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SEASONAL ABUNDANCE OF AQUATIC INSECTS IN WESTERN NORTH CAROLINA TROUT STREAMS

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Introduction

One phase of a Dingell-Johnson project conducted by the North Carolina Wildlife Resources Commission in the Coweeta Experimental Forest in Macon County, North Carolina, was a quantitative and qualitative evaluation of the seasonal variations in standing crops of invertebrate bottom organisms in the forest streams. These data, collected from typical Southern Appalachian trout streams, provide information on seasonal variations of the predominantly insect fauna which should be of interest to students and collectors of aquatic insects of the Southern Appalachians. They should also be of value to aquatic biologists for quantitative comparisons of trout foods during different seasons of the year in streams of this area.

The Coweeta Experimental Forest was established by the United States Forest Service in 1933 for research in watershed management. The forest is located in a mountainous area with elevations ranging from 2,200 to 5,200 feet, and it encompasses an area of 4,000 acres which is approximately evenly divided between two major drainage basins. These two basins are drained by two creeks—Ball Creek on the south and Shope Creek on the north (Fig. 1)—which join within the forest to form Coweeta Creek, which subsequently flows into the Little Tennessee River.

Both Shope and Ball creeks are typical small Southern Appalachian trout streams with very soft, slightly acid water (Table I). They are characterized by steep gradients with series of cascades and low waterfalls interspersed with large pools. The bottom is predominantly rubble and gravel with occasional outcrops of granite bedrock. The average monthly streamflow for a six-year period in Shope Creek ranged from a low 2.31 cfs during October to 8.32 cfs during February. Water temperature on the lower part of these streams reaches a maximum of 70°F. during the month of August.

Over a period of seventeen months a total of 276 samples were collected with a Surber square-foot sampler from riffles at two stations on Ball Creek and one station on Shope Creek. These samples were combined by months to measure the seasonal variations in the fauna.

Total Fauna

The streams of Coweeta Experimental Forest would be classified by most standards as poor producers of bottom organisms. The maximum average monthly volume of 0.86 cc. per square foot was obtained in June, 1954. The maximum volume of bottom organisms in any

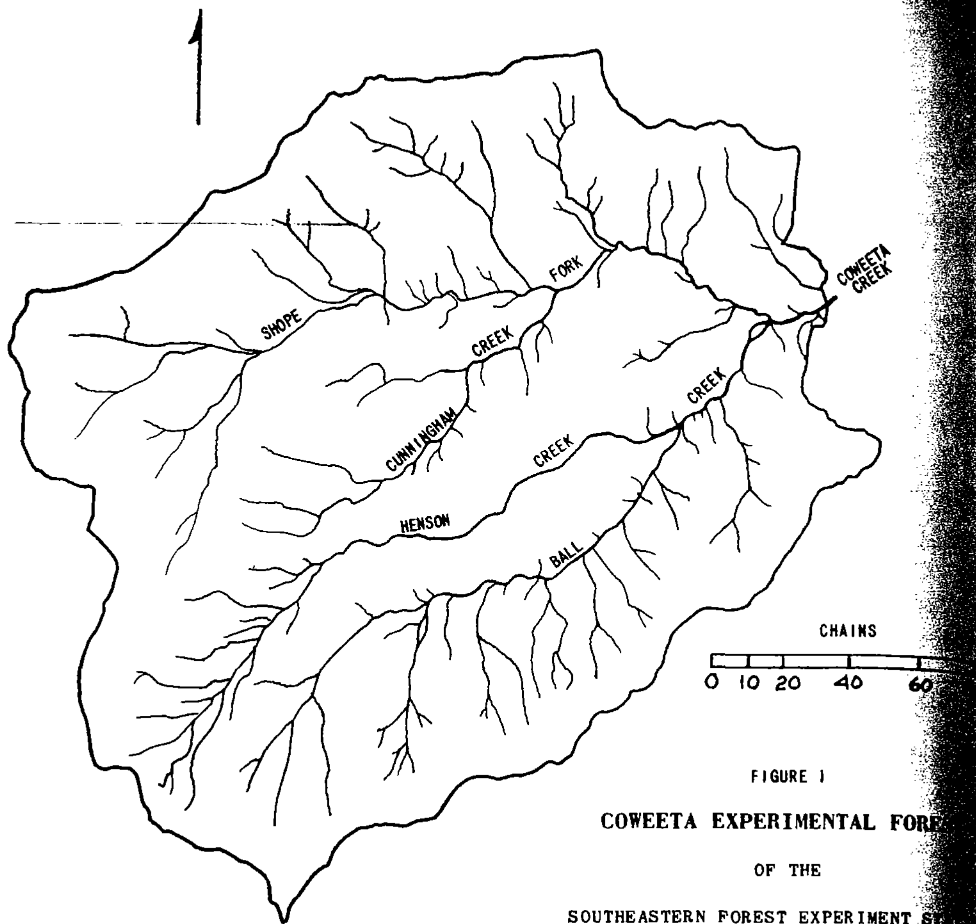


FIGURE I

COWEETA EXPERIMENTAL FOR[illegible]

OF THE

SOUTHEASTERN FOREST EXPERIMENT S[illegible]

Table I
Characteristics of Ball Creek and Shope Creek, Coweeta Experimental Forest, Macon County, N. C.

Characteristics	Shope Creek	Ball Creek
Average channel gradient (ft./mile)	581	644
Drainage area (acres)	1,877	1,788
Aspect	ENE	NE
Elevation at source (feet)	4,000	4,000
pH	6.8	6.8
M.O. Alk. ppm.*	8.0	8.0
Phenolphthalein Alk. ppm.*	0.0	0.0
CO_2 ppm.*	3.5	3.5

* These readings were obtained on January 19, 1953.

one sample was 3.96 cc. taken in a sample from Ball Creek in June, 1953.

Only 27 of the 282 samples exceeded one cc. in total volume. The average number of [illegible] organisms per month ranged from a [illegible] 19.2 in February to a high of 93.1 coll[illegible] September (Table II).

The standard deviation of the total [illegible] of organisms in these samples varied [illegible] per cent to 86 per cent of the mean. [illegible] is somewhat higher than the 20 per cent [illegible] per cent mentioned by Allen (1951) [illegible] discussion of data published by a number of workers. It should be noted that in only four of the eighteen months sampled did the standard deviation exceed 60 per cent of the mean.

Needham and Usinger (1956) in a comprehensive study of a single riffle area conclude that quantitative routine sampling in streams to determine weights and numerical data is impractical. They state that "194 samples would be required to give significant figures on total weight of organisms, and 73 samples would be necessary to give significant figures on total numbers at a 95 percent level

Table II

Mean number and volume of bottom organisms collected from stations in Ball and Shope creeks, Coweeta Experimental Forest, October, 1952 to April, 1954.

Month	No. samples	Total no. organisms	Total volume in cc.	Mean no. per sq. ft.	Standard deviation	Mean vol. per sq. ft.
Nov. 1952	6	281	4.85	46.8	40.64	0.81
Dec.	18	370	6.80	20.6	13.12	0.38
Jan. 1953	18	430	7.65	23.9	13.07	0.43
Feb.	18	345	2.60	19.2	16.53	0.14
Mar.	12	426	5.25	35.5	16.90	0.44
Apr.	18	1,408	8.04	78.2	42.99	0.45
May	6	259	2.00	43.2	21.18	0.33
June	18	1,129	15.52	62.7	32.93	0.86
July	18	1,191	8.72	66.2	21.88	0.48
Aug.	18	953	6.19	52.9	27.01	0.34
Sept.	18	1,676	12.62	93.1	56.54	0.70
Oct.	18	1,013	9.28	68.7	36.32	0.52
Nov.	6	264	2.70	44.0	18.41	0.45
Dec.	18	457	8.77	25.4	14.31	0.49
Jan. 1954	18	383	5.22	21.3	9.88	0.29
Feb.	12	615	6.42	51.3	39.48	0.54
Mar.	18	775	4.77	54.1	24.7	0.27
Apr.	18	1,483	7.49	82.4	41.23	0.42

of confidence." These workers do not state what they mean by significant figures, since no comparisons were being made. We assume that the stated number of samples would be required to keep the standard deviation within a certain percentage of the mean. The excessive number of samples required to reduce the standard deviation, however, does not obviate the possibility of making valid quantitative statistical comparisons based on a reasonable number of samples.

Although the standard deviation of the numbers and mass of organisms in the stream bottom samples was high in the Coweeta studies, it was possible to establish significant differences between silted and nonsilted areas (Tebo, 1955) and between areas with forested and cleared stream banks (Hassler and Tebo, 1958). These comparisons were based on six samples per month in treated and control areas.

The peak in abundance of aquatic insects in these streams occurs during September (Fig. 2), and it is concurrent with an increase in the numbers of the very abundant caddis flies, beetles and two-winged flies (Figs. 11, 19, 34). A gradual decrease in the number of aquatic insects occurs during the fall months until the minimum is reached during December and January. This decrease occurs in all major orders represented in the samples.

After the January low, the numbers increased to a peak during April. The April high coincides with the peak of abundance of May flies and is attributed almost entirely to May flies and two-winged flies. The increase among two-winged flies, after the winter low, begins somewhat sooner than among the May flies, and the two-winged flies are at a fairly high level of abundance during February and March. There is a considerable decrease in all groups during May, and this decrease is associated with a major period of emergence of all groups except Trichoptera. After this May decrease in numbers, comparatively high levels are maintained during the summer months.

Peaks in the volume of aquatic insects occurred during November, 1952, June, 1953, and September, 1953. The November, 1952, and June, 1953, highs coincide with the maximum abundance of two large crane-fly larvae, *Tipula abdominalis* Say and *Tipula (A.) Williamsiana.* The high in September volume coincides with a peak in the number of organisms.

It is our opinion that numbers of aquatic organisms in the Coweeta samples give a better appraisal of the fauna than does volume. In a stream which has low standing crops of bottom fauna, large specimens, although scarce, give a distorted picture in terms of volume. While these large specimens may provide an occasional "bonus meal" and are utilized by larger trout, their scarcity makes it improbable

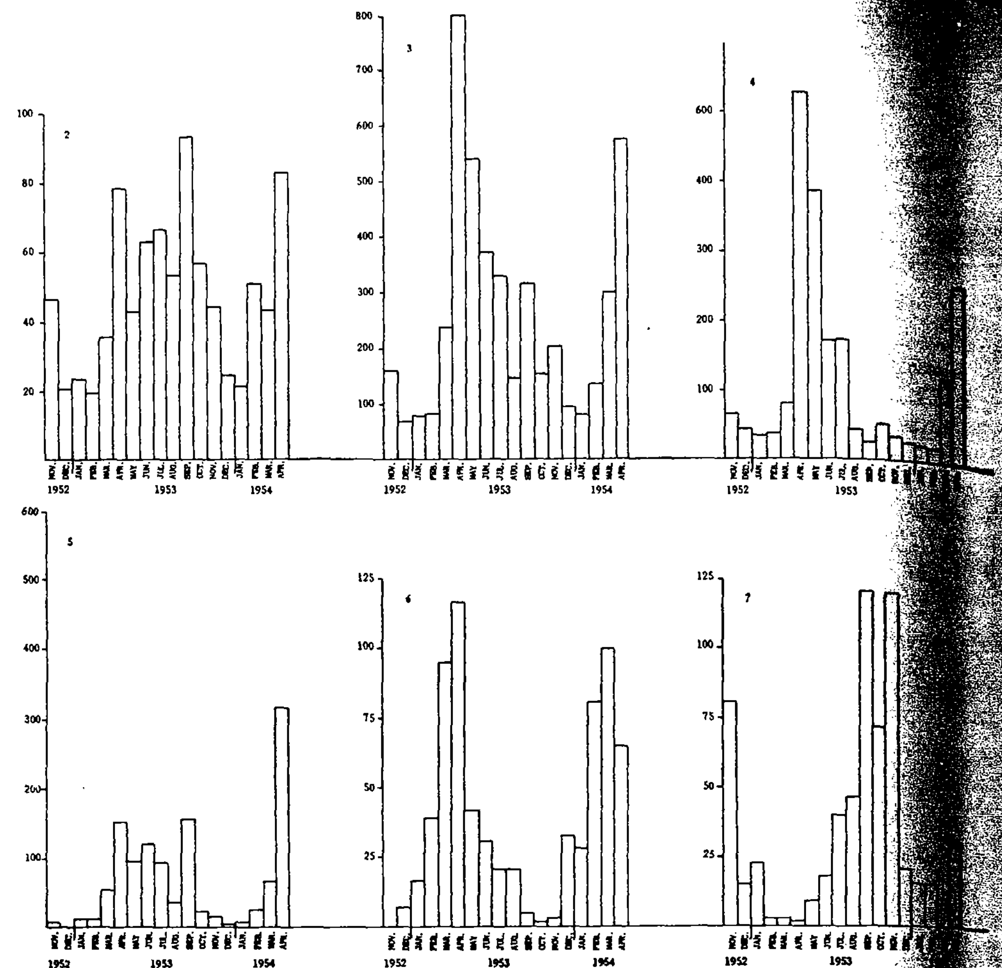


FIG. 2. Mean number of bottom organisms collected per month from Shope and Ball creeks, Coweeta Experimental Forest, from November, 1952, through April, 1954. FIGS. 3–7. Total number of nymphs collected per month from Shope and Ball creeks, Coweeta Experimental Forest. Adjusted to eighteen samples per month. Number of samples actually collected is given in Table III. FIG. 3. Ephemeroptera nymphs. FIG. 4. *Empherella spp.* FIG. 5. *Pseudocloeon spp.* FIG. 6. *Epeorus spp.* FIG. 7. *Stenonema sp.*

that they will be of importance in the daily foraging of the trout population.

The three orders—Ephemeroptera, Trichoptera, and Diptera, in that rank—comprised approximately three-fourths of the total collections for the eighteen-month period (Table III). The remaining one-fourth was composed of Plecoptera and Coleoptera. The Odonata and Oligochaetes contributed less than 1 per cent of all organisms collected. Except for the absence of the Megaloptera from the Coweeta collections, this distribution is similar to that found by Needham (1938), Surber (1951), and others. Although Megaloptera are present in Southern Appalachian streams, they are relatively scarce and were not collected in any of the Coweeta streams.

Representatives of the Coleoptera, comprising 10.5 per cent of the total collection, were more abundant in the Coweeta streams than in streams sampled in other parts of the country. The peak representation occurred during November and December, and this may account for their relative insignificance in studies carried out during the warmer months of the year (Table III). Aquatic Coleoptera were also abundant in the winter samples collected from Big Spring Creek in Virginia by Surber (1936).

There is a striking difference in the composition of the population by orders during different months of the year (Table III). The caddis flies are the dominant order from June through October. During November and

Table III

Total number and percentage composition of major groups of bottom organisms collected from Shope and Ball creeks, Coweeta Experimental Forest (per cent by months).

Order	Total no.	% total	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.
Ephemeroptera	4,657	30.4	18.5	17.5	17.7	23.6	41.2	57.2	69.0	32.7	27.5
Trichoptera	3,330	21.8	26.0	25.8	17.7	2.9	5.7	6.1	3.9	34.8	34.8
Diptera	3,279	21.4	16.0	16.0	25.1	60.0	36.9	22.1	15.5	10.7	9.8
Plecoptera	2,349	15.4	26.3	26.6	23.0	7.9	9.4	11.3	8.1	14.0	22.5
Coleoptera	1,602	10.5	12.8	12.9	16.0	5.0	6.9	3.2	3.5	7.1	4.8
Odonata	49	0.3	.0	0.8	0.5	0.3	.0	0.1	.0	0.6	0.5
Oligochaetes	28	0.2	0.4	0.3	.0	0.3	.0	.0	.0	.0	0.1

Order	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Ephemeroptera	15.3	18.7	15.4	25.4	20.0	19.8	17.9	38.6	32.6
Trichoptera	49.1	32.4	30.6	19.3	24.1	13.7	10.9	9.4	12.8
Diptera	9.9	22.7	12.7	9.5	12.9	34.5	44.3	34.3	28.8
Plecoptera	17.3	12.9	19.0	23.1	17.8	12.1	23.0	8.6	7.8
Coleoptera	7.0	13.2	21.4	22.7	19.7	13.3	14.6	8.4	7.3
Odonata	0.7	0.1	0.8	.0	0.2	0.5	0.1	0.8	0.1
Oligochaetes	0.7	0.1	0.0	0.0	.0	0.5	0.1	.0	0.7

mber the stone flies gain ascendance by a narrow margin. In January and Febru- the larvae of two-winged flies are much abundant than the other orders, and the is completely dominated by May flies g March, April, and May.

presentative specimens of certain groups sent to the following taxonomists for ification and verification of specimens al- identified by project personnel: Ephem- era, E. W. Hamilton; Trichoptera, Dr. H. Ross; Plecoptera, Dr. A. R. Gaufin; idae, Dr. J. Speed Rogers; Coleoptera, Harry G. Nelson. Dr. H. K. Townes identi- the specimens from approximately fifty of the samples included in this report.

Because of the lack of definite characters because many of the nymphs and larvae not been reared and associated with the , it is impossible to identify positively the nymphs and larvae of many aquatic insects to the species level. Many of those which have positive characters can be identified only from the mature nymph or larvae. In cases where early instar larvae and nymphs could not be separated, all specimens were grouped under the genus.

Ephemeroptera

May-fly nymphs, represented by twelve , were the most abundant order of insects total collections. The group reaches its peak of abundance during April, gradually decreases throughout the summer months, and attains a minor peak of abundance during September (Fig. 3). The seasonal low occurs during the winter months of December, January, and February.

With few exceptions, it was impossible positively to assign the May-fly nymphs to species.

Ephemerella spp. The genus Ephemerella, represented by at least eight species (including *E. bicolor*, *E. conestee*, *E. doris*, *E. dorothea*, *E. funeralis*, *E. fuscata*, *E. longicornis*, and *E. wayah*) is the most abundant genus of May flies in the collections Although the several species were grouped in Figure 4, the genus exhibits well-defined peaks and lows The peak occurs during April, and this peak, which is accompanied by the presence of the genus Epeorus, is primarily responsible for the April high for Ephemeroptera.

Pseudocloeon sp. and Baetis sp. These two genera were combined because of the impossibility of separating early instar nymphs. Most of the mature nymphs sorted belonged ~~to the genus Pseudocloeon. These genera at-~~ tain peaks in April and September and are relatively abundant during the summer months. They are least abundant from October through February (Fig. 5).

Epeorus spp. Epeorus, the third most abundant genus of May flies, is represented by the unidentified nymphs of several species. The peak of abundance of the nymphs occurs during March and April, with well-defined lows during September, October, and November (Fig. 6).

Stenonema Spp. Nymphs of this genus, represented by *S. pudicium, S. carolina*. and *S. annexum* in the adult collections, are very abundant during September, October, and November and are at a very low level from December through June (Fig. 7).

Baetisca carolina. This species, although not abundant in the samples, exhibited a well-defined peak during November, after which none were collected in the samples until the following April (Fig. 8).

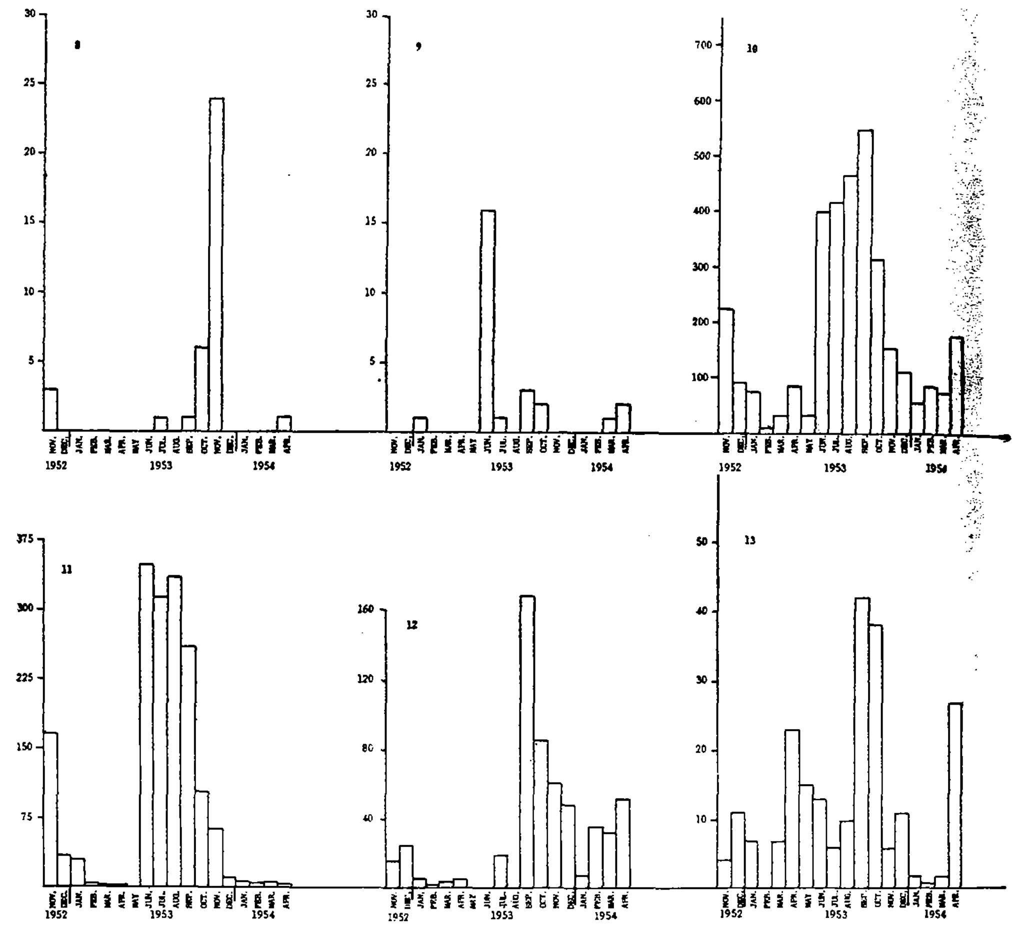
Isonychia sp. This genus, represented by several species (adults of *I. thalia, I. georgiae,* and *I. aurea* were collected), exhibited a peak during June. A few specimens were picked up sporadically during other months of the year (Fig. 9).

Trichoptera

Many larvae could not be assigned to definite species because of the lack of definite characters and the fact that relatively few adult Trichoptera from the Southern Appalachians have been associated with the larvae.

Caddis flies were the second most abundant order and represented 21.8 per cent of the total collections (Table III). This group was the most diverse order, and twenty different genera were identified from the collections.

Caddis-fly larvae build up to a high population during June and maintain this level until the peak is reached in September (Fig. 10). During this same period, the caddis flies are the dominant order in the combined



FIGS. 8–13. Total number of nymphs or larvae of aquatic insects collected per month from streams of Cowetta Experimental Forest. FIG. 8. *Baetisca carolina* FIG. 9. *Isonychia spp.* FIG. 10. Trichoptera larvae. FIG. 11. *Brachycentrus sp.* FIG. 12. *Cheumatopsyche spp.* FIG. 13. *Trentonius distinctus.*

collections (Table III). The order is at its lowest abundance during January, February, March, and April.

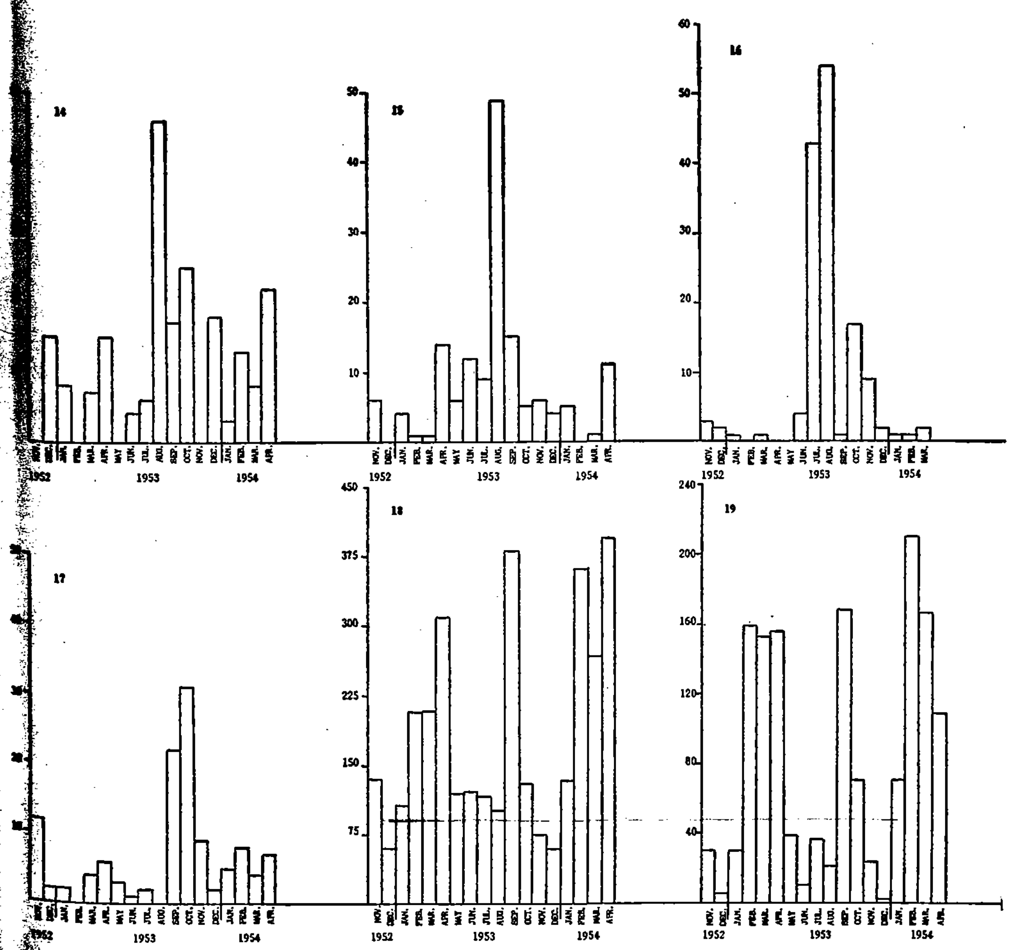
Brachycentrus sp. This is the most abundant caddis fly collected from the Coweeta Forest streams. Using Ross (1944), these specimens were all identified as *Brachycentrus numerous;* however no adults of this species were collected at Coweeta. The only adult member of the genus collected was *Brachycentrus spinae* Ross. The species exhibits a definite seasonal fluctuation and is most abundant in the stream during June through September, which coincides with the abundance for the whole order (Figs. 10 and 11). The species apparently emerges during early fall, and few larvae are collected from December through May.

Pneumatopsyche spp. This, the second most abundant genus of caddis flies, exhibits a definite peak during September, and after some fluctuation declines to a low during January. Few specimens are taken during the spring and summer (Fig. 12).

Trentonius distinctus. The larvae of this species exhibits two fairly well-defined peaks of abundance, one during April and another in September (Fig. 13). This corresponds with the reported production of adults during the entire year (Ross, 1944).

Diplonectra modesta. The larvae of this species fluctuates rather erratically, with a well-defined peak during August (Fig. 14). In other areas, the emergence is reportedly confined to spring and early summer (Ross, 1944). In the small, cold Coweeta streams, most of the adults appear to emerge during early fall.

Glossosoma nigrior. The larvae of this species also exhibits a well-defined peak during August



FIGS. 14–19. Total number of larvae of aquatic insects collected per month from streams of Coweeta Experimental Forest. FIG. 14. *Diplonectra modesta.* FIG. 15. *Glossosoma nigrior.* FIG. 16. *Hydropsyche* FIG. 17. *Rhyacophila fuscula.* FIG. 18. Diptera. FIG. 19. *Simulium sp.*

but are not abundant in samples during the remainder of the year (Fig. 15).

Hydropsyche sp. Identifying larvae of this genus to the species level with certainty is difficult. However, the indication is that only one species (*Hydropsyche sparna*) was represented in the collections. Larvae of the genus exhibit a well-defined high during July and August, but are scarce during the remainder of the year (Fig. 16).

Rhyacophila fuscula. This very distinctive species was never abundant in the Coweeta streams. The larvae reached their peak in the stream samples during September and October (Fig. 17).

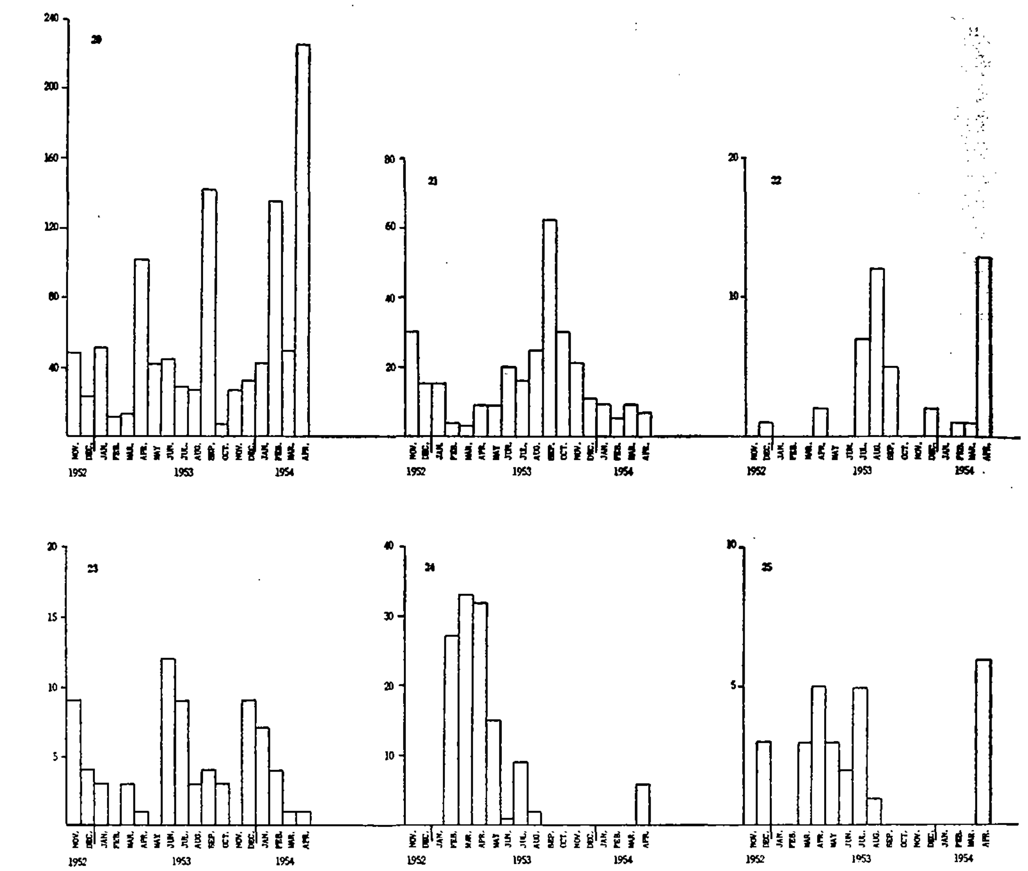
Diptera

The two-winged flies exhibit two major periods of abundance—in September and during the early spring months of February, March, and April (Fig. 18). This group becomes abundant earlier in the year than any of the other orders and is the dominant group in the collections during January, February, and March (Table III).

Simulium sp. Black-fly larvae were the most abundant two-winged flies collected in the samples. Their seasonal distribution is almost identical with that for the order (Figs. 18 and 19).

Tendipedidae. Members of the midge family, Tendipedidae, were the second most abundant group of two-winged flies. Not all of these specimens have been identified to date; however, the majority of midge larvae collected belong to the subfamily Hydrobaeninae. Again, the seasonal distribution of this group coincides closely with that for the order (Figs. 18 and 20).

Atherix variegata. This fly, a member of the snipe-fly family, Rhagionidae, was very abundant in the samples. The species is most



FIGS. 20–25. Total number of larvae of aquatic insects collected per month from streams of Coweeta Experimental Forest. FIG. 20. Tendipedidae FIG. 21. *Atherix variegata.* FIG. 22. *Blepharocera tenuipes.* FIG 23. *Tipula spp.* FIG. 24. *Antocha sp.* FIG. 25. *Protoplasa fitchii.*

abundant during September and the least abundant during February and March (Fig. 21).

Blepharocera tenuipes. This species reached its maximum abundance in the samples of February, March, and April of 1953 (Fig. 24). A few specimens were collected in the sampling from May through August and then the species was absent from the samples until April, 1954.

Tipula spp. This genus is represented by *Tipula abdominalis* and an unknown tipulid which may be *Tipula* (*a*). *williamsiana,* the adults of which were collected in the area. These two species were the largest two-winged fly larvae in the collections. Seasonal distribution was erratic with highs during November, 1952, June, 1953, and December, 1953 (Fig. 23).

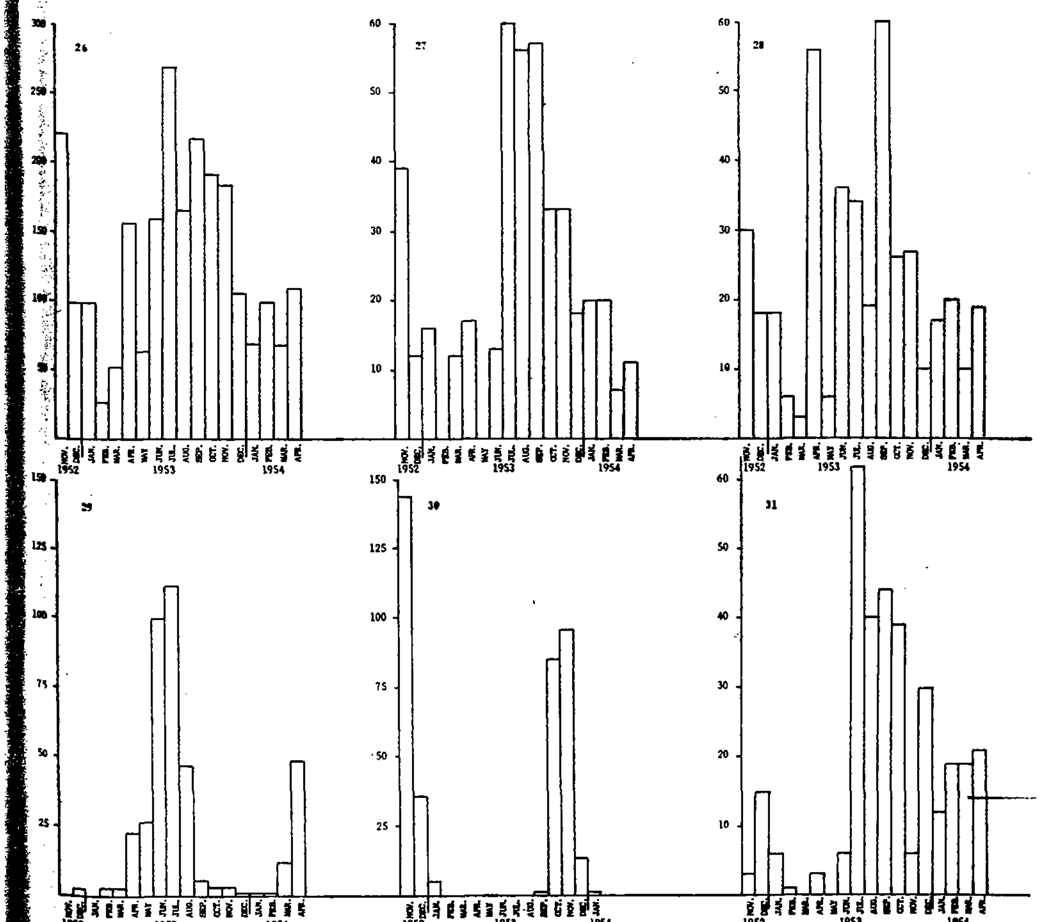
Antocha sp. This genus was not abundant in the samples and the largest number of specimens were collected during July, August, and April (Fig. 22).

Protoplasa fitchii. The larvae of this species were present in small numbers from March through August (Fig. 25).

Plecoptera

Stone flies ranked fourth in abundance among the orders of aquatic insects present in the samples (Table III). During November and December they were the dominant order in the total collections. The group reaches its maximum numbers in the samples during July and was at a high level from May through November (Fig. 26).

Peltoperla maria. This very distinctive stonefly nymph was the dominant species in the order. The species reaches its greatest abundance in the samples during July, August, and



FIGS. 26–31. Total number of nymphs of aquatic insects collected per month from streams of Coweeta Experimental Forest. FIG. 26. Plecoptera. FIG. 27. *Peltoperla maria.* FIG. 28. *Pteronarcys scotti.* FIG. 29. *Leuctra sp.* FIG. 30. *Taeniopteryx maura.* FIG. 31. *Acroneuria abnormis.*

September and is at a low level from December through June (Fig. 27).

Pteronarcys scotti. This stone fly was almost as abundant as *P. maria* and is the largest aquatic insect collected from Coweeta streams. Fully developed specimens reach a length of almost two inches. *P. scotti* nymphs require more than one year for development and the seasonal distribution is erratic, with highs during April and September (Fig. 28).

Leuctra sp. Some nymphs of this genus can probably be assigned to *Leuctra sara*, the adults of which were collected during February and April. The nymphs are very abundant in Coweeta streams with well-defined peaks of abundance during June and July (Fig. 29). Few specimens were collected during the fall and winter.

Taeniopteryx maura. The nymphs of another abundant stone fly, *T. maura,* reach their peak of abundance during October and November and are completely absent from the samples from February through August (Fig. 30). This species apparently emerges in midwinter and the adults are abundant during January.

Acroneuria abnormis. This stone-fly nymph is exceeded in size only by *P. scotti.* The nymphs are abundant in the streams from July through October with the peak in July (Fig. 31).

Brachyptera fasciata. The nymphs of this stone fly, similar in appearance to *T. maura,* occur somewhat later than *T. maura* and are abundant during December and January (Fig. 32). The nymphs are completely absent from most of samples from February through November.

A number of other stone flies were collected in the samples but were not present in sufficient numbers to measure their seasonal distribution.

Coleoptera

Because the adults and larvae of aquatic beetles were not recorded separately in some samples, it is not possible to compare the seasonal distribution of the larvae.

The largest collections of beetles occurred during the months of September, October, and November (Fig. 33). The beetle fauna was composed almost entirely of two species—*Anchytarsus bicolor* and *Heterlimnius ovalis.*

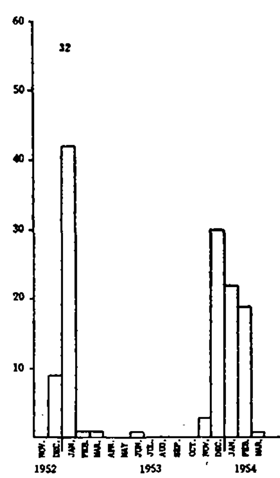
Odonata

The only dragonfly nymph collected from Coweeta streams was a member of the genus Lanthus. This nymph was not abundant and comprised only 0.3 per cent of the entire collections (Table III).

Summary

A total of 267 square-foot samples were collected over an eighteen-month period at three sampling stations on Shope and Ball Creeks, Coweeta Experimental Forest, Macon County, N. C. These streams had low standing crops of bottom fauna and the monthly average ranged from a low of 19.2 organisms per square foot during February to a high of 93.1 organisms per square foot during September.

The average monthly volume ranged from a low of 0.14 cc. during February to a high of 0.86 cc. during June. There were two peaks in the numerical abundance of the bottom organisms with the major peak in September and



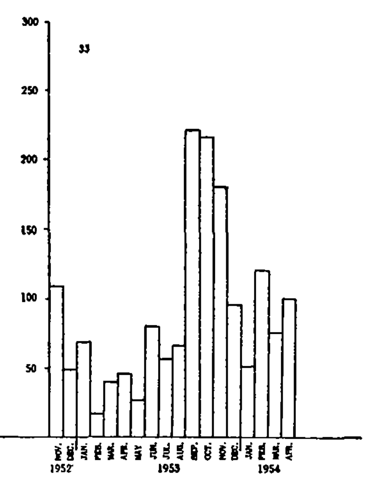


FIG. 32. Total number of nymphs of *Brachyptera fasciata* collected per month. FIG. 33. Total number of Coleoptera larvae and adults collected per month.

a lesser peak during April. Bottom organisms were least abundant during December and January in Shope and Ball creeks.

The three orders Ephemeroptera, Trichoptera, and Diptera—in that rank—comprised approximately three-fourths of the total collection. The remaining one-fourth was composed of Plecoptera and Coleoptera. Odonata and Oligochaetes comprised less than 1 per cent of all organisms collected.

There was considerable variation in the species composition during different months of the year. Trichoptera were dominant from June through October, Plecoptera during November and December, Diptera during January and February, and Ephemeroptera from March through May.

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BRYOPHYTES OF THE PRIMEVAL FOREST

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The vast primeval forest of the Blue Ridge, extending from northern Alabama and Georgia to New York, has almost disappeared. It seems important to record in as much detail as possible the composition of that forest before all traces of it are lost.

A remnant of the primeval hemlock-hardwood forest, about 30 acres, still survives 4½ miles east of Highlands, N. C., on U. S. Highway 64. The tract is part of the original Ravenel Forest, and now belongs to Mr. Henry Wright and his brother. It is part of the area studied by Oosting & Billings (1939). These authors have adequately described the vascular vegetation of the forest, thus giving an ideal foundation for the study of the bryophytes in relation to the communities of higher plants.

The area studied by Oosting and Billings was "roughly 1½ mile by 1 mile in extent," not burned, grazed, or cut. "From nearby elevations, the general aspect of the forest is that of a continuous hemlock stand."

The forest lies at about 35° 2′ N; elevation 4,400 feet. Temperatures at Highlands are mild, the January and July means being 39.7°F. and 70.4°F. respectively. The average precipitation is 79.77 inches, quite evenly distributed throughout the year. By months the averages are:

Jan.	7.37 inches	July	9.38 inches
Feb.	6.25	Aug.	7.98
Mar.	8.73	Sept.	5.33
Apr.	5.90	Oct.	4.86
May	5.11	Nov.	5.43
June	6.35	Dec.	7.58

Frequency and duration of droughts are important for plants, especially for epiphytic plants (Barkman, 1958). Van Bavel and Verlinden (1956) state that "in the mountains [of North Carolina] drought is non-existent in April, almost so in May, and rises to an expectancy of about 15 per cent in June and then becomes extinct again for the remainder of the season [April through September]."

It is interesting and sometimes useful to try to correlate the plant communities with environmental conditions (as shown by climatic and edaphic data) and historical relations both short term and long. But I have long believed that the plant community gives a better summation of all of the factors than the most precise instruments or the most competent