

FINAL REPORT

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Production of Benthic Macroinvertebrates
in the New River at Sandstone Falls in 1987

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EXECUTIVE SUMMARY

The secondary production of the dominant benthic macroinvertebrates was measured in the New River at Sandstone Falls from June through November 1987. The purpose of this study was to establish baseline data on the levels of production and the factors affecting production in a year without applications of Bti for black fly control. The results of this study are intended to serve as comparisons in future years when Bti is applied in the New River Gorge National River. Total production on the rock outcrops at Sandstone Falls was 30.8 g/m^2 . This level of production is similar to what has been reported for streams of about the same size as the New River. Production at Sandstone Falls was considerably lower than previous measurements at Bluestone Dam (330.7 g/m^2 in 1983 and 173.9 g/m^2 in 1986). Water temperature and the amount of habitat provided by the submerged macrophyte Podostemum were approximately the same at both sites. The most likely reason for lower production at Sandstone Falls was lower concentrations of seston (suspended particulate organic matter), which provides the major source of food for many of the organisms in the New River. Abundant quantities of energy-rich seston are released from Bluestone Lake, but this material probably settles out in pools or is consumed by the biota as it passes downstream. Of the total production at Sandstone Falls, mayflies accounted for 51%, chironomids 34%, caddisflies 10%, and black flies only 5%. At Bluestone Dam prior to treatment with Bti (1983), the relative contributions of the various taxa to total production was considerably different: chironomids 72%, caddisflies 20%, black flies 8%, and mayflies only <1%.

INTRODUCTION

From May through September 1986, the West Virginia Department of Natural Resources (WVDNR) applied the bacterial pesticide Bacillus thuringiensis israelensis (Bti) to the New River in order to control populations of the black fly Simulium jenningsi. These applications were restricted to the sections upstream from the Route 20 bridge, but effects of the pesticide were measured farther downstream within the New River Gorge National River boundary (Voshell et al. 1987a). A comparison of the production of the dominant benthic macroinvertebrates below Bluestone Dam indicated that production in 1986 was only 53% of what it had been in 1983, when there were no pesticide applications (Voshell et al. 1988). The reduced production was observed for taxa other than black flies, and the pesticide applications appeared to be at least partially responsible. There was no black fly pest management program in 1987, but it was anticipated that the program would be resumed in 1988 and would continue for at least several years. It was also anticipated that the pesticide applications would extend as far downstream as Sandstone Falls, well into the boundaries of the New River Gorge National River.

In order to properly manage the valuable natural resource under its jurisdiction, the U.S. National Park Service (NPS) has initiated a detailed ecological monitoring program in the New River to assess any possible adverse impacts from the black fly pest management program. The purpose of the study reported in this document was to establish baseline data at Sandstone Falls during a year when there were no pesticide applications, which could then be used for comparison with future years when Bti would be applied.

In recent years there have been three studies in the New River that included quantitative analyses of the benthic macroinvertebrates at Sandstone Falls. Voshell (1983) conducted a summer survey that dealt only with black flies. Kondratieff and Voshell (1983) reported on the food habits of invertebrate predators, but included analyses of benthic macroinvertebrate community structure. Their description of the community structure was based on a composite of samples taken from different habitats during the summer. Virginia Polytechnic Institute and State University (1985) conducted a survey that included summer and winter sampling that was stratified according to three habitats: rock outcrops, cobble/pebble riffles, and Justicia. The latter study also included analyses of water quality, seston, and macrophytes. Results of all of these studies were summarized by Voshell et al. (1987b).

The objectives of this study were as follows:

- 1) Measure the secondary production of the dominant insect taxa occurring on the rock outcrops at Sandstone Falls from June to November 1987;
- 2) Analyze water quality, food, and habitat in order to consider the factors other than Bti applications that might affect secondary production;
- 3) Determine the function of the dominant insect taxa as potential prey by measuring their production levels;
- 4) Determine the function of the dominant insect taxa in detritus processing by measuring their consumption and egestion levels;
- 5) Extrapolate the results to the reach of the New River that is similar to the study site at Sandstone Falls.

STUDY SITE

This study was conducted in the area of the New River immediately above Sandstone Falls, 16 km below Bluestone Dam. Just below the site, the New River drops approximately 8-10 m over Sandstone Falls. The river is shallow enough to be wadable (0.1-1.0 m) during summer flow conditions for approximately 0.8 km upstream from the falls. From that point upstream a distance of 3.7 km, the river is almost a continuous deep pool with very little current. The Sandstone Falls study site is delimited as the 0.8-km reach of shallow, flowing waters above the falls. The width of this section is approximately 300 m. The substrate in this area consists almost entirely of rock outcrops, with only a few small cobble/pebble riffles adjacent to both banks. There are two major aquatic macrophytes: the submerged Podostemum ceratophyllum (river weed) that grows on the rock outcrops and the emergent Justicia americana (water willow) that grows along the banks and a few small islands. The rock outcrops often have dense growths of filamentous algae during the summer months.

The New River is a 6th order stream at Sandstone Falls, the same as at Bluestone Dam. There are 12 tributaries between Sandstone Falls and Bluestone Dam. Eleven of these are very small streams, but the Greenbrier River, which enters from the east 1 km below Bluestone Dam, contributes 29% of the annual discharge below the confluence. At the Hinton gauge, which includes the contribution of the Greenbrier, the 50-yr average (1936-86) mean daily discharge for the New River has been 7,889 cfs. During this 50-yr period the maximum mean daily discharge was 246,000 cfs on Aug 15, 1940 and the minimum was 620 cfs on Nov 3, 1981. Water temperatures at Sandstone Falls range from 0 to 28.5

°C, with dissolved oxygen ranging from 6.8 to 13.2 mg/liter. This area is used for sport fishing, but not as heavily as the area immediately below Bluestone Dam. Crayfish are harvested for bait, primarily at night when they move to small pools and eddies among the rock outcrops for molting.

METHODS

Environmental Characteristics

Discharge at Sandstone Falls was considered to be the same as at the nearest gauging station at Hinton, and data were obtained from the Huntington District of the U.S. Army Corps of Engineers. The Hinton Gauge is located 13 km upstream from the Sandstone Falls sampling site, but the flows of the tributaries that enter the New River in that reach are insignificant in comparison to the flows of the New and Greenbrier Rivers upstream from the gauge. Temperature was recorded continuously with a thermograph (Ryan Instruments Model J) placed at Sandstone Falls from July through December 1987. In addition, temperature was recorded manually with a long-stem thermometer on each date that samples were collected. The temperature data were used to calculate cumulative degree-days above 0 °C. Conductivity and pH were measured with separate meters (YSI Model 33 and Fisher Model 640, respectively). The pH meter was equipped with universal and calomel reference electrodes. The azide modification of the Winkler technique (American Public Health Association et al. 1981) was used to determine the amount of dissolved oxygen. The organic seston concentration was determined by standard methods that included filtering a measured volume of water (about 1 liter) through a pre-ashed (500°C for 1 hr) and preweighed glass fiber filter. The filter was then dried at 60°C for 24 hrs, weighed (dry weight), heated to 500°C for 1 hr, wetted to replace water of hydration, dried again at 60°C for 24 hrs, and reweighed (ash dry weight). The concentration of organic seston was calculated as the difference between the dry weight and ash dry weight (ash-free dry weight or loss on ignition). The biomass of the dominant submersed macrophyte on the rock outcrops (Podostemum) was determined by removing all pieces of the plant contained in each macroinvertebrate sample (described below) then drying (60°C for 24 hrs) and weighing (dry weight) the material.

Production

Seven taxa dominated the benthic macroinvertebrate fauna on the rock outcrops at Sandstone Falls and occurred at sufficiently high densities to measure production. These included three mayflies (Ephemeroptera), Baetis intercalaris (Baetidae), Serratella deficiens (Ephemerellidae), Tricorythodes spp. (Tricorythidae); two caddisflies

(Trichoptera), Cheumatopsyche campyla (Hydropsychidae), Oecetis spp. (Leptoceridae); and two true flies (Diptera), Simulium jenningsi (Simuliidae), Chironominae/Orthocladiinae (Chironomidae). Simulium jenningsi is the black fly that is the object of the pest management program. The Chironominae/Orthocladiinae are a combination of two subfamilies of nonbiting midges, which are difficult to identify and quantify at any lower taxonomic level (genus or species).

The design and methods for measuring the production of benthic macroinvertebrates were the same as those used in previous studies in the New River at Bluestone Dam (Voshell 1985, Voshell et al. 1988) in order to facilitate long-term monitoring. Samples were collected every two weeks from June through November (June 8, June 22, July 13, July 27, August 10, August 24, September 7, September 21, October 5, October 19, November 2, November 16, and November 27). The study was begun in June because this was the earliest that flows were low enough to permit sampling and ended in November because that was the latest that S. jenningsi larvae had been found in the New River during previous studies. A stratified random design was employed with a single sampling stratum, mats of Podostemum on rock outcrops. Ten 0.01-m² samples were taken on each occasion with the Rock Outcrop Community Sampler (ROCS) that was designed specifically for New River studies (Voshell 1985). Samples were preserved in 5% formaldehyde and returned to the laboratory for sorting, identification, enumeration, measuring, and weighing. Details of these methods can be found in Voshell (1985). After sorting the organisms from the original sample, the specimens were preserved in 70% ethanol. The delimitation of the size classes or instars can be found in Appendix Table A1 and the mean weights of individuals are presented in Appendix Table A2. All weights were determined from preserved specimens and then corrected for loss of weight due to preservation as described by Voshell et al. (1988): 1.3X for Ephemeroptera, 1.2X for Trichoptera, and 1.4X for Diptera. The size frequency method (Benke 1984) was used to calculate the secondary production of each taxon mentioned above. The method of Krueger and Martin (1980) was used to place 95% confidence limits on those measurements; however, the time compensation equation was removed from the calculations because our sample dates were evenly spaced. All production measurements were reported in units of dry weight.

The procedure of Benke and Wallace (1980) was used to calculate the trophic basis of production. A detailed explanation can be found in Voshell (1985). Because feeding habits were not part of this study at Sandstone Falls, some assumptions had to be made. Taxa at Sandstone Falls that also occurred at Bluestone Dam were assumed to have the same feeding habits as they did at Bluestone Dam (Voshell 1985).

Taxa common to both sites included Baetis intercalaris, Cheumatopsyche campyla, Simulium jenningsi, and Chironominae/Orthoclaadiinae. The two additional taxa of mayflies at Sandstone Falls, Serratella deficiens and Tricorythodes spp., were assumed to have the same feeding habits as Baetis intercalaris (8% diatoms, 1% other algae, 91% fine detritus). Merritt and Cummins (1984) reported that all three genera of mayflies obtain their food partly by scraping algae from rocks and plants and partly by collecting fine detritus from the bottom sediments. Members of the genus Oecetis are known to obtain their food partly by collecting fine detritus and partly by preying on other invertebrates (Merritt and Cummins 1984), therefore, their diet was considered to consist of 50% animals and 50% fine detritus. Slight inaccuracies in these estimates of feeding habits would not be important for the purposes of this study, which were to estimate the overall levels of consumption and egestion by the benthic macroinvertebrate community.

RESULTS

Environmental Characteristics

Results of the physical/chemical analyses of water made on each sampling date are recorded in Table 1. All measurements were within the range that would be expected for flowing surface waters and would present no adverse conditions for aquatic life. Temperature measurements are presented in Fig. 1 as well as Table 1. At the outset of the study in June the temperature was still rising, with a maximum of 28.5°C reached in July, followed by fairly consistent warm temperatures until the end of August, when normal seasonal cooling began. Discharge for all of 1987 is shown in Fig. 2. Bluestone Lake has very little storage capacity and the Greenbrier River is free flowing, hence the discharge follows a normal seasonal pattern. Flows during 1987 (average mean daily discharge = 9,430 cfs) were slightly higher than the 50-yr norm (average mean daily discharge = 7,889 cfs). The standing stock of the submersed macrophyte Podostemum on each sampling date is presented in Fig. 3. This plant, which provides habitat for macroinvertebrates, followed a typical pattern exhibiting the highest standing stock early in the summer and declining thereafter. Some of the environmental characteristics that are most likely to affect production levels are summarized for the period from June through November in Table 2.

Table 1. Physical/chemical properties of the New River at Sandstone Falls from June through November. MD = missing data.

Date	Temp (°C)	Conductivity (umhos)	pH	Oxygen (mg/L)	Seston (mg/L)
8 June 87	23.5	140	7.9	8.3	1.40
22 June 87	27.5	100	7.9	8.3	1.52
13 July 87	27.5	130	8.4	9.2	0.73
27 July 87	28.5	140	8.5	9.2	0.74
10 Aug 87	28.0	180	7.9	6.8	MD
24 Aug 87	27.0	115	8.6	10.9	MD
7 Sept 87	23.0	130	8.0	7.5	MD
21 Sept 87	22.0	145	8.0	8.2	MD
5 Oct 87	15.5	140	8.3	8.3	0.18
19 Oct 87	14.0	135	8.5	11.1	0.20
2 Nov 87	13.5	170	8.9	12.7	0.31
16 Nov 87	9.0	215	8.5	13.2	0.40
27 Nov 87	8.5	130	7.8	9.5	0.60

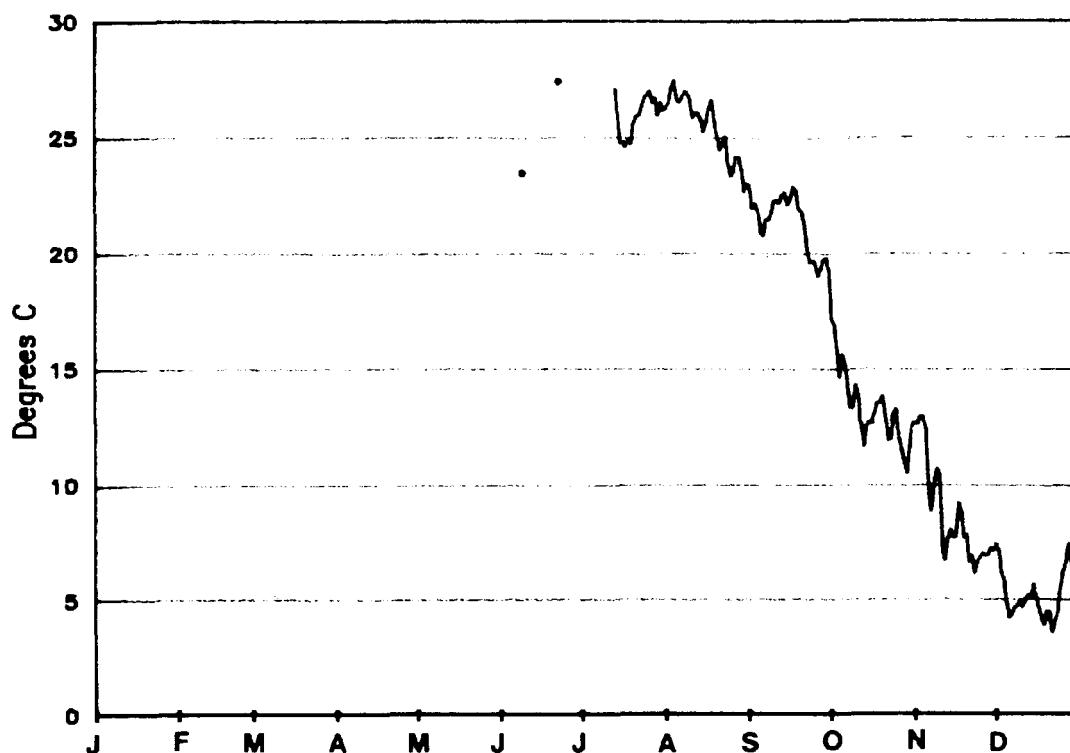


Fig. 1. Temperature of the New River at Sandstone Falls during 1987. The two independent points in June were obtained with a hand-held thermometer before the continuous recording instrument was installed.

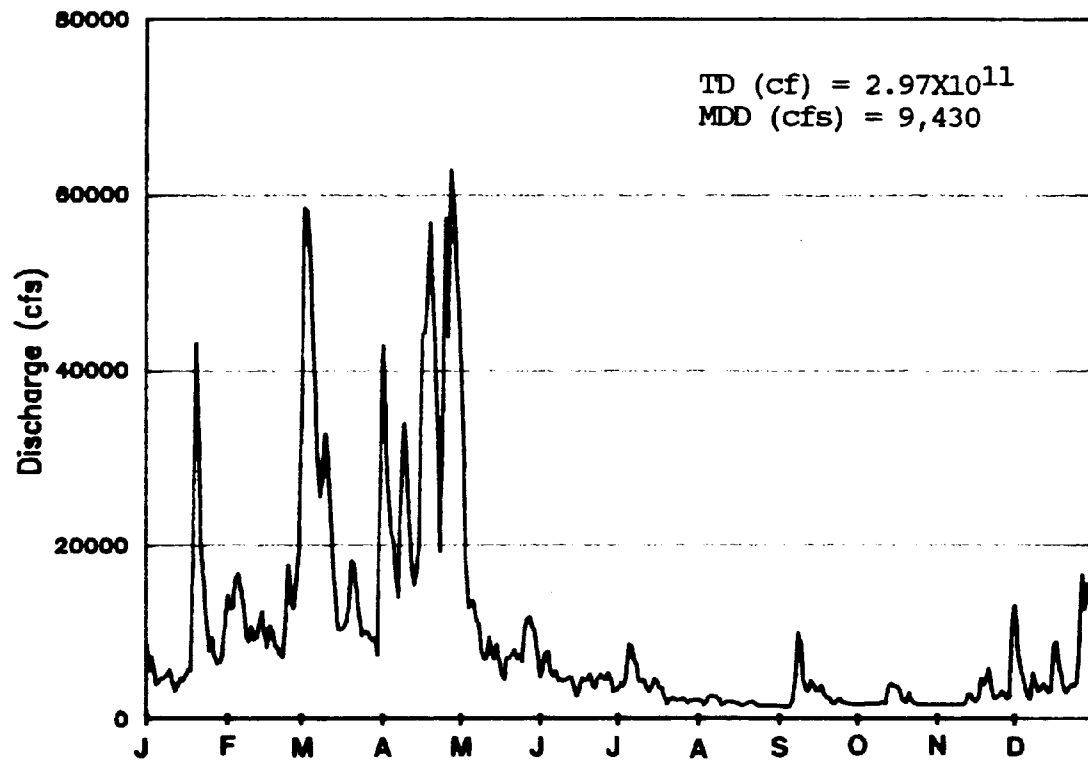


Fig. 2. Discharge of the New River at Sandstone Falls during 1987. MDD = Mean Daily Discharge, TD = Total Discharge for 1987.

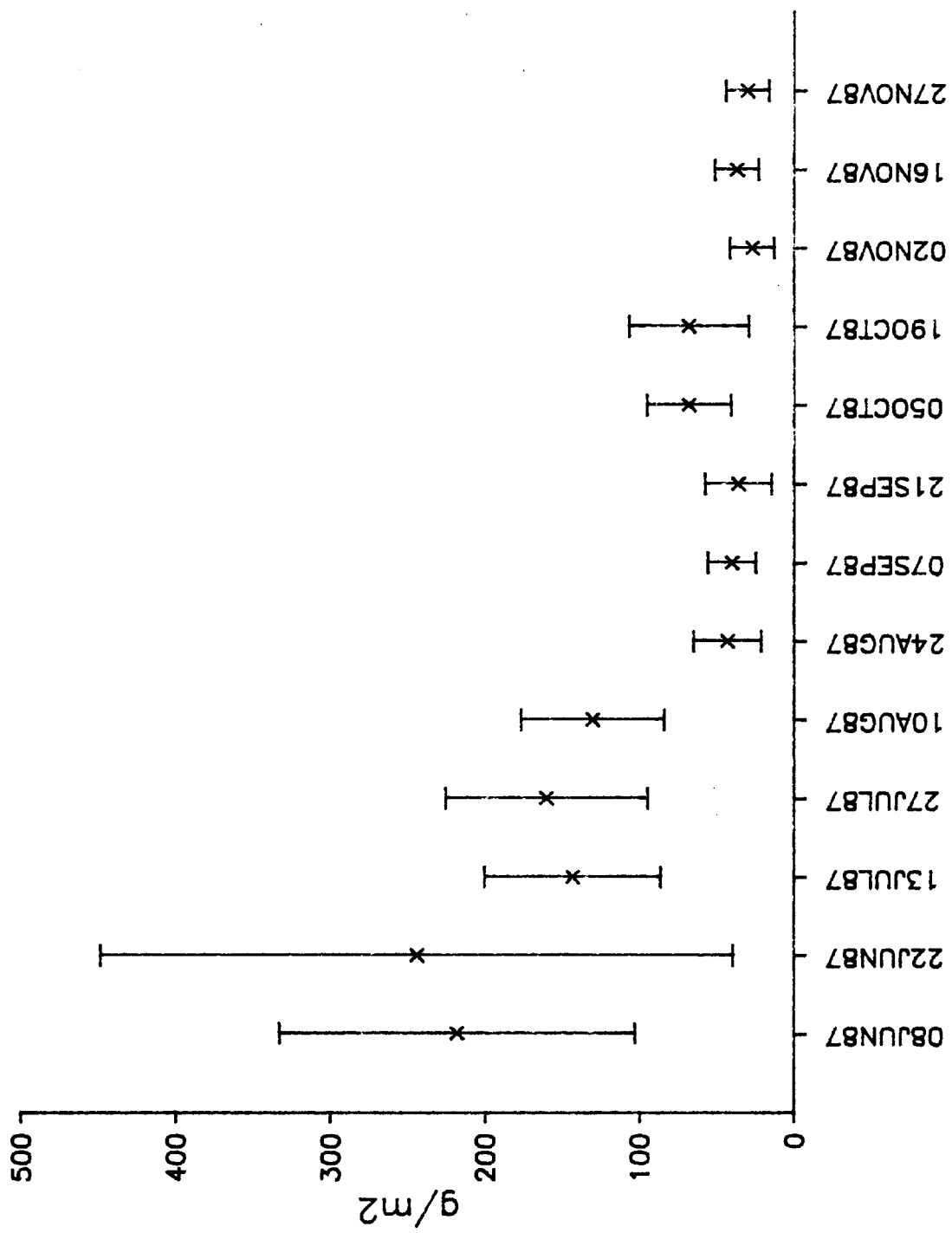


Fig. 3. Mean standing stock, with 95% confidence limits, of Podostemum ceratophyllum on each sample date.

Table 2. Summary of major environmental characteristics of the New River at Sandstone Falls from June through November 1987.

Cumulative degree-days	3680
Mean daily discharge (cfs)	2987
Total discharge (cf)	4.72×10^{10}
Mean <u>Podostemum</u> standing stock (g/m ²)	95
Mean Seston (mg/L)	0.68

Life Cycles and Cohort Production Intervals

Because the duration of this study was only for one-half of a year (June through November), it was necessary to use information from previous New River studies and other studies reported in the scientific literature to elucidate annual life cycles and appropriate cohort production intervals (CPI).

Baetis intercalaris (Appendix Table A3) -- The life cycle appears to be the same at Sandstone Falls as at Bluestone Dam (Voshell 1985): one generation per year, with prolonged recruitment and emergence from June through October. The size frequency distribution indicated no clear peak of emergence followed by recruitment of early instars. There were fairly consistent numbers of individuals in the larger size classes from June through October and in the smaller size classes from June through November. This pattern agrees with other studies in Wisconsin (Bergman and Hilsenhoff 1978) and Virginia (Kondratieff and Voshell 1981b). Although Bergman and Hilsenhoff (1978) and Kondratieff and Voshell (1981b) suggested that this species might diapause in the egg stage over the winter, there is no indication of that life cycle in the New River. At Sandstone Falls there was a distinct increase in the numbers of small size classes during November, indicating that B. intercalaris nymphs are present the entire year. The only time that is considered to be lost from production is the time required for the eggs to hatch and the duration of the subimago and imago stages until oviposition. Murphy (1922) reported that the eggs of B. vagans required 28 days to hatch. The duration of the subimago and imago stages was estimated to total 1 day (Edmunds et al. 1976). The CPI for B. intercalaris was calculated as $365 - 28 \text{ (egg)} - 1 \text{ (subimago, imago)} = 336 \text{ days}$.

Serratella deficiens (Appendix Table A4) -- All members of the family Ephemerellidae are thought to be univoltine (Edmunds et al. 1976, Clifford 1982, Unzicker and Carlson 1982). Clifford (1982) further classified the genus Serratella as having either a seasonal summer cycle (population overwinters in the egg stage with hatching, growth, and emergence in the summer) or a seasonal winter cycle (population overwinters in the nymphal stage with emergence in the spring or summer followed by oviposition, hatching and initiation of growth). In the New River, S. deficiens appears to exhibit a seasonal winter cycle. The largest size class was present from June through September, with the greatest numbers occurring during July. At the end of November the majority of the population was in middle size classes, indicating that there is no egg diapause over the winter. Sweeney and Vannote (1981) studied the life history of S. deficiens in a small stream in Pennsylvania and reported one generation per year with adult emergence

from late May until the first of July and eggs requiring 41 days to develop. The life cycle of S. deficiens at Sandstone Falls in the New River is in general agreement with that reported by Sweeney and Vannote (1981), except that adult emergence and recruitment of smaller size classes appear to be prolonged over the entire summer. Little is known about the duration of the subimago and imago stages. Edmunds et al. (1976) reported that the subimago stage of the closely related genus Ephemerella lasted 22 - 30 hours. Unzicker and Carlson (1982) indicated only that the imago stage of the family Ephemerellidae was "short lived." The CPI for S. deficiens was calculated as $365 - 41 \text{ (egg)} - 1 \text{ (subimago, imago)} = 323 \text{ days}$.

Tricorythodes spp. (Appendix Table A5) -- Most studies of members of this genus report a bivoltine life cycle. In Idaho, the first generation of T. minutus emerges in June and the second in August and September, with overwintering as small nymphs (Newell and Minshall 1978). In Minnesota, overwintering eggs of T. atratus hatch in early June, produce the first generation 5 - 7 weeks later, spend about 30 days as summer eggs, and then produce a second generation with adults emerging until November (Hall et al. 1975, 1980, Edmunds et al. 1976). The life cycle of Tricorythodes spp. in the New River at Sandstone Falls appears similar to that reported for T. atratus. It is clear that winter is spent in the egg stage. The size frequency distribution indicated that the first generation emerged in June and continued into July, but emergence probably began in May prior to sampling for this study. Adults of a species of Tricorythodes "near" allectus were collected in May in Virginia (Kondratieff and Voshell 1981b). Therefore, it was estimated that the overwintering eggs hatched at the end of March. The eggs produced by the first generation probably took about 1 month to develop, then the second generation began emerging at the end of July and continued through October. Although only 1 nymph in the largest size class was collected in October, there were probably a few "stragglers" throughout the month. Records of Tricorythodes spp. being collected in October include: T. stygiatus in Michigan (Leonard and Leonard 1962), T. atratus in Minnesota (Hall et al. 1975), and T. allectus in Virginia (Kondratieff and Voshell 1981b). The duration of the subimago and imago stages are thought to be exceptionally short in this group. Newell and Minshall (1978) found that the subimago stage lasted less than 30 min and imago stage less than 6 hrs. The CPI for Tricorythodes spp. was calculated as $365 - 147 \text{ (1st generation egg)} - 30 \text{ (2nd generation egg)} - 0 \text{ (subimago, imago)} = 188 / 2 \text{ generations} = 94 \text{ days}$.

Cheumatopsyche campyla (Appendix Table A6) -- The life cycle is probably the same at Sandstone Falls as at Bluestone Dam (Voshell 1985): bivoltine, with a spring generation that begins emerging in April, followed by a

summer generation characterized by prolonged emergence and recruitment. The spring generation had already emerged when this study began on June 8. The size frequency distribution indicated that the summer generation emerged from June through August. Recruitment of next year's spring generation began in August, and continued through November, with a peak on October 19. Overwintering was primarily in middle instars. Parker and Voshell (1983) combined information in the literature (Fremling 1960, Rhame and Stewart 1976) with original observations in the North and South Anna Rivers, Virginia to estimate the nonproductive stages of C. parentum as 14 days for eggs, 6 days for pupae, and 1 day for adults until oviposition. The CPI for C. campyla was calculated as $365 - 28$ (both generations egg) - 12 (both generations pupa) - 2 (both generations adult) = $323 / 2$ generations = 161.5 days.

Oecetis spp. (Appendix Table A7) -- The size frequency distribution indicated one generation per year, with emergence throughout the summer. Fourth and fifth instar larvae were collected from June through August. Although no first instars were collected, second instar larvae began to appear in September and continued through November. Most of the population overwintered in middle instars. No information on the life history of members of this genus could be found in the literature for comparisons. Unzicker et al. (1982) reported that all members of the family Leptoceridae have univoltine life cycles. Resh (1976a,b) conducted detailed studies of several species in the related genus Ceraclea and found that eggs hatch in 1 - 3 weeks, pupae develop in 21 days at 21°C, and less than 2% of adults live longer than 2 days. The CPI for Oecetis spp. was calculated as $365 - 14$ (egg) - 21 (pupa) - 2 (adult) = 328 days.

Simulium jenningsi (Appendix Table A8) -- Previous studies in the New River at Bluestone Dam indicated that this species produced five generations per year: April, June, July, August, and September (Voshell 1983). In this study at Sandstone Falls, the first generation probably emerged before sampling began, and the high proportion of seventh instar larvae collected on June 8 reflected the emergence of the second generation. A third generation followed in July and a fourth in early October. The size frequency distribution showed no indication of a generation in August, thus, there was one less generation at Sandstone Falls than at Bluestone Dam. The fourth generation produced eggs that diapaused over winter, because there were no early instars collected after October. Voshell (1985) reviewed the applicable literature on the biology of black flies (Brenner and Cupp 1980, Peterson 1981, Wenk, 1981, Choe et al. 1984) to arrive at the following conservative estimates

for the durations of the life stages of S. jenningsi: pupa, 4 days; adult, 3 days; summer egg, 4 days; winter egg, 90 days. The CPI for S. jenningsi was calculated as $365 - 12$ (summer egg) $- 90$ (winter egg) $- 16$ (pupa) $- 12$ (adult) $= 235 / 4$ generations $= 58.8$ days.

Chironominae/Orthocladiinae (Appendix Table A9) -- Because of the collective designation of chironomid larvae as two subfamilies, which contain many species, it was not possible to determine life cycles from the size frequency distribution. Voshell (1985) used applicable information from the literature (Mackey 1977, Benke et al. 1984, Layton 1985) to estimate the CPI at Bluestone Dam as 24.3 days. This is a conservative estimate because studies have shown that some chironomids produce a generation in only 8 days (Benke et al. 1984). Until studies are conducted at lower taxonomic levels (genus or species) in the New River, the CPI for Chironominae/Orthocladiinae will be estimated as 24.3 days.

Standing Stock

The standing stock (biomass) of each taxon on each sampling date can be found in Appendix Tables A3 - A9, and these data are summarized in Figs. 4 and 5. The total standing stock was considerably higher during June and July than at any other times during the study (Fig. 4). Cheumatopsyche campyla and the three species of mayflies accounted for the majority of the biomass during June and July (Fig. 5). The three species of mayflies have been grouped together because of their ecological similarities. The standing stock of C. campyla decreased markedly by the end of July, but the standing stock of the mayflies increased progressively during this period and on 27 July they accounted for almost all of the total biomass. Tricorythodes spp. exhibited much higher standing stock than any other mayfly, and on 27 July this taxon exhibited the highest value of any encountered during the study at Sandstone Falls (Appendix Table A5). Mayflies continued to be the dominant organisms in terms of biomass until November when chironomids became the dominant organisms (Fig. 5). Cheumatopsyche campyla contributed a significant portion of the total biomass on 24 August, coinciding with the peak emergence of the summer generation and recruitment of the next spring generation (Appendix Table A6). Simulium jenningsi did not comprise a major portion of the standing stock at any time during the study (Fig. 5). The highest standing stock of S. jenningsi occurred during June and early July, with a slight increase again during early October (Appendix Table A8).

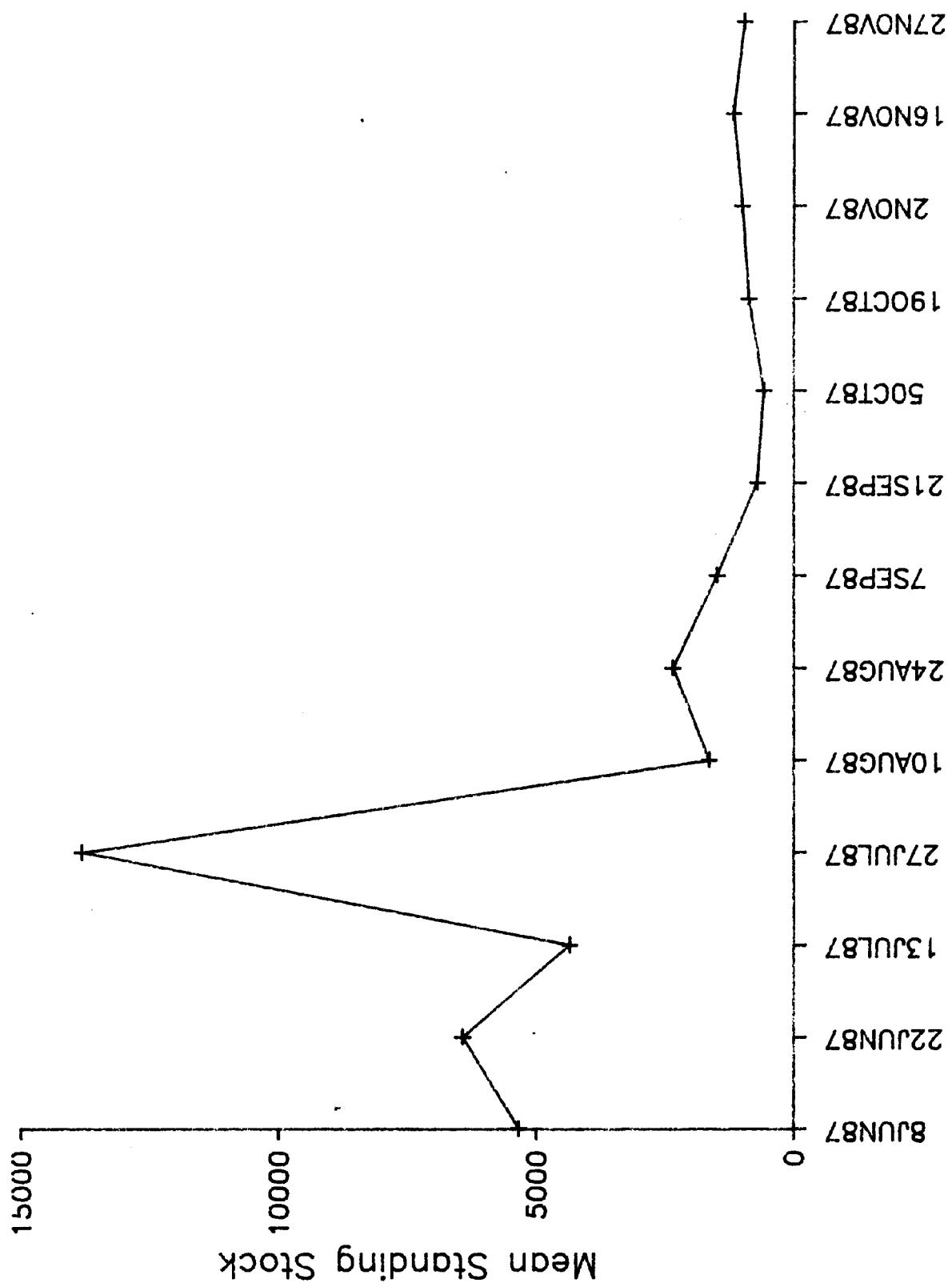


Fig. 4. Mean total standing stock of dominant aquatic insects on each sample date.



Fig. 5. Temporal trends for the relative contributions of the four most abundant taxa to the mean total standing stock biomass.

Production

Production calculations for each taxon are included in Appendix Tables A10 - A16. The values for all taxa are summarized in Table 3 and compared in Fig. 6. The total production for all taxa on the rock outcrops at Sandstone Falls from June through November was 30,759 mg/m². The mayfly Tricorythodes spp. was the highest producing organism, accounting for almost one-half (46.2%) of the total. Together, the three species of mayflies elaborated approximately one-half (51.0%) of the total production. Chironomids in the subfamilies Chironominae/Orthocladiinae were the second highest producers (34.0%). Of the remaining 15% of the total production, Cheumatopsyche campyla contributed 9.8%, Simulium jenningsi 4.9%, and Oecetis spp. 0.3%.

Ecosystem Function

In this study we are considering "function" to mean the roles of particular organisms in ecosystem dynamics, and we are limiting our considerations to functions in trophic dynamics. Determining the trophic basis of production (Benke and Wallace 1980) provides insight into how much organic matter is necessary to support the observed levels of production (consumption) and how much organic matter passes through the biota unused (egestion). The detailed calculations for the trophic basis of production are presented in Appendix Table A17. The major results of these calculations are summarized in Table 4. The total production of the dominant aquatic insects was achieved by consuming 607.9 g/m², of which 546.4 g/m² was egested as detritus that could be used again as food.

The best approach for considering the function of these particular organisms in the overall New River ecosystem is to extrapolate the results from mass per unit area of stream bottom to total mass in the reach of the New River under study. We believe that the results of this study can be extrapolated validly to the reach of river extending 0.8 km upstream from the falls (see Study Site). The total area of rock outcrops that provide suitable habitat in this reach was calculated to be 0.171 km² by means of the following estimates: length = 0.8 km; width = 0.300 km; shallow area with current = 75% of total; outcrop = 95% of shallow area with current. The total production, consumption, and egestion of all taxa on the rock outcrops in the vicinity of Sandstone Falls are summarized in Table 5 in units of metric tons (1 metric ton = 1000 kg = 2205 lb). The most important observation that should be made from Table 5 is that the dominant aquatic insects on the rock outcrops in the vicinity of Sandstone Falls consume 113.95 metric tons of food (primarily fine detritus and algae) and egest 93.43 metric tons of fine detritus in the form of their feces.

Table 3. Production statistics for dominant aquatic insects on rock outcrops in the New River at Sandstone Falls from June through November. P = Production (mg/m^2); N = Mean density (# individuals/ m^2); B = Mean standing stock (mg/m^2).

Taxa	Year	P	95% Conf. Limits	N	B	P/B
<u>Baetis</u> <u>intercalaris</u>	1987	1,087	975-1,200	5,132	403	2.7
<u>Serratella</u> <u>deficiens</u>	1987	388	337-439	1,862	175	2.2
<u>Tricorythodes</u> spp.	1987	14,197	12,037-16,357	6,695	1,268	11.2
<u>Cheumatopsyche</u> <u>campyla</u>	1987	3,026	2,595-3,457	2,838	673	4.5
<u>Oecetis</u> spp.	1987	100	77-122	325	35	2.9
<u>Simulium</u> <u>jenningsi</u>	1987	1,497	1,223-1,771	1,811	101	14.8
Chironominae/ Orthocladiinae	1987	10,464	9,681-11,247	20,802	470	22.3
Total	1987	30,759		39,465	3,125	9.8

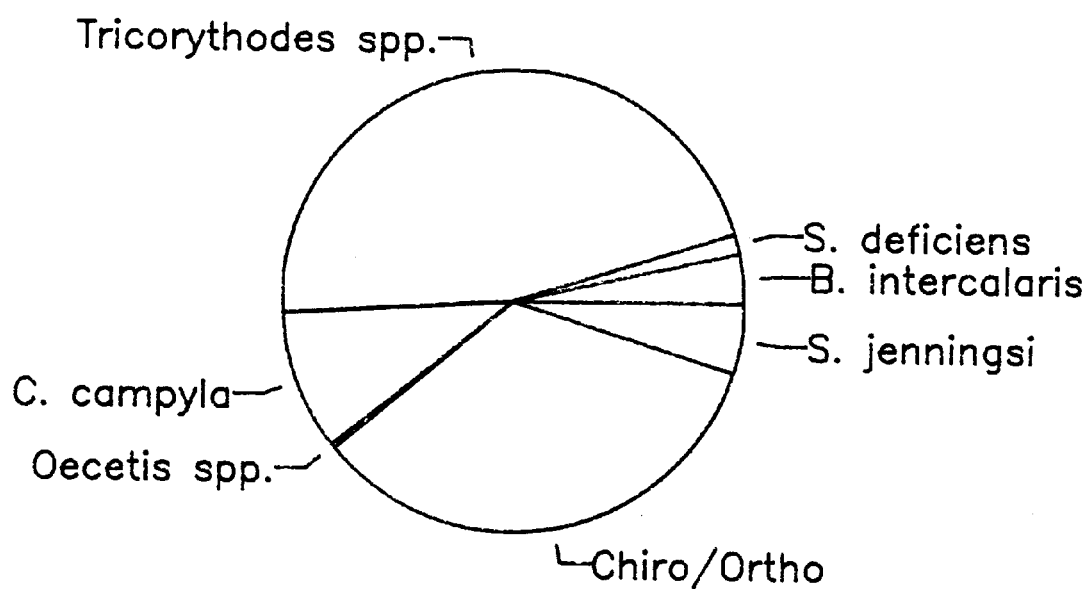


Fig. 6. Proportion (%) of total production contributed by each taxon of dominant aquatic insects at Sandstone Falls in 1987.

Table 4. Production, consumption, and egestion (all in g/m²) on the rock outcrops at Sandstone Falls from June through November.

	Year	Production	Consumption	Egestion
<u>Baetis intercalaris</u>	1987	1.1	18.4	16.3
<u>Serratella deficiens</u>	1987	0.4	6.6	5.8
<u>Tricorythodes</u> spp.	1987	14.2	240.6	212.2
<u>Cheumatopsyche campyla</u>	1987	3.0	37.4	31.3
<u>Oecetis</u> spp.	1987	0.1	.5	.3
<u>Simulium jenningsi</u>	1987	1.5	50.7	47.8
Chironominae/Orthocladiinae	1987	10.5	253.7	232.7
Total	1987	30.8	607.9	546.4

Table 5. Extrapolation of total production, consumption, and egestion (all in metric tons) for the 0.8 km section of the New River above Sandstone Falls from June through November.

	Year	Production	Consumption	Egestion
<u>Baetis intercalaris</u>	1987	0.19	3.15	2.79
<u>Serratella deficiens</u>	1987	0.07	1.13	0.99
<u>Tricorythodes</u> spp.	1987	2.43	41.14	36.29
<u>Cheumatopsyche campyla</u>	1987	0.51	6.40	5.35
<u>Oecetis</u> spp.	1987	0.02	0.09	0.05
<u>Simulium jenningsi</u>	1987	0.26	8.67	8.17
Chironominae/Orthocladiinae	1987	1.80	43.38	39.79
Total	1987	5.27	113.95	93.43

DISCUSSION

The results of this study are intended primarily to provide a baseline for comparison when black fly pest management is implemented in the vicinity of Sandstone Falls and for monitoring long term trends. The 1987 production results by themselves are difficult to interpret because there are few comparisons that can be made. There have been very few studies of the total production of the benthic macroinvertebrate community in flowing waters. In those studies where total production was measured, sampling was usually not stratified by habitat and the results were likely to be highly variable. Lastly, many of the comprehensive production studies have been done in streams that are much smaller than the New River. In spite of the problems with making comparisons, we have assembled the few previous estimates of total production in flowing waters (Table 6).

What is most noteworthy about the information that is summarized in Table 6 is that the production levels on the rock outcrops at Sandstone Falls are not exceptional, either high or low, for flowing waters. The measurement at Sandstone Falls in 1987 was higher than some values reported for very small streams, but was generally similar to other streams nearer the size of the New River, except for the Speed River in Ontario. It is also interesting to note that, within the New River, production at Sandstone Falls was considerably less than what had been reported previously at Bluestone Dam. In a previous survey of this reach of the New River (Virginia Polytechnic Institute and State University 1985), total standing stock decreased downstream from Bluestone Dam in both summer and winter. Seston concentrations were also shown to decrease progressively downstream. In the present study the average seston concentration at Sandstone Falls was 0.68 mg/liter, whereas the average of all values reported by Voshell et al. (1988) for the site below Bluestone Dam was 1.31 mg/liter. The influence of seston as food for the dominant organisms probably accounts for most of the lower production at Sandstone Falls. Other factors that could account for the difference in production levels are temperature and amount of Podostemum for habitat. Greater numbers of degree-days are generally thought to cause higher production levels, but the number of degree-days at Sandstone Falls in 1987 (3680) exceeded that at Bluestone Dam in 1983 (3120) or 1986 (3024). The amount of Podostemum (g/m²) at Sandstone Falls in 1987 (95) was intermediate between the amounts that occurred at Bluestone Dam in 1983 (161) and 1986 (45).

The most distinctive difference between the production at Sandstone Falls and Bluestone Dam is the relative proportion of production contributed by the various members of the community living in Podostemum on the rock outcrops.

Table 6. Summary of measurements of total production by benthic macroinvertebrate communities.

Reference	Description of Stream	Fauna and Habitat	Production (g dry wt/m ² /yr)
Nelson and Scott (1962)	Middle Oconee River, Georgia; on piedmont; 55 m wide	Herbivores and detritivores in <u>Podostemum</u> on rock outcrop	55.6
Hynes and Coleman (1968)	Speed River, Ontario; 7 m wide.	All in cobble/pebble riffle to a depth of 30 cm.	200.0
Neves (1979)	Factory Brook, Massachusetts; 2nd order, 3.9-5.6 m wide; 2 years.	Epilithic (on rock surfaces) in riffle.	4.3, 4.8
Krueger and Waters (1983)	North Branch Creek, Blackhoof River, Caribou River, Minnesota; all 1st order streams.	Herbivores and detritivores in riffle.	16.2, 22.1, 71.8
Benke, et al. (1984)	Satilla River, Georgia; subtropical on coastal plain; "large"; 2 sites.	Primary consumers on snags (fallen trees).	51.9, 67.1
Smock, et al. (1985)	Cedar Creek, South Carolina; 2nd order, 8-12 m wide; blackwater stream in coastal plain swamp; 3 sites.	All on snags.	1.3, 1.1, 0.6
Layton (1985)	Kanawha River, West Virginia; 6th order, 170-207 m wide; 2 sites.	All on cobble/pebble.	15.9, 42.9

Table 6. Continued.

Voshell, et al. (1988)	New River, West Virginia; at Bluestone Dam; 6th order, 300 m wide; no treatment.	All in <u>Podostemum</u> on rock outcrop.	661.4*
Voshell, et al. (1988)	New River, West Virginia; at Bluestone Dam; 6th order, 300 m wide; Bti treatments.	All in <u>Podostemum</u> on rock outcrop.	347.8*
This study	New River West Virginia; at Sandstone Falls; 6th order, 300 m wide; no treatment.	All in <u>Podostemum</u> on rock outcrop.	61.6*

* Production measurement from June through November multiplied by 2 in order to approximate annual values reported in other studies.

At Bluestone Dam in a year without Bti treatment (1983), chironomids were the dominant group in the community (72%), followed by a net-spinning caddisfly (C. campyla - 20%), a black fly (S. jenningsi - 8%), and two species of mayflies (B. intercalaris, H. curiosum - <1% together). In the present study at Sandstone Falls, also without Bti treatment, one of three taxa of mayflies was dominant (Tricorythodes spp. - 46%), followed by chironomids (34%). C. campyla only comprised 10% of the community and S. jenningsi only 5%. Tricorythodes spp. and another mayfly (S. deficiens, 1.3% of total production) were not present at Bluestone Dam. Kondratieff and Voshell (1981a) found that surface release reservoirs can reduce populations of mayflies in tailwaters as compared to downstream areas because of subtle changes in the annual temperature cycle. The dominance of mayflies in the vicinity of Sandstone Falls indicates that this reach of the New River is more "typical" or "normal" for shallow, rocky-bottomed flowing waters than the area immediately below Bluestone Dam.

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APPENDIX TABLES A1 - A17

Appendix Table A1. Delimitation of size classes or instars (mm) used in production calculations for 1983 and 1986.

Taxon	1	2	3	4	5	6	7
<u>Baetis</u>							
<u>intercalaris</u>	0.00-	0.20-	0.40-	0.60-	0.80-	≥1.00	
(size classes)	0.19	0.39	0.59	0.79	0.99		
<u>Serratella</u>							
<u>deficiens</u>	0.00-	0.20-	0.40-	0.60-	0.80-	≥1.00	
(size classes)	0.19	0.39	0.59	0.79	0.99		
<u>Tricorythodes</u>	0.00-	0.20-	0.40-	0.60-	0.80-	≥1.00	
spp.	0.19	0.39	0.59	0.79	0.99		
(size classes)							
<u>Cheumatopsyche</u>							
<u>campyla</u>	0.00-	0.21-	0.36-	0.54-	≥0.79		
(instars)	0.20	0.35	0.53	0.78			
<u>Oecetis</u>							
spp.	0.00-	0.12-	0.24-	0.38-	≥0.60		
(instars)	0.11	0.23	0.37	0.59			
<u>Simulium</u>							
<u>jenningsi</u>	0.00-	0.09-	0.12-	0.16-	0.22-	0.28-	≥0.34
(instars)	0.08	0.11	0.15	0.21	0.27	0.33	
<u>Chironominae/</u>							
<u>Orthocladiinae</u>	0.00-	0.16-	≥0.25				
(size classes)	0.15	0.24					

Appendix Table A2. Calculation of mean individual biomass (mgDW) for size classes or instars used in production estimates for June-November 1987. Individual weights on a given date are averages of a group of organisms that were weighed together (number of organisms in parentheses). All weights were determined from preserved specimens and then corrected for loss of weight due to preservation. See text for explanation of correction factors.

	Date	Size Class or Instars						
		1	2	3	4	5	6	7
<u>Baetis</u> <u>intercalaris</u>	8 June						.52	
							(5)	
	22 July		.014	.06	.18	.32		
			(25)	(83)	(84)	(58)		
	10 Aug		.02	.08	.14	.22		
			(45)	(83)	(48)	(12)		
	7 Sept	.02						
		(28)						
	16 Nov		.03	.08				
			(100)	(22)				
	MEAN	.02	.02	.07	.12	.24	.52	
<u>Serratella</u> <u>deficiens</u>	13 July		.016	.04	.09	.18	.45	
			(94)	(105)	(94)	(77)	(60)	
	24 Aug		.018	.04	.09	.18	.40	
			(24)	(48)	(46)	(15)	(16)	
	16 Nov		.016	.05	.16			
			(50)	(38)	(25)			
	MEAN	.006*	.017	.04	.11	.18	.43	
<u>Tricorythodes</u> spp.	22 June			.05	.13	.48	.92	
				(43)	(51)	(50)	(24)	
	13 July	.013	.008					
		(17)	(100)					
	10 Aug		.018	.04	.12	.34		
			(27)	(40)	(40)	(43)		
	MEAN	.013	.013	.04	.12	.41	.92	
<u>Cheumatopsyche</u> <u>campyla</u>	8 June	.008						
		(100)						
	22 June		.019	.07	.22	.92		
			(88)	(50)	(50)	(50)		
	24 Aug		.017	.07	.20	.73		
			(50)	(22)	(23)	(46)		
	19 Oct	.006						
		(100)						
	16 Nov		.02	.07				
			(63)	(50)				
	MEAN	.007	.019	.07	.21	.82		
<u>Oecetis</u> spp.			.012	.02	.07	.52		
			(20)**	(58)**	(67)**	(48)**		
	MEAN	.009*	.012	.02	.07	.52		

Appendix Table A2. Continued.

<u>Simulium</u> <u>jenningsi</u>	13 July	.007 (25)	.01 (75)	.015 (100)	.03 (75)	.07 (100)	.18 (100)
	21 Sept	.006 (41)	.01 (52)				
	5 Oct			.018 (62)	.03 (33)	.06 (48)	.10 (26)
	<u>MEAN</u>	<u>.001*</u>	<u>.006</u>	<u>.01</u>	<u>.016</u>	<u>.03</u>	<u>.06</u> <u>.14</u>
Chironominae/ Orthocladiinae	22 June	.01 (100)	.018 (100)	.08 (100)			
	10 Aug	.007 (100)	.013 (100)				
	24 Aug			.08 (100)			
	16 Nov	.008 (200)	.03 (100)	.14 (100)			
	<u>MEAN</u>	<u>.008</u>	<u>.02</u>	<u>.10</u>			

* Denotes 1983 weights or literature weights because insufficient specimens collected in 1987.

** All specimens collected from June through November were combined in order to have enough mass for weighing.

Appendix Table A6. Size-frequency distribution and biomass of *Cheumatopsyche campyla* on each sample date from June through November 1987.

Actual Data From Samples		Jun 8	Jun 22	Jul 13	Jul 27	Aug 10	Aug 24	Sep 7	Sep 21	Oct 5	Oct 19	Nov 2	Nov 16	Nov 27
Size	Weight	Jun 8	Jun 22	Jul 13	Jul 27	Aug 10	Aug 24	Sep 7	Sep 21	Oct 5	Oct 19	Nov 2	Nov 16	Nov 27
5	0.820	300	263	134	20	8	66	5	3	1	6	8	7	2
4	0.210	203	248	73	8	8	34	3	14	22	9	1	3	4
3	0.070	116	288	41	8	1	26	24	25	1	5	57	59	27
2	0.019	164	107	82	4	1	52	27	3	0	65	181	67	14
1	0.007	183	38	59	0	0	51	35	17	23	347	34	4	0
		966	944	389	40	18	229	94	62	47	432	281	140	47
Data Converted to Individuals per square meter														
Size	Weight	Jun 8	Jun 22	Jul 13	Jul 27	Aug 10	Aug 24	Sep 7	Sep 21	Oct 5	Oct 19	Nov 2	Nov 16	Nov 27
5	0.820	3000	2630	1340	200	80	660	50	30	10	60	80	70	20
4	0.210	2030	2480	730	80	80	340	30	140	220	90	10	30	40
3	0.070	1160	2880	410	80	10	260	240	250	10	50	570	590	270
2	0.019	1640	1070	820	40	10	520	270	30	0	650	1810	670	140
1	0.007	1830	380	590	0	0	510	350	170	230	3470	340	40	0
														608.5
														633.1
														484.6
														521.5
														590.0
														608.5
Density		9660	9440	3890	400	180	2290	940	620	470	4320	2810	1400	470
Biomass		3011.47	2901.99	1300.51	187.16	83.29	644.25	71.68	73.26	56.71	108.24	144.37	118.01	46.36
														672.9
Data Converted to Percentage total number														
Size	Weight	Jun 8	Jun 22	Jul 13	Jul 27	Aug 10	Aug 24	Sep 7	Sep 21	Oct 5	Oct 19	Nov 2	Nov 16	Nov 27
5	31%	28%	34%	50%	44%	29%	29%	5%	5%	2%	1%	3%	5%	4%
4	21%	26%	19%	20%	44%	15%	15%	3%	23%	47%	2%	0%	2%	9%
3	12%	31%	11%	20%	6%	11%	11%	26%	40%	2%	1%	20%	42%	57%
2	17%	11%	21%	10%	6%	23%	23%	29%	5%	0%	15%	64%	48%	30%
1	19%	4%	15%	0%	0%	22%	22%	37%	27%	49%	80%	12%	3%	0%
														22%
														17%
														18%
														21%
														21%
Graphic Representation of Percentages														
Size	Weight	Jun 8	Jun 22	Jul 13	Jul 27	Aug 10	Aug 24	Sep 7	Sep 21	Oct 5	Oct 19	Nov 2	Nov 16	Nov 27
5	+++	+++	+++	++++	++++	+++	+++	+	+	+	+	+	+	+
4	++	+++	++	++	++++	+	+	+	++	++++	+	+	+	+
3	+	+++	+	++	+	+	+	+	++++	+	+	+	++++	++++
2	++	+	++	+	+	++	++	++	+	+	+	++++	++++	+
1	++	.	++	.	.	++	++	++++	++	++++	++++	+	.	.

Appendix Table A10. Calculation of production for *Baetis intercalaris* from June through November 1987

Instar	Mean Density (no./m ²)	Mean Indiv. Biomass (mg)	Mean Standing Stock (mg/m ²)	Number Lost (per m ²)	Indiv. Biomass at Loss (mg)	Biomass Loss (mg/m ²)	Biomass Correction Factor (loss x 6)
1	102.3	0.020	2.0	-1867.7	0.020	-37.4	-224.1
2	1970.0	0.02	39.4	444.6	0.037	16.6	99.8
3	1525.4	0.070	106.8	503.9	0.092	46.2	277.1
4	1021.5	0.12	122.6	541.5	0.170	91.9	551.4
5	480.0	0.240	115.2	447.7	0.353	158.2	949.0
6	32.3	0.520	16.8	32.3	0.520	16.8	100.8
N=	5131.5	B=	402.8	Uncorrected P (mg/m ²)		=	1978.0
				Correction factor (365/CPI)	x	=	0.55
				Production (mg/m ²)		=	1087.9
				Upper 95% Conf. Limit		=	975.0
				Lower 95% Conf. Limit		=	1199.7

Appendix Table A11. Calculation of production for *Serratella deficiens* from June through November 1987

Instar	Mean Density (no./m ²)	Mean Indiv. Biomass (mg)	Mean Standing Stock (mg/m ²)	Number Lost (per m ²)	Indiv. Biomass at Loss (mg)	Biomass Loss (mg/m ²)	Biomass Correction Factor (loss x 6)
1	28.5	0.006	0.2	-526.9	0.010	-5.3	-31.9
2	555.4	0.017	9.4	-50.0	0.026	-1.3	-7.8
3	605.4	0.040	24.2	276.9	0.066	18.4	110.2
4	328.5	0.11	36.1	154.7	0.141	21.8	130.6
5	173.8	0.180	31.3	3.0	0.278	0.8	5.0
6	170.8	0.430	73.4	170.8	0.430	73.4	440.7
N=	1862.4	B =	174.7	Uncorrected P (mg/m ²)		=	686.5
				Correction factor (365/CPI)	x	=	0.57
				Production (mg/m ²)		=	391.3
				Upper 95% Conf. Limit		=	336.8
				Lower 95% Conf. Limit		=	438.9

Appendix Table A12. Calculation of production for Tricorythodes spp. from June through November 1987

Instar	Mean Density (no./m ²)	Mean Indiv. Biomass (mg)	Mean Standing Stock (mg/m ²)	Number Lost (per m ²)	Indiv. Biomass at Loss (mg)	Biomass Loss (mg/m ²)	Biomass Correction Factor (loss x 6)
1	76.2	0.013	1.0	-2236.1	0.013	-29.1	-174.4
2	2312.3	0.013	30.1	1076.1	0.023	24.5	147.2
3	1236.2	0.040	49.4	281.6	0.069	19.5	117.1
4	954.6	0.12	114.6	-756.9	0.222	-167.9	-1007.3
5	1711.5	0.410	701.7	1307.7	0.614	803.1	4818.9
6	403.8	0.920	371.5	403.8	0.920	371.5	2229.0
N=	6694.6	B=	1268.3	Uncorrected P	(mg/m ²)	=	7312.1
				Correction factor	(365/CP1)	x	1.94
				Production	(mg/m ²)	=	14185.5
				Upper 95% Conf. Limit		=	12037.0
				Lower 95% Conf. Limit		=	16356.6

Appendix Table A13. Calculation of production for *Cheumatopsyche campyla* from June through November 1987

Instar	Mean Density (no./m ²)	Mean Indiv. Biomass (mg)	Mean Standing Stock (mg/m ²)	Number Lost (per m ²)	Indiv. Biomass at Loss (mg)	Biomass Loss (mg/m ²)	Biomass Correction Factor (loss x 5)
1	608.5	0.007	4.3	18.5	0.012	0.2	1.1
2	590.0	0.019	11.2	68.5	0.036	2.5	12.5
3	521.5	0.070	36.5	36.9	0.121	4.5	22.4
4	484.6	0.21	101.8	-148.5	0.415	-61.6	-308.1
5	633.1	0.820	519.1	633.1	0.820	519.1	2595.7
N=	2837.7	B=	672.9	Uncorrected P (mg/m ²)		=	2631.6
				Correction factor (365/CPI) x		=	1.15
				Production (mg/m ²)		=	3026.4
				Upper 95% Conf. Limit		=	2595.5
				Lower 95% Conf. Limit		=	3456.9

Appendix Table A14. Calculation of production for *Oecetis* spp. from June through November 1987

Instar	Mean Density (no./m ²)	Mean Indiv. Biomass (mg)	Mean Standing Stock (mg/m ²)	Number Lost (per m ²)	Indiv. Biomass at Loss (mg)	Biomass Loss (mg/m ²)	Biomass Correction Factor (loss x 5)
1	0.0	0.009	0.0	-54.6	0.010	-0.6	-2.8
2	54.6	0.012	0.7	-66.9	0.015	-1.0	-5.2
3	121.5	0.020	2.4	20.7	0.037	0.8	3.9
4	100.8	0.07	7.1	52.3	0.191	10.0	49.9
5	48.5	0.520	25.2	48.5	0.520	25.2	126.1
N=	325.4	B=	35.4	Uncorrected P (mg/m ²) Correction factor (365/CPI) x	=	179.9 0.56	
				Production (mg/m ²)	=	100.7	
				Upper 95% Conf. Limit	=	77.6	
				Lower 95% Conf. Limit	=	122.4	

Appendix Table A15. Calculation of production for Simulium jenningsi from June through November 1987

Instar	Mean Density (no./m ²)	Mean Indiv. Biomass (mg)	Mean Standing Stock (mg/m ²)	Number Lost (per m ²)	Indiv. Biomass at Loss (mg)	Biomass Loss (mg/m ²)	Biomass Correction Factor (loss x 7)
1	22.3	0.001	0.0	-163.9	0.002	-0.4	-2.8
2	186.2	0.006	1.1	-96.9	0.008	-0.8	-5.3
3	283.1	0.010	2.8	-18.4	0.013	-0.2	-1.6
4	301.5	0.016	4.8	48.4	0.022	1.1	7.4
5	253.1	0.030	7.6	-26.9	0.042	-1.1	-8.0
6	280.0	0.060	16.8	-204.6	0.092	-18.8	-131.3
7	484.6	0.140	67.8	484.6	0.140	67.8	474.9
N=	1810.8	B=	101.0	Uncorrected P (mg/m ²)		=	482.3
				Correction factor (365/CPI) x		=	3.1
				Production (mg/m ²)		=	1495.2
				Upper 95% Conf. Limit		=	1223.5
				Lower 95% Conf. Limit		=	1770.8

Appendix Table A16. Calculation of production for Chironominae/Orthocladinae from June through November 1987

Instar	Mean Density (no./m ²)	Mean Indiv. Biomass (mg)	Mean Standing Stock (mg/m ²)	Number Lost (per m ²)	Indiv. Biomass at Loss (mg)	Biomass Loss (mg/m ²)	Biomass Correction Factor (loss x 3)
1	13697.7	0.008	109.6	9320.8	0.013	117.9	353.7
2	4376.9	0.02	87.5	1649.2	0.045	73.8	221.3
3	2727.7	0.100	272.8	2727.7	0.100	272.8	818.3
N=	20802.3	B=	469.9	Uncorrected P (mg/m ²)		= 1393.3	
				Correction factor (365/CPI) x		= 7.51	
				Production (mg/m ²)		= 10463.5	
				Upper 95% Conf. Limit		= 9680.6	
				Lower 95% Conf. Limit		= 11247.2	

Appendix Table A17. Trophic basis of production for all taxa from June through November 1987. AE = assimilation efficiency (assimilation/consumption); NPE = net production efficiency (production/assimilation); GPE = gross production efficiency (AE x NPE).

Taxon	Food Types	Gut Content (%)	AE	NPE	Relative Amount to Production	Production Attributed to Food Type (%)	Production Attributed to Food Type (mg/m ²)	GPE	Consumption to Account for Production (mg/m ²)	Egested as Detritus (mg/m ²)
<i>Baetis intercalaris</i>										
Diatoms	8	0.30	0.5	0.5	1.20	0.20	221	0.15	1,474	1,032
Other Algae	1	0.30	0.5	0.5	0.15	0.03	28	0.15	184	129
Fine Detritus	91	0.10	0.5	0.5	4.55	0.77	839	0.05	16,771	15,094
Total							1,087		18,429	16,255
<i>Serratella deficiens</i>										
Diatoms	8	0.30	0.5	0.5	1.20	0.20	79	0.15	526	368
Other Algae	1	0.30	0.5	0.5	0.15	0.03	10	0.15	66	46
Fine Detritus	91	0.10	0.5	0.5	4.55	0.77	299	0.05	5,982	5,384
Total							388		6,574	5,798
<i>Tricorythodes</i> spp.										
Diatoms	8	0.30	0.5	0.5	1.20	0.20	2,887	0.15	19,250	13,475
Other Algae	1	0.30	0.5	0.5	0.15	0.03	361	0.15	2,406	1,684
Fine Detritus	91	0.10	0.5	0.5	4.55	0.77	10,948	0.05	218,968	197,071
Total							14,197		240,624	212,231
<i>Cheumatopsyche campyla</i>										
Animals	3	0.70	0.5	0.5	1.05	0.13	392	0.35	1,121	336
Diatoms	6	0.30	0.5	0.5	0.90	0.11	336	0.15	2,242	1,569
Other Algae	16	0.30	0.5	0.5	2.40	0.30	897	0.15	5,978	4,184
Fine Detritus	75	0.10	0.5	0.5	3.75	0.46	1,401	0.05	28,020	25,218
Total							3,026		37,360	31,308
<i>Oecetis</i> spp.										
Animals	50	0.70	0.5	0.5	17.50	0.88	88	0.35	250	75
Fine Detritus	50	0.10	0.5	0.5	2.50	0.13	13	0.05	250	225
Total							100		500	300
<i>Simulium jenningsi</i>										
Diatoms	2	0.50	0.5	0.5	0.50	0.17	254	0.25	1,015	507
Fine Detritus	98	0.05	0.5	0.5	2.45	0.83	1,243	0.03	49,734	47,248
Total							1,497		50,749	47,755
<i>Chironominae/Orthocladinae</i>										
Diatoms	8	0.30	0.5	0.5	1.20	0.29	3,044	0.15	20,294	14,206
Other Algae	5	0.30	0.5	0.5	0.75	0.18	1,903	0.15	12,683	8,878
Fine Detritus	87	0.05	0.5	0.5	2.18	0.53	5,517	0.03	220,693	209,658
Total							10,464		253,670	232,742
Grand Total							30,759		607,908	546,389