14
Other	3	3	5	1	-	1	3	3	3	6	2	2	2
Watershed size (km^2)	1.02	0.91	0.28	2.25	3.65	3.98	2.93	7.04	16.08	25.9	7.58	-	-
Slope (m/m)	0.14	0.18	0.10	0.22	0.24	0.16	0.06	0.05	0.01	0.11	0.11	-	-

(1973), because tabulation of percent abundance of major taxonomic groups requires identification only to the level of order.

Many differences in abundance can be related to watershed size and stream gradient. These factors were grouped and included in Table 6 when available. High percentages of Plecoptera (> 20%) were observed only in streams with very small watersheds (SW-1 and BR-1). This phenomenon was not evident at BC-1 (tributary to Beech Creek), a site that was not sampled in the fall when most Plecoptera would probably be present. In these very small first order streams, low flow rates allow large accumulations of leaves. Such accumulations ("leaf packs") are the preferred habitat of "shredder" Plecoptera genera, especially *Allocapnia*, *Peltoperla* and *Taeniopteryx*.

High gradient streams with watersheds of from 2 to 4 km^2 (PC-1, BL-1, and Cox-1) were strongly dominated by Ephemeroptera, especially *Epeorus* (*Iron*) and *Rithrogenia*. These streams are characterized by many small waterfalls. Water velocity is sufficient to quickly remove leaf accumulations and the substrate often has a very "clean" appearance. We suspect that these watershed characteristics were also true for those studied by Talak (1977).

Larger streams (CF-1, TM-1, DR-1; and Tebo and Hassler 1961) were dominated by a combination of Ephemeroptera and Trichoptera. These streams are characterized by somewhat less canopy cover, greater amounts of fine particulate organic matter, and higher flow. The composition of the benthic fauna for this group of streams is similar to that described for mountain rivers in Table 3.

Seasonal Trends

Abundance: River Stations.—Abundance values showed large between-year and between-station variability (Fig. 3). However, several distinct trends may be observed.

Organism abundance was usually greatest at station 4 and can be correlated with substrate characteristics. Station 4 is located in an area of heavy *Podostemon* (riverweed) growth. According to Anderson and Sedell (1979), macrophytes may increase the density of benthic macroinvertebrates although not serving as food. Macrophytes structurally modify the river bed by increasing the available benthic area and reducing flow. A reduction in flow in turn results in both less scour and greater retention of detritus. This hypothesis is supported by the convergence of abundance values (Fig. 3) at all stations during winter and early spring, a period of *Podostemon* dieback.

All stations appeared to have a "refuge" from scouring. Following the 1979 spring flood (Fig. 1), the number of benthic invertebrates did not appear much lower than those observed in the spring of 1978, despite a lower 1978 flow. Extremely high flows appeared to have minimal

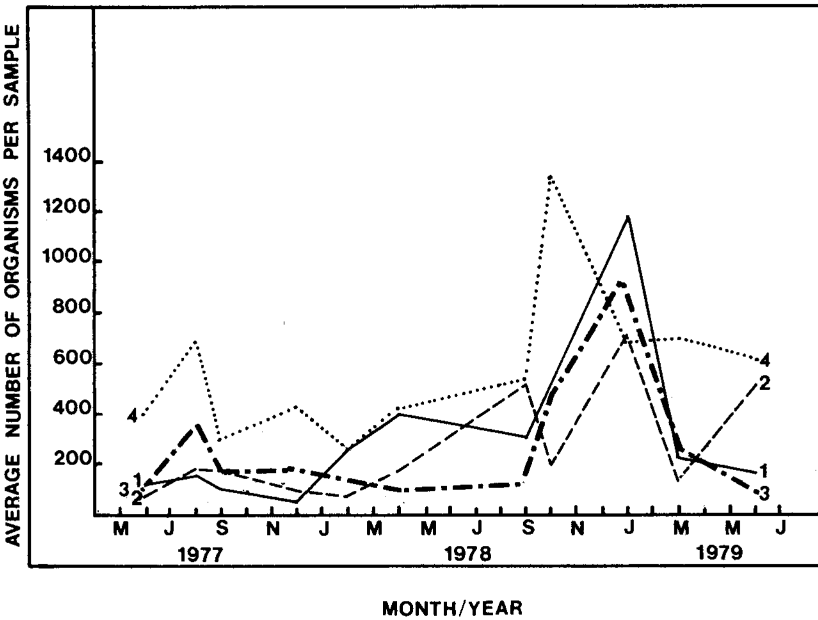

Fig. 3. Average number of organisms per sample, French Broad River, June 1977-July 1979.

effect on benthic fauna in the French Broad River.

A sharp increase in the number of benthic organisms was associated with low discharge rates, especially in the fall of 1978 (Fig. 1). However, a decline in the number of organisms at station 2 was observed in October 1978. This decline may have been caused by activities in the watershed of the North Fork. We learned that a fish kill occurred just above station 2 in late July 1978. According to the *Asheville Citizen* (1978), 1,200 fish (mostly brown trout) were killed in Johnnies Creek, Tucker Creek, and parts of the North Fork of the French Broad. The suspected cause of the kill was a pesticide in the Johnnies Creek watershed. Passage of a pesticide (as a "slug dose") through station 2 could have caused the fluctuations in density observed there. Plecoptera, which are highly sensitive to a variety of pesticides (Jensen and Gaufin 1964; Courtemanch and Gibbs 1977; Eidt 1975), were not collected from this area in September 1978.

Taxa Richness: River Stations.—Only 1978 and 1979 data are presented in Figure 4, because pre-1978 collections were identified mostly to genus. Several trends may be observed. Taxa richness at station 1 was remarkably constant, particularly for the last six sample periods. This pattern suggests that total taxa richness in this area is independent of

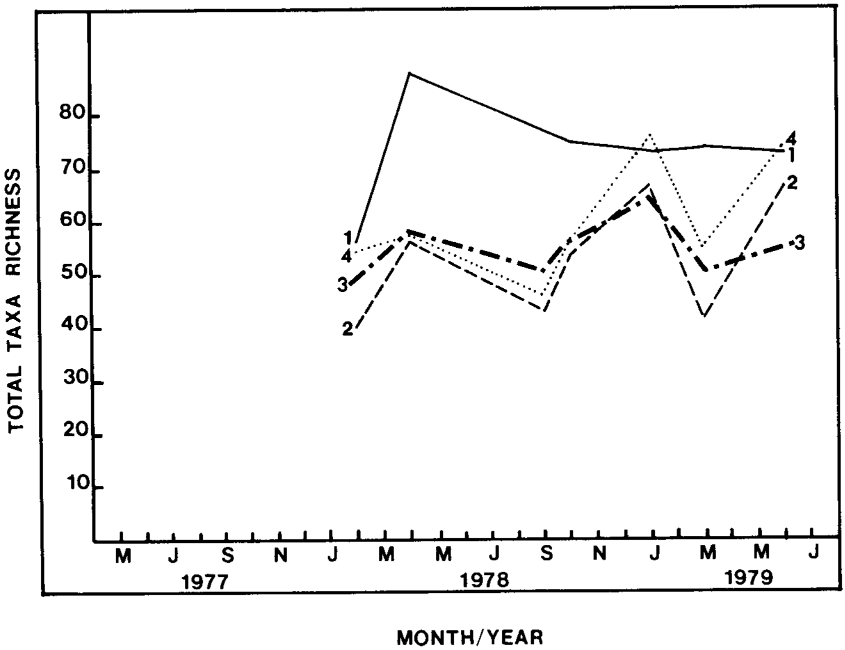

Fig. 4. Total taxa richness, French Broad River, February 1978-June 1979.

both season and discharge rate. However, total taxa richness at other stations showed considerable seasonal fluctuation. This fluctuation is not random; two distinct patterns may be observed. First, taxa richness values at these other stations were roughly parallel, suggesting that the same factor (above station 2) controlled the benthos at all stations. Second, reductions in taxa richness occurred primarily during the spring and/or summer period. Taxa richness values at all stations tended to converge in winter and fall.

Abundance: Stream Stations.—Although five stream stations were sampled, data are presented only for the "control" stations of Morgan Mill (MM-1) and Cherryfield (CF-1) creeks (Fig. 5). There appear to be two peaks (spring and fall) per year. This is an expected pattern for temperate streams (Hynes 1972). Organism abundance was greater at station MM-1 than that observed at station CF-1, but seasonal trends were parallel for these two areas.

Taxa Richness: Stream Stations.—Taxa richness values suggest little seasonal variation, although values tended to be slightly higher in winter and early spring (Fig. 6). A marked divergence between stations MM-1 and CF-1 was observed only during the period October 1978 through January 1979. This is the same period when the fish kill occurred above station 2 on the French Broad.

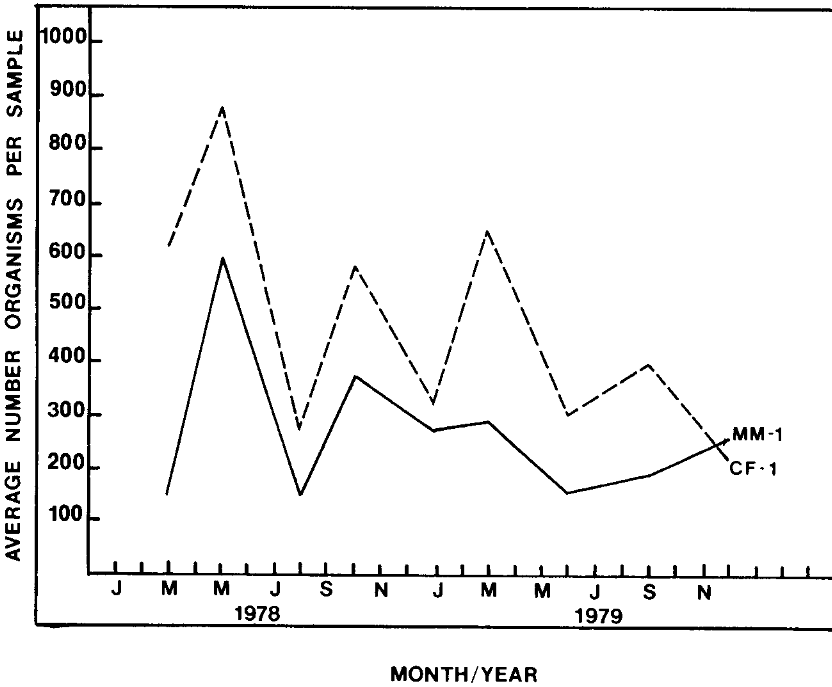

Fig. 5. Average number of organisms per sample, Cherryfield (CF-1) and Morgan Mill (MM-1) creeks, February 1978-December 1979.

SPECIES (OR TAXA) LEVEL INFORMATION

Table 7 lists all benthic macroinvertebrates collected in the Upper French Broad River Basin, and includes 267 taxa, derived from identification of 81,000 organisms. Data on frequency and seasonal distribution are included. Frequency data are based on the number of times each taxon was collected rather than on any quantitative measure of abundance.

Table 7 also lists the "months of maximum abundance." Since this is a highly qualitative procedure, the analysis was very cautious. When no clear seasonal pattern was apparent this column was left blank. It was also left blank for all rare taxa.

Life History Data.—Many taxa were found to have two or three distinct seasonal peaks in abundance. In many cases, these peaks may correspond to separate generations. Multiple peaks in abundance were recorded for Ephemeroptera (12 taxa), Trichoptera (4 taxa) and Diptera (15 taxa). Most of these taxa are grazers or filter-feeders. Since this group of organisms included many classified as "abundant", a large proportion of the benthos would be expected to have two or three generations per year.

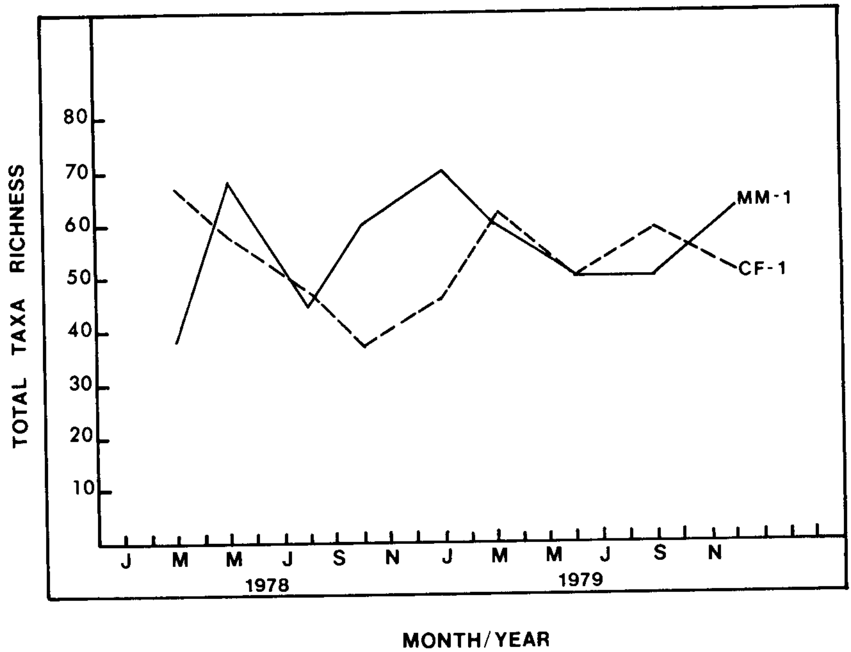

Fig. 6. Total taxa richness per collection, Cherryfield (CF-1) and Morgan Mill (MM-1) creeks, February 1978-December 1979.

The growth rate of many benthic species varies geographically, principally due to differences in the temperature regime (Vannote and Sweeney 1980). Water temperature will affect either the number of generations per year or the reproductive success of polyvoltine species. Neves (1979) studied the benthic macroinvertebrates of a Massachusetts stream and found that 14% of the standing crop was based on species with two to four generations per year. These polyvoltine species comprised 32% of the total production. Neves' study was conducted in a stream with a mean annual temperature of 8.3° C. In the French Broad River, higher mean temperatures (about 13° C) might be expected to increase the number of polyvoltine species. We found that taxa with two to three peaks per year comprised 44% of the standing crop at stream stations and 55% of the standing crop at river stations (unpublished data). This implies that polyvoltine species make up a large proportion of the French Broad River fauna. Production studies in the southeastern United States must be careful to evaluate this factor.

For species with similar morphology and feeding type, differences in seasonal distribution may help to avoid competition. Many such species pairs can be seen in Table 7. A few examples include: *Epeorus*

Table 7. List of organisms recorded from the French Broad River and tributaries, showing relative abundance in each major area and months of maximum abundance. S = streams, UR = upper river-montane, UL = upper river lowland. R = Rare; present in 1-5% of samples. C = Common; present in 6-25% of samples. A = Abundant; present in at least 26% of samples. + = identification to species only during last collection.

Taxon	Frequency S	Frequency UR	Frequency LR	Month(s) of maximum abundance
EPHEMEROPTERA				
Isonychia spp.	R	A	A	J,Ju-O
Baetis spp.[1]	A	A	A	J, J-O
B. amplus	+	+	+	-
B. nr. *intercalaris*	+	+	+	-
B. tricaudatus	+	+	+	-
Gen. nr. *Centroptilum*	-	-	+	-
Centroptilum sp.	-	-	R	-
Pseudocloeon spp.	A	A	A	Ap, Ju, S-O
Cinygmula subaequalis	A	C	C	Mr-Ap
Epeorus (*Iron*) spp.	A	A	A	Mr-Ap
E. (*I.*) sp. 2[2]	A	A	C	J-Mr
Rhithrogenia sp.	C	A	A	J, Mr-Ap
Stenacron pallidum/carolina	C	C	C	J
S. interpunctatum	R	C	-	-
Stenonema carlsoni	C	R	-	J-Ju
S. ithaca	A	A	A	D-F
S. modestum[3]	A	A	C	J,S-O
S. pudicum	C	C	C	-
S. terminatum(?)	C	R	-	-
Habrophlebia vibrans	R	-	-	-
Paraleptophlebia sp.	C	A	R	Ju-A
Ephemerella (Attenella) attenuata[4]	-	C	R	Ju
E. (*Drunella*) *tuberculata*	R	-	-	-
E. (*D.*) *conestee*	C	R	-	Ju
E. (*D.*) *cornutella*	C	R	-	Ap
E. (*D.*) *lata*	R	C	C	Ap-Ju
E. (*D.*) *longicornis*	C	-	R	Ju
E. (*D.*) *walkeri*	R	R	R	Ap
E. (*D.*) *wayah*	C	-	R	Ju-S
E. (*Danella*) *lita*	R	-	-	-
E. (*D.*) *simplex*	R	R	R	Ju
E. (*Ephemerella*) *berneri*	-	R	R	-

[1] Originally identified to genus level, species later identified from selected samples using Morihara and McCafferty (1979).

[2] *Epeorus* sp. 2 was distinguished by difference in coloration and the presence of spatulate claws.

[3] Early instars of other species may have been lumped with *S. modestum*.

[4] Some taxonomists now consider previous *Ephemerella* subgenera to have generic status.

E. (E.) catawba gr.[5]	A	A	A	Mr-Ap-O (stream) J (river)
E. (E.) crenula (?)	-	-	R	-
E. (E.) hispida	C	A	A	J-F, S-O
E. (E.) invaria gr.	R	C	C	J-Ap
E. (E.) rossi	R	C	C	D-Mr
E. (E.) rotunda	R	-	-	-
E. (Eurylophella) bicolor	-	C	R	Mr, O
E. (E.) funeralis	-	R	R	-
E. (E.) temporalis gr.	R	-	C	-
E. (Serratella) carolina	C	R	R	Ju-A
E. (S.) deficiens	C	C	C	Ju, O
E. (S.) serrata	C	C	C	Ju
E. (S.) serratoides	-	R	C	Ju-A, S-O
Neoephemera purpurea	-	A	C	S
Brachycercus nitidis	-	-	R	-
Caenis sp.	R	R	C	A-S
Baetisca berneri	R	-	-	-
B. carolina	R	R	C	J-Ap
Ephemera blanda	R	A	A	-
E. guttalata	-	R	R	-
Hexagenia munda (?)	R	R	-	Ap
PLECOPTERA				
Allonarcys sp.	A	C	A	-
Peltoperla sp.	A	C	C	O
Taeniopteryx burksi	C	C	C	O-D
Strophopteryx sp.	C	C	C	D
Amphinemura spp.	A	R	R	Ap
Leuctra sp.	C	C	C	A
Allocapnia spp.	A	C	C	Ap-A, O
Acroneuria abnormis	A	A	A	-
A. carolinensis	-	-	R	-
A. georgiana	C	C	C	Ju-A
Perlesta sp.	R	R	R	Ju-A
Paragnetina immarginata	R	C	C	Ju-A
Phasgonophora capitata	-	C	C	-
Eccoptera xanthenes	R	-	-	-
Cultus decisus	C	C	C	J-Mr
Isogenoides nr. *hansoni*	R	-	-	-
Malirekus hastatus	C	R	R	-
Remus bilobatus	R	R	-	Ap
Isoperla holochlora	R	-	R	-
I. namata	C	C	C	Mr
I. orata	C	C	C	Ap
I. cf. *slossonae*	R	R	C	-
I. transmarina	-	-	R	-
Alloperla sp.[6]	C	C	C	-
Sweltsa sp.[6]	R	R	R	-

[5] Probably includes *E. dorothea*.
[6] These genera misidentified in early samples and confused with *Hastaperla*.

ODONATA				
Cordulegaster sp.	R	R	-	-
Lanthus parvulus	C	C	C	-
Stylurus scudderi	-	R	R	-
Boyeria vinosa	-	R	R	A-S
Aeschna sp.	-	R	-	-
Calopteryx sp.	R	-	-	-
COLEOPTERA				
Gyrinus sp.	-	-	R	-
Dineutes sp.	-	-	R	-
Bidessus sp.	R	-	-	-
Hydroporus spp.	R	R	R	-
Ectopria nervosa	C	C	C	A-O
Psephenus herricki	R	R	A	-
Macronychus glabratus	R	R	-	-
Optioservus sp.	-	-	-	A-O
Oulimnius latiusculus	A	C	C	-
Promoresia elegans	C	C	C	Ap
P. tardella	A	A	A	O
Stenelmis sp.	-	R	R	-
Anchytarsus bicolor	R	C	-	-
TRICHOPTERA				
Brachycentrus sp.	R	A	A	Ju-A
Micrasema wataga	R	-	C	Ap-A
Agapetus sp.	C	C	C	Ap-Ju
Glossosoma nigrior	A	A	A	J, Ju, S-O
Matrioptila jeanae	R	-	R	Ap
Helicopsyche borealis	-	R	-	-
Arctopsyche irrorata	R	-	R	-
Cheumatopsyche spp.	A	A	A	J-Mr, O
Diplectrona modesta	A	R	R	O-J
Hydropsyche betteni	R	R	R	-
H. demora	-	-	R	-
H. mississippiensis	-	R	-	-
Symphitopsyche bronta	R	C	A	-
S. macleodi	-	-	R	-
S. morosa	R	-	C	O
S. sparna	A	A	A	Mr, A-O
Parapsyche cardis	R	-	-	-
Ochrotrichia sp.	-	-	R	O
Lepidostoma sp.	C	C	R	Ap
Oecetis spp.	-	R	C	Mr, S
Setodes sp.	-	C	R	-
Goera sp.	-	R	R	-
Hydatophylax argus	R	R	R	D-J
Neophylax spp.	C	C	C	D-Mr
Pseudostenophylax uniformis	-	-	R	-
Pychopsyche guttifer	-	C	R	J-Mr
P. lepida	-	R	R	J
Doliphilodes sp.	C	C	C	Ju-O
Wormaldia sp.	R	-	-	-

Neureclipsis sp.	-	-	R	-
Nyctiophylax nephophilus	-	-	R	-
Polycentropus spp.[7]	C	C	R	-
Lype diversa	R	R	-	-
Rhyacophila acutiloba	-	-	R	-
R. amicis	R	-	-	-
R. atrata	C	-	-	-
R. carolina	A	C	R	O
R. fuscula	A	A	C	-
R. nigrita	C	R	R	-
R. torva	R	R	-	-
MEGALOPTERA				
Corydalus cornutus	-	-	R	-
Nigronia spp.[8]	C	A	C	-
Sialis sp.	R	R	R	-
HEMIPTERA				
Gerris sp.	-	-	R	-
Trepobates sp.	-	-	R	-
Microvelia sp.	-	-	R	-
DIPTERA: (General)				
Blephariceria sp.	C	C	R	Mr-Ju
Pericoma sp.	R	-	-	-
Psychoda sp.	R	-	-	-
Atrichopogon sp.	R	-	-	-
Palpomyia (complex)	A	X	X	-
Ptychoptera sp.	-	-	R	-
Protoplasa fitchii	C	C	C	Ap-S
Dixa sp.	R	R	-	-
Chrysops sp.	R	-	R	-
Tabanus sp.	-	-	R	-
Atherix lantha	A	A	A	S-O
Dolichopodidae	-	R	R	-
Empididae	A	A	A	-
Antocha sp.	A	A	A	O
Dicranota sp.	A	R	R	Mr-Ap
Gonomyia gr.	R	-	R	-
Hexatoma sp.	C	R	R	-
Limonia sp.	R	-	-	-
Polymeda / Ormosia	R	R	R	-
Tipula spp.	A	C	C	S
Cnephia mutata	-	-	R	-
Prosimulium mixtum	C	-	R	D-Mr
Simulium (*Phosterodoros*) spp.	R	C	C	Ju-O
S. decorum	R	-	R	-
S. vittatum gr.	A	A	A	Ju-O

[7] Paper in preparation by John Morse, Clemson University, and co-workers indicates this genus includes *Cernotina* and *Plectrocnemia*.

[8] Primarily *N. fasciatus*, but *N. serricornis* also present.

DIPTERA:				
CHIRONOMIDAE				
Chironomus sp.	R	-	-	-
Cryptochironomus fulvus gr.	R	R	C	Ju-O
Demicryptochironomus gr.	C	R	R	Ap
Dicrotendipes sp.	-	-	R	-
Microtendipes sp.	R	C	C	-
Parachironomus sp.	-	R	-	-
Paratendipes sp.	R	-	-	-
Polypedilum aviceps	A	C	C	Ap-Ju, S-O
P. convictum	R	R	R	-
P. angulum	C	R	R	-
P. fallax	C	R	C	-
P. laetum (?)	R	-	-	-
P. illinoense	R	R	R	-
P. halterale gr.	R	-	-	-
P. scalaenum	R	-	R	-
Saetheria tylus	-	-	R	-
Stictochironomus sp.	-	-	R	-
Tribelos jucundus	-	C	C	A-S
Cladotanytarus sp.	R	-	R	-
Micropsectra spp.	A	C	C	-
Rheotanytarsus spp.	A	A	A	J-S
Tanytarsus spp.	C	C	R	Ju
T. (*Sublettea*) *coffmani*	R	-	R	-
Zavrelia sp.	R	-	-	-
Conchapelopia gr.	A	A	C	O
Brundinia eumorpha	-	R	R	-
Ablabesmyia parajanta	-	R	-	-
Diamesa spp.	C	A	C	Mr-A, O-D
Odontomesa cf. *fulva*	-	-	R	-
Pagastia sp.	C	C	C	J, Ju-S
Potthastia cf. *gaedi*	-	C	C	Ju-O
P. nr. *longimanus*	C	C	C	J, S-O
Prodiamesa olivacea	R	-	-	-
Syndiamesa zavreli	-	-	R	-
Brillia sp.	A	C	C	O
Cardiocladius sp.	C	C	C	-
Cordites sp.	R	-	-	-
Corynoneura spp.	C	C	R	O
Cricotopus (*C.*) *tremulus* gr. sp. 1 (=*infuscatus*?) (C/O sp. 5)[9]	R	R	R	-
C. (*C.*) *tremulus* gr. sp. 2 (C/O sp. 6)	C	C	R	S-O
C. (*C.*) nr. *flavocinctus* (C/O sp. 50)	R	-	-	-

[9] In-house keys for the *Cricotopus/Orthocladius* group (C/O), and reports from the Biological Monitoring Unit, Division of Environmental Management, use a number for various species and/or species groups. This number is included for comparison with other DEM reports.

Cricotopus (?) *acutilabis* (C/O sp. 48)	R	R	-	-
Orthocladius (*O.*) nr. *dorenus (C/O sp. 7)*	R	R	R	-
O.(*O.*) cf. *robacki* (C/O sp. 12)	R	-	R	-
O. (*O.*) cf. *obumbratus* (C/O sp. 10)	C	C	C	Ap
O. (*O.*) cf. *nigritus* (C/O sp. 47)	-	R	R	-
O. (*O.*) nr. *clarkei* (C/O sp. 54)	C	C	C	Ap-My, S-D-
O. (*Euorthocladius*)[10] sp. 1 (C/O sp. 2)	-	R	C	-
O. (*E.*) sp. 2 (C/O sp. 3)	-	R	R	-
O. (*E.*) sp. 3 (C/O sp. 13)	A	C	C	Mr-Ap, S-D
O. (*E.*) sp. 4 (C/O sp. 20)	C	C	R	Ap-Ju
O. (*E.*) sp. 5 (C/O sp. 29)	R	R	-	-
O. (*E.*) sp. 6 (C/O sp. 51)	R	C	R	-
Epoicocladius cf. *flavens*	-	R	R	-
Heterotrissocladius cf. *marcidus*	-	R	R	-
Parakiefferiella sp.	-	R	-	-
Heleniella sp.	R	R	-	-
Hydrobaenus sp.	-	R	R	-
Limnophyes sp.	R	-	R	-
Nanocladius spp.	R	-	-	-
N. nr. *balticus*	-	R	R	-
Parachaetocladius sp.	A	A	C	J,O
Paraphaenocladius sp. 1	A	C	C	-
P. sp. 2				
Eukiefferiella bavarica gr.[11]	A	C	C	Ap-Ju, O
E. claripennis gr.	A	C	C	O
E. clypeata gr.	R	-	-	-
E. devonica gr.	R	C	A	Ap-Ju, S-O
E. discoloripes gr.	C	A	A	Ap-Ju, S-O
Rheocricotopus cf. *robacki*	R	R	R	O
R. sp. 2	R	-	-	
R. sp. 3	R	-	-	
Synorthocladius sp.	R	-	-	-
Thienemaniella spp.	A	C	C	Ap, O
OLIGOCHAETA				
Opisthopora	C	-	-	-
Lumbriculidae	A	A	A	J-Mr, O
Cambarincola (?)	R	-	-	-
Limnodrilus hoffmeisteri	R	R	C	-
Peloscolex variegatus	R	-	-	-

[10] *Euorthocladius* and other subgenera of *Orthocladius* are poorly known; this group may contain several (probably undescribed) subgenera.

[11] Follows William Bode's unpublished key to species groups.

Nais behningi	R	-	-	-
N. elinguis	R	R	R	-
N. simplex	R	R	-	-
Pristina idrensis	R	-	R	-
P. longiseta (?)	R	-	-	-
Specaria josinae	R	-	-	-
CRUSTACEA				
Lirceus sp.	R	-	-	-
Crangonyx sp.	R	-	-	-
Cambarus spp.	C	R	-	-
MOLLUSCA				
Goniobasis sp.	A	C	-	-
Gyraulus sp.	-	R	-	-
Ferrissia sp.	C	A	C	-
Sphaerium sp.	R	R	-	-
Pisidium sp.	-	-	R	-
"OTHER"				
Nematoda	-	R	-	-
Hydracarina	R	R	-	-
Dugesia tigrina	R	-	-	-
Cura foremanii	R	-	R	-
Prostoma graecens	-	R	C	-

(*Iron*) and *Stenonema ithaca*; *Promoresia elegans* and *P. tardella; Micrasema wataga* and *Brachycentrus;* and *Prosimulium mixtum* and *Simulium* spp..

Spatial Patterns.—Table 8 shows the number of taxa (by group) with a preference for each area of the river basin. Data are not tabulated for unusual taxa. Within this group, 86 taxa (64%) showed some spatial preference.

Longitudinal zonation along lotic systems has been demonstrated many times in rivers throughout the world, and Hynes (1972) listed over 100 examples. Our intent here is simply to illustrate the expected pattern in a small southeastern river.

Comments on Particular Taxa.—The French Broad River data set contained many unusual collection records, especially for Ephemeroptera and Chironomidae. An extremely high diversity was found within the genus *Ephemerella* (24 species). These species often had a slight degree of spatial and temporal overlap; single river stations in the spring of 1979 had up to 20 species of *Ephemerella*.

The "new genus near *Centroptilum*" is a highly unusual mayfly, characterized by long gills on the fore coxae. The morphology of this species will be described by Carlson and Lenat (in prep.). *Brachycercus nitidis* is infrequently collected in routine stream collections (Berner 1977). We found this species only in samples taken near the river bank. *Baetisca berneri* was recently described from West Virginia by Tarter

Table 8. Number of taxa by group, showing spatial preferences for second order streams (S), Upper River-Montane (UR), Upper River-Lowland (LR), streams and Upper River-Montane (S-UR) and Upper River-Montane and Upper River-Lowland (UR-LR).

		# with spatial preference				
	Total Taxa	S	UR	LR	S-UR	UR-LR
Ephemeroptera	52	8	4	3	2	8
Plecoptera	25	4	-	1	-	2
Odonata	6	-	-	-	-	-
Coleoptera	14	1	1	1	-	-
Trichoptera	40	4	2	3	3	1
Megaloptera	3	-	1	-	-	-
Hemiptera	3	-	-	-	-	-
Diptera: General	25	5	-	-	1	1
Diptera: Chironomidae	74	10	1	3	6	4
Oligochaeta	11	1	-	1	-	-
Crustacea	3	1	-	-	-	-
Mollusca	5	1	1	-	-	-
Miscellaneous	6	-	-	1	-	-
Totals	267	35	10	14	12	15

and Kirchner (1978). Several specimens were collected at our stream stations.

Many stream/river surveys neglect the Chironomidae, citing taxonomic difficulties. However, recent work in this important group has made identifications much easier. Mozley (1980) provided a generic key to North Carolina Orthocladiinae that should further reduce the difficulty of identifications within this subfamily. We identified 74 taxa within the Chironomidae, which probably included more than 85 species. This number of taxa agrees well with many other intensive surveys of lotic chironomids (see data cited by Lindegaard-Peterson 1972). However, many more species might be expected with more precise taxonomy (especially if pupae and adults are used). Coffman (1973) identified 143 chironomids from a single Pennsylvania stream, and Lehmann (1971) recorded 245 species from the Fulda River. The latter study included data from many stations along a 220-km river segment.

The chironomid fauna of the upper French Broad River is dominated by the Orthocladiinae and Diamesinae, a trend expected for cool lotic systems (Oliver 1971). The Tanytarsini were also important, especially *Micropsectra* (stream stations) and *Rheotanytarsus* (river stations). Several unusual Diamesinae were collected, especially *Pagastia* sp. These specimens were verified by D. T. Oliver (pers. comm.), who stated they were "similar to an undescribed species near *P. orthogonia*." Most recent chironomid keys omit this genus, but it is illustrated in Mason (1973) under the name *Pseudodiamesa pertinax*.

The *Cricotopus/Orthocladius* group contained 15 taxa, many of which are species groups. The "*Euorthocladius*" group (which may contain several subgenera) is particularly in need of taxonomic revision.

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