

FINAL REPORT

Ecological Monitoring in the New River Gorge National River:
Analysis of Environmental Impacts from the
Black Fly Pest Management Program

J. Reese Voshell, Jr.¹ and Donald J. Orth²

¹ Department of Entomology

² Department of Fisheries and Wildlife Sciences
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

November 1995

In partial fulfillment of Cooperative Agreement CA4000-8-8008
Modification 1 between Virginia Polytechnic Institute and State
University and USDI; National Park Service, New River Gorge
National River, Oak Hill, West Virginia 25901

Table of Contents

Executive Summary -----	7
Introduction -----	10
Background -----	10
Purpose -----	11
Literature Review -----	11
<u>Efficacy of Bti</u> -----	11
<u>Potential Environmental Effects of Bti</u> -----	12
<u>Previous New River Studies</u> -----	16
Study Sites -----	19
Bluestone Dam -----	19
Sandstone Falls -----	20
Prince -----	20
Thurmond -----	21
Fayette Station -----	21
Methods -----	21
Benthic Macroinvertebrates -----	21
Fishes -----	25
Results -----	31
Black Fly Pest Management -----	31
Environmental Characteristics -----	31
<u>Bluestone Dam</u> -----	31
<u>Sandstone Falls</u> -----	32
Production of Benthic Macroinvertebrates -----	34
<u>Bluestone Dam</u> -----	34
<u>Sandstone Falls</u> -----	35
Growth and Condition of Fishes -----	37
<u>Growth</u> -----	37
<u>Condition</u> -----	40
Community Structure of Benthic Macroinvertebrates -----	41
<u>Summary of All Sites</u> -----	41
<u>Analysis Before and After Bti Treatments</u> -----	43
Community Structure of Fishes -----	43
<u>Numerical Percentage By Order and Family</u> -----	43
<u>Numerical Percentage By Species</u> -----	44
<u>Total Number of Species</u> -----	46
<u>Distribution Records</u> -----	46
<u>Metrics</u> -----	47
<u>Similarity</u> -----	49
<u>Persistence</u> -----	49

Discussion	50
Production of Benthic Macroinvertebrates	50
Growth and Condition of Fishes	51
<u>Minnows</u>	52
<u>Rock Bass</u>	53
<u>Smallmouth Bass</u>	53
Community Structure of Benthic Macroinvertebrates	54
Community Structure of Fishes	54
Conclusions	58
Literature Cited	58

Figures (Attached)

1. Map of New River with study sites.
2. Water temperature at Bluestone Dam in 1983 and 1986.
3. Water temperature at Bluestone Dam in 1988 and 1989.
4. Water temperature at Bluestone Dam in 1990.
5. Water temperature at Sandstone Falls in 1987 and 1988.
6. Water temperature at Sandstone Falls in 1989 and 1990.
7. Discharge at Bluestone Dam in 1983 and 1986.
8. Discharge at Bluestone Dam in 1988 and 1989.
9. Discharge at Bluestone Dam in 1990.
10. Discharge at Sandstone Falls in 1987 and 1988.
11. Discharge at Sandstone Falls in 1989 and 1990.
12. Standing stock of *Podostemum* at Bluestone Dam in 1983 and 1986.
13. Standing stock of *Podostemum* at Bluestone Dam in 1988 and 1989.
14. Standing stock of *Podostemum* at Bluestone Dam in 1990.
15. Standing stock of *Podostemum* at Sandstone Falls in 1987 and 1988.
16. Standing stock of *Podostemum* at Sandstone Falls in 1989 and 1990.
17. Percentage of production for individual dominant taxa of benthic macroinvertebrates at Bluestone Dam in 1983 and 1986.
18. Percentage of production for individual dominant taxa of benthic macroinvertebrates at Bluestone Dam in 1988 and 1989.
19. Percentage of production for individual dominant taxa of benthic macroinvertebrates at Bluestone Dam in 1990.
20. Percentage of production for individual dominant taxa of benthic macroinvertebrates at Sandstone Falls in 1987 and 1988.
21. Percentage of production for individual dominant taxa of benthic macroinvertebrates at Sandstone Falls in 1989 and 1990.
22. Production of benthic macroinvertebrates (Total, *Baetis intercalaris*, *Heterocloeon curiosum*, *Cheumatopsyche campyla*) at Bluestone Dam in all years.

23. Production of benthic macroinvertebrates (*Simulium jenningsi*, *Simulium vittatum*, Chironominae/Orthocladiinae) at Bluestone Dam in all years.
24. Production of benthic macroinvertebrates (Total, *Baetis intercalaris*, *Serratella deficiens*, *Tricorythodes* spp.) at Sandstone Falls in all years.
25. Production of benthic macroinvertebrates (*Cheumatopsyche campyla*, *Oecetis* spp., *Simulium jenningsi* spp., Chironominae/Orthocladiinae) at Sandstone Falls in all years.
26. Growth in length for bigmouth chub, rock bass, and smallmouth bass at Bluestone Dam in all years.
27. Growth in weight for bigmouth chub, rock bass, and smallmouth bass at Bluestone Dam in all years.
28. Growth in length for bigmouth chub, rock bass, and smallmouth bass at Sandstone Falls in all years.
29. Growth in weight for bigmouth chub, rock bass, and smallmouth bass at Sandstone Falls in all years.

Tables (Attached)

1. Dates of fish collections at study sites.
2. Bti applications during study period.
3. Environmental characteristics at Bluestone Dam site during study period.
4. Environmental characteristics at Sandstone Falls site during study period.
5. Production statistics for dominant benthic macroinvertebrates at Bluestone Dam site during study period.
6. Production statistics for dominant benthic macroinvertebrates at Sandstone Falls site during study period.
7. Mean lengths for fish species at Bluestone Dam site during study period.
8. Mean weights for fish species at Bluestone Dam site during study period.
9. Mean lengths for fish species at Sandstone Falls site during study period.
10. Mean weights for fish species at Sandstone Falls site during study period.
11. Mean condition factors for fish species at Bluestone Dam site during study period.
12. Mean condition factors for fish species at Sandstone Falls site during study period.
13. Statistical analysis of benthic macroinvertebrate community (Total Density) among years at Bluestone Dam site during study period.
14. Statistical analysis of benthic macroinvertebrate community (Taxa Richness) among years at Bluestone Dam site during study period.
15. Statistical analysis of benthic macroinvertebrate community (EPT Index) among years at Bluestone Dam site during study period.

16. Statistical analysis of benthic macroinvertebrate community (Shannon Diversity Index) among years at Bluestone Dam site during study period.
17. Statistical analysis of benthic macroinvertebrate community (Hilsenhoff Biotic Index) among years at Bluestone Dam site during study period.
18. Statistical analysis of benthic macroinvertebrate community (Total Density) among years at Sandstone Falls site during study period.
19. Statistical analysis of benthic macroinvertebrate community (Taxa Richness) among years at Sandstone Falls site during study period.
20. Statistical analysis of benthic macroinvertebrate community (EPT Index) among years at Sandstone Falls site during study period.
21. Statistical analysis of benthic macroinvertebrate community (Shannon Diversity Index) among years at Sandstone Falls site during study period.
22. Statistical analysis of benthic macroinvertebrate community (Hilsenhoff Biotic Index) among years at Sandstone Falls site during study period.
23. Similarity analysis of benthic macroinvertebrate community (Percent Similarity Index) among years at Bluestone Dam site during study period.
24. Similarity analysis of benthic macroinvertebrate community (Pinkham and Pearson Similarity Index) among years at Bluestone Dam site during study period.
25. Similarity analysis of benthic macroinvertebrate community (Percent Similarity Index) among years at Sandstone Falls site during study period.
26. Similarity analysis of benthic macroinvertebrate community (Pinkham and Pearson Similarity Index) among years at Sandstone Falls site during study period.
27. Percentages of fish orders and families at Bluestone Dam site during study period.
28. Percentages of fish orders and families at Sandstone Falls site during study period.
29. Percentages of fish orders and families at Prince site during study period.
30. Percentages of fish orders and families at Thurmond site during study period.
31. Percentages of fish orders and families at Fayette Station site during study period.
32. Percentages of fish species at Bluestone Dam site during study period.
33. Percentages of fish species at Sandstone Falls site during study period.
34. Percentages of fish species at Prince site during study period.
35. Percentages of fish species at Thurmond site during study period.
36. Percentages of fish species at Fayette Station site during study period.
37. Numbers of fish species at each site during study period.

38. Fish community metrics at Bluestone Dam site during study period.
39. Fish community metrics at Sandstone Falls site during study period.
40. Fish community metrics at Prince site during study period.
41. Fish community metrics at Thurmond site during study period.
42. Fish community metrics at Fayette Station site during study period.
43. Similarity analysis of fish community (Percent Similarity Index) among years for each site during study period.
44. Similarity analysis of fish community (Pinkham and Pearson Index) among years for each site during study period.
45. Persistence of fish community between adjacent years for each site during study period.

Appendices (Attached)

1. Community structure of benthic macroinvertebrates in riffles at the Bluestone Dam site in 1982.
2. Community structure of benthic macroinvertebrates in riffles at the Bluestone Dam site in 1984.
3. Community structure of benthic macroinvertebrates in riffles at the Bluestone Dam site in 1988.
4. Community structure of benthic macroinvertebrates in riffles at the Bluestone Dam site in 1989.
5. Community structure of benthic macroinvertebrates in riffles at the Bluestone Dam site in 1990.
6. Community structure of benthic macroinvertebrates in riffles at the Sandstone Falls site in 1982.
7. Community structure of benthic macroinvertebrates in riffles at the Sandstone Falls site in 1984.
8. Community structure of benthic macroinvertebrates in riffles at the Sandstone Falls site in 1988.
9. Community structure of benthic macroinvertebrates in riffles at the Sandstone Falls site in 1989.
10. Community structure of benthic macroinvertebrates in riffles at the Sandstone Falls site in 1990.
11. Taxonomic list of fish from the New River in the study area, with their trophic group, origin, and tolerance.

Executive Summary

A pest management program for the black fly, *Simulium jenningsi* Malloch (Diptera: Simuliidae) was implemented by the state of West Virginia in the New River in 1986. The West Virginia Department of Natural Resources (WVDNR) made extensive and frequent applications of the bacterial pesticide, *Bacillus thuringiensis* var. *israelensis* (Bti), from late-spring to early autumn to kill black fly larvae before they emerged as adults. The purpose of this study was to determine if the black fly pest management program caused adverse environmental effects to the New River. There were two major components of the overall project: (1) intensive studies of aquatic insect production and fish growth and condition at two sites on the New River (immediately below Bluestone Dam and immediately above Sandstone Falls) and (2) extensive studies of macroinvertebrate and fish community structure at selected sites throughout the New River from Bluestone Dam to the downstream boundaries of New River Gorge National River at Fayette Station.

Potential direct and indirect effects of black fly pest management on the benthic macroinvertebrates in the New River included changes in community structure and reduced productivity. Data from treatment years were compared with pretreatment data to test for effects of black fly pest management. The benthic macroinvertebrate community was sampled quantitatively immediately below Bluestone Dam, immediately above Sandstone Falls, Prince, Thurmond, and Fayette Station in summer. Productivity of dominant taxa was estimated immediately below Bluestone Dam and immediately above Sandstone Falls by sampling every 2 weeks when flows were low enough for wading (usually June 1 to November 30) and applying the size frequency method.

Total benthic macroinvertebrate production immediately below Bluestone Dam in 1990 was the highest in the 4 years of the study and was 3% higher than 1983, the reference year with no Bti treatment. Results of secondary production measurements of aquatic insects immediately below Bluestone Dam provide evidence that factors other than Bti treatments are responsible for the different levels of production that have been observed during this study. The only nontarget taxon that exhibited lower production in 1990 as compared to 1983 was the mayfly *H. curiosum*, which was practically nonexistent at this study site after 1986. It is unlikely that the demise of *H. curiosum* was caused by Bti treatments because another mayfly in the same family, *B. intercalaris*, achieved higher production in three of the four treatment years as compared to the reference year without treatment. Both of the major taxa accounting for most of the aquatic insect production, the caddisfly *C. campyla* and chironomids in the subfamilies Chironominae/Orthocladiinae, achieved higher levels of production in 1990 as compared to 1983. Bti treatments do not appear to have caused either direct (toxicity) or indirect (food chain) adverse effects to nontarget organisms.

Results of production studies immediately above Sandstone Falls also do not suggest any immediate adverse effects from *Bti* treatment to the fauna other than to the target organism *S. jenningsi*. Production differences that have occurred appear to be more related to yearly differences in flow and macrophytes than to *Bti* treatment. Chironomids are the nontarget organisms most likely to exhibit toxicity to *Bti*, and their production was higher in all treatment years than the nontreatment years.

Water quality analyses did not indicate any exceptional conditions that would be deleterious to aquatic life. The greatest amounts of phytoplankton occurred immediately below Bluestone Dam and Sandstone Falls, illustrating the influence of Bluestone Lake on this section of the New River. Periphyton exhibited its greatest abundance farther downstream at Prince. The emergent macrophyte *Justicia* was abundant immediately below Bluestone Dam, whereas the submerged macrophyte *Podostemum* occurred in about equal abundance immediately below Bluestone Dam, Sandstone Falls, and Thurmond. *Justicia* and *Podostemum* did not occur at Prince and Fayette Station.

Macroinvertebrates were much more abundant immediately below Bluestone Dam than any other site. There was a progressive decrease in density going downstream from Bluestone Dam, which is typical for macroinvertebrate communities below impoundments. Macroinvertebrate abundance was very low at Fayette Station. The diversity index was quite low immediately below Bluestone Dam as a result of exceptionally high numbers of net-spinning caddisflies and chironomids. This often occurs below impoundments. Diversity indices were rather uniform at the other four sites and were in a range that would be considered indicative of good environmental conditions. Taxa richness (total number of taxa without consideration of abundance) was about equal at all sites except Fayette Station, which was had a much lower value. Low taxa richness and abundance at Fayette Station is probably the result of poor macroinvertebrate habitat. A reasonably diverse and abundant macroinvertebrate community was found immediately above Sandstone Falls, Prince, and Thurmond, including proportions of taxa that are considered to be indicative of a "healthy" environment.

Potential effects of *Bti* applications and black fly removal on New River fishes included species loss, changes in community structure, and changes in growth and condition. Data from treatment years (1988, 1989, and 1990) were compared with pretreatment (prior to 1986) data from the literature to test for effects of black fly removal on New River fishes. The fish community was sampled during treatment years with electrofishing gear immediately below Bluestone Dam, Sandstone Falls, Prince, Thurmond, and Fayette Station in mid-summer. Fish growth and condition during treatment years were estimated immediately below Bluestone Dam and Sandstone Falls by collecting additional samples in the early summer and mid-fall.

Species composition of fishes varied among years at each site. Immediately below Bluestone Dam and Sandstone Falls several species collected during pretreatment years were not collected during treatment years. The apparent "disappearance" of species during treatment years is more likely a result of differences in pretreatment and treatment year sampling methods than an actual species loss resulting from black fly removal. Some pretreatment samples were collected with different gear and at different locations than samples collected during treatment years.

Fish community structure varied greatly between sample years; however, this was attributed more to variable river discharge and the apparent non-equilibrium of the New River fish community than black fly removal. River discharge, which influences spawning success of some fish species, fluctuated greatly during the period of study. Fish introductions, which have been common in the New River both historically and recently, imply that the New River fish community is at non-equilibrium. No dramatic changes in the New River fish community were apparent during treatment years and subtle changes possibly resulting from black fly removal could not be distinguished from other factors mentioned above.

Growth and condition of fishes were compared among sample years for three species immediately below Bluestone Dam and five species immediately above Sandstone Falls. During treatment years, growth and condition were as good or better than during pretreatment years immediately below Bluestone Dam and Sandstone Falls. The majority of the species examined are insectivorous but not specialized feeders. Growth and condition may not have decreased because of opportunistic feeding on prey types other than black flies.

In summary, no changes in the New River macroinvertebrates or fish can be attributed to *Bti* applications and black fly removal. Biotic measures listed in this document should be tracked through time during future monitoring.

Introduction

Background

In the early 1980s, some citizens in southern West Virginia expressed complaints about the biting and general nuisance of large numbers of "gnats" during the warm months of the year. Amrine (1982) determined that the problems were being caused by adults of a species of black fly, *Simulium jenningsi* Malloch (Diptera: Simuliidae) that breeds in flowing waters. He suggested applying a bacterial pesticide, *Bacillus thuringiensis* var. *israelensis* (*Bti*), to kill the larvae before they emerged as adults. He claimed that all problems with this species could be solved for many years by making a single application of *Bti* in the New River tailwaters of Bluestone Lake. Citizens who were complaining about black flies then petitioned the State of West Virginia to make the recommended treatment of the New River with *Bti*. Voshell (1983) was contracted by the West Virginia Department of Natural Resources (WVDNR) to conduct a thorough survey of black flies in the area and to analyze the life cycle in several streams. He determined that *Bti* would have to be applied numerous times each year in many miles of the New River and several of its tributaries. One of the major breeding sites for *S. jenningsi* is the section of the New River from Bluestone Dam to Sandstone Falls, almost all of which lies within New River Gorge National River (NRGMR) boundaries.

The implementation of an extensive pest management program in the New River raises significant questions because the New River is a valuable natural resource that is used extensively by the public for fishing and other forms of recreation. Of primary concern is the productive warmwater fishery that exists in the tailwaters of Bluestone Lake. National Park Service (NPS) policy recognizes that native insects and diseases existing under natural conditions are natural elements of the ecosystem. Native insects are allowed to function unimpeded except when certain criteria for control are met. For these reasons, NPS objected to the application of *Bti* within NRGMR boundaries. In 1986, WVDNR made a limited application of *Bti* in the New River from Bluestone Dam to the Route 20 bridge, which is just above NRGMR boundaries. The issues of possible environmental impacts and NPS policies were then addressed in the Federal Supplemental Appropriations Act of 1987, which gave the state permission to spray *Bti* in the New River within NPS boundaries for a period of 8 years and required that the state and the NPS jointly conduct an ecological monitoring program. In 1987, WVDNR began to make widespread applications of *Bti* throughout the New River and some of its tributaries. NPS contracted Virginia Polytechnic Institute and State University (VPI&SU) to conduct the ecological monitoring, the results of which are reported in this document.

Purpose

The overall purpose of this research was twofold. First, it was to accomplish the specific task of assessing the environmental impacts of the black fly pest management program in the New River. Second, it was to develop a Long-Term Ecological Monitoring System (LTEMS) that NPS personnel could continue to use for monitoring the aquatic natural resources in NRGNR. The second aspect of the research has already been reported in detail in the NRGNR LTEMS User Manuals, one for Database Management and one for Field and Laboratory Methods (Va. Polytech. Inst. and St. Univ. 1994, Voshell et al. 1995, respectively). This report addresses the results of the analyses of potential environmental impacts from the black fly pest management program. There were two major components: (1) intensive studies of aquatic insect production and fish growth and condition at two sites on the New River (Bluestone Dam and Sandstone Falls) and (2) extensive studies of macroinvertebrate and fish community structure at selected sites throughout the New River from Bluestone Dam to the downstream boundaries of NRGNR at Fayette Station. The study design of both components was to make measurements during each of three years when *Bti* was applied to the New River (1988-1990), then compare the results to reference data from the same section of the New River before the black fly pest management program began. In addition, there were *Bti*-treatment data available for aquatic insect production in 1986 Voshell et al. 1988a).

Literature Review

Efficacy of *Bti*

The control of black flies with *Bti* and other microbial pesticides has been reviewed by Lacey and Undeen (1986). The toxic component of the bacterium is the endotoxin located in the parasporal inclusions that are produced with the spore during sporulation. The toxin becomes activated in the high pH conditions of the midgut in black flies and mosquitoes. Within minutes after ingestion of *Bti*, histological changes begin to occur in the midgut. The toxin is thought to produce a complete loss of osmotic regulation in the midgut cells. Eventually the cells swell, lyse, and are sloughed into the lumen of the gut. Death follows within 6 min at high concentrations or within 24 hr at low concentrations.

Bti has been used widely in tropical regions as a successful means for suppressing populations of *Simulium damnosum*, the vector of onchocerciasis (river blindness). Black flies do not vector debilitating diseases in North America, however, *Bti* has begun to be used here for managing populations of several species which achieve pest status by virtue of their biting and general nuisance. Field evaluations have been reported in the literature from programs in Newfoundland (Colbo and O'Brien 1984), Quebec (Back et al. 1985), New York (Molloy and Jamnback 1981), New

Hampshire (Pistrang and Burger (1984), Tennessee (Lacey and Undeen (1984), and South Carolina (Horosko and Noblet (1986). In addition, there is a large-scale program for controlling black flies in the Susquehanna River at Harrisburg, Pennsylvania, which has not yet been reported in the primary literature.

All of these studies indicate that applications of *Bti* can significantly reduce densities of black fly larvae. Concentrations of *Bti* and durations of application which have proven to be effective range from 10 to 15.9 ppm of stream discharge for 1 min, 0.2 to 2 ppm for 10 min, and 0.5 to 1.3 ppm for 15 min (summary by Gaugler and Finney 1982 and more recent papers by Colbo and O'Brien 1984, Lacey and Undeen 1984, Pistrang and Burger 1984, Lacey and Heitzman 1985, Horosko and Noblet 1986, Moor and Car 1986). Factors which affect downstream transport of *Bti* include discharge, turbulence, pools, and width/depth ratio; effectiveness is also influenced by larval feeding rates which are inhibited by excessive suspended particulate matter or low temperatures (Lacey and Undeen 1986). Populations of some species recover quickly after *Bti* applications, hence frequent larviciding is necessary, sometimes as frequently as every week (Horosko and Noblet 1986).

Potential Environmental Effects of *Bti*

The effects of *Bti* on nontarget organisms have been examined in a few studies, but in general, far less attention has been devoted to measuring ecological effects than improving efficacy. Molloy and Jamnback (1981) treated a small stream at 0.5 ppm for 15 min and evaluated the effects on nontarget organisms by taking Surber samples at 1 day pretreatment and 5 days post-treatment at downstream locations and an upstream control. They reported increased densities of Ephemeroptera, Trichoptera, Plecoptera, Chironomidae, and Elmidae at all sites and concluded that there were no adverse effects on any nontarget populations. Their results were somewhat confusing because populations increased by higher percentages at the upstream control site. Lacey et al. (1982) treated a large river in the Ivory Coast at 1.5 ppm for 10 min and collected nontarget organisms with artificial substrates before and 20 and 50 hr after treatment. They found no evidence of adverse effects, although the numbers of organisms on the artificial substrates were quite low, probably due to the short colonization time (1 week). Pistrang and Burger (1984) treated a small stream at 10 ppm for 1 min and analyzed effects on nontarget organisms by taking drift samples and 5-min kick samples. They observed temporary increases in the drift of Ephemeroptera, Trichoptera, and possibly Plecoptera, but the only nontarget organisms for which they observed direct mortality were some Chironomidae. The results of this study are also difficult to interpret because of design problems. Sampling units were not large enough, leading to few individuals being collected, and there were no replicates to facilitate statistical comparisons.

Chironomidae, which belong to the nematoceros Diptera along with the Simuliidae, are variably susceptible to *Bti* depending on feeding habits, physiology, and habitat (Lacey and Undeen 1986). Ali et al. (1981) conducted 48 hr laboratory bioassays with first and third instars of several species of chironomids. LC_{50} values (concentration that is lethal to 50% of the test organisms) for first instar larvae ranged from 0.034 to 0.18 ppm, while LC_{90} values (concentration that is lethal to 90% of the test organisms) ranged from 1.32 to 3.71 ppm. For third instar larvae, LC_{50} values were 3.23 to 14.71 ppm, and LC_{90} values were 6.85 to 38.60 ppm. Back et al. (1985) deliberately treated a small lake-outlet stream at 5.86 ppm for 15 min, a dosage that was 5.48X greater than the maximum recommended application. They monitored the impacts on nontarget organisms using drift nets and artificial substrates. There was no evidence of increased drift in Ephemeroptera, Plecoptera, Trichoptera, or Chironomidae, but larvae of another family of nematoceros Diptera, the Blephariceridae, increased their drift by 50X. Densities of nontarget organisms on the artificial substrates were not reduced except for two genera of chironomids which were reduced by 74 and 61%. Drifting larvae of another genus showed symptoms of toxemia from *Bti*. The affected organisms were thought to have ingested *Bti* sedimented on the bottom of the stream or attached to periphyton growing on rocks. Moor and Car (1986) recorded a decrease in Chironomidae, as well as several genera of Ephemeroptera and Trichoptera, after a normal application of *Bti* (1.6 ppm for 10 min). However, their sampling design (5 replicate stones in current) was not sufficient to detect significant statistical differences. Moor and Car (1986) recommended careful screening of *Bti* against co-existing aquatic fauna in each area where it is to be used. They also pointed out that all tests on nontarget organisms have been of short duration, and recommended that studies on the long term effects of *Bti* be undertaken.

In summary, black fly pest management programs with *Bti* have included only superficial efforts at ecological monitoring. Typically, the samples that are taken are either not quantitative, or, if they are quantitative, only structural parameters indicative of acute toxicity are examined. The effects of repeated *Bti* applications on ecosystem function have never been addressed, although at least one recent paper has pointed out the necessity for doing this on a site-by-site basis (De Moor and Car 1986). The protocol developed by Undeen and Lacy (1982) and employed by Voshell et al. (1987a) in the New River is only adequate for measuring the immediate acute toxicity of *Bti* to black flies and non-target organisms. Short-term toxicity tests also do not demonstrate long-term food-chain effects or the effects of reduced growth that might be brought about by chronic toxicity.

There are several ways that *Bti* could cause adverse effects on the successful function of the New River ecosystem. Many fish, at least during part of their life cycles, rely on aquatic insects for food. Relatively few aquatic insect taxa account for most of

the secondary production in the tailwaters of Bluestone Lake (Voshell 1985). *Simulium jenningsi* accounts for only about 5% of total benthic macroinvertebrate production, but many species of fish have been shown to rely on *S. jenningsi* for food (Hess 1983). In two New River sportfish, smallmouth bass (*Micropterus dolomieu*) and spotted bass (*Micropterus punctulatus*), Hess (1983) reported the average diet (based on numbers of prey) to be: 44% mayflies, 23% black flies, 16% net-spinning caddisflies (family Hydropsychidae including *Cheumatopsyche* and *Hydropsyche*), and 13% chironomids. Aquatic insects are also an important component in the diets of the forage fish in the New River. The stomach contents (numbers of prey) of all species of shiners combined contain 40% black flies, 35% chironomids, 4% net-spinning caddisflies, and 2% mayflies (Hess 1983).

In addition, several invertebrate predators were found to feed on significant amounts of black flies (Kondratieff and Voshell 1983). Hellgrammites (*Corydalus cornutus*), which are harvested commercially and by individual fishermen for bait in the New River, feed almost entirely on net-spinning caddisflies (23 - 81%), mayflies (8 - 52%), and black flies (7 - 25%) (Kondratieff and Voshell 1983, Voshell 1985). *Bti* is not entirely specific for killing black flies. The material also kills chironomids, except higher doses are required (Ali et al. 1981, Back et al. 1985). Chironomids accounted for 79% of the production in the tailwaters below Bluestone Lake in 1983-84 (Voshell 1985); hence, any non-target effects on this group could also eliminate significant amounts of production for higher consumer organisms, such as fish and invertebrate predators (Roell and Orth 1993, 1994, in press).

Another potentially important role of black flies in the New River ecosystem is detritus processing. Black flies filter very fine particles of organic matter (<100 μ m) and egest larger particles (> several hundred μ m). Because black flies only use about 5% of the energy that they consume for their own growth and respiration, their feces make large quantities of organic matter available to other detritivores. The fate and utilization of insect feces in aquatic ecosystems is not thoroughly understood, but the topic has begun to attract the attention of ecologists.

Shepard and Minshall (1981, 1984a,b) have suggested that invertebrate feces could be one of the most important detrital components of lotic ecosystems.

Flowing water ecosystems are characterized by being inefficient or "wasteful," in that they export large amounts of energy and nutrients. By capturing and assimilating some of the organic matter, aquatic insects function to retain some of the nutrients and energy that otherwise would be lost downstream. This mechanism for material cycling in streams has been termed "spiralling" by Webster and Patten (1979). Detritivores typically have low assimilation efficiencies, therefore, the effectiveness of spiralling can be enhanced by successive ingestion of egested materials (Wallace et al. 1977). The ecological effects of

coprophagy (ingestion of fecal material) have been discussed for a variety of aquatic insects in lotic habitats. The plecopteran shredder *Pteronarcys californica* was found to increase the availability of nutrients to the collector-filterers *Hydropsyche* and *Simulium* (Short and Maslin 1977). In experiments with radiolabelled alder leaves in the presence and absence of shredders, they found 35-100% more ^{32}P in *Hydropsyche* and 600-700% more ^{32}P in *Simulium* when shredders were present. Grafius and Anderson (1979) found that production (as dry mass) of the trichopteran shredder *Lepidostoma quercina* was very low (190 $\text{mg}/\text{m}^2/\text{yr}$) in comparison to the Simuliidae which were dominant in the riffles (2,200 $\text{mg}/\text{m}^2/\text{yr}$); however, these authors calculated that the shredder produced enough fecal material to support 1/4 to 1/2 of the production of the collector-filterers. In a study of coexisting filter-feeding caddisflies at various locations, several species which spin coarse mesh nets in fast current and *Macrostemum zebratum*, which spins a fine mesh net in slow current, were found to have their highest production at the same site below a reservoir (Parker and Voshell 1983). Diet analyses indicated that most of the production for the species with coarse mesh nets was attributed to zooplankton, while the production of *M. zebratum* was attributed to detritus. The egestion of unassimilated animal matter as detritus (dry mass) was calculated to be more than sufficient (159,800 mg/m^2) to account for the production of *M. zebratum* (7,800 mg/m^2).

Direct evidence for coprophagy by filter-feeding aquatic insects was provided by Wotton (1980). By means of charcoal banding experiments and counts of bacteria, he demonstrated that black fly larvae reingest feces. Filter feeding can be inefficient for black flies because they are non-selective in the type of material they ingest, and at least 95% of bacteria will pass through their cephalic fans. Coprophagy is an economic tactic for black flies because they filter large particles more efficiently than small ones, and consuming one fecal pellet can provide the number of bacteria that would be obtained by filtering 23 - 100 ml of water. Coprophagy among black flies was proposed as the explanation for their dense aggregations immediately below lake outlets (Wotton 1979, 1984).

Laboratory experiments that were conducted as part of a previous New River production study (Voshell 1985), provided evidence that *Cheumatopsyche campyla* increases its production by utilizing the feces of *Simulium jenningsi*. The experiments were designed so that the only variable was the presence or absence of black flies that produced feces. *Cheumatopsyche campyla* grew significantly more in the presence of the black flies. Their guts were checked to make sure that they were not merely eating the black flies. Further evidence for coprophagy was obtained by measuring the size of the black fly feces and mesh of the caddisfly capture nets to prove that the nets were capable of retaining the feces.

Previous New River Studies

This final interpretive report builds upon studies of the New River in southern Western Virginia that were conducted by Dr. Donald J. Orth and Dr. J. Reese Voshell, Jr. over the past 13 years. As a result of these studies there have been numerous reports to sponsors, graduate theses, and published articles in journals and symposium proceedings. It would be too lengthy to summarize all of this literature here; however, because these papers will be used extensively in this report, a list with authors, dates, titles, and types of publication is provided below. Complete bibliographic information for these papers is included in the Literature Cited section at the end of this report.

Authors	Year	Title	Type
Austen, R. O.	1984	Evaluation of the effects of a 305-mm minimum length limit on the smallmouth bass populations in the New River	M.S. thesis
Austen, R. O. and D. J. Orth	1988	Evaluation of a 305-mm minimum length limit for smallmouth bass in the New River, Virginia and West Virginia	Journal article
Easton, R. S., and D. J. Orth	1994	Fishes of the main channel New River, West Virginia	Journal article
Easton, R. S., D. J. Orth, and N. M. Burkhead	1991	The first collection of rudd, <i>Scardinius erythrophthalmus</i> (Cyprinidae), in the New River, West Virginia	Journal article
Easton, R. S., D. J. Orth, and J. R. Voshell, Jr.	1995	Spatial and annual variation in diet and foraging success of age-0 smallmouth bass, <i>Micropterus dolomieu</i> (Lacopede)	Journal article
Graham, R. J.	1984	Time and duration of spawning by smallmouth bass (<i>Micropterus dolomieu</i>) in the New River drainage	M.S. thesis
Kondratieff, B. C. and J. R. Voshell, Jr.	1983	A study of the black fly invertebrate predators in the New River below Bluestone Dam	Report to WVDNR
Lobb, M. D., III	1986	Habitat use by fishes of the New River, West Virginia	M.S. thesis
Lobb, M. D., III, and D. J. Orth.	1988	Microhabitat use by the bigmouth chub <i>Nocomis platyrhynchus</i> in the New River, West Virginia	Journal article
Lobb, M. D., III, and D. J. Orth	1991	Habitat use by an assemblage of fish in a large warmwater stream	Journal article

Roell, M. J.	1989	The roles of predation, competition, and exploitation in the community dynamics of the New River in West Virginia	Ph.D. dissertation
Roell, M. J. and D. J. Orth	1988	Impacts of commercial harvest of invertebrate baits on the predator-prey interactions in the New River	Report to WVDNR
Va. Polytech. Inst. and St. Univ.	1985	An ecological investigation of the New River and Bluestone Lake.	Report to USACOE
Voshell, J. R., Jr.	1983	Assessment of black fly populations in a portion of southern West Virginia	Report to WVDNR
Voshell, J. R., Jr.	1984	The ecology of black flies in the New River and its major tributaries in southern West Virginia	Symposium proceedings
Voshell, J. R., Jr.	1985	Trophic basis of production for macroinvertebrates in the New River below Bluestone Dam	Report to WVDNR
Voshell, J. R., Jr.	1991	Life cycle of <i>Simulium jenningsi</i> (Diptera: Simuliidae) in southern West Virginia	Journal article
Voshell, J. R., Jr., S. W. Hiner, and R. J. Layton	1992	Evaluation of a benthic macroinvertebrate sampler for rock outcrops in rivers	Journal article
Voshell, J. R., Jr., R. J. Layton, and S. W. Hiner	1987	Monitoring the black fly population management program in the New River below Bluestone Dam	Report to NPS
Voshell, J. R., Jr., R. J. Layton, and S. W. Hiner	1987	An ecological survey of the New River below Bluestone Lake	Symposium proceedings
Voshell, J. R., Jr., R. J. Layton, and S. W. Hiner	1988	Analysis of secondary production to determine the ecological effects of the 1986 black fly pest management in the New River below Bluestone Dam	Report to NPS
Voshell, J. R., Jr., R. J. Layton, and S. W. Hiner	1988	Field techniques for determining the effects of toxic substances on benthic macroinvertebrates in rocky-bottomed streams	Symposium proceedings
Voshell, J. R., Jr., S. W. Hiner, V. D. Christman, and A. G. Silvia, III	1988	Production of benthic macroinvertebrates in the New River immediately above Sandstone Falls in 1987	Report to NPS
Voshell, J. R., Jr., D. J. Orth, V. D. Christman, R. S. Easton, and S. W. Hiner	1991	Preliminary report on a long-term ecological monitoring system for New River Gorge National River	Symposium proceedings

In addition, as part of this contract with NPS, nine numbered interim reports and two user manuals have been written. These are listed chronologically below, in abbreviated form, with authors, years, numbers (if any), and subjects. For brevity and clarity, interim reports will be referred to by number throughout this final report.

Authors	Year	Number	Title
Voshell, J. R., Jr., D. J. Orth, S. W. Hiner, A. G. Silvia, III, R. S. Eaton, M. J. Roell, S. M. Smith, and V. D. Christman	1989	Interim Report No. 1	Secondary production immediately above Sandstone Falls in 1988
Voshell, J. R., Jr., D. J. Orth, S. W. Hiner, A. G. Silvia, III, R. S. Eaton, M. J. Roell, S. M. Smith, and V. D. Christman	1989	Interim Report No. 2	Secondary production immediately below Bluestone Dam in 1988
Voshell, J. R., Jr., D. J. Orth, S. W. Hiner, R. S. Easton, and V. D. Christman	1990	Interim Report No. 3	Progress report on LTEMs and results of 1988 survey
Voshell, J. R., Jr., D. J. Orth, S. W. Hiner, R. S. Easton, and V. D. Christman	1990	Interim Report No. 4	Secondary production immediately above Sandstone Falls in 1989
Voshell, J. R., Jr., D. J. Orth, S. W. Hiner, R. S. Easton, and V. D. Christman	1990	Interim Report No. 5	Secondary production immediately below Bluestone Dam in 1989
Voshell, J. R., Jr., D. J. Orth, S. W. Hiner, R. S. Easton, and V. D. Christman	1991	Interim Report No. 6	Progress report on LTEMs and results of 1989 survey
Voshell, J. R., Jr., D. J. Orth, S. W. Hiner, R. S. Easton, and V. D. Christman	1991	Interim Report No. 7	Secondary production immediately above Sandstone Falls in 1990
Voshell, J. R., Jr., D. J. Orth, S. W. Hiner, R. S. Easton, and V. D. Christman	1991	Interim Report No. 8	Secondary production immediately below Bluestone Dam in 1990
Voshell, J. R., Jr., D. J. Orth, R. S. Easton, and S. W. Hiner	1992	Interim Report No. 9	Progress report on LTEMs and results of 1990 survey
Va. Poytech. Inst. and St. Univ.	1994	None	User manual for database management system
Voshell, J. R., Jr., D. J. Orth, S. W. Hiner, and R. S. Easton	1995	None	User manual for field and laboratory methods

Study Sites

The exact location of all sites can be found on topographic maps included in the user manual for field and laboratory methods (Voshell et al. 1995)

Bluestone Dam

This site was the section 100-300 m immediately below Bluestone Dam at the public park maintained by the U.S. Army Corps of Engineers (Town of Hinton, Summers County, West Virginia) (Fig. 1). The New River is a 6th order stream immediately below Bluestone Dam. For a distance of approximately 12 river km below Bluestone Dam the New River is rather shallow with the bottom consisting of rock outcrops, boulders, and cobble/pebble riffles. There are two major aquatic macrophytes: the submerged *Podostemum ceratophyllum* (river weed) that grows on the rock outcrops and boulders, and the emergent *Justicia americana* (water willow) that grows along the banks and islands. The substratum often has dense growths of filamentous algae during the summer months.

The Bluestone Lake impoundment exerts a strong influence on the New River tailwaters (VPI&SU 1985). At the normal summer pool the reservoir has a surface area of 816 ha. Water is released from 16 inversely gated sluices that measure 3.0 m high x 1.7 m wide. The bottoms of the gates are situated 6.3 m below the reservoir surface. Because of the small size of the reservoir in comparison to the inflow, retention time is short, and there is no permanent thermal stratification. When temporary stratification does occur in the summer, the metalimnion usually forms at 8-9 m; therefore, water is always released from the epilimnion and there are no problems with reductions in temperature or dissolved oxygen, which sometimes occur with hypolimnetic releases. Because Bluestone Lake is eutrophic, the water released from the epilimnion is somewhat warmer than ambient temperatures in the New River and contains moderately high concentrations of organic seston. The seston contains a high proportion of algae because of the abundance of phytoplankton in the eutrophic reservoir. The detritus in the seston also probably originates from the phytoplankton in the reservoir. The extremely high productivity of aquatic insects in the tailwaters has been attributed to the rich food resource provided by the seston released from Bluestone Lake (Voshell 1985). Almost all of this site has moderate current. At normal summer flows (approximately 3500 cfs), the average depth of the river below Bluestone Dam is approximately 1 m, and the width is approximately 300 m. At the Bluestone gauge, which measures discharge immediately below the dam, the 54-year average for mean daily discharge has been 5600 cfs. Water temperatures in the section of the New River above the confluence of the Greenbrier River range from 0 to 29 °C, and dissolved oxygen is consistently at or near saturation, with concentrations ranging from 6.6 to 13.0 mg/liter.

Sandstone Falls

This study site was the section 50-250 m immediately above Sandstone Falls, 16 river km below Bluestone Dam (Fig. 1). 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 immediately above Sandstone Falls, the same as immediately below 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 river 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 immediately above 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.

Prince

The Prince site is located approximately 41.5 river km below Bluestone Dam (Fig. 1). The specific location was the 200-m section that is 1.75 km upstream of the Route 19 and 41 bridge. The New River is approximately 150 m wide at the Prince study site. Under summer flow conditions much of the river is wadable; however, the main channel and several backwaters are too deep or swift to wade. Cobbles and boulders are the dominant substratum; however, there are also several sandy areas. The only macrophyte present is *Justicia*, which occurs in low abundance and is usually out of the water during normal summer flows. Twelve tributaries enter the New River between the Sandstone Falls and the Prince study sites; however, the discharge at Prince is only slightly greater than immediately above Sandstone Falls.

Thurmond

The Thurmond study site is located approximately 61.6 river km below Bluestone Dam (Fig. 1). The exact location was a 50-m section of riffle approximately 50 m upstream of the Stonecliff bridge. At the Thurmond study site the New River is approximately 150 m wide. The site consists of a 50-m riffle between two long, deep pools. Under summer flow conditions most of the riffle is wadable except for the thalweg. Only the extreme river margins of the pools are wadable. Cobbles and boulders are the dominant substratum in the riffle. The substratum of the pool margins is mostly silt and sand. The dominant aquatic macrophytes include *Justicia* and *Podostemum*. Eight tributaries enter the New River between Prince and Thurmond. A gauge is located at Thurmond, 0.1 km upstream of Dunloup Creek on the right bank. The 6-yr average for mean daily discharge at the Thurmond site between 1981 and 1987 was 9003 cfs.

Fayette Station

This study site is located approximately 91.4 river km downstream from Bluestone Dam (Fig. 1). The specific location was a 300-m section extending upstream from the riffle at the confluence of Wolf Creek. The river is approximately 100 m wide at the Fayette Station site. Sampling at this site is limited to the extreme river margins because of the high current velocity in the riffle and the depth of the pools. Boulders are the dominant substratum in the riffles, and sand is dominant in the pools. No aquatic macrophytes are present at this site. Fifteen tributaries enter the New River between Thurmond and Fayette Station, but the discharge at Fayette Station is only slightly greater than at Thurmond.

Methods

Most of the methods used in this study are the same as those used in the NRGNR LTEMs, so they have been described in great detail in the User Manual for Field and Laboratory Methods (Voshell et al. 1995). This section of the final report includes only those methods not covered in the User Manual. Most of the methods described below are for measuring aquatic insect production and fish growth and condition. These measurements are appropriate for answering questions that require ecological research (e.g., trophic dynamics), but they are too intensive for routine continuous monitoring programs such as the NRGNR LTEMs. In addition, statistical procedures for analyzing changes in community structure are briefly explained.

Benthic Macroinvertebrates

For this study, production of aquatic insects was calculated in each of three years with *Bti* treatments (1988-1990) immediately below Bluestone Dam and Sandstone Falls. Production had been calculated previously in years without *Bti* treatments (Bluestone

Dam in 1983 [Voshell 1985] and Sandstone Falls in 1987 [Voshell et al. 1988]) and with *Bti* treatments (Bluestone Dam in 1986 [Voshell et al. 1988a]). The methods for measuring production of aquatic insects were consistent for all studies of the New River, both before and after *Bti* treatment. The only difference was in sampling design. In some of the earlier studies, samples were collected more frequently, sampling extended over more months of the year, or more replicate samples were taken. To make accurate comparisons among years, production values from earlier studies were recalculated according to the design of this study described below. When it was necessary to recalculate production from fewer replicates, they were chosen randomly.

The sampling schedule was to collect samples every 2 wk from June 1 through November 30 in 1988, 1989, and 1990, but exceptionally high flows occasionally caused sampling dates to be missed. Studies began in June because that was the earliest that flows were low enough for sampling and ended in November because that was the latest that *S. jenningsi* larvae would be present (Voshell 1985). The specific dates can be found in Fig. 15 for standing stock of *Podostemum*, because the *Podostemum* was taken from the benthic macroinvertebrate production samples. A stratified random design was employed with a single sampling stratum, mats of *Podostemum* on rock outcrops. Replicate 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 et al. 1992). Five samples were collected at each site on each date. Samples were preserved in 95% ethanol 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.

Size classes or instars were delimited by analyzing head capsule measurements. Mean weights of individuals in each size class or instar 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 accuracy of using correction factors was investigated during 1988-89 by comparing weights of fresh and preserved specimens (Voshell et al. 1989a). The results confirmed the correction factors for weight loss from preservation that had been used previously.

The size frequency method (Benke 1984) was used to calculate production of each of the dominant taxa occurring on the rock outcrops. The equation for estimating production for the June 1-November 30 study period was:

$$P = \sum_{i=1}^k (N_i - N_{i+1}) ((W_i) (W_{i+1})^{0.5})^k (183/1/2 \text{ CPI})$$

where:

P = production for 183 day study period from June 1 to November 30
(mg/m²)

k = number of size groups

N_i = average density of size group i (number/sample)

N_{i+1} = average density of size group $i+1$ (number/sample)

w_i = average individual dry weight for size group i (mg)

w_{i+1} = average individual dry weight for size group $i+1$ (mg)

CPI = cohort production interval (days)

Dominant taxa were those that occurred in sufficient numbers to calculate production. Dominant taxa were not consistent among years. Although some other taxa did occur on the rock outcrops, we estimated that collectively they accounted for less than 5% of the total benthic macroinvertebrate production.

All taxa for which production was calculated in at least one year immediately below Bluestone Dam were:

Ephemeroptera (mayflies)

Baetis intercalaris

Heterocloeon curiosum

Trichoptera (caddisflies)

Cheumatopsyche campyla

Diptera: Simuliidae (black flies)

Simulium jenningsi

Simulium vittatum

Diptera: Chironomidae (midges or chironomids)

Chironominae/Orthocladiinae

All taxa for which production was calculated in at least one year immediately above Sandstone Falls were:

Ephemeroptera (mayflies)

Baetis intercalaris

Serratella deficiens

Tricorythodes spp.

Trichoptera (caddisflies)

Cheumatopsyche campyla

Oecetis spp.

Diptera: Simuliidae (black flies)

Simulium jenningsi

Diptera: Chironomidae (midges or chironomids)

Chironominae/Orthoclaadiinae

The method of Krueger and Martin (1980) was used to place 95% confidence limits on production measurements. All production measurements were reported in units of dry weight. The cohort production intervals (CPI) used in the calculations for the fauna at this site were: *B. intercalaris* - 336 days; *S. deficiens* - 323 days; *Tricorythodes* spp. - 94 days; *C. campyla* - 161.5 days; *Oecetis* spp. - 328 days; *S. jenningsi* - 44.8 days; Chironominae/Orthoclaadiinae - 24.3 days (Voshell 1985). Because production was estimated for the period from June 1 to November 30 (183 days), one-half of these CPI values were used in the production equation (see above).

For analyzing changes in community structure of macroinvertebrates, data were available from Bluestone Dam and Sandstone Falls for 2 years before *Bti* treatments (1982 and 1984) and for 3 years after *Bti* treatments (1988-1990). The data for 1988-1990 are part of the NRGNR LTEMs database. Only cobble/pebble riffle samples were analyzed because previous studies had shown that these contained the most diverse community. The following metrics were used to analyze community structure: total density, taxa richness, Ephemeroptera, Plecoptera, Trichoptera (EPT) Index, Shannon Diversity Index, and Hilsenhoff Biotic Index (HBI). These were analyzed by Kruskal-Wallis and Wilcoxon Rank Sum Tests, with $\alpha = 0.05$. In addition, community structure was analyzed by two similarity indices: Percent Similarity Index and Pinkham and Pearson Index. These are explained below in the Methods section for Fish.

Fishes

Fish were collected from shallow habitats (less than 1.0 m deep) in the New River immediately below Bluestone Dam, Sandstone Falls, Prince, Thurmond, and Fayette Station (Fig. 1) in 1988, 1989, and 1990. Data were collected on three occasions each year immediately below Bluestone Dam and Sandstone Falls corresponding roughly with the beginning (early summer), middle (mid-summer), and end (mid-fall) of the growing season. Three collections were made to provide data for growth estimation at both of these sites. At Prince, Thurmond, and Fayette Station collections were made each year during the mid-summer only (Table 1; see Easton and Orth 1994).

The electrofishing system included a 120-volt, 1500-watt generator and a variable voltage pulsator (Coffelt model VVP-2C) with two hand-held anodes. Sampling was accomplished by wading upstream and capturing all stunned fish during thirteen 10-minute periods.

In the field, larger fish (greater than 80 mm total length, TL) were identified, measured (mm), weighed (g), and returned to the river. Smaller fish (less than 80 mm TL) were preserved (either by freezing or formalin) and later identified, measured, and weighed in the laboratory. During early summer and mid-fall collections immediately below Bluestone Dam and Sandstone Falls, scale samples were taken from all centrarchids (sunfish and bass) to provide age estimates used in growth analyses. Scales were removed from the area immediately above the lateral line near the tip of the depressed pectoral fin. In the laboratory, ages of centrarchids were assigned by counting the number of annuli present on the scales (Jearld 1983). Age-0 centrarchids collected in mid-summer and non-centrarchid species collected in early summer, mid-summer, and mid-fall were aged from length-frequency data where possible.

Data were entered onto computer files and analyzed with the Statistical Analysis System (SAS 1985) and Quattro Pro 3.0 (Borland International 1991). Data collected by Stauffer et al. (1980) and Lobb (1986) were analyzed with similar methods. These data were used to determine if changes in fish communities occurred between pretreatment years (1979 and 1984; prior to the first applications of *Bti* to the New River) and treatment years (1988, 1989 and 1990; years in which *Bti* was applied). Data from Stauffer et al. (1980) and Lobb (1986) were collected in summer and, therefore, compared with mid-summer collections from 1988, 1989, and 1990. Because of differences in sampling methods among periods it was not possible to compare catch per sampling time with the Stauffer et al. data.

Sampling by Stauffer et al. (1980) was conducted in June and August of 1979. Collections were made by electrofishing into a 1.5 m X 3.0 m seine or with a 1.5 m X 7.6 m bag seine. For each collection, sampling was conducted until additional effort

produced no additional species. For comparisons with our data, collections from several locations were pooled to represent sites similar in location to our five sample sites (Fig. 1). Six collections between Bluestone Dam and the city of Hinton were referred to as Bluestone Dam collections. Four collections between Brooks Island and the mouth of Meadow Creek were referred to as Sandstone Falls collections. One collection at the mouth of Piney Creek was referred to as a Prince collection. One collection immediately upstream of Stone Cliff was referred to as a Thurmond collection.

Sampling by Lobb (1986) was conducted from early July to mid-September of 1984. Most collections were made using a raft-mounted generator, Coffelt (VVP-2C) control box, and two hand-held electrodes; however, two Sandstone Falls collections were made with a Coffelt backpack electrofisher and another Sandstone Falls collection was made by electrofishing into a seine. Each collection consisted of a 15-minute electrofishing period. For comparisons with our data, collections from several locations were pooled to represent sites similar in location to our five sample sites (Fig. 1). Five collections made between Bluestone Dam and the town of Barksdale were referred to as Bluestone Dam collections. Ten collections made between 0.8 km upstream from Sandstone Falls and 1.6 km downstream from the mouth of Meadow Creek were referred to as Sandstone Falls collections. Fifteen collections made between the mouth of Glade Creek and 3.3 km downstream of the town of Terry were referred to as Prince collections. Nine collections made between the town of Thayer and the mouth of Ephraim Creek were referred to as Thurmond collections. No collections were made near the Fayette Station site.

Pretreatment and treatment collections were compared using the following measures often included in indices of biotic integrity (Karr 1986; Ohio Environmental Protection Agency 1987; Lyons 1992):

- 1) number of species,
- 2) percent by order, family, and species,
- 3) diversity (by number),
- 4) number of darter species,
- 5) number of sunfish species,
- 6) number of intolerant species,
- 7) number of tolerant species,
- 8) percent green sunfish *Lepomis cyanellus*,
- 9) percent omnivores,
- 10) percent insectivorous cyprinids,
- 11) percent piscivores, and
- 12) number of fish collected per 10 minutes.

In addition, the similarity in composition of the fish assemblages was compared with percent similarity index (Washington 1984), Pinkham and Pearson index (Washington 1984), and persistence index (Meffe and Berra 1988).

The identification of two species of shiner (*Luxilus albeolus* white shiner and *Luxilus crysocephalus* striped shiner) proved to be problematic and therefore no consistent distinction could be made between these species in all studies. For all analyses including species counts, these *Luxilus* spp. were treated as a single species. Hybrid fishes, which were rare (< 0.1%), were excluded from all analyses.

Diversity was calculated on numbers of each species using the Shannon index which is calculated as:

$$H' = -\sum \frac{n_i}{N} \log_e \frac{n_i}{N}$$

where;

H' = diversity of the sample,

n_i = number of the i^{th} species in the sample, and

N = total number of fish in the sample.

Number of darter species was calculated as the number of both *Etheostoma* and *Percina* species in a collection. The number of sunfish species was calculated as the total number of *Lepomis* species. For calculation of number of intolerant species, number of tolerant species, percent omnivores, percent insectivorous cyprinids, and percent piscivores, species were categorized on the basis of information from Ohio EPA (1987), Plafkin et al. (1989), and Jenkins and Burkhead (1994) as indicated in Appendix 11.

The percent similarity index was used to determine the similarity in fish communities between two collections from different years. The percent similarity index ranges from 0 to 100 and uses relative species abundance data. This index has been shown to be sensitive to changes in community structure with an emphasis on abundant species (Washington 1984). Percent similarity was calculated as:

$$PSC = 100 - 0.5 \sum_{i=1}^K |a_i - b_i|$$

where;

PSC = percent similarity for collections A and B,

K = total number of species in collections A and B,

a = percentage of species i in collection A,

b = percentage of species i in collection B.

The Pinkham and Pearson index was also used to determine the similarity in fish communities between two collections from different years. The Pinkham and Pearson index ranges from 0 to 1 and uses relative species abundance data. The Pinkham and Pearson

index has been shown to be sensitive to changes in community structure, however, this index emphasizes changes in rare species (Washington 1984). Pinkham and Pearson's index was calculated as:

$$B = \frac{1}{K} \sum_{i=1}^K \frac{\min(X_{ia}, X_{ib})}{\max(X_{ia}, X_{ib})}$$

where;

B = Pinkham and Pearson similarity index for collections a and b ,

K = total number of species in collections a and b ,

X_{ia} = percentage of species i in collection a ,

X_{ib} = percentage of species i in collection b .

Pinkham and Pearson's indices were converted to percentages by multiplying by 100.

The persistence index (Meffe and Berra 1988) was used to determine changes in the community stability between two collections from different years. The persistence index ranges from 0 to 1 and uses presence and absence data. Persistence was calculated as:

$$P = 1 - \frac{C + E}{S_A + S_B}$$

where;

P = persistence of species from collection A to collection B ,
 C = number of colonizations from collection A to collection

B ,

E = number of extinctions from collection A to collection B ,

S_A = number of species in collection A ,

S_B = number of species in collection B .

Growth and condition were calculated for Bluestone Dam and Sandstone Falls collections. Growth in length (mm/d) was calculated as a linear growth rate, H , (Ricker 1975) from:

$$H = \frac{l_{t+d} + l_t}{d}$$

where;

H = growth in length (mm d⁻¹),

l_t = mean length (mm) at time t ,

l_{t+d} = mean length (mm) at time $t+d$,

d = time period (days) between estimated lengths.

The variance in the growth rate (H) was calculated as:

$$V(H) = \frac{V(l_t) + V(l_{t+d})}{d^2}$$

where;

$V(H)$ = variance in growth rate in length,
 $V(l_t)$ = variance of mean length at time t ,
 $V(l_{t+d})$ = variance of mean length at time $t+d$,
 d = time period (days) between estimated lengths.

Growth rates for weight data were calculated as instantaneous growth rate, G (day^{-1} ; Ricker 1975), according to:

$$G = \frac{\log_e \left(\frac{w_{t+d}}{w_t} \right)}{d}$$

where;

G = instantaneous growth in weight (day^{-1}),
 w_t = mean weight at time t ,
 w_{t+d} = mean weight at time $t+d$,
 d = time period (days) between estimated weights.

An estimate of the variance of G was obtained by adding the variances of the natural logarithms of the mean (Newman and Martin 1983). The estimate of the variance of G is calculated as:

$$V(G) = \frac{V(\log_e w_{t+d}) + V(\log_e w_t)}{d^2}$$

where;

$V(G)$ = estimate of the variance of G ,
 $V(\log_e w_t)$ = variance of the natural logarithm of mean weight for time t ,
 $V(\log_e w_{t+d})$ = variance of the natural logarithm of mean weight for time $t+d$,
 d = time period (days) between estimated weights.

The variance of the natural logarithm of the mean was approximated from:

$$V(\log_e w_t) = \frac{V(w_t)}{w_t^2}$$

where;

$V(\log_e w_t)$ = variance of the natural logarithm of mean weight for time t,

$V(w_t)$ = variance of mean weight at time t,

w_t = mean weight at time t.

^t
Mean lengths and weights of age-0 smallmouth bass (*Micropterus dolomieu*) collected on three dates in 1982 from the New River near Meadow Creek (approximately 7.9 river km downstream from Sandstone Falls; Graham 1982) were used for comparison with treatment collections. Mean length and weight at age of rock bass (*Ambloplites rupestris*) and smallmouth bass collected between 1982 and 1985 (Austen 1984, Roell 1989) were used for comparison with mean sizes of these species at the end of the growing season during treatment years.

In addition to growth rates, condition factors (K; Anderson and Gutreuter 1983) were calculated using Fulton's formula:

$$K = \frac{w_i \times 10^5}{l_i^3}$$

where;

K = condition of individual i,

w_i = weight (g) of individual i,

$l_{i,i}$ = length (mm) of individual i.

ⁱ
Condition factors are indicative of changes in food availability. For comparison with treatment years, pretreatment condition of age-0 smallmouth bass was calculated from individual length and weight data in Graham (1982). No other pretreatment data were available for comparison with treatment data, therefore criteria created by Carlander (1944) and Bennett (1948) for rock bass and bluegill (*Lepomis macrochirus*) in Minnesota and Illinois were used to evaluate the condition of these species.

Results

Black Fly Pest Management Program

A complete record of all *Bti* applications can be found in Table 2. In 1986, *Bti* was applied only from Bluestone Dam to just above the NPS NRGNR boundary (Route 20 bridge at Hinton). In 1988-1990, *Bti* was applied from Bluestone Dam to below Sandstone Falls.

The application rate is expressed as the concentration of *Bti* that organisms would be exposed to for a period of 1 minute. The application rate of *Bti* was 22 ppm for 1 min for most of the dates during this study (1988-1990). In 1986, the application rate was 27 or 30 ppm from June through September. The frequency of application was determined by examining the instar distribution of the *S. jenningsi* population (Mike Zeto, West Virginia Department of Natural Resources, personal communication). *Bti* was applied about the same number of times in 1986, 1988, and 1990. *Bti* was not applied as often during 1989 because of high flows.

Environmental Characteristics

Bluestone Dam

A record of all water quality measurements immediately below Bluestone Dam can be found in Appendix 12 of Interim Report No. 8. Water quality measurements were made in all *Bti*-treatment years (1986, 1988, 1989, and 1990), but not in the pretreatment year when baseline studies on aquatic insect production were conducted (1983). Limited data on temperature, discharge, and macrophyte biomass were available from 1983, and other data on temperature, pH, dissolved oxygen, and seston were available from 1982 and 1984. Therefore, all available data from 1982 to 1984 were used as comparisons with data from the treatment years to analyze for any effects on aquatic life that might have been brought about by changes in water quality (Table 3). All measurements were within the range that would be expected for flowing surface waters and would present no adverse conditions for aquatic life. Mean temperature, dissolved oxygen, pH, and seston were nearly the same in all years and exhibited no statistically significant differences. Results of seston analyses are particularly noteworthy because seston is the most important source of food for the dominant aquatic insects in the New River. There were some statistically significant differences in conductivity among years for which data were available ($P \leq 0.05$), but the magnitude of difference was probably not enough to cause any differences in the biological communities.

Water temperatures over the entire study period are graphed in Figs. 2-4, and the accumulated degree-days for each year are recorded in Table 3. The values for accumulated degree-days are not amenable to statistical testing for significant differences

because there is only one value for each year. Temperature was slighter cooler in 1989 than any other year. From June through November the accumulated degree-days were only 3% less in 1986 and 2% less in 1988 as compared to the same months in 1983; however, accumulated degree-days were 9% less in 1989 than 1983. Maximum temperature (highest recorded value) was also slightly less in 1989. The seasonal pattern of warming and cooling was almost identical in all years except 1986. In 1986 the temperature rose more rapidly in early summer and cooled more slowly in early fall than in the other 3 years; however, it is not likely that this slight difference in temperature pattern would have any effect on the biota.

Discharge of the New River below Bluestone Dam was highly variable among the 5 years that studies were conducted (Table 3 and Figs. 7-9). Using the pretreatment year (1983) for comparison, mean daily discharge during the June to November study period was significantly lower in 1986 and 1988 and significantly higher in 1989; however, mean daily discharge was not significantly different in 1990 (Table 3). Mean daily discharge during the study period was 27% less in 1986, 54% less in 1988, 139% greater in 1989, but only 19% greater in 1990 (all compared to 1983). The temporal patterns of discharge (Figs. 7-9) were distinctly different in 1988 and 1989 as compared to 1983, but were more similar in 1983 and 1986. In 1983 and 1986, there were high flows in late winter and early spring followed by low flows during summer and increased flows in autumn. In 1988, there were consistently low flows throughout the year. Flows were low during winter and early spring of 1989 but were exceptionally high throughout summer and autumn. The most normal seasonal pattern of discharge occurred in 1983, and the most comparable year to 1983 was 1986. Flows in 1988 and 1989 were near the lowest and highest on record, respectively.

The mean standing stock of the submersed macrophyte *Podostemum* from June 1 through November 30 of each year is presented in Table 3 and Figs. 12-14. This plant, which provides habitat for macroinvertebrates, was considerably more abundant in 1983 than in any other year. Mean standing stock was statistically significantly lower in 1986, 1988, and 1990, as compared to 1983 ($P \leq 0.05$). Mean standing stock was 72% less in 1986, 91% less in 1988, 51% less in 1989, and 56% less in 1990, as compared to 1983. The lack of statistical difference for the lower mean standing stock in 1989 was probably the result of high variability in the data.

Sandstone Falls

A record of all water quality measurements immediately above Sandstone Falls can be found in Appendix 3 of Interim Report No. 7. Yearly means of water quality measurements (temperature, conductivity, pH, and dissolved oxygen) for the period of June through November are summarized in Table 4. All measurements were

within the range that would be expected for flowing surface waters and would present no adverse conditions for aquatic life. There were no significant differences between years for means of any water quality parameter ($P = 0.05$; Kruskal-Wallis analysis of variance [Snedecor and Cochran 1980]). Water temperature data are also summarized in Figs. 5-6 and calculated as accumulated degree-days in Table 4. Values for accumulated degree-days are not amenable to statistical analyses, because there is only one measurement for each year. Accumulated degree-days were almost identical in 1987, 1988, 1989, and 1990.

Discharge of the New River immediately above Sandstone Falls for each entire year is presented in Figs. 10-11 and summarized for the sampling period from June through November in each year in Table 4. Because Bluestone Lake is not used for storage and the Greenbrier River is free-flowing, discharge usually follows a normal seasonal pattern with highest flows in late winter and spring (e.g., 1987). Average mean daily discharge for the entire year (Figs. 10-11) was similar in 1987, 1989, and 1990 (9,430, 9,898, and 9,252 cfs, respectively), but was only about one-third as much in 1988 (3,545 cfs). The 50-yr norm for average mean daily discharge during the entire year has been 7,889 cfs; therefore, average mean daily discharge was only slightly above normal for all of 1987, 1989, and 1990 but was far below normal in 1988. Particularly noticeable was the absence of high flows during the spring of 1988.

In spite of some similarities for average mean daily discharge during the entire years of 1987, 1989, and 1990, the average mean daily discharge for the sampling period from June through November was significantly different in each year of the study ($P = 0.05$; Kruskal-Wallis analysis of variance followed by two sample rank-sum tests, [Snedecor and Cochran 1980]; Table 4). The years in which flows were the most different during the sampling period were 1988 (exceptionally low) and 1989 (exceptionally high). Average mean daily discharge during the sampling period in 1988 was approximately one-third, three-fourths, and two-thirds lower than during the sampling period in 1987, 1989, and 1990, respectively. The lowest recorded mean daily discharge was 620 cfs on November 3, 1981. From July 7-12, 1988 the mean daily discharge remained at 800 cfs, approaching record low flows. In 1989, flows were lower than usual during winter and most of spring but were much higher during the sampling period in summer and autumn. For the sampling period from June through November, flows in 1989 were approximately 3X, 5X, and 2X higher than 1987, 1988, and 1990, respectively.

Data on seston and the submersed macrophyte *Podostemum*, which are important as food and habitat, respectively, are summarized in Table 4. There were no significant differences between years for mean seston concentration ($P = 0.05$; Kruskal-Wallis analysis of variance [Snedecor and Cochran 1980]). Mean biomass of *Podostemum* was significantly lower in 1987 than any other year ($P = 0.05$; Kruskal-Wallis analysis of variance followed by two sample rank-

sum tests [Snedecor and Cochran 1980]). The average standing stock of *Podostemum* for the June to November sampling period in 1988 was only about one-third, one-third, and one-half of what it was in 1987, 1989, and 1990, respectively (Table 4). The temporal distribution of *Podostemum* standing stock is presented in Figs. 15-16. In 1987, this plant followed a typical seasonal pattern exhibiting the highest standing stock early in summer and declining thereafter. In 1988, *Podostemum* was nearly absent from the New River immediately above Sandstone Falls, with the greatest difference between other years occurring from June through early August. Temporal distribution of *Podostemum* was similar in 1989 and 1990, and both years differed from 1987 in that standing stock was higher in the early summer of 1987.

Production of Benthic Macroinvertebrates

Bluestone Dam

Production levels of the dominant taxa and total benthic macroinvertebrate production in all 5 years are compared in Table 5 and Figs. 22-23. It is not possible to conduct standard statistical tests (e.g., t-test) on these production data because there is only one value for each year. However, the method of Krueger and Martin (1980) can be used to calculate 95% confidence limits for the production measurement of each taxon in each year. Confidence limits for individual taxa are reported in Table 5 and illustrated in Figs. 22-23. The differences in production between any 2 years are considered to be significantly different (i.e., not due to random variation) if the 95% confidence intervals do not overlap. If the 95% confidence intervals overlap, then the differences cannot be distinguished from random variation that occurs in the New River and are considered to be not significant. It is not appropriate to calculate 95% confidence limits for total benthic macroinvertebrate production, which is determined by summing the production of individual taxa, because 95% confidence limits are not additive.

Total benthic macroinvertebrate production was 48%, 42%, and 78% less in 1986, 1988, and 1989, respectively, as compared to 1983; however, total benthic macroinvertebrate production was slightly higher (3%) in 1990 than 1983. Production of the target of the pest management program, *S. jenningsi*, was significantly lower in all treatment years than in the pretreatment year (1983) ($P \leq 0.05$). Production of *S. jenningsi* was barely measurable in 1986 and 1989, increased slightly in 1989, then declined again in 1990. Production of *S. jenningsi* in the years with *Bti* treatment ranged from 1.2 to 12.3% of the 1983 level before treatment. Production of the highest and second highest producing organisms (Chironominae/Orthocladiinae and *C. campyla*, respectively) was significantly lower than the pretreatment year (1983) in the first three of the treatment years that production measurements were made (1986, 1988, 1989), with the lowest levels for both groups measured in 1989. In 1990, production of both taxa exceeded the

levels in the pretreatment year (1983). The increase in production of *C. campyla* in 1990 (27.1%) was statistically significant as compared to 1983 ($P \leq 0.05$), but the increase in production of Chironominae/Orthocladiinae (7.1%) was not. Production of *B. intercalaris* was 49% lower in 1986 but 35% higher in 1988, 64% higher in 1989, and 30.6% higher in 1990 as compared to 1983. Production levels of *B. intercalaris* were significantly different only in 1986, 1988, and 1989, as compared to 1983 ($P \leq 0.05$). *H. curiosum* achieved low levels of production in 1983 and 1986, then declined to levels that were not measurable in later years. Production of *S. vittatum* was only measurable in 1983.

The relative amount of production that each individual taxon contributed to total benthic macroinvertebrate production is shown in Figs. 17-19. The increases or decreases of *B. intercalaris*, *H. curiosum*, and *S. vittatum* appear to be inconsequential when considered in this perspective. The caddisfly species *C. campyla* and the chironomid subfamilies Chironominae/Orthocladiinae consistently accounted for almost all of the production (92% before treatment, 95 - >99% after treatment). *S. jenningsi* accounted for 7% of production before treatment and <1 - 4% in years with *Bti* treatment.

Sandstone Falls

Production values for all taxa in each year are summarized in Table 6 and compared in Figs. 24-25. The relative amount of production that each individual taxon contributed to total benthic macroinvertebrate production is shown in Figs. 20-21. In 1987 the total benthic macroinvertebrate production for all taxa on the rock outcrops immediately above 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 accounted for approximately one-half (51.0%) of the total benthic macroinvertebrate production. Chironomids in the subfamilies Chironominae/Orthocladiinae were the second highest producers (34.0%). Of the remaining 15% of the total benthic macroinvertebrate production, *C. campyla*, *S. jenningsi*, and *Oecetis* spp. contributed 4.9%, 0.3%, and 9.8%, respectively.

In 1988, the total benthic macroinvertebrate production of all taxa was 36,391 mg/m². Chironomids in the subfamilies Chironominae/Orthocladiinae accounted for a much higher proportion of the total benthic macroinvertebrate production (87.3%) than any other organisms. The mayfly *Tricorythodes* spp. was again the second highest producing organism, but only accounted for 5.2% of the total. Together, all three species of mayflies were responsible for 8.2% of the total. Production of the caddisfly *C. campyla* was about the same as *Tricorythodes* spp. and accounted for 4.2% of the total. Of the remaining dominant members of the rock outcrop community, the caddisfly *Oecetis* spp.

produced a barely detectable amount of biomass that was 0.4% of the total, and production of the black fly *S. jenningsi* was below the limit of measurement. In 1988 a total of only 17 *S. jenningsi* larvae were found in the 65 samples taken from June through November.

In 1989, the total benthic macroinvertebrate production of all taxa was 26,712 mg/m². Chironomids in the subfamilies Chironominae /Orthocladiinae accounted for the highest proportion of the total benthic macroinvertebrate production (87.3%). The caddisfly *C. campyla* was the second highest producing organism, accounting for 20.4% of the total. Together, all three species of mayflies were responsible for 14.6% of the total. Of the members of the rock outcrop community that had been dominant in previous years, the caddisfly *Oecetis* spp. and the black fly *S. jenningsi* were below the limit of production measurement.

In 1990, the total benthic macroinvertebrate production of all taxa was 40,610 mg/m². Chironomids in the subfamilies Chironominae /Orthocladiinae accounted for the highest proportion of the total benthic macroinvertebrate production (88.9%). The caddisfly *C. campyla* was the second highest producing organism (2,357 mg/m²), accounting for 5.8% of the total. Three taxa of mayflies accounted for the rest of the production on the rock outcrops, with the production of each being about the same. Together, all three species of mayflies were responsible for 5.3% of total benthic macroinvertebrate production. The caddisfly *Oecetis* spp. and the black fly *S. jenningsi* were again below the limit of production measurement.

In comparison to 1987, which was the reference year with no *Bti* treatments, the total benthic macroinvertebrate production of all taxa was 18% higher in 1988, 13% lower in 1989, and 32% higher in 1990. The higher total benthic macroinvertebrate production in 1988 and 1990 was mostly brought about by greatly increased production of chironomids in the subfamilies Chironominae/Orthocladiinae. Production of chironomids was significantly higher in each of the treatment years (1988, 1989, 1990) as compared to 1987. Production of chironomids was not significantly different between 1988 and 1990, but production in 1989 was significantly lower than 1988 or 1990.

The three taxa of mayflies that were abundant on the rock outcrops exhibited irregular levels of production. *Tricorythodes* spp. achieved a significantly higher level of production in 1987 than any of the treatment years. *Tricorythodes* production was fairly uniform in all of the treatment years. The 13% lower total benthic macroinvertebrate production of all taxa in 1989 was mostly accounted for by lower production of *Tricorythodes* and not so great an increase in chironomid production. The mayfly *Serratella deficiens* had significantly lower production in 1988 and significantly higher production in 1989 as compared to 1987, but its production in 1990 was not significantly different from 1987. The third mayfly, *Baetis intercalaris*, achieved levels of

production in 1988 and 1989 that were not significantly different from 1987; however, production in 1990 was significantly lower than any of the preceding years.

The net-spinning caddisfly *Cheumatopsyche campyla* also exhibited irregular levels of production during the 4 years of the study. In comparison to 1987, *C. campyla* production was significantly lower in 1988, significantly higher in 1989, and not significantly different in 1990. Production was significantly different between each of the treatment years. One other taxon of caddisfly, the predaceous *Oecetis* spp., achieved measurable levels of production in 1987 and 1988, then occurred in insufficient numbers to measure production in 1989 and 1990. Production of *Oecetis* spp. was not significantly different between 1988 and 1987.

The only other taxon that achieved measureable levels of production during the 4 years of the study was the black fly *Simulium jenningsi*, which was the target of the pest control program. *S. jenningsi* accounted for 4.9% of total benthic macroinvertebrate production in 1987, then did not occur in sufficient numbers to measure production in any of the treatment years.

Growth and Condition of Fishes

Growth

Mean lengths and weights were calculated for 12 species immediately below Bluestone Dam (Tables 7-8) and 11 species immediately above Sandstone Falls (Tables 9-10). Immediately below Bluestone Dam growth rates for length and weight were calculated for central stoneroller, bigmouth chub, rock bass, redbreast sunfish, bluegill, smallmouth bass, and spotted bass (*Micropterus punctulatus*); however, only age-0 bigmouth chub, age-1 and age-2 rock bass, and age-0 smallmouth bass were collected consistently enough to allow for comparisons of growth among two or more treatment years (Figs. 26 & 27). All other mean size at age and growth calculations listed in Tables 7-8 are provided for future reference.

Immediately above Sandstone Falls, growth rates for length and weight were calculated for central stoneroller, *Luxilus* spp., bigmouth chub, spottail shiner, telescope shiner, northern hog sucker, rock bass, bluegill, and smallmouth bass; however, only age-0 central stoneroller, age-0 *Luxilus* spp., age-0 bigmouth chub, age-0 and age-1 rock bass, and age-0 smallmouth bass were collected consistently enough to allow for comparisons of growth among two or more treatment years (Figs. 28-29). All other mean size at age and growth calculations listed in Tables 9-10 are provided for future reference.

Central stoneroller: Growth patterns for length and weight of age-0 central stonerollers immediately above Sandstone Falls were similar among all three treatment years (Figs. 28-29). Mean length and weight at the end of the growing season was greater in 1988 than 1989. Insufficient numbers ($n < 10$) of age-0 central stonerollers were collected immediately above Sandstone Falls at the end of the growing season in 1990, therefore no means were calculated for comparison. Immediately below Bluestone Dam, growth comparisons for age-0 central stonerollers were not made because too few were collected.

Luxilus spp.: Growth patterns for length and weight of age-0 *Luxilus* spp. immediately above Sandstone Falls were similar in 1988 and 1989 (Figs. 28-29). Mean length and weight at the end of the growing season was greater in 1988 than 1989. Insufficient numbers ($n < 10$) of age-0 *Luxilus* spp. were collected immediately above Sandstone Falls in 1990, therefore no means were calculated for comparison. Immediately below Bluestone Dam, growth comparisons for *Luxilus* spp. were not made because too few were collected.

Bigmouth chubs: Immediately below Bluestone Dam, growth patterns for length and weight of age-0 bigmouth chubs were similar in 1988 and 1990 (Figs. 26-27). Mean length for age-0 bigmouth chubs immediately below Bluestone Dam at the end of the growing season was greater in 1990 than 1988. Mean weights for age-0 bigmouth chubs immediately below Bluestone Dam at the end of the growing season were equal in 1988 and 1990. Insufficient numbers ($n < 10$) of age-0 bigmouth chubs were collected immediately below Bluestone Dam in 1989, therefore no means were calculated for comparison.

Growth patterns for length and weight of age-0 bigmouth chubs immediately above Sandstone Falls were similar among all three treatment years (Figs. 28-29). Mean length and weight of age-0 bigmouth chubs at the end of the growing season were greatest in 1988 and lowest in 1989.

Rock bass: Growth patterns for length and weight of age-0 rock bass immediately above Sandstone Falls were similar in 1988 and 1990 (Figs. 28-29). In 1988 and 1990 mean lengths and weights of age-0 rock bass immediately above Sandstone Falls were greater at the end of the growing season than the length and weight estimated at first annulus for rock bass collected in 1984 and 1985 (Roell 1989). In 1989 the length and weight of age-0 rock bass at the end of the growing season immediately above Sandstone Falls was less than the length and weight estimated at first annulus (equivalent to end of first growing season) for rock bass collected in 1984 and 1985 (Roell 1989). Immediately below Bluestone Dam, growth comparisons for age-0 rock bass were not made because too few were collected.

Growth patterns for length and weight of age-1 rock bass immediately below Bluestone Dam were similar in 1988 and 1989. Insufficient numbers ($n < 10$) of age-1 rock bass were collected immediately below Bluestone Dam in 1990 to allow for calculation of growth estimates. Mean lengths and weights in 1988, 1989, and 1990 of age-1 rock bass immediately below Bluestone Dam were greater at the end of the growing season than the length and weight estimated at second annulus for rock bass collected in 1984 and 1985 (Roell 1989).

Growth patterns for length and weight of age-1 rock bass immediately above Sandstone Falls were similar in 1988 and 1989. Insufficient numbers ($n < 10$) of age-1 rock bass were collected immediately above Sandstone Falls in 1990 to allow for calculation of growth estimates. Mean weight in 1988 of age-1 rock bass immediately above Sandstone Falls at the end of the growing season was greater than the weight estimated at second annulus for rock bass collected in 1984 and 1985 (Roell 1989). Mean length in 1988 and 1989 and mean weight in 1989 for age-1 rock bass immediately above Sandstone Falls at the end of the growing season were less than the length and weight estimated at second annulus for age-1 rock bass collected in 1984 and 1985 (Roell 1989).

Growth patterns for length and weight of age-2 rock bass immediately below Bluestone Dam were similar for all three treatment years. Mean lengths and weights in 1988, 1989, and 1990 of age-2 rock bass immediately below Bluestone Dam were greater at the end of the growing season than the length and weight estimated at third annulus for rock bass collected in 1984 and 1985 (Roell 1989). Immediately above Sandstone Falls, growth comparisons for age-2 rock bass were not made because too few were collected.

Smallmouth bass: In 1988 and 1990, growth patterns for length and weight of age-0 smallmouth bass immediately below Bluestone Dam were similar to growth patterns of age-0 smallmouth bass collected in 1982 (Graham 1982). In 1988 and 1990, mean lengths and weights of age-0 smallmouth bass immediately below Bluestone Dam were greater at the end of the growing season than the lengths and weights estimated at the first annulus for smallmouth bass (equivalent to end of first growing season) collected in 1982 and 1983 (Austen 1984) and in 1984 and 1985 (Roell 1989). Insufficient numbers ($n < 10$) of age-0 smallmouth bass were collected immediately below Bluestone Dam in 1989 to allow for calculation of growth estimates.

In 1988, 1989, and 1990, growth patterns for length and weight of age-0 smallmouth bass immediately above Sandstone Falls were similar to growth patterns of age-0 smallmouth bass collected in 1982 (Graham 1982). Mean lengths and weights in 1988, 1989, and 1990 of age-0 smallmouth bass immediately above Sandstone Falls were similar at the end of the growing season to the lengths and weights estimated at the first annulus for smallmouth bass

collected in 1982 and 1983 (Austen 1984) and in 1984 and 1985 (Roell 1989).

Condition

Immediately below Bluestone Dam, condition (K) ranged from 0.74 for age-0 spottail shiners collected in the mid-fall of 1990 to 2.35 for age-2 rock bass collected in the early summer and mid-fall of 1988 (Table 11). In general, species condition values varied and showed no trends throughout the growing season or among treatment years. In 1982, the condition of age-0 smallmouth bass collected from the New River (calculated from Graham 1982) was 1.22 (n=28, variance=0.006) on July 21, 1.13 (n=27, variance=0.004) on August 27, and 1.19 (n=20, variance=0.003) on October 1. Immediately below Bluestone Dam in 1988 and 1990, the condition of age-0 smallmouth bass ranged from 1.20 in the mid-fall of 1990 to 1.56 in the mid-summer of 1988, with four of the five condition values surpassing the greatest condition values calculated from the 1982 data (Graham 1982).

For rock bass in Minnesota, Carlander (1944) reported condition values less than 1.80 as poor, greater than 2.49 as excellent, and between 1.80 and 2.49 as average. Using this criteria, the mean condition of rock bass from Bluestone site in 1988, 1989, and 1990 was average. For bluegill in Minnesota, Carlander (1944) reported condition values less than 1.66 as poor, greater than 2.52 as excellent, and between 1.66 and 2.52 as average. For bluegill in Illinois, Bennett (1948) reported condition values less than 1.39 as poor, greater than 2.22 as good, and between 1.39 and 2.22 as average. Using these criteria, the mean condition of bluegill at Bluestone Dam site in 1988, 1989, and 1990 was average or good; exception was for age-0 bluegill in one sample (fall 1989).

At Sandstone Falls, condition (K) ranged from 0.56 for age-0 flathead catfish collected in the mid-summer of 1990 to 2.25 for age-0 and age-1 rock bass collected in the early summer of 1988 (Table 12). In general, species condition values varied and showed no trends throughout the growing season or among treatment years. At Sandstone Falls in 1988, 1989, and 1990 the condition of age-0 smallmouth bass ranged from 0.83 in the early summer of 1989 to 1.53 in the early-summer of 1988 with five of the eight values being greater than or equal to the highest value calculated from the 1982 date (Graham 1982). Using the criteria created by Carlander (1944) for rock bass in Minnesota, the mean condition of rock bass collected at Sandstone Falls in 1988, 1989, and 1990 was average. Using the criteria created by Carlander (1944) and Bennett (1948) the mean condition of bluegill collected at Sandstone Falls in 1988 was poor or average.

Community Structure of Benthic Macroinvertebrates

The main purpose of this part of the report is to determine if the *Bti* treatments changed the community structure of macroinvertebrates in the New River. Because the only pretreatment data were restricted to Bluestone Dam and Sandstone Falls, those sites will be the focus of this section. It was decided to use the results of sampling the cobble/pebble habitat for analyzing the structure of the macroinvertebrate community because the greatest diversity occurs there, including the greatest number of taxa rare to the New River. Also, this habitat is the only one that is common and consistent in quality at all sites. The two aquatic plants do not occur at some sites, thus eliminating habitat and lowering the quality of the outcrop habitat. A brief summary of all sites is presented, followed by statistical analyses of Bluestone Dam and Sandstone Falls among years.

Metrics that are emphasized include: total density, taxa richness, EPT index, Shannon diversity index, and Hilsenhoff biotic index (HBI). Total density can either increase or decrease when a community is disturbed. Taxa richness is simply the number of taxa present, without regard to abundance of individuals, and it almost always goes down when a community is disturbed. The EPT index is the number of taxa belonging to three pollution sensitive orders of insects: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). It decreases under conditions of stress, sometimes more dramatically than taxa richness. A diversity index is a mathematical equation that reflects both taxa richness and the abundance of individual taxa. Diversity values for the Shannon index go down when a community is disturbed. The HBI is a mathematical equation that combines taxa richness, abundance of individual taxa, and the sensitivity of the constituent fauna to pollution. It is arranged so that higher values indicate disturbed conditions.

Summary of All Sites

The total density of organisms was much higher immediately below Bluestone Dam than any other site. There was a progressive decrease in density going downstream from the Bluestone site. Taxa richness was usually slightly higher at Prince than the other sites. EPT was usually highest at Prince and lowest at Bluestone. Diversity at Bluestone was approximately one-half that at the other sites. HBI values generally followed a trend of high to low in a downstream direction.

The composition of the macroinvertebrate community varied considerably among sites. Immediately below Bluestone Dam, one family of caddisflies (Hydropsychidae) and one family of true flies (Chironomidae) together often accounted for almost 90% of the community. Both families are often abundant below dams because they feed upon plankton and fine particles of detritus

released from the reservoir. Chironomidae are usually regarded as being very tolerant of a wide variety of perturbations. More than 10 other families occurred at Bluestone, but only one (Caenidae, mayflies) of those ever accounted for more than 1% of the community.

Immediately above Sandstone Falls, the community was more evenly balanced among a greater variety of families than at any other site. About 17 families usually occurred immediately above Sandstone Falls, but usually only 7 families individually accounted for more than 1% of the community. Hydropsychidae were the most abundant organisms, comprising about 30% of the community. Chironomidae accounted for only about 10% of the community, while three families of pollution-sensitive Ephemeroptera (Oligoneuriidae, Baetidae, Ephemerellidae) together were about 40% of the fauna. Other abundant "clean-water" organisms at Sandstone were Elmidae (riffle beetles) and Pleuroceridae (gill breathing snails).

The number of families at Prince (usually about 14) was not quite as high as Sandstone, but 2 of the dominant families were ones that are indicative of clean water. Baetidae mayflies and Pleuroceridae snails accounted for about 50% and 10% of the community, respectively. Chironomidae were only about 15% of the community.

At Thurmond, Pleuroceridae snails comprised the greatest proportion of the community (about 40%), followed by another pollution-sensitive family of mayflies, Heptageniidae (about 15%). Other abundant families were Hydroptilidae (caddisflies) and Elmidae (riffle beetles), which were almost 10% each. Chironomidae comprised less than 5% of the community at Thurmond.

The fewest families (about 8) were usually collected at Fayette Station. The two most abundant families were Heptageniidae (mayflies) and Elmidae (riffle beetles), each accounting for 25% of the community. Chironomidae comprised about 20% of the community at Fayette Station.

In summary, a reasonably diverse community of benthic macroinvertebrates was found at Sandstone Falls, Prince, and Thurmond, including considerable proportions of taxa that are considered to be indicative of a "healthy" environment. The community at Bluestone Dam was not very balanced, but dominance by Hydropsychidae and Chironomidae is common below surface-release reservoirs, such as Bluestone Lake. Low numbers and diversity at Fayette Station may have been the result of naturally poor habitat quality. Most of the macroinvertebrate habitat at Fayette Station is subjected to torrential flows.

Analysis Before and After Bti Treatments

Detailed data on the kinds and numbers of all benthic macroinvertebrates at the lowest possible taxonomic level in each year at Bluestone Dam are summarized in Appendices 1-5, and similar data are presented for Sandstone Falls in Appendices 6-10. Results of statistical analyses (Kruskal-Wallis and Wilcoxon Rank Sum tests) of various community metrics are presented in Tables 13-17 for Bluestone Dam and Tables 18-22 for Sandstone Falls. Similarity of the macroinvertebrate community among years at the two sites is analyzed by the Percent Similarity and Pinkham and Pearson Indices in Tables 22-25. These analyses demonstrated that there was as much, if not more, difference between pretreatment years (1982 and 1984) than there was between pretreatment and treatment years (1988, 1989, and 1990). Of the 60 statistical tests between pretreatment and treatment years in Tables 13-22, there were 23 instances of significant differences ($P \leq 0.05$) between a pretreatment and a treatment year. However, only in 4 instances were both pretreatment years significantly different from a treatment year. Apparently there is considerable natural variability in the macroinvertebrate communities of the New River because the 2 pretreatment years were significantly different in 7 of the 10 comparisons in Tables 13-22.

The similarity analyses showed the same results (Tables 23-26). Usually there was less similarity between the communities in the 2 pretreatment years than between the communities in the pretreatment and treatment comparisons.

Community Structure of Fishes

Numerical percentage by order and family

Four orders and six families of fish were represented immediately below Bluestone Dam over the five collection years for summer data (Table 27). The dominant fish orders immediately below Bluestone Dam were Cypriniformes and Perciformes which together comprised greater than 96.4 percent of the fish captured in each of the collection years. In 1979, the dominant families immediately below Bluestone Dam were Cyprinidae, Centrarchidae, and Percidae which together comprised 95.6 percent of the fish captured. The dominant families collected in 1984, 1988, 1989, and 1990 were Cyprinidae and Centrarchidae which together comprised greater than 87.7 percent of the fish captured in each of these years.

Four orders and six families of fish were represented immediately above Sandstone Falls over the five collection years (Table 28). The dominant fish orders collected immediately above Sandstone Falls were Cypriniformes and Perciformes which together comprised greater than 96.0 percent of the fish captured in each of the collection years. The dominant families collected immediately above Sandstone Falls were Cyprinidae and

Centrarchidae which together comprised greater than 79.9 percent of the fish captured in each of the collection years.

Three orders and five families of fish were represented at Prince over the five collection years (Table 29). The dominant fish orders at Prince were Cypriniformes and Perciformes which together comprised greater than 97.2 percent of the fish captured in each of the collection years. The dominant families varied among the five collection years. In 1979 and 1984, Cyprinidae comprised 74.6 and 84.1 percent of the families collected, respectively. Cyprinidae, Centrarchidae, and Percidae were the dominant families collected from Prince in 1988 and 1990; when combined these families comprised 99.2 and 91.0 percent of the fish collected, respectively. In 1989, Cyprinidae and Centrarchidae together comprised 94.3 percent of the fish collected from Prince.

Four orders and six families of fish were represented at Thurmond over the five collection years (Table 30). The dominant fish orders at Thurmond were Cypriniformes and Perciformes which together comprised greater than 98.3 percent of the fish captured in each of the collection years. The dominant families varied among the five collection years. In 1979, Cyprinidae and Percidae together comprised 92.2 percent of the fish collected at Thurmond. In 1984, the dominant family was Cyprinidae which comprised 82.1 percent of the fish captured. Cyprinidae, Centrarchidae, and Percidae were the dominant families captured at Thurmond in 1988 and 1989, together comprising 99.4 and 97.2 percent, respectively, of the fish collected. Cyprinidae, Catostomidae, and Centrarchidae were the dominant families captured at Thurmond in 1990, together comprising 95.4 percent of the fish collected.

Three orders and five families of fish were represented at Fayette Station over the three collection years (Table 31). The dominant fish order at Fayette Station was Perciformes which comprised greater than 83.3 percent of the fish captured in each of the collection years. The dominant family collected at Fayette Station was Centrarchidae, which comprised greater than 71.1 percent of the fish in each of the collection years.

Numerical percentage by species

Of the six families recovered in mid-summer collections immediately below Bluestone Dam there were 14 species of Cyprinidae, 2 species of Catostomidae, 3 species of Ictaluridae, 1 species of Atherinidae, 10 species of Centrarchidae, and 6 species of Percidae (Table 32). Nine species (central stoneroller [*Campostoma anomalum*], *Luxilus* spp., bigmouth chub [*Nocomis platyrhynchus*], flathead catfish [*Pylodictis olivaris*], rock bass, bluegill, smallmouth bass, greenside darter [*Etheostoma blennioides*], and rainbow darter [*Etheostoma caeruleum*]) were collected immediately below Bluestone Dam in all five collection years and the proportion of the collection comprised by each of

these species varied among years. One species (bluntnose minnow [*Pimephales notatus*]) was present in both pretreatment collections and was not found in any treatment collections. One species (largemouth bass [*Micropterus salmoides*]) was not present in either pretreatment collection and was found in all treatment collections.

Of the six families recovered in mid-summer collections immediately above Sandstone Falls there were 14 species of Cyprinidae, 1 species of Catostomidae, 3 species of Ictaluridae, 1 species of Atherinidae, 8 species of Centrarchidae, and 6 species of Percidae (Table 33). Seven species (central stoneroller, *Luxilus* spp., bigmouth chub, northern hog sucker [*Hypentelium nigricans*], rock bass, smallmouth bass, and greenside darter) were collected immediately above Sandstone Falls in all five collection years and the proportion of the collection comprised by each of these species varied among years. Seven species (spotfin shiner [*Cyprinella spiloptera*], common carp [*Cyprinus carpio*], rosyface shiner [*Notropis rubellus*], mimic shiner [*Notropis volucellus*], bluntnose minnow, longnose dace [*Rhinichthys cataractae*], and sharpnose darter [*Percina oxyrhynchus*] were present in both pretreatment collections and were not found in any treatment collections. One species (yellow bullhead *Ameiurus natalis*) was not present in either pretreatment collection and was found in all treatment collections.

Of the five families recovered in mid-summer collections at Prince there were 11 species of Cyprinida, 1 species of Catostomidae, 3 species of Ictaluridae, 10 species of Centrarchidae, and 6 species of Percidae (Table 34). Nine species (central stoneroller, telescope shiner *Notropis telescopus*, northern hog sucker, rock bass, smallmouth bass, greenside darter, rainbow darter, sharpnose darter, and Roanoke darter *Percina roanoka*) were collected at Prince in all five collection years and the proportion of the collection comprised by each of these species varied among years. No species were lost or gained between pretreatment and treatment periods at this site.

Of the six families recovered in mid-summer collections at Thurmond there were 1 species of Clupeidae, 12 species of Cyprinidae, 1 species of Catostomidae, 1 species of Ictaluridae, 7 species of Centrarchidae, and 5 species of Percidae (Table 35). Seven species (*Luxilus* spp., bigmouth chub, telescope shiner, northern hog sucker, rock bass, greenside darter, and sharpnose darter) were collected at Thurmond in all five collection years and the proportion of the collection comprised by each of these species varied among years. One species (spottail shiner *Notropis hudsonius*) was not present in either pretreatment collection and was found in all treatment collections. No species were lost between pretreatment and treatment periods at this site.

Of the five families recovered in mid-summer collections at Fayette Station there were 5 species of Cyprinidae, 1 species of Catostomidae, 3 species of Ictaluridae, 8 species of

Centrarchidae, and 5 species of Percidae (Table 36). Seven species (northern hog sucker, flathead catfish, rock bass, redbreast sunfish [*Lepomis auritus*], smallmouth bass, greenside darter, and rainbow darter) were collected at Fayette Station in all three collection years and the proportion of the collection comprised by each of these species varied among years.

Total number of species

A total of 41 fish species, representing five orders and seven families were recovered in mid-summer collections of the New River between Bluestone Dam and Fayette Station from 1979 to 1990 (Table 37). Immediately below Bluestone Dam, the number of species collected ranged from 14 in 1988 to 32 in 1979. Immediately above Sandstone Falls, the number of species collected ranged from 11 in 1988 to 27 in 1979. At Prince, the number of species collected ranged from 17 in both 1979 and 1988 to 24 in 1990. At Thurmond the number of species collected ranged from 11 in 1979 to 21 in 1984. At Fayette Station, the number of species collected ranged from 11 in 1990 to 17 in 1988. When all years were pooled for each site, the total number of species collected was highest immediately below Bluestone Dam (36 species) and decreased with distance downstream.

Number of native species ranged from 19 immediately below Bluestone Dam in 1979 to 5 at Fayette Station in 1990 (Table 37). The percentage of native species ranged from 43% immediately above Sandstone Falls in 1989 to 73% at Thurmond in 1979. Introduced species comprised 40-50 percent of the total number of species collected at each site when data from 1979 to 1990 were pooled.

Distribution records

Early summer and mid-fall collections immediately below Bluestone Dam and Sandstone Falls are considered in addition to mid-summer collections for reporting distribution records of the 1988, 1989, and 1990 collections. Distribution records resulting from the 1988, 1989, and 1990 collections include gizzard shad (*Dorosoma cepedianum*) and mountain redbelly dace (*Phoxinus phoxinus*). This is the first account of gizzard shad in the mainstem New River in West Virginia. One individual was collected on October 31, 1989 from the Bluestone Dam site and 13 specimens were collected from the Bluestone Dam (12 fish) and Thurmond (1 fish) sites in 1990. Two individuals collected on November 1, 1990 immediately below Bluestone Dam exceeded 400 mm TL and one specimen was 480 mm TL.

Whitetail shiners have previously been recorded from sections of the New River in Virginia (Jenkins et al. 1972, Lee et al. 1980); however, this is the first account from the lower New River in West Virginia (Prince and Thurmond). One whitetail shiner was collected from Sandstone Falls on August 15, 1989 and five more were collected from this site in the fall of that year. In 1990,

a total of 26 whitetail shiners were collected in the New River from four sites (Bluestone Dam, Sandstone Falls, Prince, and Thurmond).

This is the first account of mountain redbelly dace in the main channel of the New River in West Virginia. Two individuals were collected from Sandstone Falls in the early summer collection in 1990.

Metrics

At all five sites, metric values typically varied among years and showed few patterns or trends between pretreatment (1979 and 1984) and treatment (1988, 1989, and 1990) years (Tables 38-42). Immediately below Bluestone Dam, diversity ranged from 1.47 to 2.54 with no marked difference between pretreatment and treatment years. Numbers of darter species ranged from 3 to 6 and numbers of sunfish species ranged from 2 to 3 among collection years. Neither of these metrics displayed a marked difference between pretreatment and treatment years. Numbers of intolerant species ranged from 0 to 5 and numbers of tolerant species ranged from 0 to 6 among collection years. The highest number of intolerant and tolerant species were collected in 1979 and no greater than one intolerant or tolerant species was collected immediately below Bluestone Dam in subsequent years. Percent green sunfish remained low among all collection years and ranged from 0.0 to 0.2. No omnivores were present in treatment years immediately below Bluestone Dam; however, omnivores did comprise 1.8 and 21.2 percent of the collections immediately below Bluestone Dam in 1979 and 1984, respectively. Immediately below Bluestone Dam, percent insectivorous cyprinids ranged from 1.2 to 25.6, percent piscivores ranged from 20.9 to 60.1, and numbers of fish collected per 10-minutes ranged from 24.5 to 43.5. No marked difference existed between pretreatment and treatment years for these three metrics.

Immediately above Sandstone Falls, diversity ranged from 1.63 to 2.76 with no marked difference between pretreatment and treatment years. Numbers of darter species ranged from 1 to 5 among collection years, with greater numbers of darter species being recovered in pretreatment years (4 and 5 darter species collected in 1979 and 1984, respectively). Numbers of sunfish species ranged from 1 to 2 among collection years, with no marked difference between pretreatment and treatment years. Numbers of intolerant species ranged from 1 to 5 among collection years, with greater numbers of intolerant species being recovered in pretreatment years (5 and 4 darter species collected in 1979 and 1984, respectively). Numbers of tolerant species ranged from 1 to 3 among collection years, with no marked difference between pretreatment and treatment years. Percent green sunfish remained low among all collection years and ranged from 0.0 to 0.1. No omnivores were recovered in treatment years immediately above Sandstone Falls; however, omnivores did comprise 10.9 and 4.9

percent of the years immediately above Sandstone Falls in 1979 and 1984, respectively. Percent insectivorous cyprinids ranged from 2.0 to 44.4 among collection years, with insectivorous cyprinids comprising greater proportions of the pretreatment years than treatment years. Percent piscivores ranged from 16.6 to 56.0 and numbers of fish collected per 10-minutes ranged from 21.7 to 57.5 among collection years. No marked difference existed between pretreatment and treatment years for these two metrics.

At Prince, diversity ranged from 1.64 to 2.43 with no marked difference between pretreatment and treatment years. Numbers of darter species collected remained constant at 5 for all years sampled. Numbers of sunfish species ranged from 1 to 4 among collection years, with greater numbers of sunfish species being collected in treatment years. No marked difference existed between pretreatment and treatment years for numbers of intolerant species or numbers of tolerant species. Percent green sunfish collected remained low among all collection years and ranged from 0.0 to 0.4. Omnivores comprised less than 0.6 percent of the treatment years while comprising 3.2 and 7.7 percent of the 1979 and 1984 pretreatment years, respectively. Percent insectivorous cyprinids ranged from 4.6 to 73.0 among collection years. Insectivorous cyprinids comprised a relatively high percentage (73.0 percent) of the collection in 1984. Percent piscivores ranged from 4.0 to 64.3 among collection years, with piscivores comprising markedly greater percentages of the treatment years than the pretreatment years. Numbers of fish collected per 10-minutes ranged from 18.2 to 72.6 among collection years with the 1984 pretreatment collection having a markedly higher number of fish collected per 10-minutes.

At Thurmond, diversity ranged from 1.71 to 2.42 with no marked difference between pretreatment and treatment years. Numbers of darter species ranged from 3 to 5 and numbers of sunfish species ranged from 0 to 3 among collection years. Neither of these metrics displayed a marked difference between pretreatment and treatment years. Numbers of intolerant species ranged from 1 to 5 and numbers of tolerant species ranged from 0 to 2 among collection years. Neither of these metrics displayed a marked difference between pretreatment and treatment years. Percent green sunfish collected remained low among all collection years and ranged from 0.0 to 0.5. Percent omnivores was low (less than 1.2 percent) for all collection years except 1984, where omnivores comprised 19.3 percent of the collection. Percent insectivorous cyprinids was relatively high in all collection years (28-48.3%) except 1990 when it dropped to only 6.7%. . No distinct difference existed between pretreatment and treatment years; however, in 1990 insectivorous cyprinids comprised a relatively low percentage of the collection (6.7 percent). Percent piscivores ranged from 2.6 to 44.0 among collection years, with piscivores comprising markedly greater percentages of the treatment years than pretreatment years. Average numbers of fish collected per 10-minutes ranged from 23.0 to 27.7 among collection

years with no marked difference between pretreatment and treatment years.

At Fayette Station, where pretreatment years were not available, diversity ranged from 1.05 to 2.03 and tended to decrease between 1988 and 1990. Numbers of darter species ranged from 3 to 4 and numbers of sunfish species ranged from 2 to 4 among collection years. Neither of these metrics displayed trends among collection years. Numbers of intolerant species remained constant at 2 for all three collection years. Numbers of tolerant species decreased from 2 to 0 between 1988 and 1990. Percent green sunfish collected remained low among all collection years and ranged from 0.0 to 3.5. No omnivores were collected at Fayette Station between 1988 and 1990. Percent insectivorous cyprinids indicated no trend among collection years and ranged from 0.0 to 9.6. Percent piscivores tended to increase from 51.0 percent in 1988 to 84.5 percent in 1990. Numbers of fish collected per 10-minutes showed no trends between 1988 and 1990 and ranged from 8.8 to 14.9 among collection years.

Similarity

Percent similarity values ranged from 15.68 at Prince between years 1979 and 1989 to 68.30 at Prince between years 1988 and 1990 (Table 43). At three (Bluestone Dam, Sandstone Falls, and Thurmond) of the four sites where pretreatment data were available, mean similarity for pretreatment versus treatment comparisons was lower than similarity values between pretreatment years and among treatment years. However the differences in similarity values were not very large and did not indicate consistent community changes immediately below Bluestone Dam and Sandstone Falls sites, which were mostly likely to be affected by Bti treatments. At Prince, percent similarity was lowest between pretreatment years and highest among treatment years. At Fayette Station, mean percent similarity among treatment years was 43.23.

Pinkham and Pearson similarity values ranged from 10.64 immediately above Sandstone Falls between years 1984 and 1990 to 38.14 immediately above Sandstone Falls between years 1988 and 1989 (Table 44). At two (Bluestone Dam and Sandstone Falls) of the four sites where pretreatment data were available, mean similarity for pretreatment versus treatment comparisons was lower than similarity values between pretreatment years and among treatment years. At both Prince and Thurmond, Pinkham and Pearson similarities were lowest between pretreatment years and highest among treatment years. At Fayette Station, mean Pinkham and Pearson similarity among treatment years was 20.41.

Persistence

Persistence values ranged from 0.452 immediately above Sandstone Falls between years 1984 and 1988 to 0.878 at Prince and Thurmond between years 1984 and 1989 (Table 45). Immediately

below Bluestone Dam and Thurmond, persistence values were lowest between pretreatment years and highest among treatment years. Immediately above Sandstone Falls, persistence values were lowest among pretreatment versus treatment years and highest between pretreatment years. At Prince, persistence values were lowest among treatment years and highest between pretreatment years. At Fayette Station, mean persistence was 0.698 among treatment years. Only immediately above Sandstone Falls was the decrease in persistence value from pretreatment to treatment years indicative of losses of fish from the community. Fourteen species collected immediately above Sandstone Falls in 1979 or 1984 were not collected in any of the treatment years (Table 33).

Discussion

Production of Benthic Macroinvertebrates

Results of secondary production measurements of aquatic insects immediately below Bluestone Dam provide evidence that factors other than *Bti* treatments are responsible for the different levels of production that have been observed during this study. After 3 years of total benthic macroinvertebrate production being lower than before *Bti* treatment, total benthic macroinvertebrate production became higher in 1990 than before treatment. Even the lowest level of total benthic macroinvertebrate production during this study was quite high immediately below Bluestone Dam in comparison to other flowing surface waters (see Table 8 in Voshell et al. 1989b).

The only nontarget taxon that exhibited lower production in 1990 as compared to 1983 was the mayfly *H. curiosum*, which was practically nonexistent at this study site after 1986. It is unlikely that the demise of *H. curiosum* was caused by *Bti* treatments because another mayfly in the same family, *B. intercalaris*, achieved higher production in 3 of the 4 treatment years. Both of the major taxa accounting for most of the aquatic insect production, the caddisfly *C. campyla* and chironomids in the subfamilies Chironominae/Orthocladiinae, achieved higher levels of production in 1990 as compared to 1983. Voshell (1985) had speculated that elimination of black fly larvae might indirectly reduce production of *C. campyla*, which is a filter feeder, by reducing the amount of black fly feces that would be available as a detrital food source. In addition, several studies had indicated that *Bti* could be directly toxic to chironomids. Neither the indirect nor direct adverse effects to nontarget organisms appear to have occurred. Flow (discharge) may be the primary factor determining the level of production by aquatic insects in the New River below Bluestone Dam. Mean daily discharge was not significantly different from the reference year only in 1990. In other treatment years, mean daily discharge was either significantly lower or higher than the reference year.

Production levels on the rock outcrops immediately above Sandstone Falls during all years were within the range of values

reported for flowing waters (see Table 8 in Voshell et al. 1989b). There have been very few studies of total production of the benthic macroinvertebrate community in flowing waters. In those studies where total benthic macroinvertebrate production was measured, sampling was usually not stratified by habitat, and the results were likely to be highly variable. Also, many of the comprehensive production studies have been done in streams that are much smaller than the New River. The measurements immediately above Sandstone Falls from 1987 to 1990 were higher than some values reported for very small streams, but were generally similar to most other streams nearer the size of the New River.

Results of benthic macroinvertebrate studies immediately above Sandstone Falls do not suggest any immediate adverse effects from *Bti* treatment to the fauna other than to the target organism *S. jenningsi*. Differences that have occurred appear to be more related to yearly differences in flow and macrophytes than to *Bti* treatment. Flow was about normal in the reference year (1987). In 1988 (first treatment year), exceptionally low flow led to lower abundance of *Podostemum* and greater accumulations of filamentous algae. Conditions in 1988 would be detrimental to net-spinning caddisflies because they depend upon current to bring them their food and they use *Podostemum* as structural support for their capture nets. Conditions in 1988 would be beneficial to chironomids because they are adapted for living in still water, they can move their long, thin bodies through the tangles of filamentous algae, and the algae (especially decaying algae) would be a good source of food for them. The net-spinning caddisfly *Cheumatopsyche campyla* had significantly lower production and Chironominae/Orthocladiinae had significantly higher production in 1988 as compared to 1987. If *Bti* treatment had caused the decreased production of caddisflies in 1988, then their production would have been expected to remain low in 1989 and 1990, when flow was not so low as to induce adverse conditions. However, production of *C. campyla* was significantly higher in 1989 and not significantly different in 1990 as compared to 1987. Chironomids are the non-target organisms most likely to exhibit toxicity to *Bti*, and their production was higher in all treatment years than the pretreatment year.

Growth and Condition of Fishes

Growth and condition were explored in detail for three species immediately below Bluestone Dam and five species immediately above Sandstone Falls. Normal variation in reproductive success made it impossible to collect the young of other species in sufficient numbers to calculate growth rates for each year. Growth and condition appeared to be as good during treatment years as during pretreatment years at both Bluestone Dam and Sandstone Falls. All the species studied, except the stoneroller, are primarily insectivorous (Hess 1983). The stoneroller is adapted for feeding on periphyton and detritus deposits and, therefore, should not be directly affected by

changes in insect prey availability. Black flies were present in stomachs of stonerollers below Bluestone Dam in 1982 (Hess 1983); however, they were probably ingested incidently with periphyton. Growth of age-0 stonerollers was monitored as a control for annual variation in temperature and flow that may affect growth of all fishes. The species monitored represent important forage (stoneroller, *Luxilus* spp., and bigmouth chub) and sport fishes (rock bass and smallmouth bass). With the exception of the stoneroller, these species feed on insect prey. Insect consumption is greatest during the first year of life in the case of the rock bass and smallmouth bass, which switch to a diet dominated by crayfish by age-2 (Roell and Orth 1988).

Hess (1983) reported that, as a group, minnows in the New River showed the highest reliance on black flies. Below Bluestone Dam the diets of bigmouth chub and *Luxilus* spp. was 25% and 28% black flies (by number), respectively. Diets of other minnows ranged up to 84% black flies (by number) for the spottail shiner. Among cyprinids, the bigmouth chub is not a highly specialized insect feeder; therefore, they may be able to switch diets readily if prey availability is altered. The bigmouth chub is primarily a benthic feeder, although few detailed studies have been done on its feeding habits. In other species of chubs (*Nocomis*) the adults may occasionally eat crayfish or terrestrial insects (Lachner 1950). Studies of *Luxilus* spp. (white shiner and striped shiner) diets indicate they are opportunistic, primarily feeding on aquatic and terrestrial insects, but also consuming crayfish, fish eggs, fish, algae, and detritus (Jenkins and Burkhead 1994). The bigmouth chub and *Luxilus* spp. were commonly collected and observed in riffle, run, and water willow habitats in previous surveys of the New River (Lobb and Orth 1988; Lobb and Orth 1991). Therefore, even though these fish are not specialized feeders they may be particularly vulnerable to elimination of blackflies, which are also abundant in these habitats.

The ability to detect changes in growth and condition of fishes in the New River depends on the magnitude of changes and the precision of our estimates of growth and condition. The precision of growth and condition estimates has been discussed in detail in interim reports and was generally found to be acceptable or good.

Minnows

Although there are no previous estimates of growth rates for the minnows in the New River, the lengths that age-0 fish attained in the fall samples can be compared with typical adult sizes to determine if growth rates are sufficient to permit minnows to reach maturity after one growing season. All four estimates (1988 immediately below Bluestone Dam and 1988, 1989, and 1990 immediately above Sandstone Falls) of stoneroller length at the end of the growing season exceeded the size required for sexual maturity (TL = 50 mm; Smith 1971). Five estimates (1988 and 1990

immediately below Bluestone Dam and 1988, 1989, and 1990 immediately above Sandstone Falls) of bigmouth chub length at the end of the growing season indicated that females would be sexually mature at age-1 and males at age-1 or -2 (female TL $\approx$ 80 mm, male TL $\approx$ 140 mm; Jenkins and Burkhead 1994). Two of three estimates (1988 and 1990 but not 1989 immediately above Sandstone Falls) of *Luxilus* spp. length at the end of the growing season exceeded the size required for sexual maturity (TL = 76 mm; Jenkins and Burkhead 1994) for white and striped shiners. Growth rates appear more than adequate to maintain these populations in the New River.

Rock Bass

Previous studies indicate that rock bass growth in the New River is greater than other stream-dwelling populations (Roell and Orth 1988). 1988-1990 growth estimates for length and weight of age-1 and age-2 rock bass immediately below Bluestone Dam were greater than 1984-1985 estimates made by Roell (1989). Data collected by Roell were from Brooks Island (approximately 11.8 river km downstream of Bluestone Dam) and differences in growth may be due to a better food supply at the Bluestone Dam site rather than to a temporal change. Growth immediately above Sandstone Falls for age-0 and age-1 rock bass was similar to pretreatment estimates made by Roell (1989). Because Sandstone Falls is only 4.4 river km downstream of Brooks Island, spatial differences between these estimates should be less than differences between estimates for Bluestone Dam and Brooks Island. In general, during treatment years rock bass growth immediately below Bluestone Dam was greater than pretreatment estimates and growth immediately above Sandstone Falls was similar to pretreatment estimates. Rock bass growth has not dramatically decreased as a result of black fly removal from the New River.

Condition factors for rock bass in the New River were in the average range according to Carlander's (1969) standards for Minnesota. No similar standards have been developed for southern riverine populations of rock bass. Most of the data on which those standards are based are for lake populations. Regional differences in condition factors are common. Rock bass in the New River are in average condition and do not appear to be greatly affected by removal of black fly larvae.

Smallmouth Bass

Previous studies of growth of smallmouth bass in the New River indicate that growth is faster in the West Virginia portion of the New River than other riverine populations (Austen and Orth 1988, Roell and Orth 1988). Age-0 smallmouth bass grew faster at the Bluestone Dam site than at the Sandstone Falls site. Lengths and weights at the end of the growing season were greater in both 1988 and 1990 immediately below Bluestone Dam than immediately above Sandstone Falls in any year (no age-0 smallmouth bass were collected immediately below Bluestone Dam in 1989). Spatial

differences in growth make the detection of temporal changes tenuous, because previous growth studies on smallmouth bass (Graham 1982; Austen and Orth 1986; Roell and Orth 1988) were done at other sites on the New River. However, the growth rates exhibited by smallmouth bass throughout this study indicate that the food supply was not reducing growth of smallmouth bass to unfavorable levels.

Condition factors for age-0 smallmouth bass were typically higher during treatment years immediately below Bluestone Dam and Sandstone Falls than in 1982 at Meadow Creek (Graham 1982). Differences in condition among years could be due to spatial differences or temporal changes; however, because condition of age-0 smallmouth bass did not decrease markedly during treatment years it is apparent that food has not become less available as a result of black fly removal.

Community Structure of Benthic Macroinvertebrates

Macroinvertebrates were much more abundant immediately below Bluestone Dam than any other site. There was a progressive decrease in density going downstream from Bluestone Dam, which is typical for macroinvertebrate communities below impoundments. Macroinvertebrate abundance was very low at Fayette Station. Diversity index was quite low immediately below Bluestone Dam as a result of exceptionally high numbers of net-spinning caddisflies and chironomids. This often occurs below impoundments. Diversity indices were rather uniform at the other four sites and were in a range that would be considered indicative of good environmental conditions. Taxa richness was about equal at all sites except Fayette Station, which was much lower. Low taxa richness and abundance at Fayette Station is probably the result of poor macroinvertebrate habitat. A reasonably diverse and abundant macroinvertebrate community was found immediately above Sandstone Falls, Prince, and Thurmond, including proportions of taxa that are considered to be indicative of a "healthy" environment. Other than the absence of black fly larvae (Simuliidae), the communities at the five sites do not appear to have changed because of nontarget effects of *Bti*.

Community Structure of Fishes

The total number of species collected varied at each site and among collection years (Table 37). Only immediately above Sandstone Falls did species numbers tend to decrease over time, and this trend may be a result of differences in survey methods which are discussed below.

Immediately below Bluestone Dam and above Sandstone Falls several species collected during mid-summer collections in pretreatment years were not present in mid-summer collections during treatment years. Two species not collected during mid-summer collections in treatment years were recovered during treatment year collections for growth estimation. Immediately

below Bluestone Dam, bluntnose minnows were collected in the fall of 1990. Immediately above Sandstone Falls, roseyface shiners were collected in the fall of 1989. The six other species collected immediately above Sandstone Falls during pretreatment years and not recovered during treatment years were spotfin shiner, common carp, mimic shiner, bluntnose minnow, longnose dace, and sharpnose darter. Common carp, longnose dace, and sharpnose darter were never abundant during pretreatment years, comprising less than 1% of pretreatment year collections. Differences between pretreatment and treatment year collection methods and sampling locations may have biased the species collected. These potential biases are further described below.

Persistence (Table 45) varied at each site and among all years. A loss of fish species during treatment years would be indicated by lower persistence values for comparisons of pretreatment and treatment years than for comparisons between pretreatment years and among treatment years. Only immediately above Sandstone Falls was persistence lowest for pretreatment versus treatment years.

There is little indication of species loss in the New River during treatment years. Immediately above Sandstone Falls, decreasing species numbers and low persistence values for pretreatment versus treatment year comparisons indicate possible species loss. However, differences in the species collected may have been influenced by differences in pretreatment and treatment collection methods. Collections in 1979 were conducted by electrofishing into a seine which tends to sample minnow and benthic species more efficiently than electrofishing without a seine. Sampling in 1979 was conducted until no additional species were recovered rather than keeping effort constant as was done in 1984, 1988, 1989, and 1990. Other biases may have resulted from differences between pretreatment and treatment year sampling locations. At each site, collections during treatment years were made within a 300 to 500 m section of the river whereas pretreatment years were sometimes pooled from river sections as long as 10.6 river km (Stauffer et al. 1980) or 15.4 river km (Lobb 1984). Samples by both Stauffer et al. (1980) and Lobb (1984) were commonly taken at tributary mouths, whereas tributary mouths were avoided for treatment year sampling. Sampling a larger section of the New River would likely increase the number of species collected and samples collected at tributary mouths may include species more commonly found in creeks than the main channel of the New River. The sampling method used in 1979 and the choice of sampling location in 1979 and 1984 could account for differences in the species array and number of species collected during pretreatment samples.

Food habits data collected by Hess (1983) indicated that no species relied totally on black fly larvae for food. Spottail shiners showed the greatest reliance on black fly larvae, which comprised 84% of the diet by number. Studies of spottail shiners in other systems have found a wide array of benthic

macroinvertebrate prey (Carlander 1969, Vadas 1990, Jenkins and Burkhead 1994). There is little evidence that any species in the New River is specialized for feeding on black flies and therefore no species should be lost as a direct result of black fly removal in the New River.

Changes in benthic macroinvertebrate communities have a greater effect on fish communities regulated by deterministic processes (i.e. interspecific competition, predation, or niche partitioning) than fish communities regulated by stochastic processes (i.e. variable river discharge and temperature; see Grossman et al. 1982). Deterministic processes regulate fish communities at equilibrium, while stochastic processes can lead to non-equilibrium in fish communities.

Sample composition and similarity indices indicate that fish community structure varied greatly over the five years studied. Dominant families and orders tended to be consistent; however, dominant species varied greatly between all years. Percent similarity and Pinkham and Pearson values (both based on species percentages) were generally low, indicating high annual variation. The similarity values provide little evidence of dramatic changes in fish community structure that can be attributed to black fly removal. Similarity values resulting from pretreatment and treatment year comparisons were not markedly lower than similarity values between pretreatment years or among treatment years.

High natural variability of physical factors may have resulted in low similarity values between collection years. However, methodological differences are probably not responsible for low similarity values since values from treatment year comparisons, when methodology remained constant, were equally as low as values from comparisons of other years.

High percentages of introduced species in the New River indicate possible non-equilibrium assemblage in the New River fish community. Jenkins and Burkhead (1994) reported 88 fish taxa known from the New River drainage and 42 (48 percent) of these they considered introduced. Twenty (48 percent) of the total 42 (not including both *Luxilus* spp.) fish species collected in the New River during these five collection years are considered introduced (Jenkins and Burkhead 1994). Addair (1944) reported 25 fish species from the main channel of the New River between Bluestone Dam and Fayette Station with nine (36 percent) of these considered introduced (Jenkins and Burkhead 1994). Introduced species comprise a large and possibly increasing percentage of the species composition of the New River indicating an unstable species community.

Previous authors have suggested that the fauna of New River is unsaturated, at least in parts of the drainage, possibly because of barriers such as falls and reservoirs (Jenkins et al. 1972, Hocutt et al. 1986). The recent success of gizzard shad and whitetail shiners increasing their distribution into the West

Virginia portion of the New River, provides evidence of unsaturated fauna and an unstable species complex.

This is the first account of gizzard shad in the mainstem New River in West Virginia. The size of the largest individual (TL = 480 mm), which was collected in the fall of 1990, indicates a fish age-5 or greater (Carlander 1969). If the 480 mm TL individual collected in 1990 was a lifelong resident of the New River, then gizzard shad entered the New drainage prior to 1986. Gizzard shad were also collected in Bluestone Lake by West Virginia Department of Natural Resources (WVDNR) personnel in 1989 (Mark Scott pers. comm.) and Claytor Lake by Virginia Department of Game and Inland Fisheries (VDGIF) personnel in 1988 (Joe Williams pers. comm.). A recent article in the September 10, 1992 edition of the Roanoke Times and World-News (page C3) referred to an anonymous phone-caller who claimed to have stocked thousands of gizzard shad from Smith Mountain Lake in the Roanoke drainage into Claytor Lake over a five-year period in the mid-to-late 1980's.

The establishment of whitetail shiners in the West Virginia portion of the New River and their continued dispersal between 1989 and 1990 (collected at one site in 1989 and four sites in 1990) indicates an unsaturated fish community and an unstable species complex. In 1989, above average discharge during the spawning season may have carried larval whitetail shiners through Bluestone Lake and introduced them to the lower New River.

Natural environmental fluctuations, such as floods, have been shown to influence community structure (Grossman et al. 1982). Floods during fish spawning season can result in decreased spawning success or even a completely failed year class for many fish species (Schlosser 1985). Other species may benefit from flooding through increased aquatic insect drift (Paragamian and Wiley 1987) or increased habitat through flooded vegetation (Pflieger 1975). River discharge varied greatly between collection years and may in part be responsible for variability in fish community structure.

The intent of similarity analysis was to determine if dramatic changes in fish community structure resulted from the elimination of black flies in the New River. While variation in the fish community during the period of study was high, there was no indication this variation resulted from of black fly removal. Low similarity values most likely resulted from stochastic processes which eclipsed any subtle changes in the fish community resulting from the elimination of black flies.

While the metric values (Tables 38-42) also indicated variation in fish community structure and differences between pretreatment and treatment years, these measures are more useful for long-term monitoring and determining subtle changes in the fish community. As metric trends become apparent, new studies can be employed to determine the relationship between trends and black fly removal or other environmental changes. In 1991, another

non-native species (European rudd, *Scardinius erythrophthalmus*) was collected in the New River (Easton et al. 1993), and future monitoring will help determine whether populations becomes fully established.

Conclusions

No changes in macroinvertebrate production, macroinvertebrate community structure, fish growth and condition, or fish community structure can be attributed to *Bti* applications and black fly removal. However, the New River is a large and complex aquatic system, with a great deal of natural variability and many past and present human activities in the basin that complicate the assessment of effects from a single activity such as black fly larviciding. Long-term ecological monitoring should be implemented, but not necessarily as intensively as the research reported in this document. At a minimum, the community structure measures listed in this document should be tracked through time during future ecological monitoring.

Literature Cited

- Addair, J. 1944. The fishes of the Kanawha River system in West Virginia and factors which influence their distribution. PhD dissertation. Ohio St. Univ., Columbus, OH. 225 pp.
- Ali, A., R. D. Baggs, and J. P. Stewart. 1981. Susceptibility of some Florida chironomids and mosquitoes to various formulations of *Bacillus thuringiensis* serovar. *israelensis*. J. Econ. Entomol. 74: 672 - 677.
- Allan, J. D. 1984. Hypothesis testing in ecological studies of aquatic insects. Pp. 484 - 507 in Resh, V. H. and D. M. Rosenberg, eds. The ecology of aquatic insects. Praeger Publishers, New York.
- American Public Health Association, American Water Works Association, and Water Pollution Control Federation. 1980. Standard methods for the examination of water and wastewater. 15th Edition. American Public Health Association, Washington, D.C.
- Amrine, J. W. 1982. The New River connection in the black fly problem in southern West Virginia. West Virginia Univ. Agric. Forestry Exper. Sta. 678: 1-30.
- Anderson, R.O., and S. J. Gutreuter. 1983. Length, weight, and associated structural indices. Pp. 283-300 in L.A. Neilsen and D.L. Johnson, eds. Fisheries Techniques. American Fisheries Society, Bethesda, MD.
- Austen, R.O. 1984. Evaluation of the effects of a 305-mm minimum length limit on the smallmouth bass populations in the New

River. MS thesis. Va. Poly. Inst. St. Univ., Blacksburg, VA.
109 pp.

- Austen, R.O. and D.J. Orth. 1988. Evaluation of a 305-mm minimum length limit for smallmouth bass in the New River, Virginia and West Virginia. *N. Am. J. Fish. Manage.* 8:231-239.
- Back, C., J. Boisvert, J. O. Lacoursiere, and G. Charpentier. 1985. High-dosage treatment of a Quebec stream with *Bacillus thuringiensis* serovar. *israelensis*: efficacy against black fly larvae (Diptera: Simuliidae) and impact on non-target insects. *Can. Ent.* 117: 1523 - 1534.
- Benke, A. C. 1984. Secondary production of aquatic insects. Pp. 289 - 322 in Resh, V. H. and D. M. Rosenberg, Eds., *The ecology of aquatic insects*. Praeger Publishers, New York.
- Benke, A. C. and J. B. Wallace. 1980. Trophic basis of production among net-spinning caddisflies in a southern Appalachian stream. *Ecology* 61:108-118.
- Bennett, G.W. 1948. The bass blue-gill combination in a small artificial lake. *Ill. Nat. Hist. Surv. Bull.* 24:377-412.
- Borland International. 1991. Quattro Pro: users guide. Borland International, Scotts Valley, CA.
- Carlander, K.D. 1944. Notes on the coefficient of condition K of Minnesota fishes. *Minn. Bur. Fish. Res. Invest. Rep.* 41: revised: 40 pp. type-written.
- Carlander, K.D. 1969. *Handbook of Freshwater Fishery Biology*. volume 1. Iowa St. Univ. Press, Ames, IA. 752 pp.
- Carlander, K.D. 1977. *Handbook of Freshwater Fishery Biology*. volume 2. Iowa St. Univ. Press, Ames, IA. 431 pp.
- Colbo, M. H. and H. O'Brien. 1984. A pilot black fly (Diptera: Simuliidae) control program using *Bacillus thuringiensis* var. *israelensis* in Newfoundland. *Can. Ent.* 116: 1085 - 1096.
- De Moor, F. C. and M. Car. 1986. A field evaluation of *Bacillus thuringiensis* var. *israelensis* as a biological control agent for *Simulium chutteri* (Diptera: Nematocera) in the Middle Orange River. *Onderstepoort J. Vet. Res.* 53:43-50.
- Dermott, R. M. and C. G. Paterson. 1974. Determining dry weight and percentage dry matter of chironomid larvae. *Can. J. Zool.* 52:1243-1250.
- Donald, G. R. and C. G. Paterson. 1977. Effect of preservation on wet weight biomass of chironomid larvae. *Hydrobiologia* 53:75-80.

- Easton, R. S., and D. J. Orth. 1994. Fishes of the main channel New River, West Virginia. *Virginia J. Sci.* 45:265-277.
- Easton, R. S., D. J. Orth, and N. M. Burkhead. 1993. The first collection of rudd, *Scardinius erythrophthalmus* (Cyprinidae), in the New River, West Virginia. *J. Freshwat. Ecol.* 8:263-264.
- Easton, R. S., D. J. Orth, and J. R. Voshell, Jr. 1995. Spatial and annual variation in diet and foraging success of age-0 smallmouth bass, *Micropterus dolomieu* (Lacope). *Environmental Biology of Fishes* (In Press)
- Elliott, J. M. 1977. Some methods for the statistical analysis of samples of benthic invertebrates. 2nd Edition. Freshwater Biological Association Scientific Publication No. 25. The Ferry House, Ambleside, United Kingdom.
- Frommer, R. L., J. H. Nelson, M. P. Remington, and P. H. Gibbs. 1981. The effects of extensive aquatic vegetative growth on the distribution of *Bacillus thuringiensis* var. *israelensis* in flowing water. *Mosquito News* 41:713-724.
- Gaugler, R. and J. Finney. 1982. A review of *Bacillus thuringiensis* var. *israelensis* (serotype 14) as a biological control agent of black flies (Simuliidae). *Misc. Publ. Entomol. Soc. Am.* 12: 1 - 17.
- Grafius, E. and N. H. Anderson. 1979. Population dynamics, bioenergetics, and role of *Lepidostoma quercina* Ross (Trichoptera: Lepidostomatidae) in an Oregon woodland stream. *Ecology* 60:433-441.
- Graham, R.J. 1984. Time and duration of spawning by smallmouth bass (*Micropterus dolomieu*) in the New River drainage. MS thesis. Va. Poly. Inst. St. Univ., Blacksburg, VA. 147 pp.
- Grossman, G.D., P.B. Moyle, and J.W. Whitaker, Jr. 1982. Stochasticity in structural and functional characteristics of an Indiana stream fish assemblage: a test of community theory. *Am. Nat.* 120:423-454.
- Hare, S. G. F. and R. S. Nasci. 1986. Effects of sublethal exposure to *Bacillus thuringiensis* var. *israelensis* on larval development and adult size in *Aedes aegypti*. *J. Amer. Mosq. Contr. Assoc.* 2: 325 - 328.

- Hess, L. 1983. Preliminary analysis of the food habits of some New River fishes with emphasis on black fly utilization. Pp. 15-21 in Cox, W. E. and M. Kegley, Eds., Proceedings, New River Symposium. April 14-16, 1983, Blacksburg, VA. Department of Interior / National Park Service, Oak Hill, WV.
- Hocutt, C.H., R.E. Jenkins, and J.R. Stauffer, Jr. 1986. Zoogeography of fishes of the central Appalachians and in central Atlantic coastal plain. pp. 161-211. In C.H. Hocutt and E.O. Wiley (eds.), The Zoogeography of North American Freshwater Fishes. John Wiley and Sons, New York.
- Horosko, S. and R. Noblet. 1986. Black fly control and suppression of leucocytozoonosis in turkeys. J. Agric. Entomol. 3: 10 -24.
- Howmiller, R. P. 1972. Effects of preservatives on weights of some common macroinvertebrates. Trans. Am. Fish. Soc. 101:743-746.
- Jearld, A., Jr. 1983. Age determination. pp. 301-324. In L.A. Neilsen and D.L. Johnson, eds. Fisheries Techniques. American Fisheries Society, Bethesda, MD.
- Jenkins, R.E. and N.M. Burkhead. 1994. Freshwater Fishes of Virginia. Am. Fish. Soc., Bethesda, MD. 1079 pp.
- Jenkins, R.E., E.A. Lachner, and F.J. Schwartz. 1972. Fishes of the central Appalachians drainage: Their distribution and dispersal. pp. 43-117. In P.C. Holt (ed.), The Distributional History of the Biota of the Southern Appalachians. Part III: The Vertebrates. Va. Poly. Inst. St. Univ., Res. Div. Monogr. 4, Blacksburg, VA.
- Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser. 1986. Assessing biological integrity in running waters: a method and its rationale. Ill. Nat. Hist. Surv., special publication 5, Champaign, IL.
- Kondratieff, B. C. and J. R. Voshell, Jr. 1983. A study of the black fly invertebrate predators in the New River below Bluestone Dam. Report. W. V. Dept. of Natural Resources. 42 pp.
- Krueger, C. C. and F. B. Martin. 1980. Computation of confidence intervals for the size-frequency (Hynes) method of estimating production. Limnol. and Oceanogr. 25:773-777.
- Lachner, E.A. 1950. The comparative food habits of the Cyprinid fishes *Nocomis biguttatus* and *Nocomis micropogon* in western New York. J. Wash. Acad. Sci. 40:229-236.

- Lacey, L. A. and C. M. Heitzman. 1985. Efficacy of flowable concentrate formulations of *Bacillus thuringiensis* var. *israelensis* against black flies (Diptera: Simuliidae). J. Amer. Mosq. Contr. Assoc. 1: 493 - 497.
- Lacey, L. A. and A. H. Undeen. 1984. Effect of formulation, concentration, and application time on the efficacy of *Bacillus thuringiensis* (H-14) against black fly (Diptera: Simuliidae) larvae under natural conditions. J. Econ. Entomol. 77: 412 - 418.
- Lacey, L. A. and A. H. Undeen. 1986. Microbial control of black flies and mosquitoes. Ann. Rev. Entomol. 31: 265 - 296.
- Lacey, L. A., H. Escaffre, B. Philippon, A. Seketeli, and P. Guillet. 1982. Large river treatment with *Bacillus thuringiensis* (H - 14) for the control of *Simulium damnosum* S. l. in the Onchocerciasis Control Programme. Z. Tropenmed. Parasitol. 33:97-101.
- Ladle, M. and B. S. Griffiths. 1980. A study on feces of some chalk stream invertebrates. Hydrobiologia 74:161-171.
- Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer, Jr. 1980 et seq. Atlas of North American Freshwater Fishes. N.C. St. Mus. Nat. Hist., Raleigh, NC. 854 pp.
- Lobb, M.D., III. 1986. Habitat use by fishes of the New River, West Virginia. M.S. thesis. Va. Poly. Inst. St. Univ., Blacksburg, VA. 119 pp.
- Lobb, M.D., III, and D.J. Orth. 1988. Microhabitat use by the bigmouth chub *Nocomis platyrhynchus* in the New River, West Virginia. Am. Mid. Nat. 120:32-40.
- Lobb, M.D., III, and D.J. Orth. 1991. Habitat use by an assemblage of fish in a large warmwater stream. Trans. Am. Fish. Soc. 120:65-78.
- Lyons, J. 1992. Using the index of biotic integrity (IBI) to measure environmental quality in warmwater streams of Wisconsin. U. S. Forest Service, Gen. Tech. Rep NC-149. St. Paul, Minnesota.
- Meffe, G.K and T.M. Berra. 1988. Temporal characteristics of fish assemblage structure in an Ohio stream. Copeia 1988:684-690.
- Merritt, R. W., E. D. Walker, M. A. Wilzbach, K. W. Cummins, and W. T. Morgan. 1989. A broad evaluation of B. T. I. for black fly (Diptera: Simuliidae) control in a Michigan river: Efficacy, carry and nontarget effects on invertebrates and fish. J. Am. Mosq. Control Assoc. 5: 397-415.

- Merritt, R. W. and M. S. Wipfli. 1991. Changes in feeding habits of selected nontarget aquatic insects in response to live and *Bacillus thuringiensis* var. *israelensis* De Barjac-killed black fly larvae (Diptera: Simuliidae). Can. Ent. 123: 179-185.
- Molloy, D. and H. Jamnback. 1981. Field evaluation of *Bacillus thuringiensis* var. *israelensis* as a black fly biocontrol agent and its effect on nontarget stream insects. J. Econ. Entomol. 74:314-318.
- Moor, F. C. De and M. Car. 1986. A field evaluation of *Bacillus thuringiensis* var. *israelensis* as a biological control agent for *Simulium chutteri* (Diptera: Nematocera) in the Middle Orange River. Onderstepoort J. Vet. Res. 53: 43 - 50.
- Newman, R. M., and F. B. Martin. 1983. Estimation of fish production rates and associated variances. Can. J. Fish. Aquat. Sci. 40:1729-1736.
- Ohio Environmental Protection Agency. 1988. Biological criteria for the protection of aquatic life: volume II. users manual for biological field assessment of Ohio surface waters. Document 0046e/0013e. Columbus, OH.
- Paragamian, V.L. and M.J. Wiley. 1987. Effects of variable streamflows on growth of smallmouth bass in the Maquoketa River, Iowa. N. Am. J. Fish. Manage. 7:357-362.
- Parker, C. R. and J. R. Voshell. 1983. Production of filter-feeding Trichoptera in an impounded and free flowing river. Can. J. Zool. 61:70-87.
- Pflieger, W.L. 1975. Reproduction and survival of the smallmouth bass in Courtois Creek. pp 231-239 in H. Clepper (ed.). Black Bass Biology and Management, Sport Fishing Institute, Washington D.C.
- Pistrang, L. A. and J. F. Burger. 1984. Effect of *Bacillus thuringiensis* var. *israelensis* on a genetically-defined population of black flies (Diptera: Simuliidae) and associated insects in a montane New Hampshire stream. Can. Ent. 116:975-981.
- Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish. U.S. Environmental Protection Agency report EPA/444/4-89/001, Washington, D.C.
- Resh, V. H. 1979. Sampling variability and life history features: basic considerations in the design of aquatic insect studies. J. Fish. Res. Board Can. 36: 290-311.

- Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin 191 of the Fisheries Research Board of Canada. Government Publishing Centre, Ottawa.
- Roell, M.J. 1989. The roles of predation, competition, and exploitation in the community dynamics of the New River in West Virginia. PhD. dissertation, Va. Poly. Inst. St. Univ., Blacksburg, VA. 248 pp.
- Roell, M.J. and D.J. Orth. 1988. Impacts of commercial harvest of invertebrate baits on the predator-prey interactions in the New River. Final Report to West Virginia Department of Natural Resources, Va. Poly. Inst. St. Univ., Blacksburg, VA. 194 pp.
- Roell, M.J. and D.J. Orth. 1993. Trophic basis of production of stream-dwelling smallmouth bass, rock bass, and flathead catfish in relation to invertebrate bait harvest. Trans. Am. Fish. Soc. 122:46-62.
- Roell, M.J. and D.J. Orth. 1994. The roles of predation, competition, and exploitation in the trophic dynamics of a warmwater stream: a model synthesis, analysis, and application. Hydrobiologia 291:157-178.
- Roell, M.J. and D.J. Orth. in press. Indirect effects of fishery exploitation and pest control in a riverine food web. No. Am. J. Fish. Manage.
- SAS. 1985. SAS user's guide: statistics. SAS Institute, Cary, NC.
- Schlosser, I.J. 1985. Flow regime, juvenile abundance, and the assemblage structure of stream fishes. Ecology 66:1484-1490.
- Shepard, R. B. and G. W. Minshall. 1981. Nutritional value of lotic insect feces compared with allochthonous materials. Arch. Hydrobiol. 90:467-488.
- Shepard, R. B. and G. W. Minshall. 1984a. Role of benthic insect feces in a Rocky Mountain stream. Fecal production and support of consumer growth. Holartic Ecol. 7:119-127.
- Shepard, R. B. and G. W. Minshall. 1984b. Selection of fine-particulate foods by some stream insects under laboratory conditions. Am. Midland Nat. 111:23-32.
- Short, R. A. and P. E. Maslin. 1977. Processing of leaf litter by a stream detritivore: effect on nutrient availability to collectors. Ecology 58:935-938.
- Smith, P.W. 1971. The fishes of Illinois. University of Illinois Press, Urbana, IL. 314 pp.

- Snedecor, G. W. and W. G. Cochran. 1980. Statistical methods. 7th Edition. Iowa St. Univ. Press, Ames, IA.
- Stanford, J. A. 1973. A centrifuge method for determining live weights of aquatic insect larvae with a note on weight loss in preservative. Ecology 54:449-451.
- Stauffer J.R., Jr., C.H. Hocutt, and S.L. Markham. 1980. Aquatic biological survey of the New River, Virginia and West Virginia. Final report to the U.S. Fish Wildl. Serv., Appalachian Environmental Laboratory, Univ. Md., Frostburg, MD. 36 pp.
- Undeen, A. H. and L. A. Lacey. 1982. Field procedures for the evaluation of *Bacillus thuringiensis* var. *israelensis* (H-14) against black flies (Simuliidae) and nontarget organisms in streams. Misc. Publ. Entomol. Soc. Am. 12: 25 - 30.
- U. S. Environmental Protection Agency. 1986. Hazard evaluation division, standard evaluation procedure, ecological risk assessment. EPA 540/9-85-001. U. S. Environmental Protection Agency, Office of Pesticide Programs, Washington, D.C.
- Vadas, R.L., Jr. 1990. The importance of omnivory and predator regulation of prey in freshwater fish assemblages of North America. Environ. Biol. Fish. 27:285-302.
- Va. Polytech. Inst. and St. Univ. 1985. An ecological investigation of the New River and Bluestone Lake. Report. Huntington District, U. S. Army Corps of Engineers. 185 pp. text + 241 pp. data appendix.
- Va. Polytech. Inst. and St. Univ. 1994. New River Gorge National River long-term ecological monitoring system. User manual. Database management system. Report. New River Gorge National River, U. S. Department of Interior, National Park Service, Oak Hill, West Virginia. 73 pp.
- Voshell, J. R., Jr. 1983. Assessment of black fly populations in a portion of southern West Virginia. Report. W. V. Dept. of Natural Resources. 134 pp.
- Voshell, J. R., Jr. 1984. The ecology of black flies in the New River and its major tributaries in southern West Virginia. Pages 221-230 in W. E. Cox and J. Wild, chairpersons. Proceedings, New River Symposium, 1984. U. S. Dept. of Interior, National Park Service, Oak Hill, West Virginia.
- Voshell, J. R., Jr. 1985. Trophic basis of production for macroinvertebrates in the New River below Bluestone Dam. Report. W. V. Dept. of Natural Resources. 83 pp.

- Voshell, J. R., Jr. 1991. Life cycle of *Simulium jenningsi* (Diptera: Simuliidae) in southern West Virginia. J. Econ. Entomol. 84: 1220-1226.
- Voshell, J. R., Jr., S. W. Hiner, and R. J. Layton. 1992. Evaluation of a benthic macroinvertebrate sampler for rock outcrops in rivers. J. Freshwat. Ecol. 7: 1-6.
- Voshell, J. R., Jr., R. J. Layton, and S. W. Hiner. 1987a. An ecological survey of the New River below Bluestone Lake. Pages 201-212 in J. Wild and N. DeJong, chairpersons. Proceedings, New River Symposium, 1987. Boone, North Carolina. U. S. Dept. of Interior, National Park Service, Oak Hill, West Virginia.
- Voshell, J. R., Jr., R. J. Layton, and S. W. Hiner. 1987b. Monitoring the black fly population management program in the New River below Bluestone Dam. Report. New River Gorge National River, U. S. Dept. of Interior, National Park Service. 33 pp.
- Voshell, J. R., Jr., R. J. Layton, and S. W. Hiner. 1988a. Analysis of secondary production to determine the ecological effects of the 1986 black fly pest management in the New River below Bluestone Dam. Report MAR-32. New River Gorge National River, U. S. Dept. of Interior, National Park Service. 60 pp.
- Voshell, J. R., Jr., R. J. Layton, and S. W. Hiner. 1988b. Field techniques for determining the effects of toxic substances on benthic macroinvertebrates in rocky-bottomed streams. Pp. 134-155 in U. Cowgill and L. R. Williams, eds. Aquatic toxicology and hazard assessment: 12th volume. ASTM STP 1027. American Society for Testing and Materials, Philadelphia.
- Voshell, J. R., Jr., S. W. Hiner, V. D. Christman, and A. G. Silvia, III. 1988. Production of benthic macroinvertebrates in the New River immediately above Sandstone Falls in 1987. Report. New River Gorge National River, U. S. Department of Interior, National Park Service. 49 pp.
- Voshell, J. R., Jr., D. J. Orth, R. S. Easton, and S. W. Hiner. 1992. Interim Report No. 9. Ecological monitoring in the New River Gorge National River: progress report on LTEMs and results of 1990 survey. Report. New River Gorge National River, U. S. Department of Interior, National Park Service, Oak Hill, West Virginia. 41 pp. text + 101 pp. appendix.

- Voshell, J. R., Jr., D. J. Orth, S. W. Hiner, and R. S. Easton. 1995. New River Gorge National River long-term ecological monitoring system. User manual. Database management system. Report. New River Gorge National River, U. S. Department of Interior, National Park Service, Oak Hill, West Virginia. 48 pp. text + 24 pp. appendix.
- Voshell, J. R., Jr., D. J. Orth, V. D. Christman, R. S. Easton, and S. W. Hiner. 1991. Preliminary report on a long-term ecological monitoring system for New River Gorge National River. Pages 27-36 in D. E. Kodak, chairperson. Proceedings, New River Symposium, 1991. Pipestem, West Virginia. U. S. Dept. of Interior, National Park Service, Oak Hill, West Virginia.
- Voshell, J. R., Jr., D. J. Orth, S. W. Hiner, R. S. Easton, and V. D. Christman. 1990a. Interim Report No. 3. Ecological monitoring in the New River Gorge National River: progress report on LTEMs and results of 1988 survey. Report. New River Gorge National River, U. S. Department of Interior, National Park Service, Oak Hill, West Virginia. 14 pp. text + 44 pp. appendix.
- Voshell, J. R., Jr., D. J. Orth, S. W. Hiner, R. S. Easton, and V. D. Christman. 1990b. Interim Report No. 4. Ecological monitoring in the New River Gorge National River: secondary production immediately above Sandstone Falls in 1989. Report. New River Gorge National River, U. S. Department of Interior, National Park Service, Oak Hill, West Virginia. 28 pp. text + 42 pp. appendix.
- Voshell, J. R., Jr., D. J. Orth, S. W. Hiner, R. S. Easton, and V. D. Christman. 1990c. Interim Report No. 5. Ecological monitoring in the New River Gorge National River: secondary production immediately below Bluestone Dam in 1989. Report. New River Gorge National River, U. S. Department of Interior, National Park Service, Oak Hill, West Virginia. 24 pp. text + 38 pp. appendix.
- Voshell, J. R., Jr., D. J. Orth, S. W. Hiner, R. S. Easton, and V. D. Christman. 1991a. Interim Report No. 6. Ecological monitoring in the New River Gorge National River: progress report on LTEMs and results of 1989 survey. Report. New River Gorge National River, U. S. Department of Interior, National Park Service, Oak Hill, West Virginia. 52 pp. text + 17 pp. appendix.
- Voshell, J. R., Jr., D. J. Orth, S. W. Hiner, R. S. Easton, and V. D. Christman. 1991b. Interim Report No. 7. Ecological monitoring in the New River Gorge National River: secondary production immediately above Sandstone Falls in 1990. Report. New River Gorge National River, U. S. Department of Interior, National Park Service, Oak Hill, West Virginia. 54 pp. text + 16 pp. appendix.

- Voshell, J. R., Jr., D. J. Orth, S. W. Hiner, R. S. Easton, and V. D. Christman. 1991c. Interim Report No. 8. Ecological monitoring in the New River Gorge National River: secondary production immediately below Bluestone Dam in 1990. Report. New River Gorge National River, U. S. Department of Interior, National Park Service, Oak Hill, West Virginia. 60 pp. text + 13 pp. appendix.
- Voshell, J. R., Jr., D. J. Orth, S. W. Hiner, A. G. Silvia, III, R. S. Eaton, M. J. Roell, S. M. Smith, and V. D. Christman. 1989a. Interim Report No. 1. Ecological monitoring in the New River Gorge National River: secondary production immediately above Sandstone Falls in 1988. Report. New River Gorge National River, U. S. Department of Interior, National Park Service. 72 pp. text + 33 pp. appendix.
- Voshell, J. R., Jr., D. J. Orth, S. W. Hiner, A. G. Silvia, III, R. S. Eaton, M. J. Roell, S. M. Smith, and V. D. Christman. 1989b. Interim Report No. 2. Ecological monitoring in the New River Gorge National River: secondary production immediately below Bluestone Dam in 1988. Report. New River Gorge National River, U. S. Department of Interior, National Park Service. 58 pp. text + 31 pp. appendix.
- Wallace J. B., J. R. Webster, and W. R. Woodall. 1977. The role of filter feeders in flowing waters. Arch. Hydrobiol. 79:506-532.
- Ward, J. V. and J. A. Stanford. 1979. Ecological factors controlling stream zoobenthos with emphasis on thermal modification of regulated streams. Pp. 35-55 in Ward, J. V. and J. A. Stanford, Eds., The ecology of regulated streams. Plenum Press, New York.
- Washington, H.G. 1984. Diversity, biotic and similarity indices: a review with special relevance to aquatic ecosystems. Water Res. 18:653-694.
- Webster J. R. and B. C. Patten. 1979. Effects of watershed perturbation on stream potassium and calcium dynamics. Ecol. Monogr. 49:51-72.
- Wotton, R. S. 1979. The influence of a lake on the distribution of black fly species (Diptera: Simuliidae) along a river. Oikos 32:368-372.
- Wotton, R. S. 1980. Coprophagy as an economic feeding tactic in black fly larvae. Oikos 34:282-286.
- Wotton, R. S. 1984. The importance of identifying the origins of microfine particles in aquatic systems. Oikos 43:217-221.

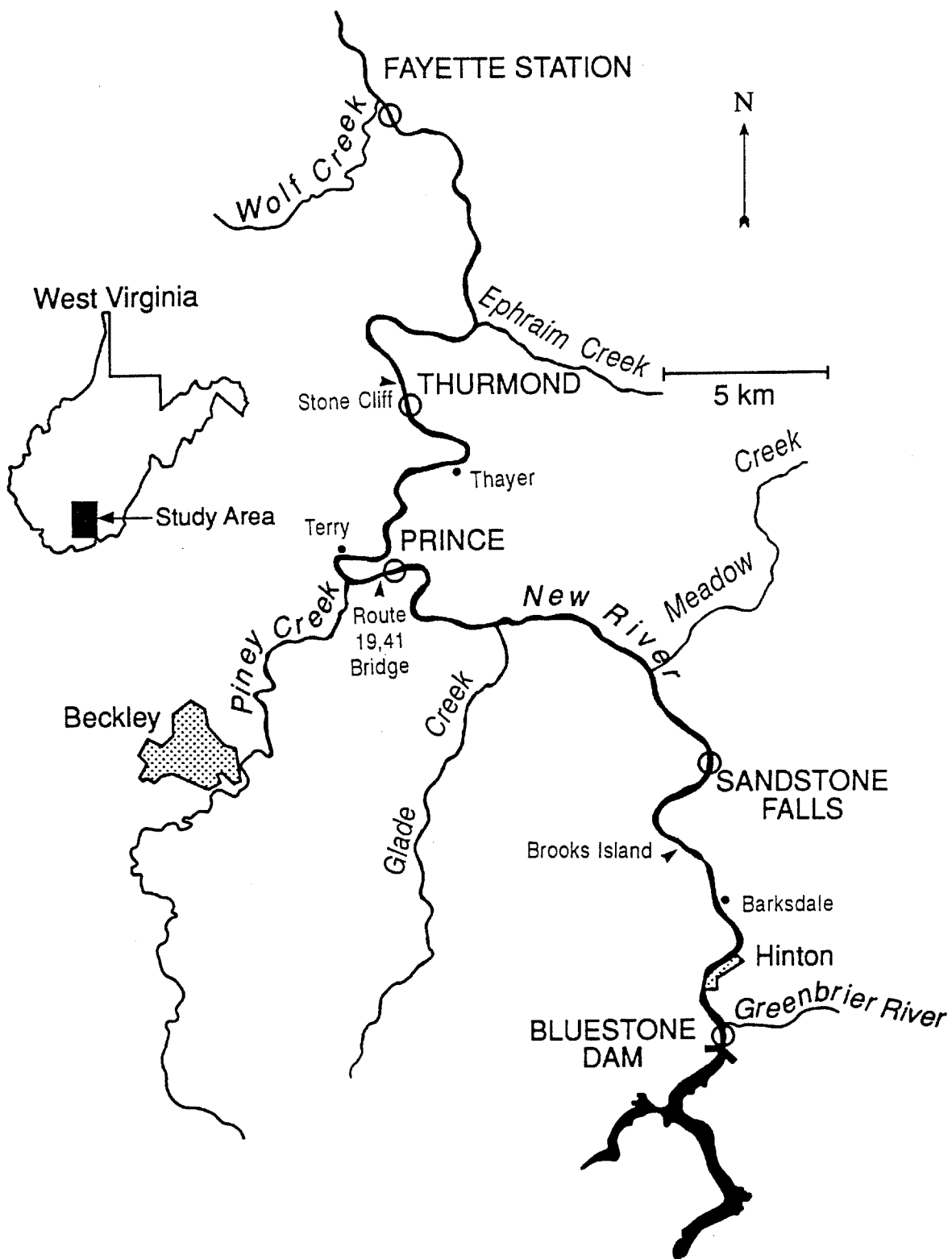


Fig. 1. Map of the New River and its major tributaries in the study area. There were five study sites (open circles): Bluestone Dam, Sandstone Falls, Prince, Thurmond, and Fayette Station. Production of dominant aquatic insects and growth of fishes were analyzed at Bluestone Dam and Sandstone Falls. Community structure of macroinvertebrates and fishes was analyzed at all study sites.

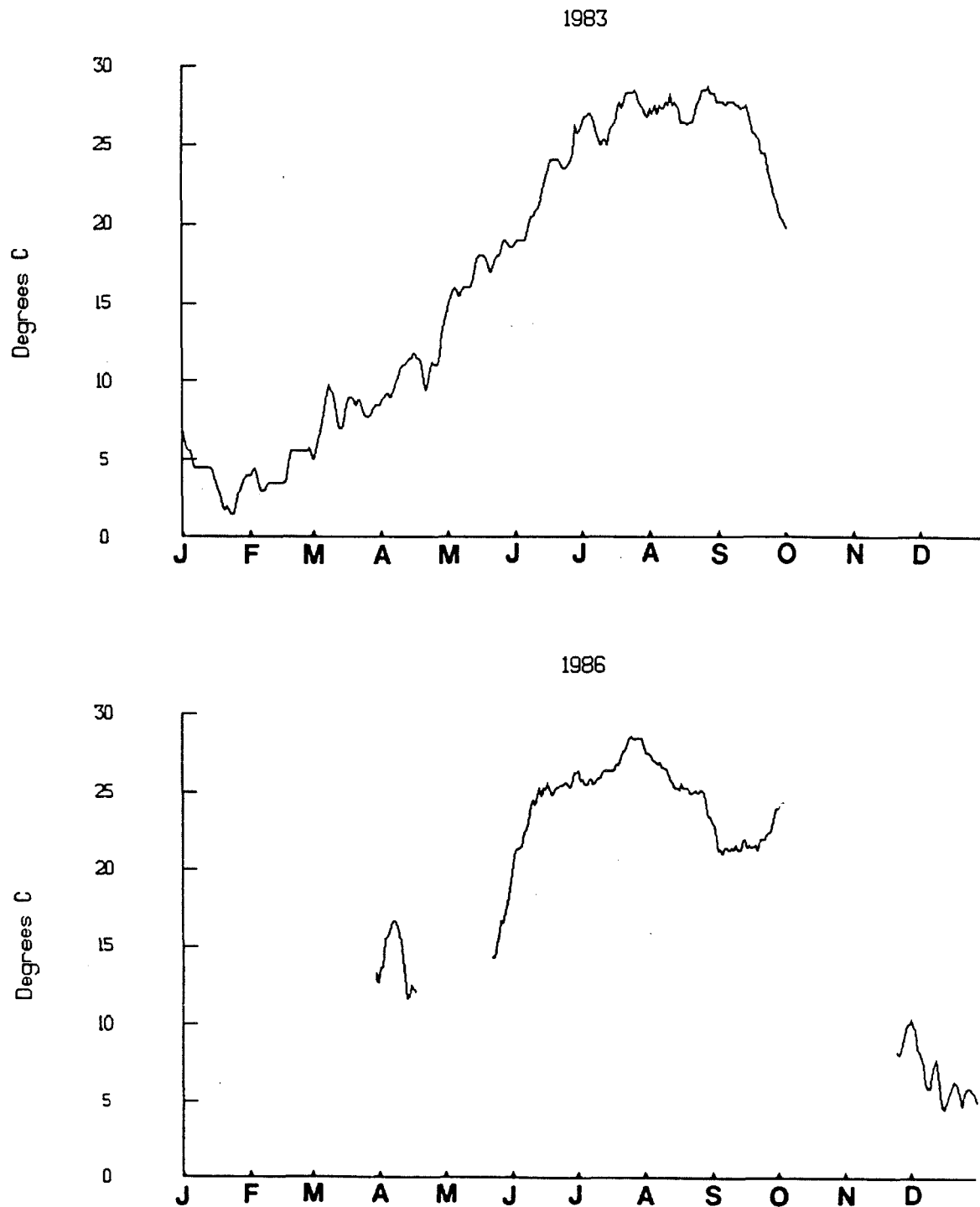


Fig. 2. Water temperature ($^{\circ}\text{C}$) of the New River at Bluestone Dam in 1983 and 1986. All data were obtained with a continuous recording thermograph. Missing data in 1986 during April-May and October-November were caused by equipment malfunction.

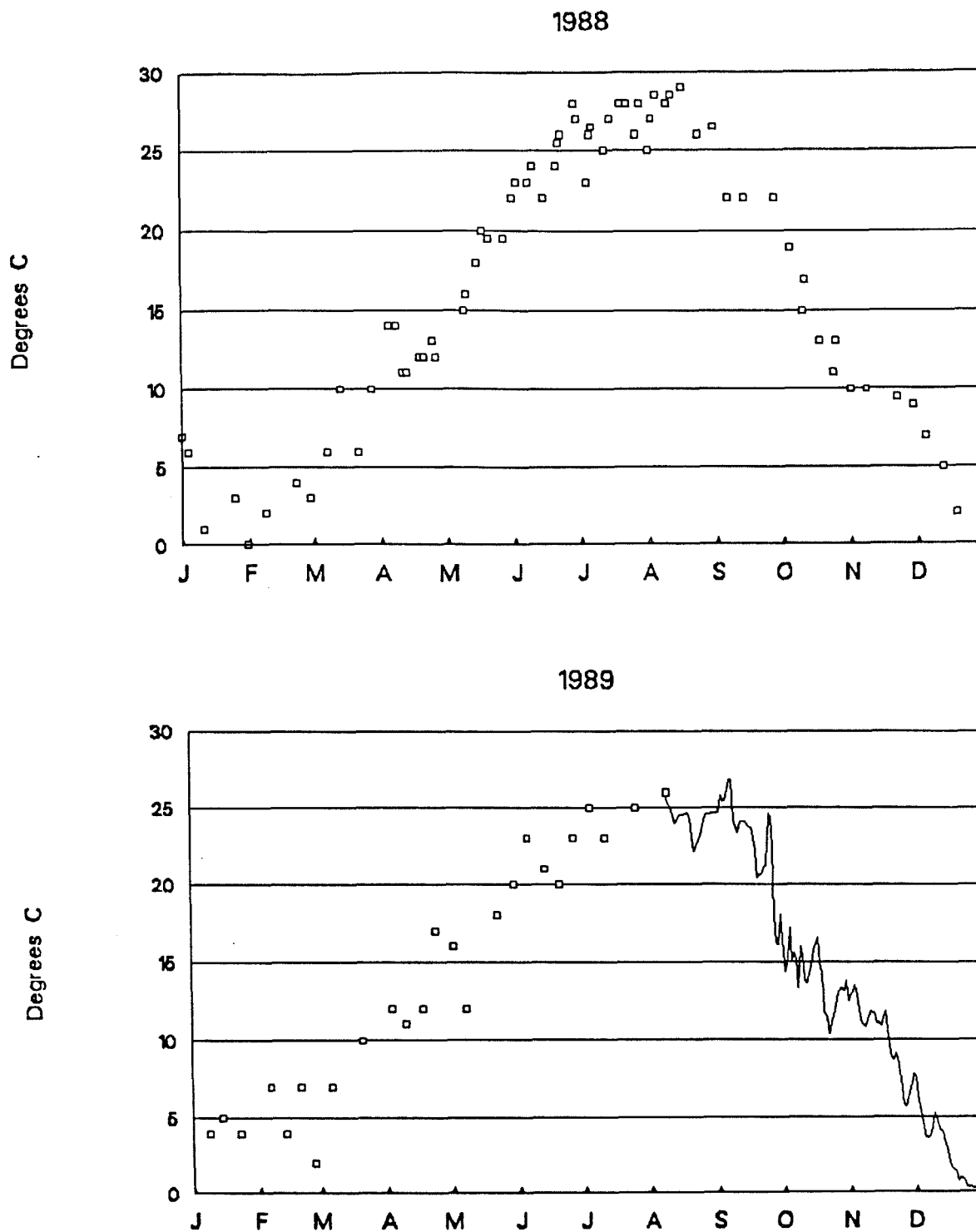


Fig. 3. Water temperature ($^{\circ}\text{C}$) of the New River at Bluestone Dam in 1988 and 1989. Most data were obtained with a hand-held thermometer on specific days (indicated by open boxes). Data from August-December 1989 were obtained with a continuous recording thermograph.

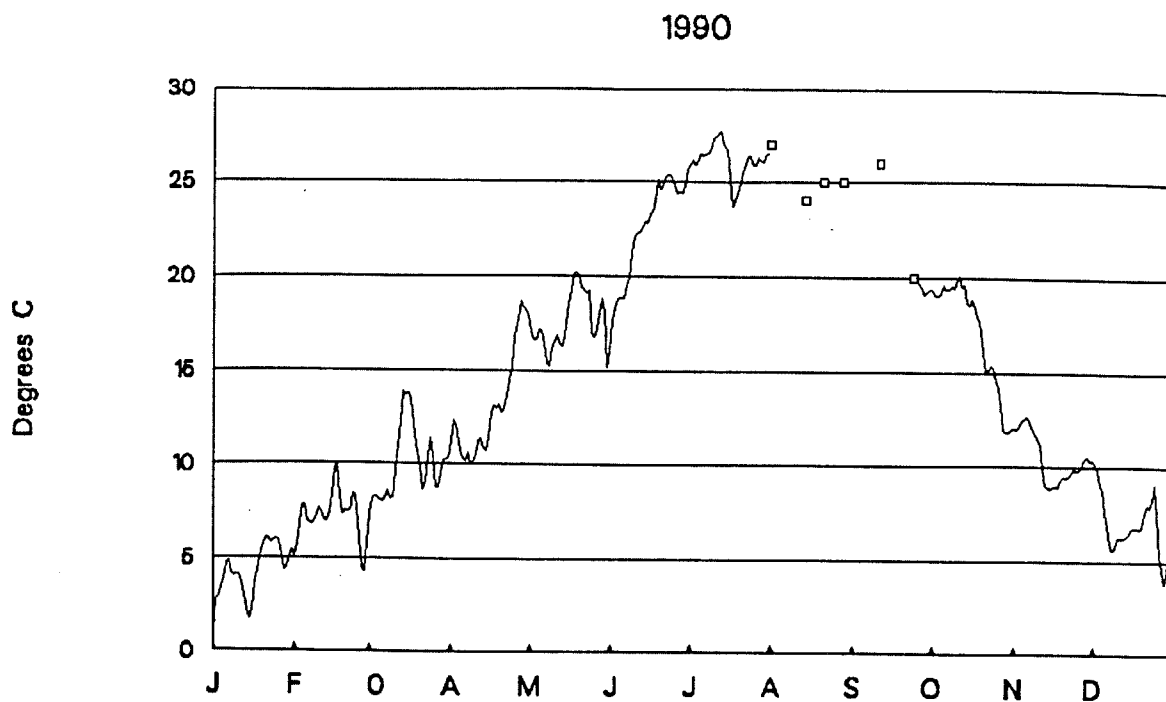
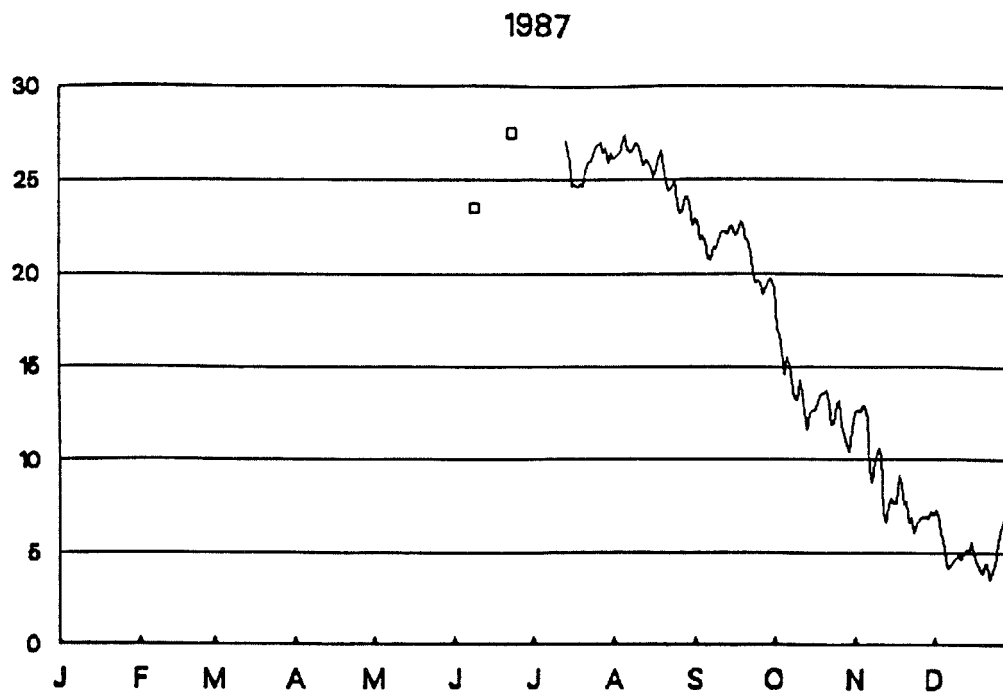


Fig. 4. Water temperature ($^{\circ}\text{C}$) of the New River at Bluestone Dam in 1990. Most data were obtained with a continuous recording thermograph. Missing data during August-September were caused by equipment malfunction. Some data were obtained during that period with a hand-held thermometer on specific days (indicated by open boxes).

Degrees C



Degrees C

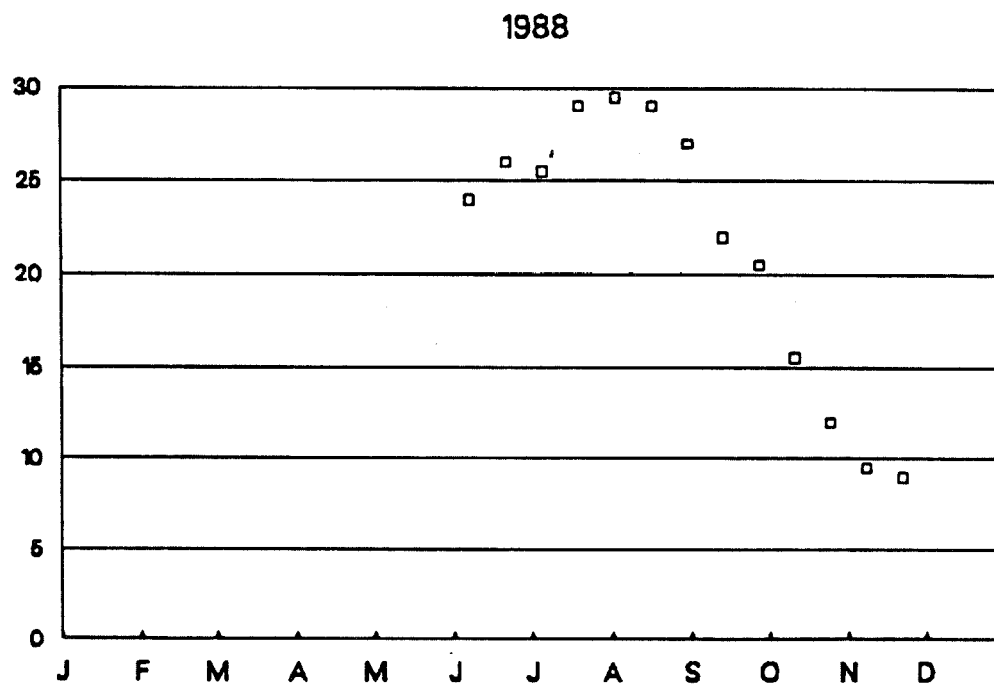


Fig. 5. Water temperature ($^{\circ}\text{C}$) of the New River at Sandstone Falls in 1987 and 1988. Most data were obtained with a continuous recording thermograph. Independent points (indicated by open boxes) were obtained with a hand-held thermometer on specific days.

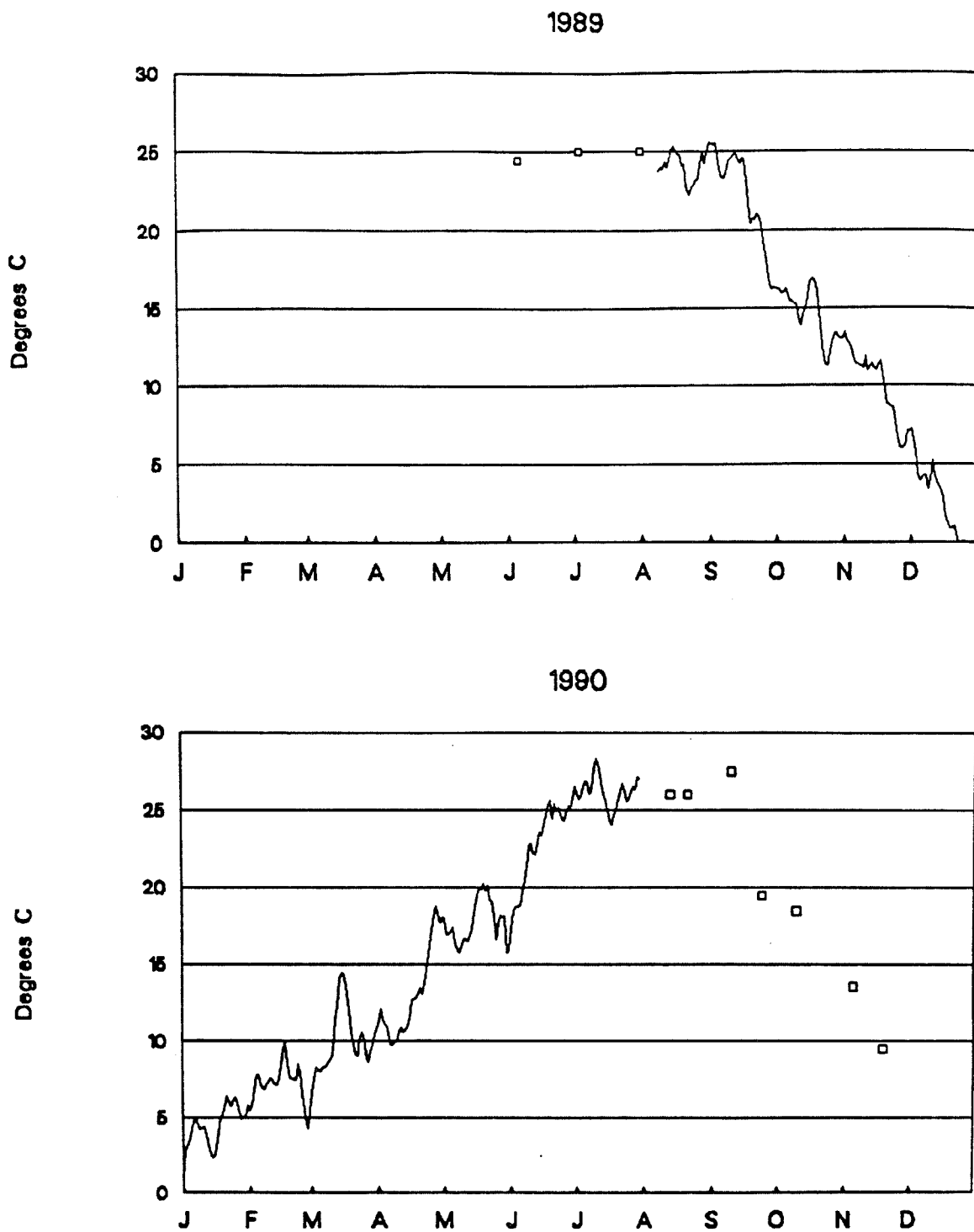


Fig. 6. Water temperature ($^{\circ}\text{C}$) of the New River at Sandstone Falls in 1989 and 1990. Most data were obtained with a continuous recording thermograph. Independent points (indicated by open boxes) were obtained with a hand-held thermometer on specific days.

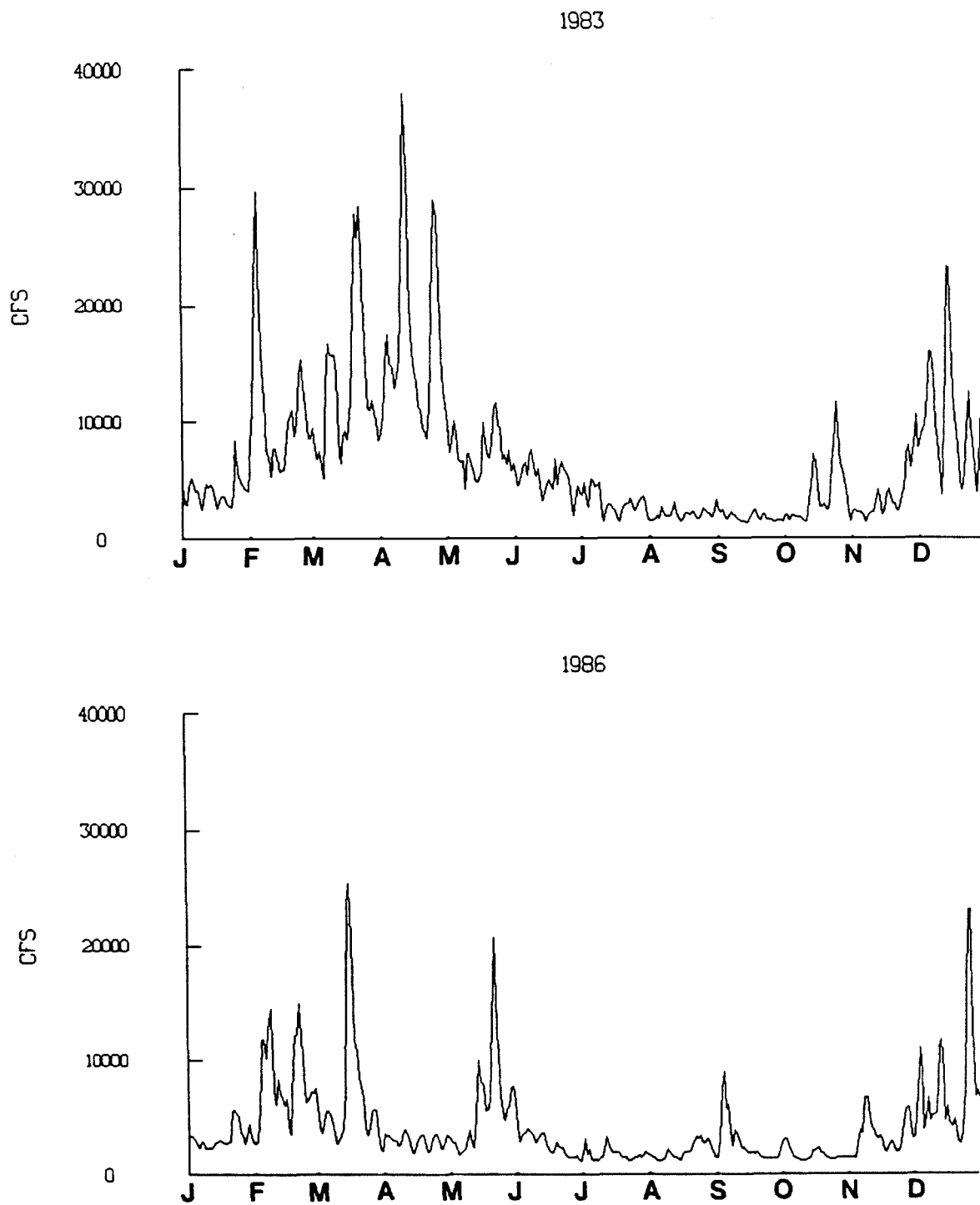


Fig. 7. Mean daily discharge (cfs) of the New River at Bluestone Dam in 1983 and 1986. Data were obtained from the Bluestone gauge (Huntington District, U. S. Army Corps of Engineers).

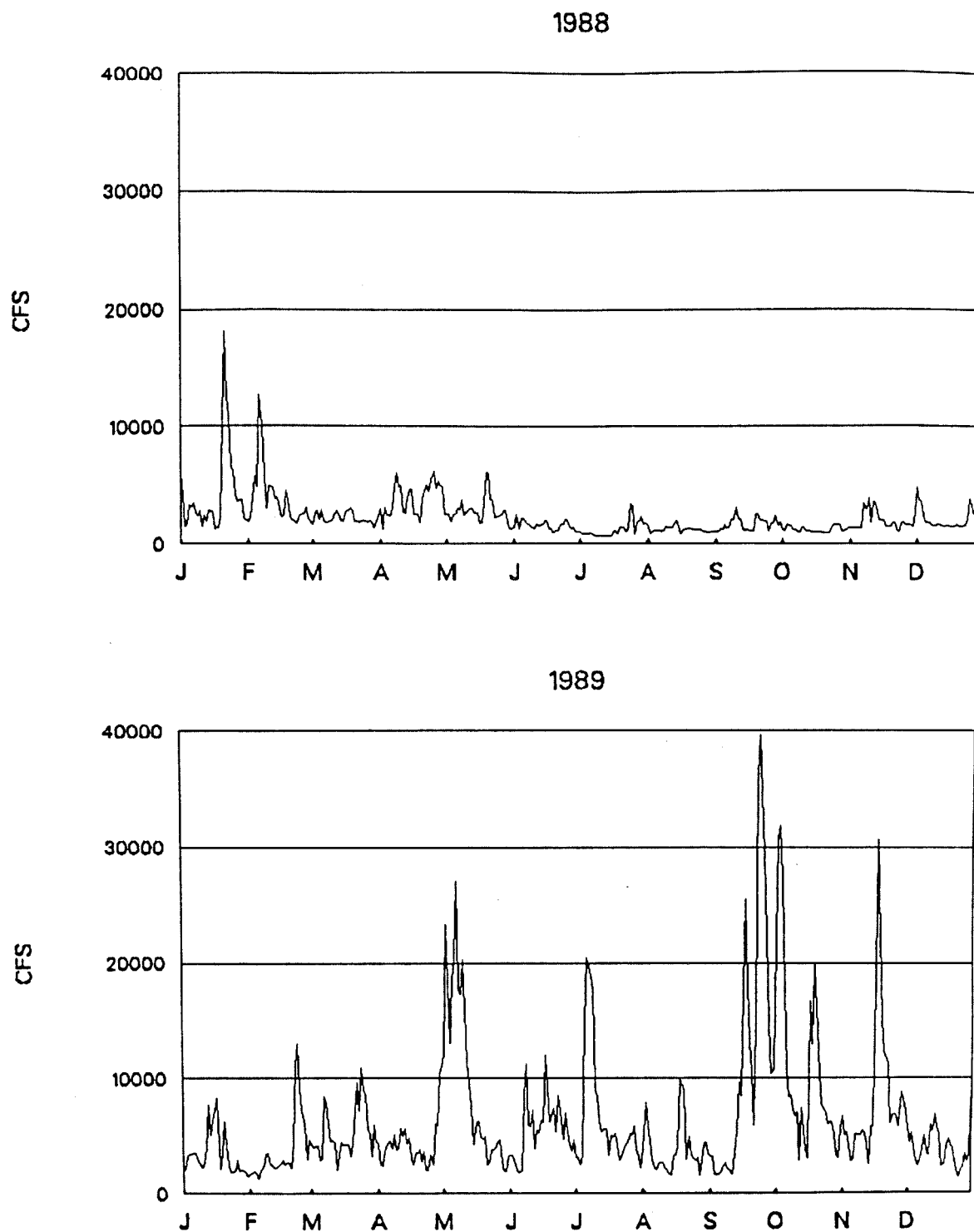


Fig. 8. Mean daily discharge (cfs) of the New River at Bluestone Dam in 1988 and 1989. Data were obtained from the Bluestone gauge (Huntington District, U. S. Army Corps of Engineers).

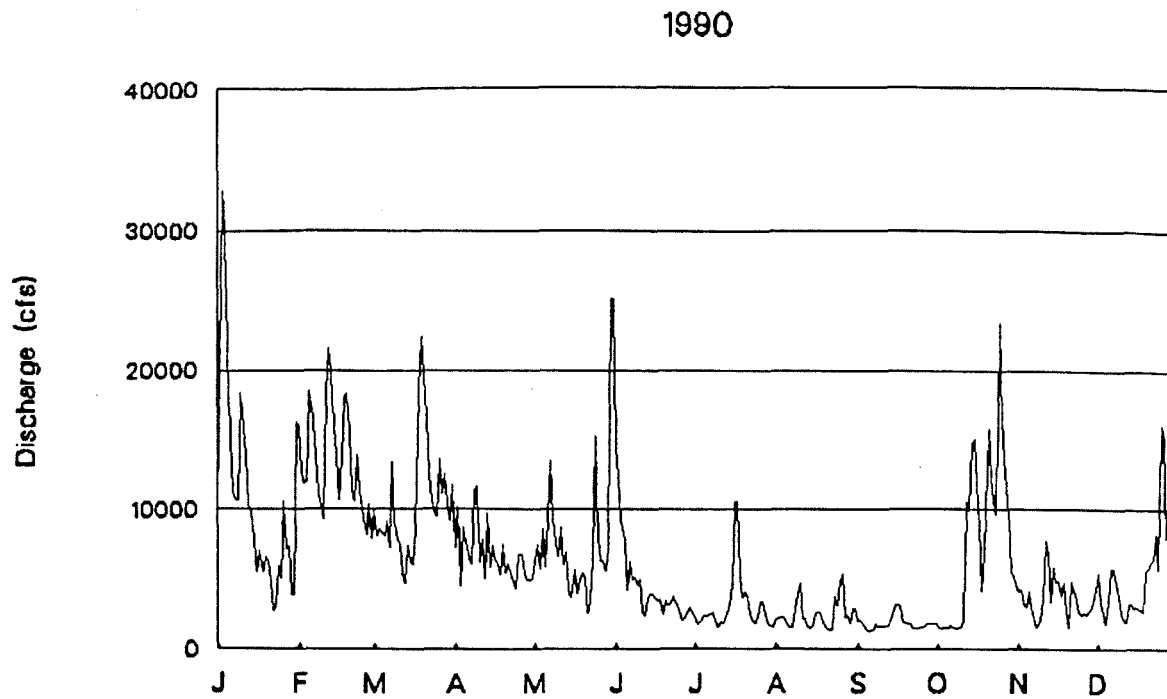


Fig. 9. Mean daily discharge (cfs) of the New River at Bluestone Dam in 1990. Data were obtained from the Bluestone gauge (Huntington District, U. S. Army Corps of Engineers).

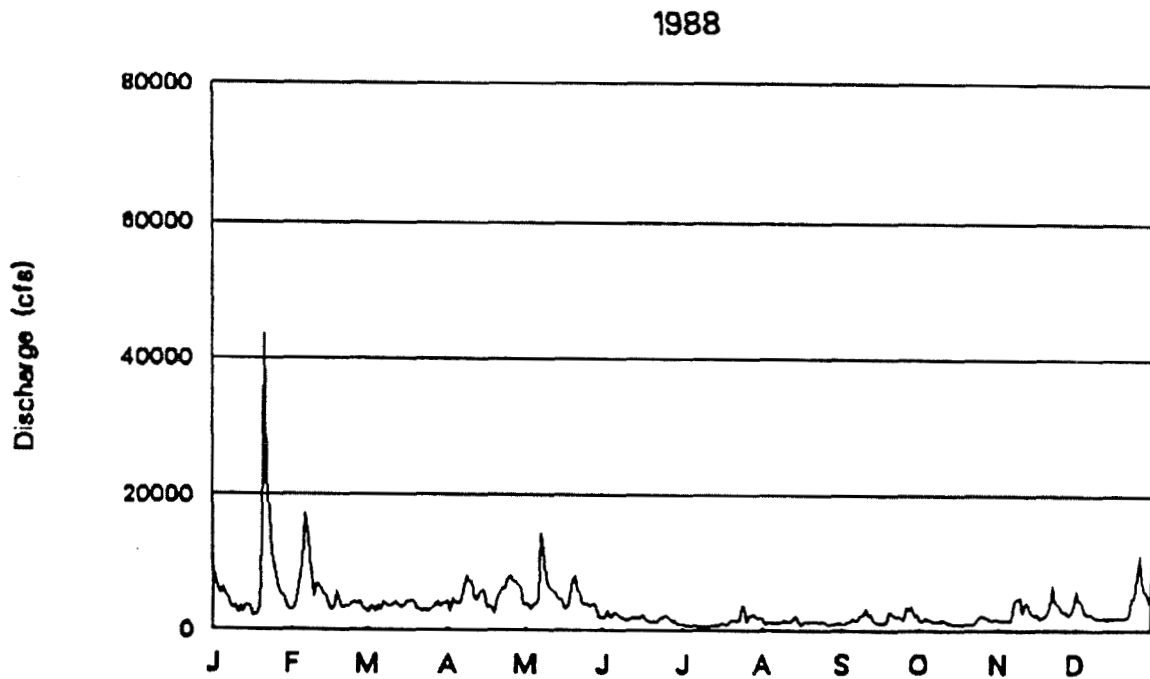
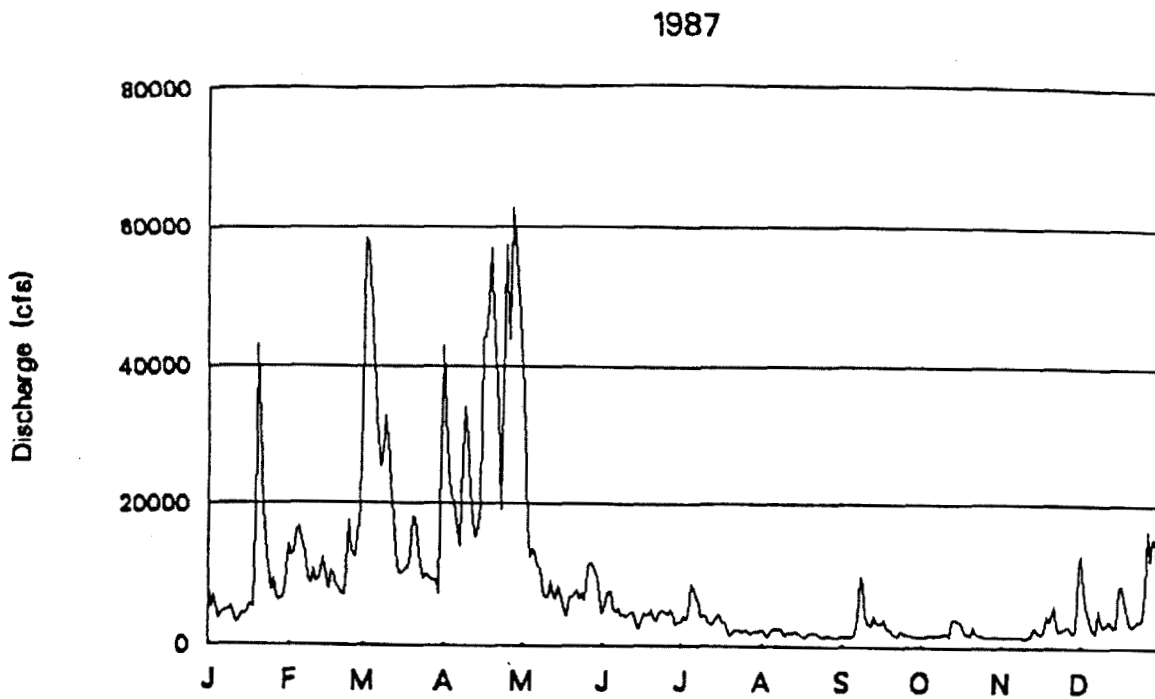


Fig. 10. Mean daily discharge (cfs) of the New River at Sandstone Falls in 1987 and 1988. Data were obtained from the Hinton gauge (Huntington District, U. S. Army Corps of Engineers).

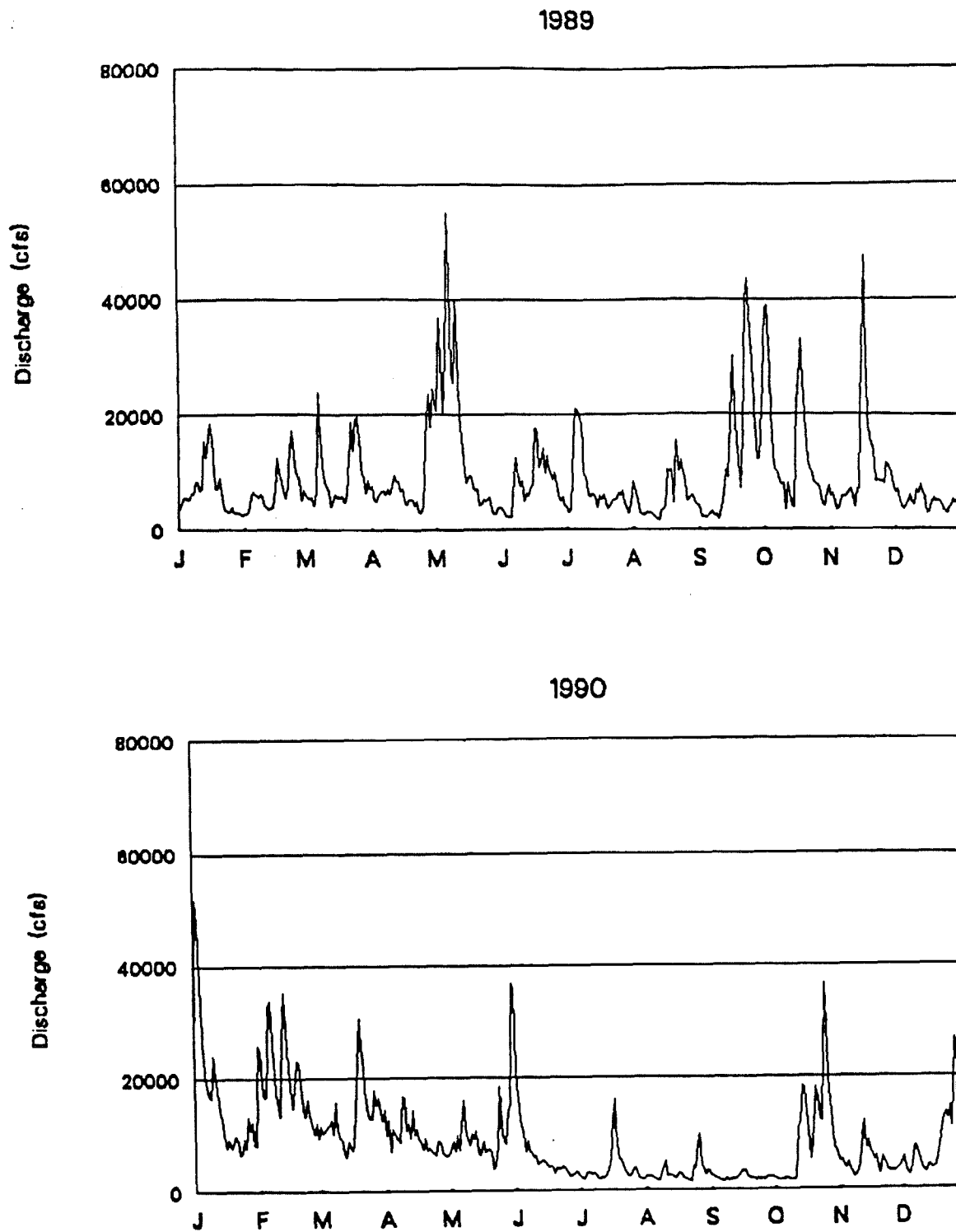


Fig. 11. Mean daily discharge (cfs) of the New River at Sandstone Falls in 1989 and 1990. Data were obtained from the Hinton gauge (Huntington District, U. S. Army Corps of Engineers).

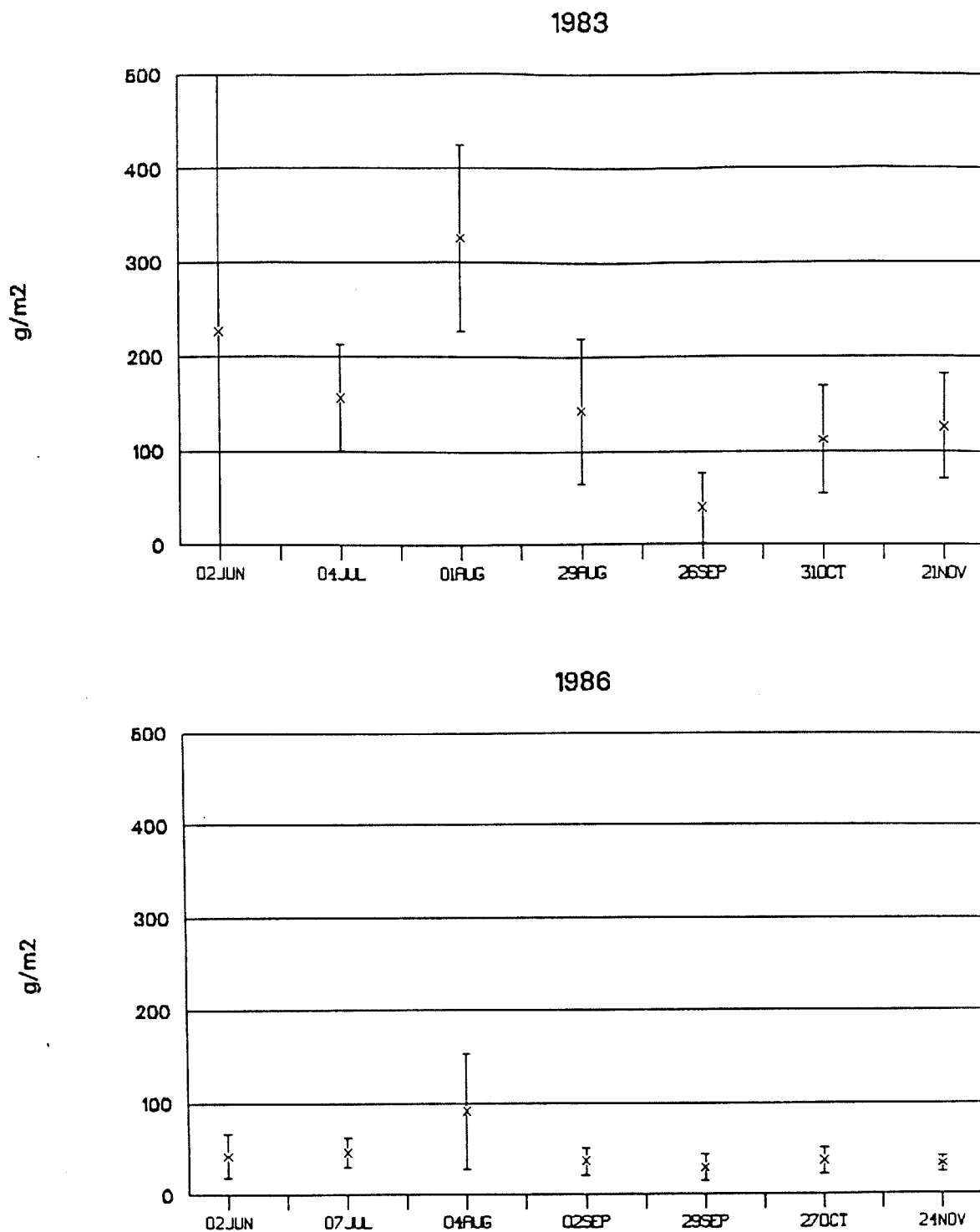


Fig. 12. Standing stock (g dry weight/m²) of submerged macrophyte *Podostemum ceratophyllum* on rock outcrops at Bluestone Dam in 1983 and 1986 (X = mean; vertical bar = 95% confidence limits). Samples consisted of the *Podostemum* found in macroinvertebrate production samples.

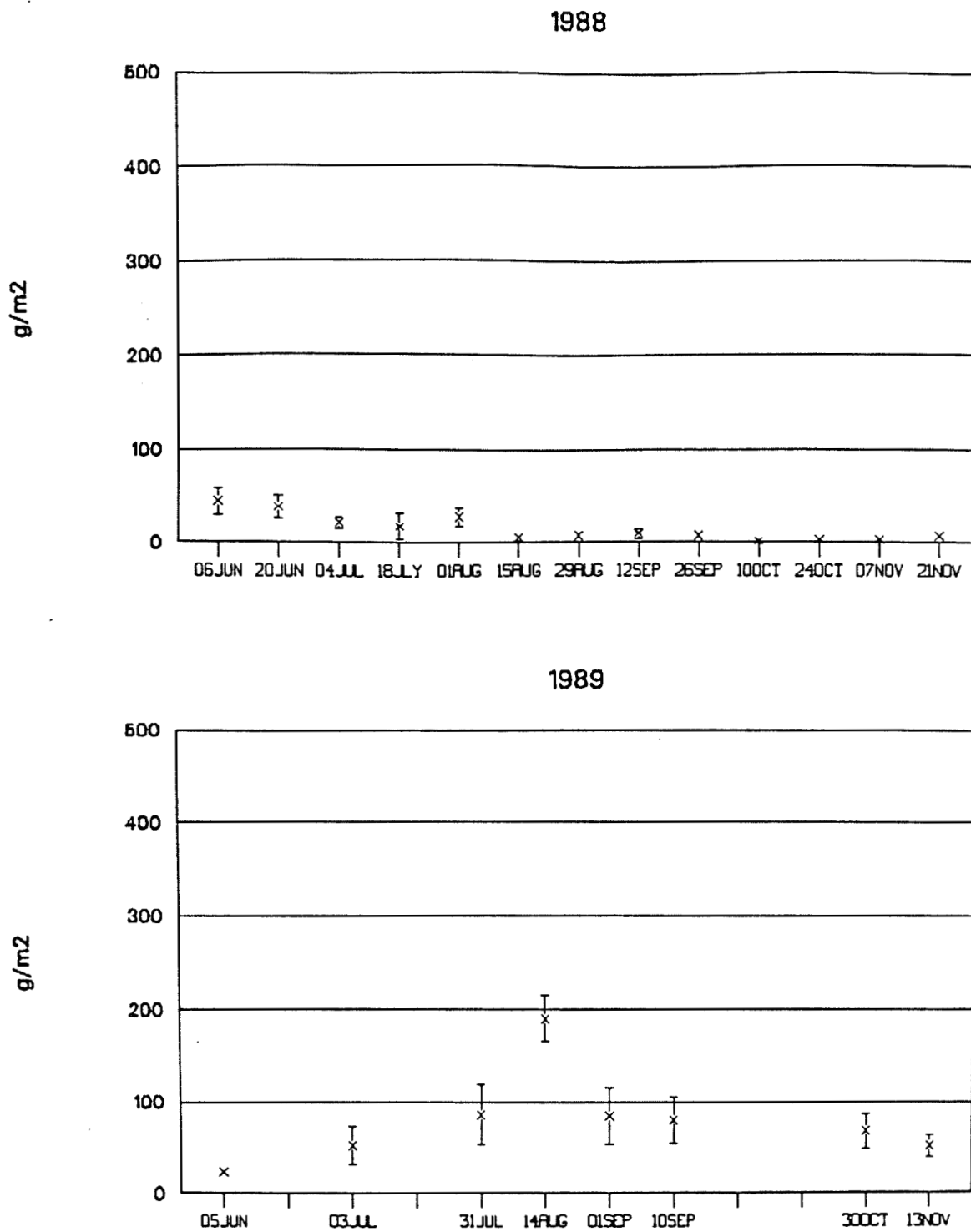


Fig. 13. Standing stock (g dry weight/m²) of submerged macrophyte *Podostemum ceratophyllum* on rock outcrops at Bluestone Dam in 1988 and 1989 (X = mean; vertical bar = 95% confidence limits). Samples consisted of the *Podostemum* found in macroinvertebrate production samples.

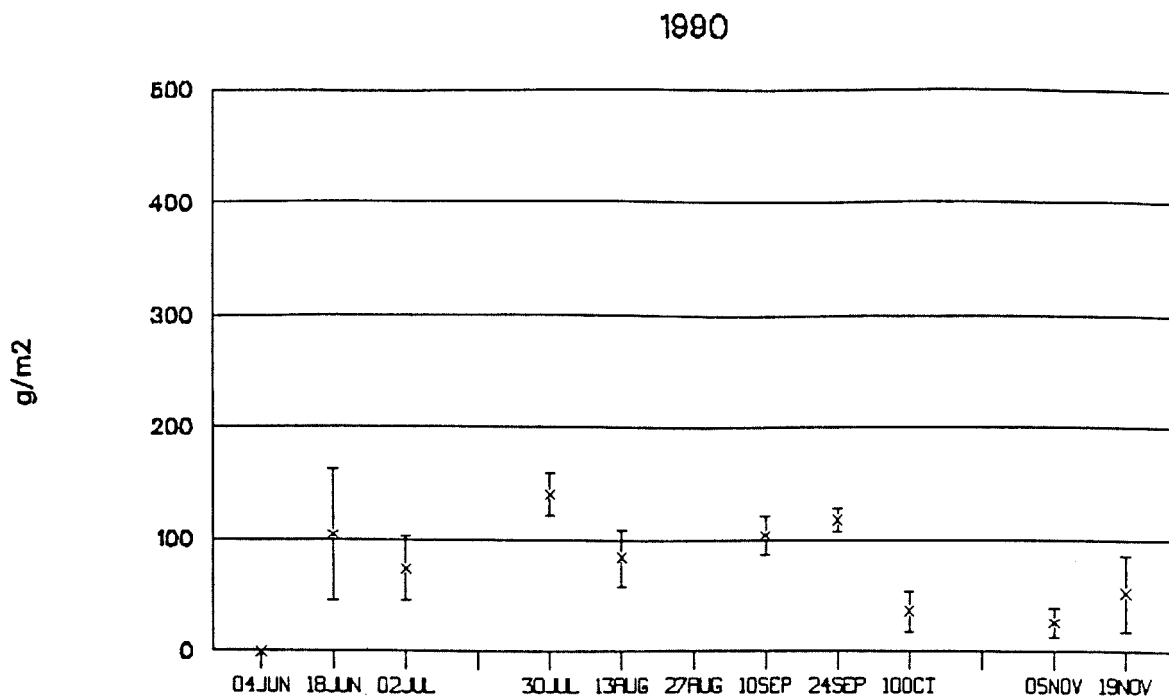


Fig. 14. Standing stock (g dry weight/m²) of submerged macrophyte *Podostemum ceratophyllum* on rock outcrops at Bluestone Dam in 1990 (X = mean; vertical bar = 95% confidence limits). Samples consisted of the *Podostemum* found in macroinvertebrate production samples.

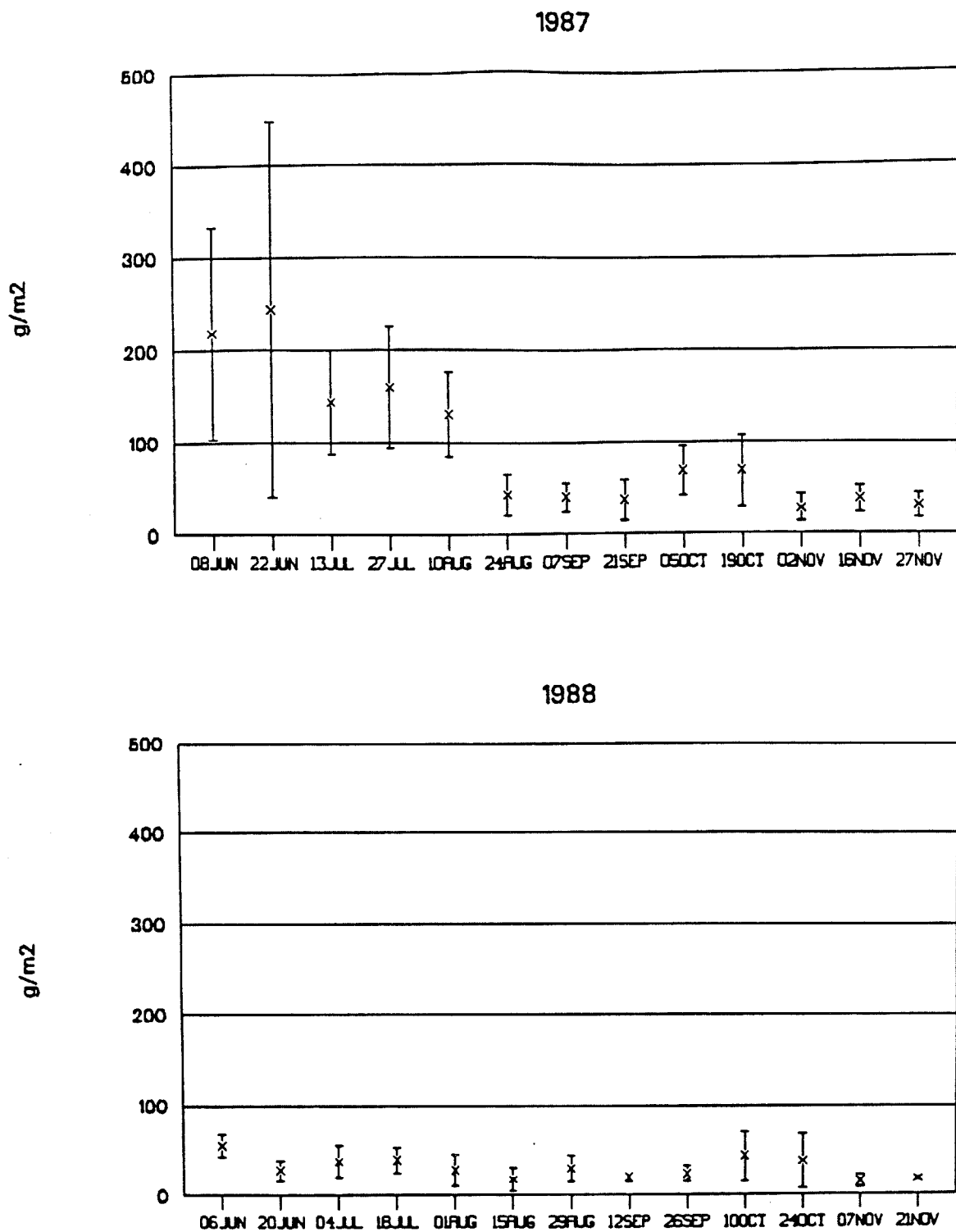


Fig. 15. Standing stock (g dry weight/m²) of submerged macrophyte *Podostemum ceratophyllum* on rock outcrops at Sandstone Falls in 1987 and 1988 (X = mean; vertical bar = 95% confidence limits). Samples consisted of the *Podostemum* found in macroinvertebrate production samples.

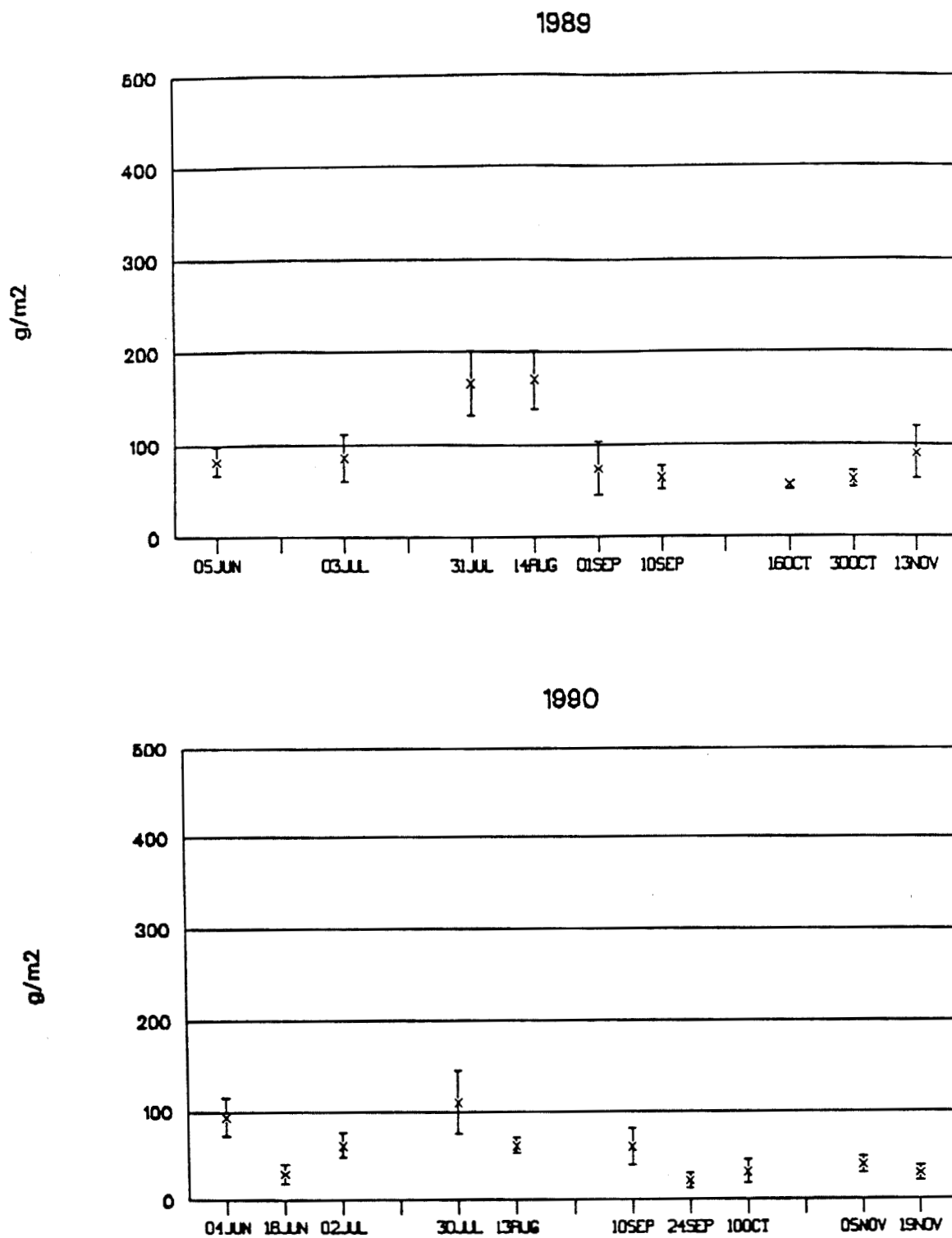


Fig. 16. Standing stock (g dry weight/m²) of submerged macrophyte *Podostemum ceratophyllum* on rock outcrops at Sandstone Falls in 1989 and 1990 (X = mean; vertical bar = 95% confidence limits). Samples consisted of the *Podostemum* found in macroinvertebrate production samples.

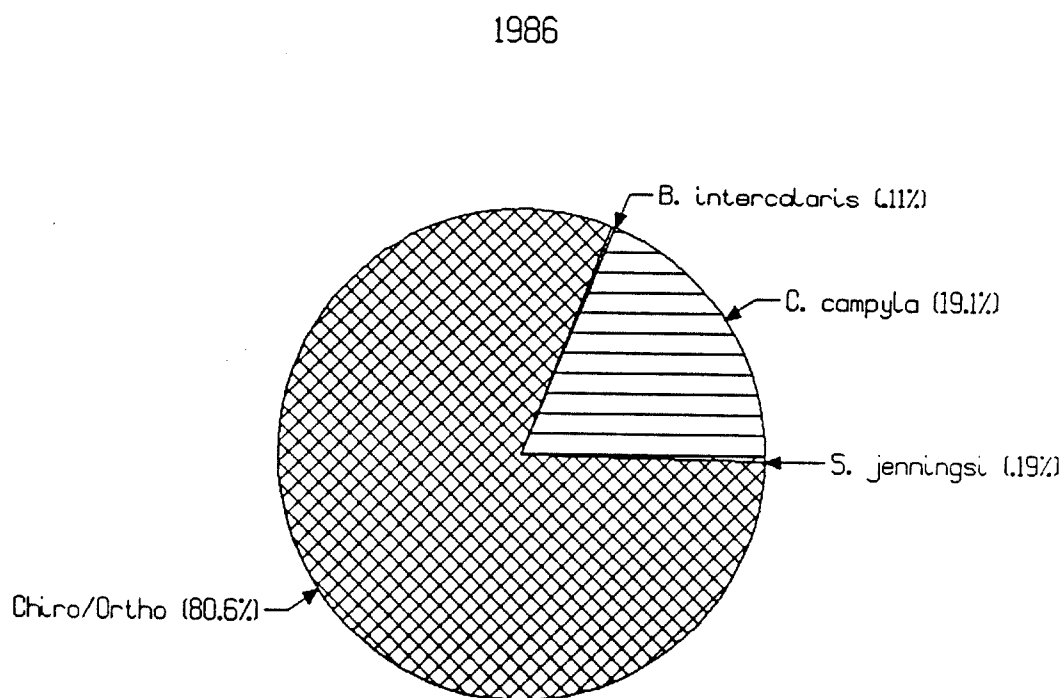
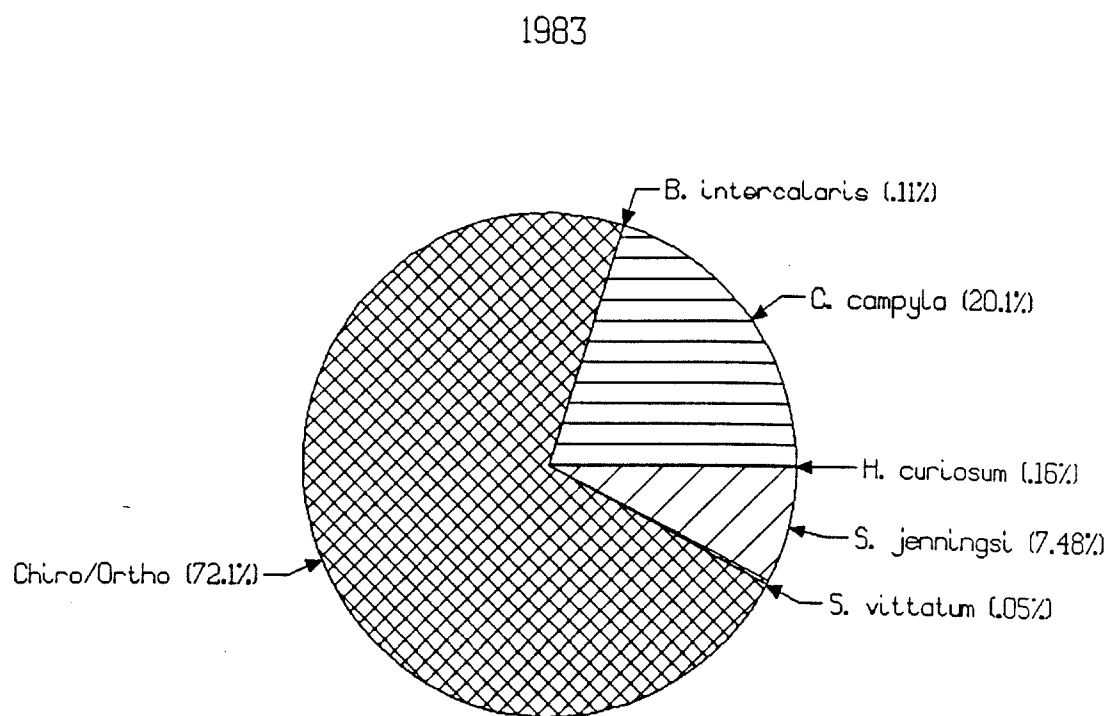
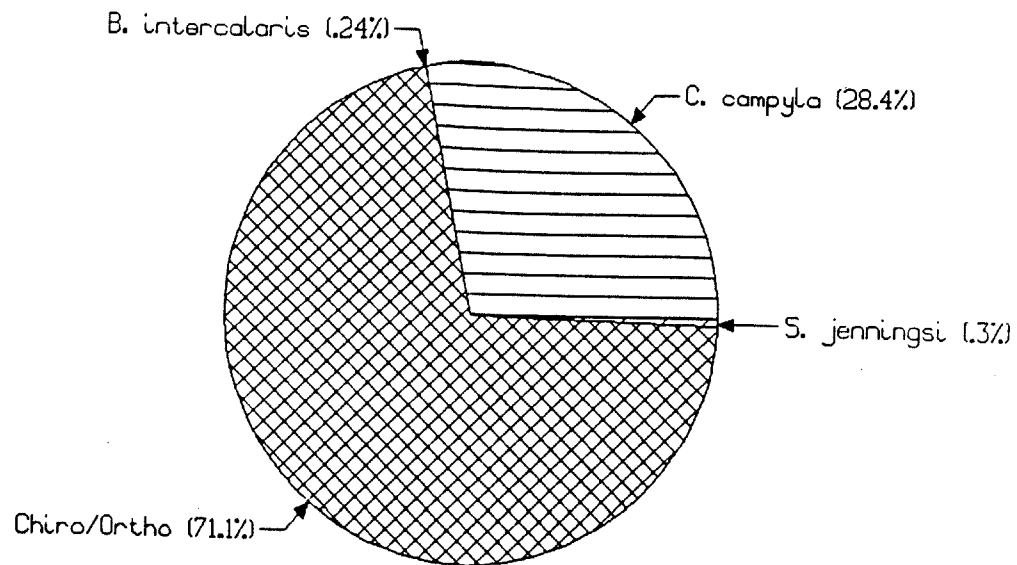


Fig. 17. Percentage (%) of total production for individual taxa of dominant aquatic insects at Bluestone Dam in 1983 and 1986. Production was measured on rock outcrops from June through November.

1988



1989

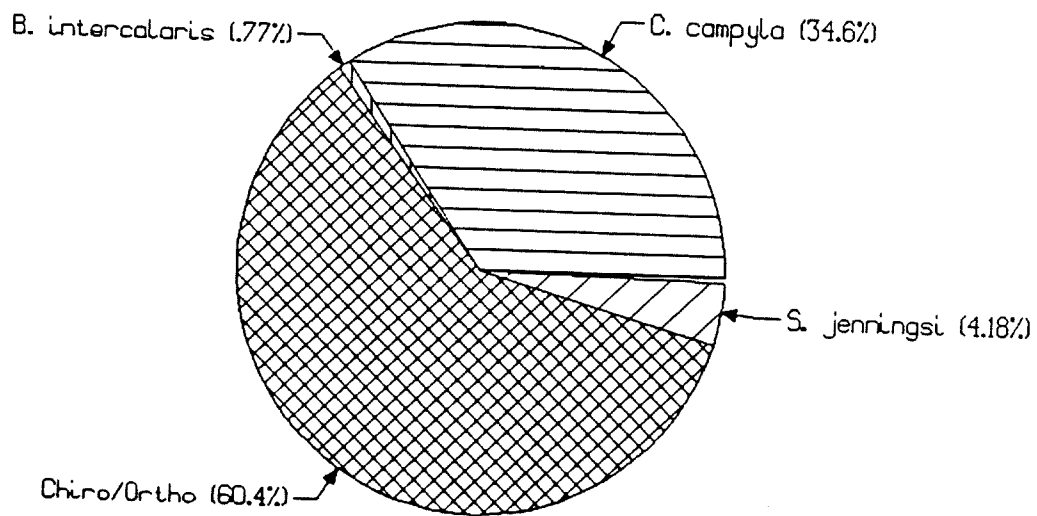


Fig. 18. Percentage (%) of total production for individual taxa of dominant aquatic insects at Bluestone Dam in 1988 and 1989. Production was measured on rock outcrops from June through November.

1990

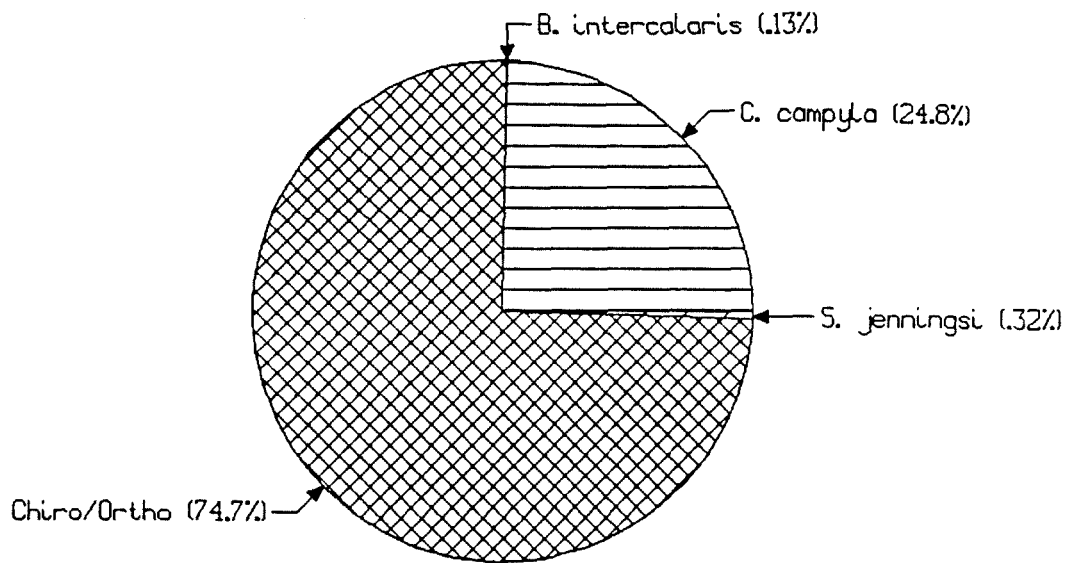


Fig. 19. Percentage (%) of total production for individual taxa of dominant aquatic insects at Bluestone Dam in 1990. Production was measured on rock outcrops from June through November.

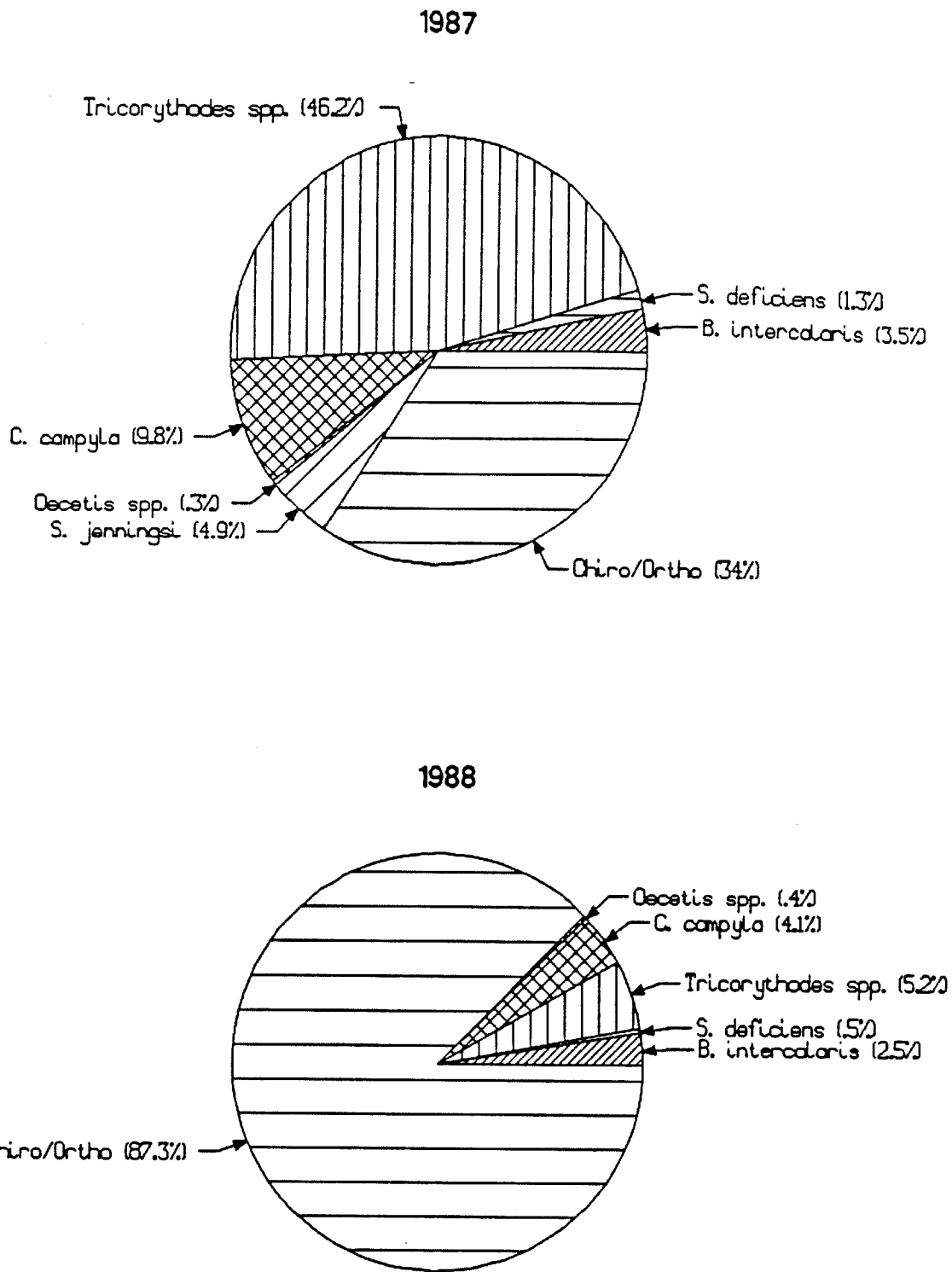
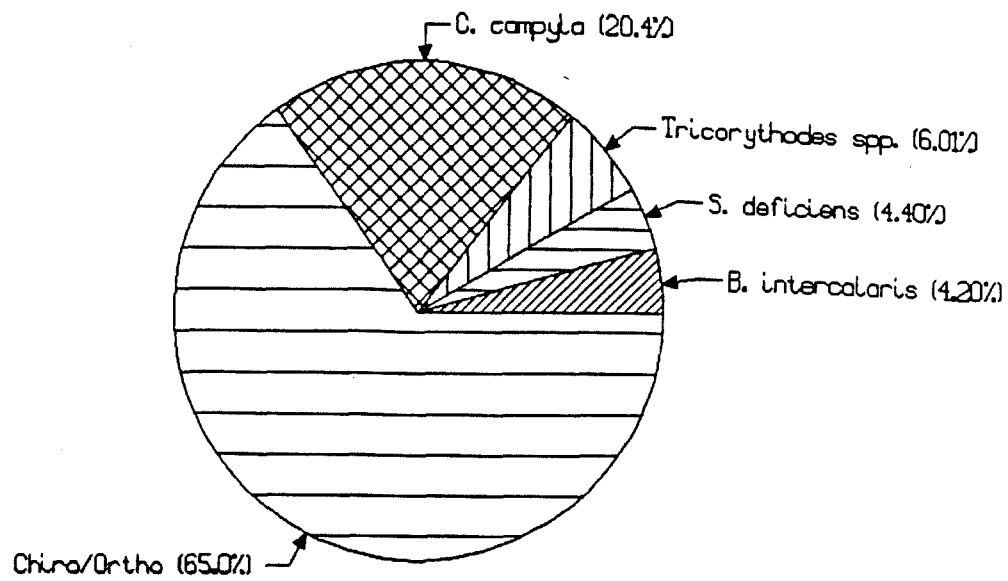


Fig. 20. Percentage (%) of total production for individual taxa of dominant aquatic insects at Sandstone Falls in 1987 and 1988. Production was measured on rock outcrops from June through November.

1989



1990

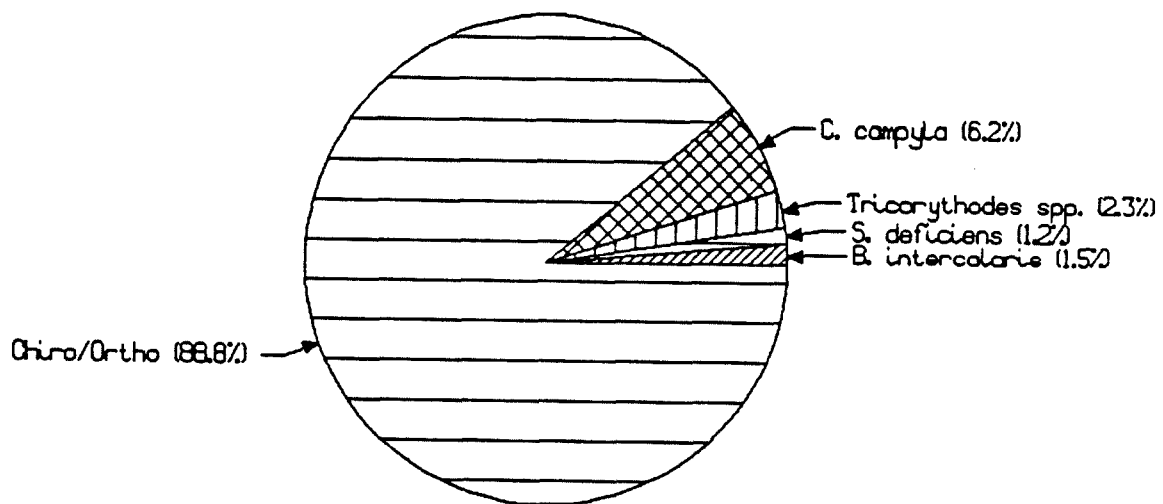


Fig. 21. Percentage (%) of total production for individual taxa of dominant aquatic insects at Sandstone Falls in 1989 and 1990. Production was measured on rock outcrops from June through November.

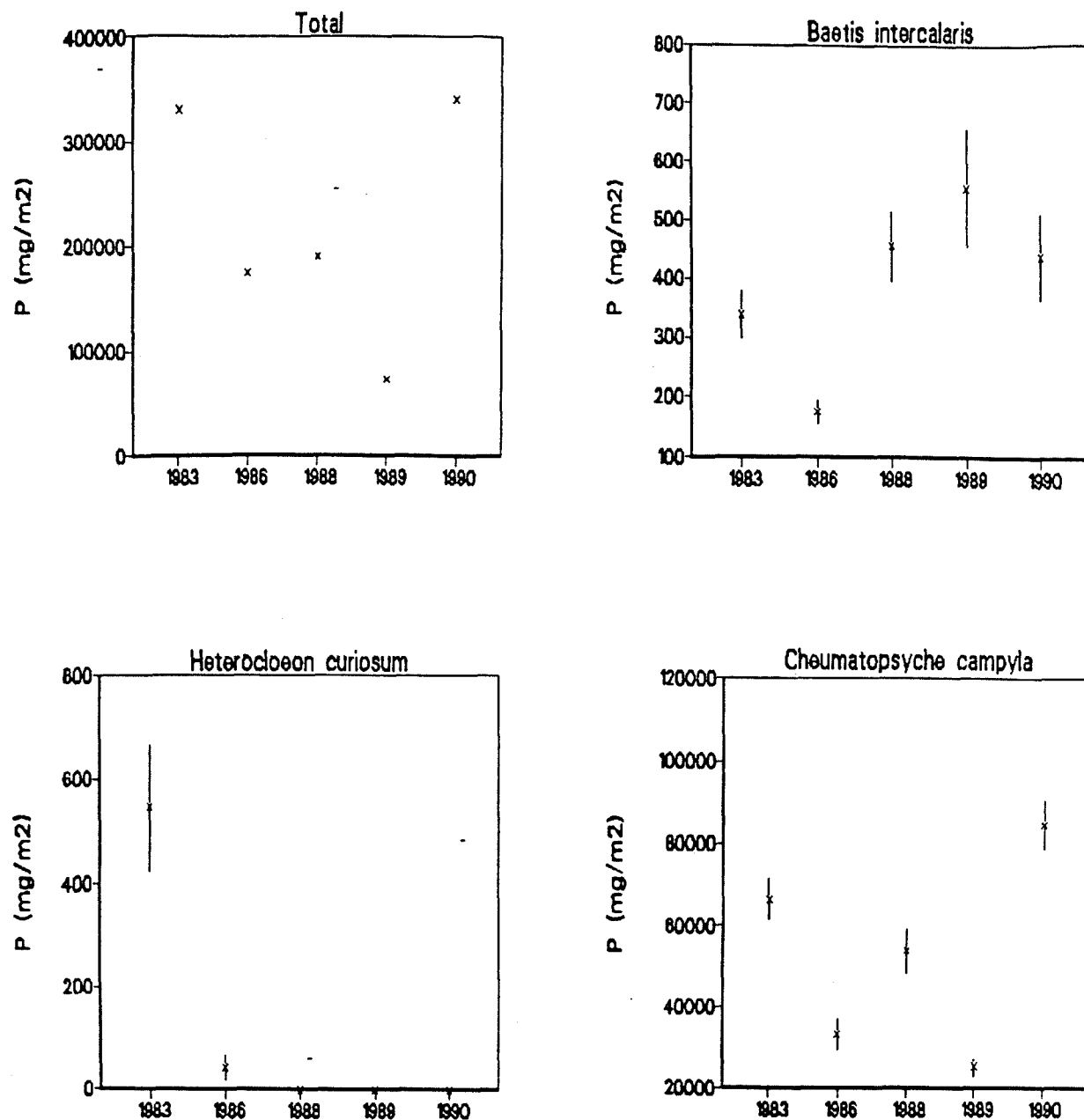


Fig. 22.

Production (P, in mg dry weight/m²) of dominant aquatic insects on rock outcrops at Bluestone Dam in 1983, 1986, 1988-1990 (X = mean; vertical bar = 95% confidence limits). Total is the sum of production for all dominant taxa. There are no confidence limits for Total because the method only calculates them for individual taxa, and confidence limits are not additive. The individual taxa shown on this figure are: *Baetis intercalaris* (a mayfly, Ephemeroptera: Baetidae), *Heterocloeon curiosum* (a mayfly, Ephemeroptera: Baetidae), and *Cheumatopsyche campyla* (a net-spinning caddisfly, Trichoptera: Hydropsychidae).

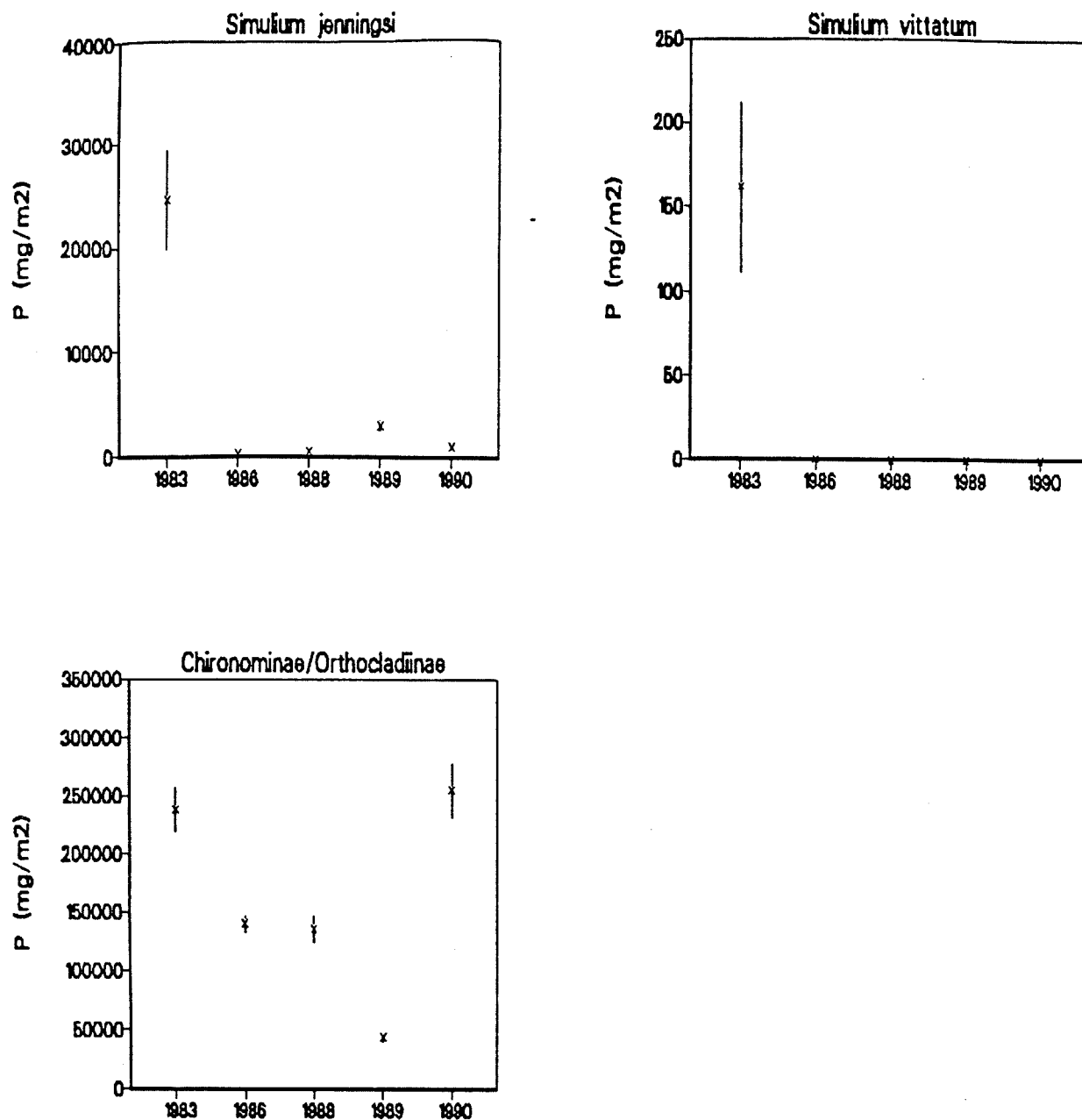


Fig. 23. Production (P, in mg dry weight/m²) of dominant aquatic insects on rock outcrops at Bluestone Dam in 1983, 1986, 1988-1990 (X = mean; vertical bar = 95% confidence limits). The individual taxa shown on this figure are: *Simulium jenningsi* (a black fly, Diptera: Simuliidae), *Simulium vittatum* (a black fly, Diptera: Simuliidae), and Chironominae/Orthocladinae (two subfamilies of nonbiting midges, Diptera: Chironomidae).

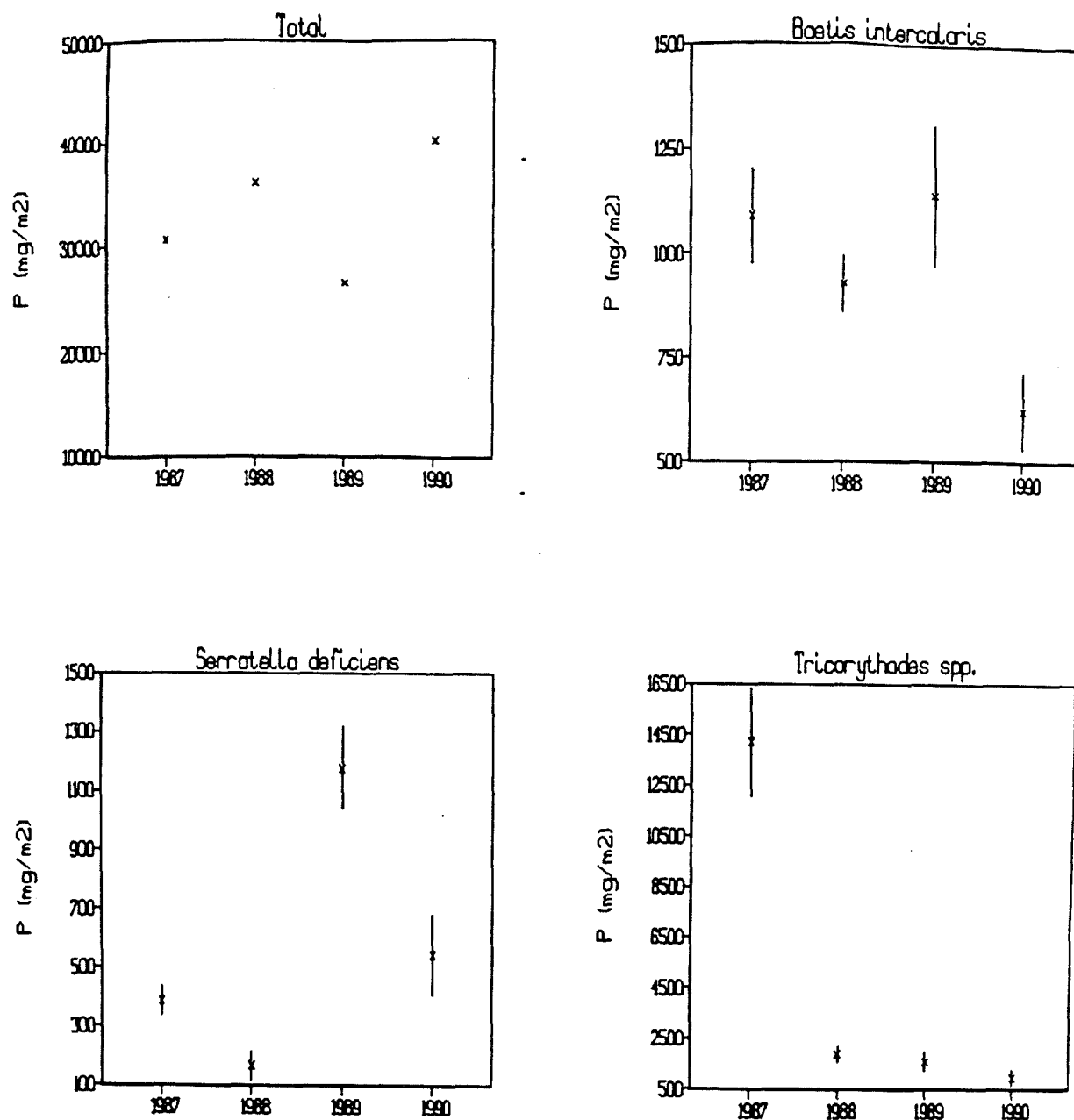


Fig. 24. Production (P, in mg dry weight/m²) of dominant aquatic insects on rock outcrops at Sandstone Falls in 1987-1990 (X = mean; vertical bar = 95% confidence limits). Total is the sum of production for all dominant taxa. There are no confidence limits for Total because the method only calculates them for individual taxa, and confidence limits are not additive. The individual taxa shown on this figure are: *Baetis intercalaris* (a mayfly, Ephemeroptera: Baetidae), *Serratella deficiens* (a mayfly, Ephemeroptera: Ephemerellidae), and *Tricorythodes* spp. (one or more species of mayflies, Ephemeroptera: Tricorythidae).

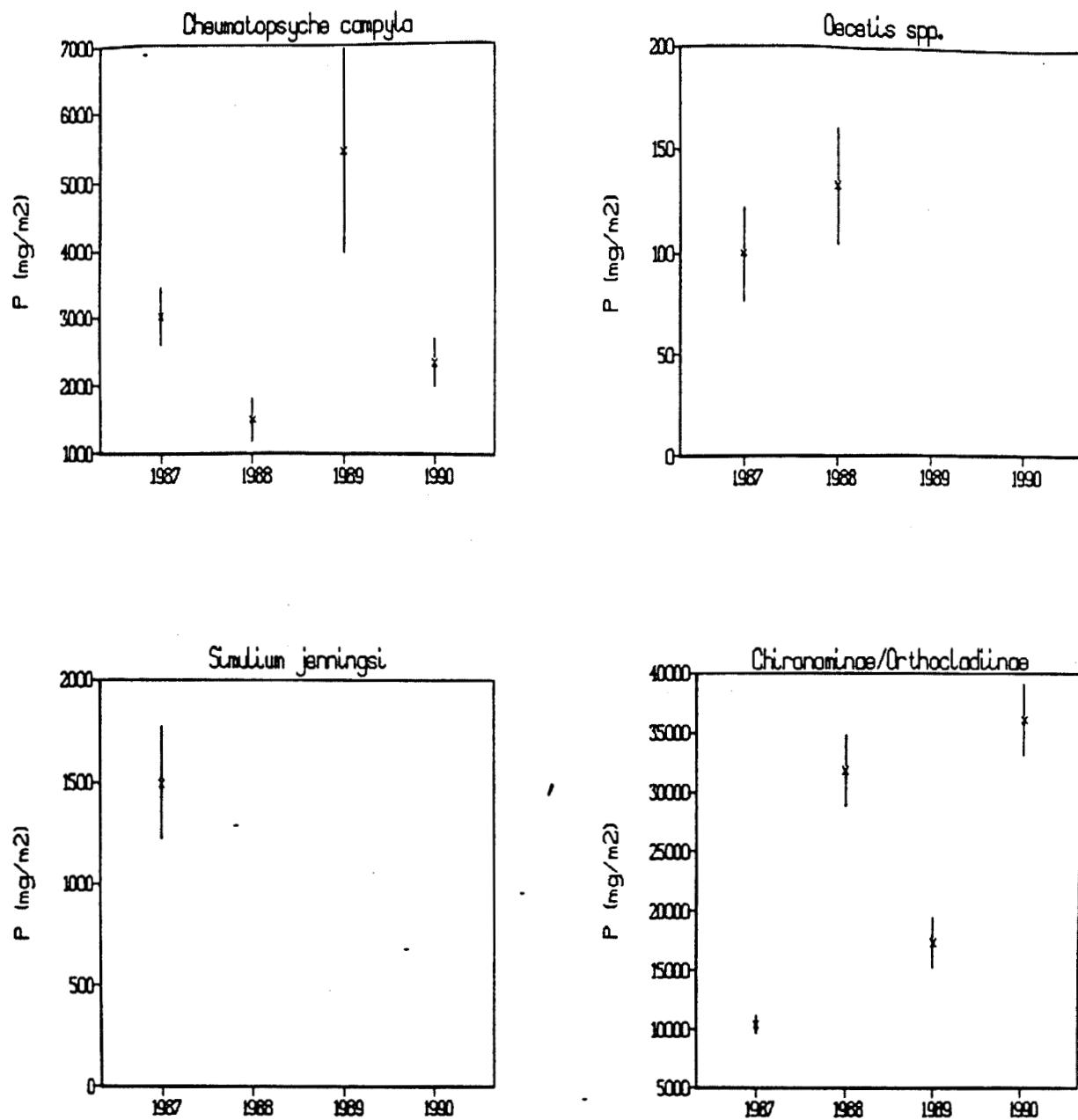


Fig. 25. Production (P, in mg dry weight/m²) of dominant aquatic insects on rock outcrops at Sandstone Falls in 1987-1990 (X = mean; vertical bar = 95% confidence limits). The individual taxa shown on this figure are: *Cheumatopsyche campyla* (a net-spinning caddisfly, Trichoptera: Hydropsychidae), *Oecetis* spp. (one or more species of caddisflies, Trichoptera: Leptoceridae), *Simulium jenningsi* (a black fly, Diptera: Simuliidae), and Chironominae/Orthocladinae (two subfamilies of nonbiting midges, Diptera: Chironomidae).

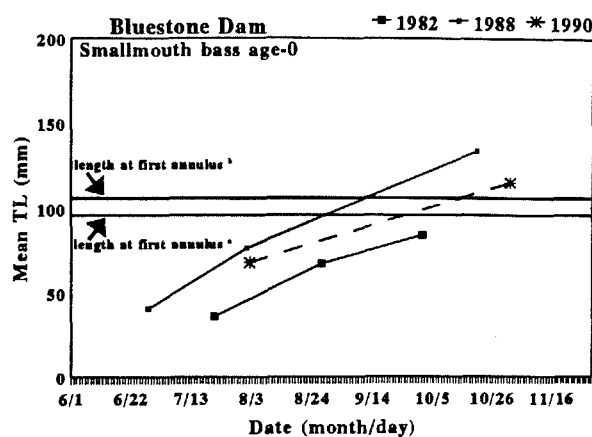
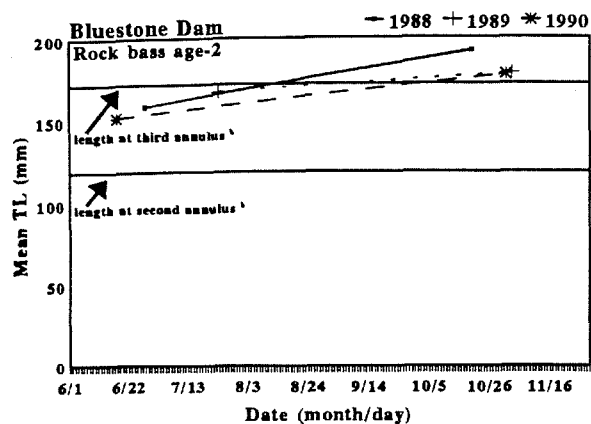
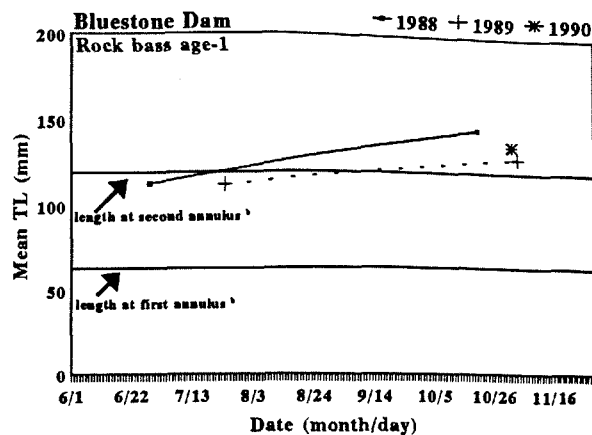
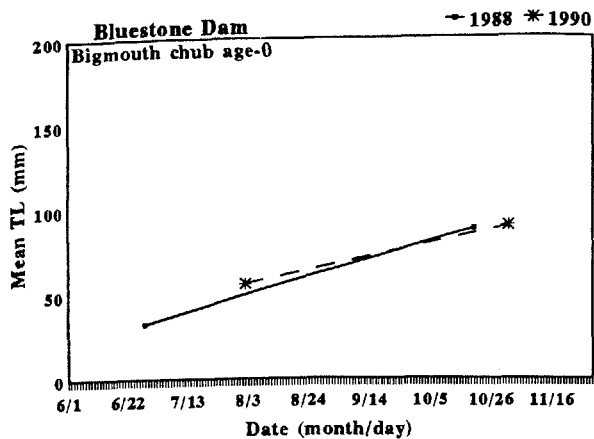


Fig. 26. Growth in length of age-0 bigmouth chub, age-1 and age-2 rock bass, and age-0 smallmouth bass from the New River below Bluestone Dam. Horizontal lines represent estimates of lengths at annuli estimated from previous studies (a=Austen 1984; b=Roell 1989)

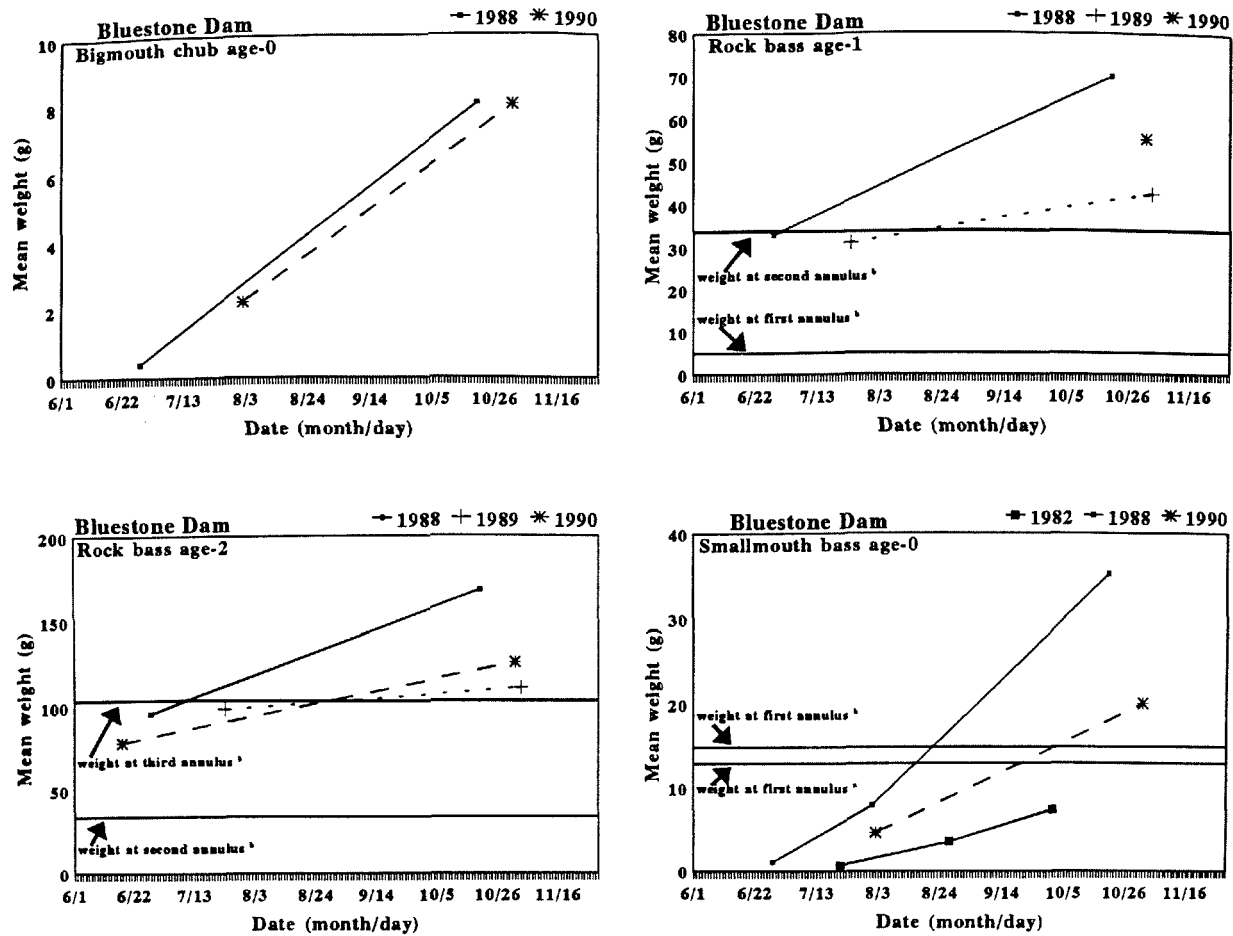


Fig. 27. Growth in weight of age-0 bigmouth chub, age-1 and age-2 rock bass, and age-0 smallmouth bass from the New River below Bluestone Dam. Horizontal lines represent estimates from previous studies (a=Austen 1984; b=Roell 1989).

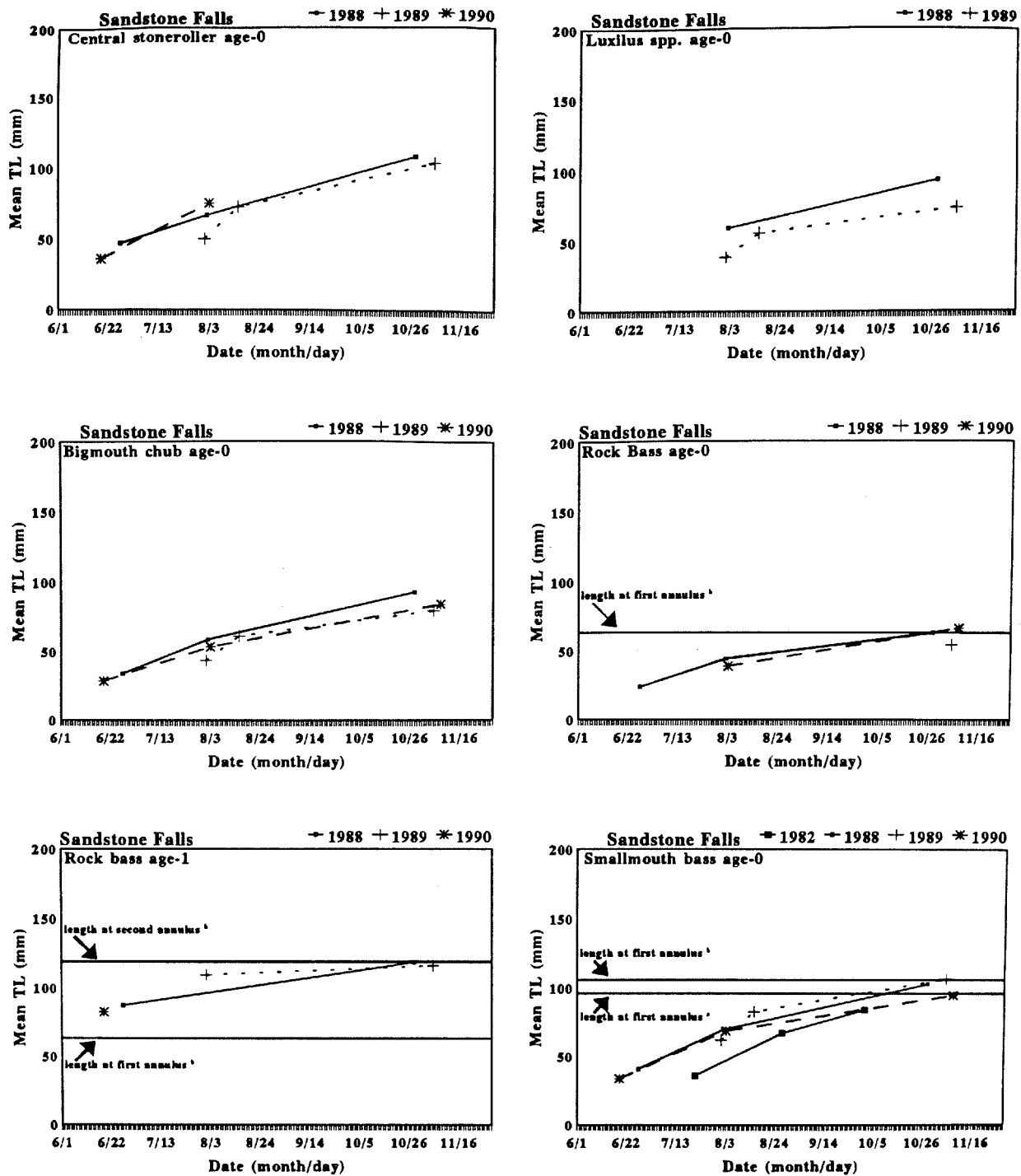


Fig. 28. Growth in length (mm) estimated for central stoneroller, *Luxilus* spp., bigmouth chub, rock bass (age-0 and age-1), and smallmouth bass from the New River at Sandstone Falls. Horizontal lines represent lengths at annulus calculated from previous studies (a=Austen 1984; b=Roell 1989).

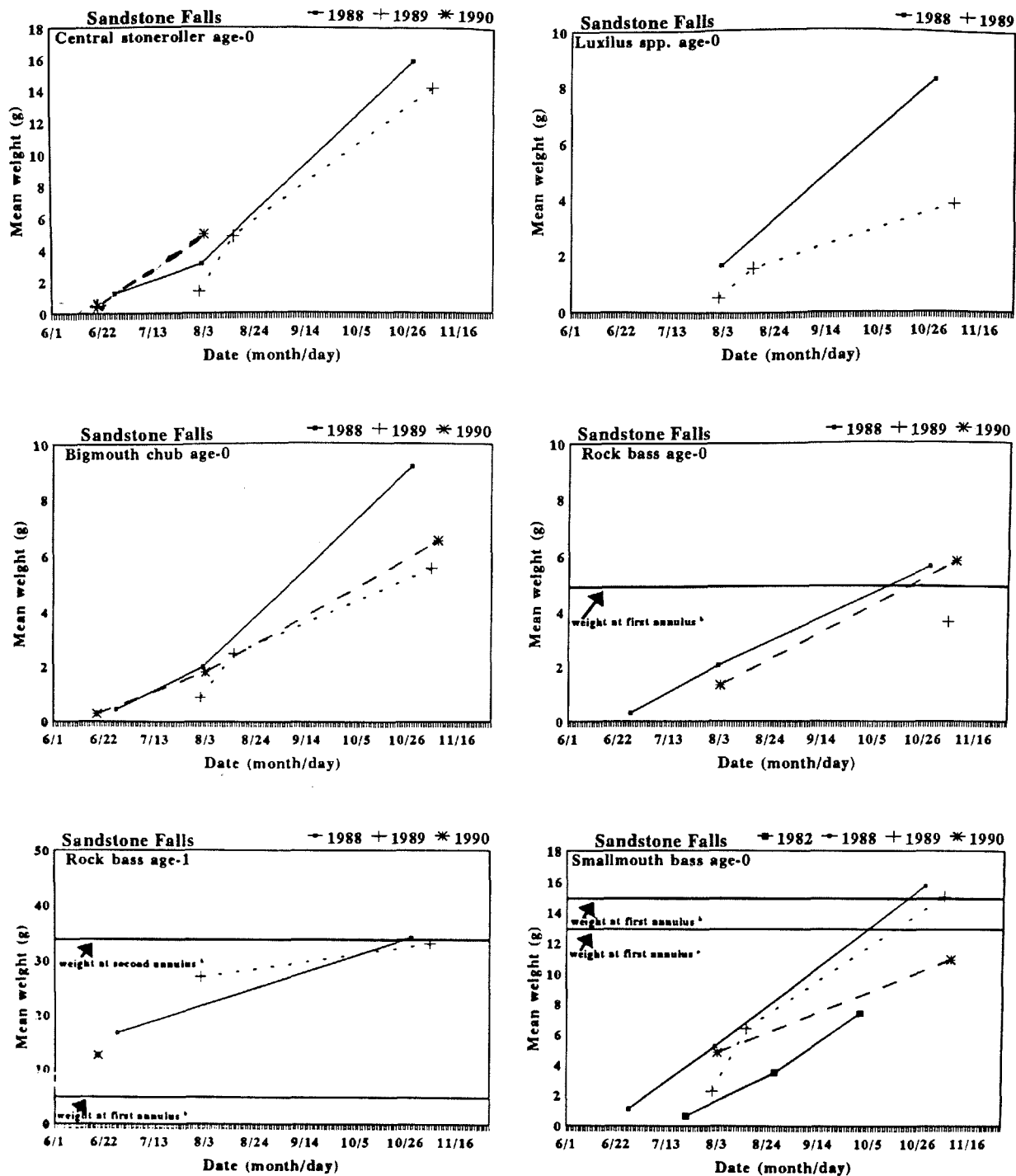


Fig. 29. Growth in weight (g) estimated for central stoneroller, *Luxilus* spp., bigmouth chub, rock bass (age-0 and age-1), and smallmouth bass from the New River at Sandstone Falls. Horizontal lines represent estimates from previous studies (a=Austen 1984; b=Roell 1989).

Table 1. Dates of fish collections made at Bluestone Dam, Sandstone Falls, Prince, Thurmond, and Fayette Station in the New River, WV. The number of 10-minute samples collected is given for each date in parentheses (N/A = not available).

Sites	Year	Early summer	Mid-summer	Mid-fall
Bluestone Dam	1988	June 28 (13)	August 1 (13)	October 20 (13)
	1989	July 17 & July 31 (8) (5)	August 14 (13)	October 31 & November 6 (7) (6)
	1990	June 18 (13)	August 2 (13)	November 1 (13)
Sandstone Falls	1988	June 27 (13)	August 2 (13)	October 21 & November 4 (10) (3)
	1989	July 31 & August 1 (6) (7)	August 15 (13)	November 5 (13)
	1990	June 19 (13)	August 3 (13)	November 8 (13)
Prince	1988	N/A	August 3 (13)	N/A
	1989	N/A	August 9 (13)	N/A
	1990	N/A	September 6 (13)	N/A
Thurmond	1988	N/A	August 10 (13)	N/A
	1989	N/A	August 7 (13)	N/A
	1990	N/A	August 31 (13)	N/A
Fayette Station	1988	N/A	August 25 (10)	N/A
	1989	N/A	August 8 (13)	N/A
	1990	N/A	August 6 & August 16 (8) (5)	N/A

Table 2.

Records of all Bti applications to the New River during 1986, 1988, 1989, and 1990 (Mike Zeto, WVDNR, personal communication). Applications are expressed as the concentrations (parts per million) that organisms would be exposed to for a period of 1 minute. In 1986, Bti was applied only from Bluestone Dam to just above the NPS NRGNR boundary (Route 20 bridge at Hinton). In 1988-1990, Bti was applied from Bluestone Dam to below Sandstone Falls.

Date	Bti Concentration (ppm for 1 min)			
	1986	1988	1989	1990
21 March				22
4 April			22	
25 April				22
26 April		22		
5 May	22			
14 May				22
18 May		22		
19 May	22		22	
31 May	22	22		
5 June			22	
8 June				22
13 June		22		
14 June	27			
21 June			22	
22 June				22
23 June		22		
27 June	27	22		
30 June		22		
2 July				22
5 July			22	
8 July		22		
9 July	27			
13 July				22
15 July		22		
17 July			22	
21 July	27			
22 July		22		
25 July				22
28 July			22	
29 July		22		
30 July	27			
5 August		22		
7 August				22
8 August	27		22	
12 August		22		
16 August	30			
17 August				22
19 August			22	
21 August		22		
25 August	30			
28 August			22	22
30 August		22		
5 September	30			
6 September				22
8 September			22	
10 September		22		
17 September	30			22
23 September		22		
29 September	30			
1 October				22
Number of Applications	14	16	11	14

Table 3.

Yearly means of environmental characteristics of the New River at Bluestone Dam from June 1 through November 30. Sample sizes are given in parentheses () below values. Yearly means followed by the same letter within rows are not significantly different ($P = 0.05$; Kruskal-Wallis analysis of variance followed by two sample rank-sum tests [Snedecor and Cochran 1980]). Accumulated degree-days is not amenable to statistical testing because there is only one value per year.

Characteristic	Study Periods						
	1982 ¹	1983	1984	1986	1988	1989	1990
Water Temperature ($^{\circ}\text{C}$) ²	23.1a (13)	----	20.9a (6)	22.5a (10)	21.4a (13)	22.0a (8)	21.2a (11)
Accumulated Degree-Days (above 0°C) ³	----	3956 ⁴	----	3859 ⁴	3794	3584	3799
Conductivity (μmhos)	----	----	----	168a (10)	149ab (13)	127b (7)	148ab (11)
pH	7.7a (13)	----	7.9a (5)	7.8a (10)	8.0a (13)	7.9a (8)	8.0a (11)
Dissolved Oxygen (mg/L)	8.4a (13)	----	8.5a (6)	8.5a (10)	8.4a (13)	8.4a (8)	8.4a (11)
Mean Daily Discharge (cfs)	----	3312a (183)	----	2335b (183)	1545c (183)	7959d (183)	3934a (183)
Seston (mg/L)	1.28a (13)	----	1.50a (6)	1.18a (10)	1.40a (9)	1.23a (8)	1.17a (9)
Podostemum (g/m^2)	----	162a (7)	----	46b (7)	15c (13)	80ab (8)	72b (11)

¹ Means of measurements taken only from June through October.

² Based on temperature measurements made on sampling dates.

³ Based on continuous temperature measurements and/or measurements made on sampling dates (data in Figs. 2-4).

⁴ Temperatures were estimated on dates when there were missing data by visually fitting a typical temperature curve between the known data (see Fig. 2).

Table 4.

Yearly means of environmental characteristics of the New River at Sandstone Falls from June 1 through November 30. Yearly means followed by the same letter within rows are not significantly different ($P = 0.05$; Kruskal-Wallis analysis of variance followed by two sample rank-sum tests [Snedecor and Cochran 1980]). Accumulated degree-days is not amenable to statistical testing because there is only one value per year.

Characteristic	Study Period			
	1987	1988	1989	1990
Water Temperature ($^{\circ}\text{C}$) ¹	20.6a (13)	21.4a (13)	21.6a (9)	21.3a (10)
Accumulated Degree-Days (above 0°C) ²	3,680	3,692	3,927	3,808
Conductivity (μmhos)	144a (13)	146a (13)	131a (9)	151a (10)
pH	8.2a (13)	8.4a (13)	8.4a (9)	8.7a (10)
Dissolved Oxygen (mg/L)	9.5a (13)	9.1a (13)	9.7a (9)	10.3a (10)
Mean Daily Discharge (cfs)	2,987a (183)	1,893b (183)	10,158c (183)	4,954d (183)
Seston (mg/L)	0.68a (9)	0.93a (9)	0.78a (9)	0.78a (8)
Podostemum (g/m^2)	95a (13)	31b (13)	94a (9)	54a (10)

¹ Based on temperature measurements made on sampling dates.

² Based on continuous temperature measurements and/or measurements made on sampling dates (data in Figs. 5 and 6).

Table 5.

Production statistics for dominant aquatic insects on rock outcrops in the New River at Bluestone Dam from June 1 through November 30 1983, 1986, and 1988-1990. P = Production (mg dry weight/m²); N = Mean density (number individuals/m²); B = Mean standing stock (mg dry weight/m²); P/B = Production to Biomass ratio. Asterisk (*) denotes insufficient numbers for calculations.

Taxa	Year	P	95% Conf. Limits	N	B	P/B
<u>Baetis</u> <u>intercalaris</u>	1983	340	300-381	1,019	130	2.6
	1986	175	156-195	548	105	1.7
	1988	460	400-519	1,960	200	2.3
	1989	556	457-660	1,650	294	1.9
	1990	444	370-517	1,234	220	2.0
<u>Heterocloeon</u> <u>curiosum</u>	1983	546	425-666	169	89	6.1
	1986	42	18-65	25	6	7.0
	1988*	---	---	---	---	---
	1989*	---	---	---	---	---
	1990*	---	---	---	---	---
<u>Cheumatopsyche</u> <u>campyla</u>	1983	66,603	61,641-71,564	31,686	15,466	4.3
	1986	33,242	29,518-36,965	18,261	6,432	5.2
	1988	54,045	48,509-59,580	54,648	11,004	4.9
	1989	25,251	22,772-27,292	26,788	5,240	4.8
	1990	84,685	78,799-90,570	34,895	19,189	4.4
<u>Simulium</u> <u>jenningsi</u>	1983	24,735	19,991-29,479	14,898	1,442	17.2
	1986	319	254-384	334	18	17.7
	1988	564	485-642	354	25	22.6
	1989	3,050	2,551-3,542	2,232	124	24.6
	1990	1,094	965-1,224	760	54	20.3
<u>Simulium</u> <u>vittatum</u>	1983	162	112-212	68	12	13.5
	1986*	---	---	---	---	---
	1988*	---	---	---	---	---
	1989*	---	---	---	---	---
	1990*	---	---	---	---	---
Chironominae/ Orthoclaadiinae	1983	238,312	218,913-257,751	74,408	7,732	30.8
	1986	140,136	133,014-147,258	94,172	4,408	31.8
	1988	135,463	124,090-146,836	146,288	3,933	34.4
	1989	44,080	40,256-47,907	47,472	2,582	17.1
	1990	255,135	231,641-278,629	123,554	7,623	33.5
Total	1983	330,698		122,248	24,871	13.3
	1986	173,914		113,340	10,969	15.9
	1988	190,532		203,250	15,162	12.6
	1989	72,937		78,142	8,240	8.9
	1990	341,357		160,443	27,086	12.6

Table 6.

Production statistics for dominant aquatic insects on rock outcrops in the New River at Sandstone Falls from June 1 through November 30 1987-1990. P = Production (mg dry weight/m²); N = Mean density (number individuals/m²); B = Mean standing stock (mg dry weight/m²); P/B = Production to Biomass ratio. Asterisk (*) denotes insufficient numbers for calculations.

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
	1988	926	857-994	6,208	320	2.9
	1989	1,136	966-1,307	3,593	416	2.7
	1990	623	533-713	1,606	232	2.7
<u>Serratella</u> <u>deficiens</u>	1987	388	337-439	1,862	175	2.2
	1988	167	120-215	1,240	66	2.5
	1989	1,177	1,041-1,315	4,489	545	2.2
	1990	547	408-686	2,232	221	2.5
<u>Tricorythodes</u> spp.	1987	14,197	12,037-16,357	6,695	1,268	11.2
	1988	1,906	1,594-2,218	2,354	176	10.8
	1989	1,599	1,220-1,979	1,062	199	8.0
	1990	967	628-1,307	404	98	9.9
<u>Cheumatopsyche</u> <u>campyla</u>	1987	3,026	2,595-3,457	2,838	673	4.5
	1988	1,497	1,186-1,809	1,843	334	4.5
	1989	5,460	3,988-6,931	7,253	1,514	3.6
	1990	2,357	2,007-2,707	3,654	639	3.7
<u>Oecetis</u> spp.	1987	100	77-122	325	35	2.9
	1988	132	104-160	383	46	2.9
	1989*	--	--	--	--	--
	1990*	--	--	--	--	--
<u>Simulium</u> <u>jenningsi</u>	1987	1,497	1,223-1,771	1,811	101	14.8
	1988*	--	--	--	--	--
	1989*	--	--	--	--	--
	1990*	--	--	--	--	--
Chironominae/ Orthocladiinae	1987	10,464	9,681-11,247	20,802	470	22.3
	1988	31,763	28,820-34,705	36,851	1,430	22.2
	1989	17,339	15,180-19,497	25,016	956	18.1
	1990	36,116	33,059-39,172	38,964	1,258	28.7
Total	1987	30,759		39,465	3,125	9.8
	1988	36,391		48,419	2,372	15.3
	1989	26,712		41,413	3,630	7.3
	1990	40,610		46,860	2,448	16.6

Table 7. Mean lengths for fish species collected from Bluestone Dam in the New River in 1988, 1989, and 1990. Sample sizes and variances are given in parentheses below means. Growth in length (mm d⁻¹) is given in bold and centered below corresponding samples. The standard error (also in bold) of the growth estimate is given in parentheses below the growth estimate.

species	age	year	early summer	mid- summer	mid- fall
Central stoneroller	0	1988	38.6 (462,22.80)	57.7 (340,58.51)	86.4 (306,297.84)
			0.561 (0.2652)	0.359 (0.2360)	
		1989		56.1 (24,17.04)	
		1990		78.4 (28,51.13)	
Spotfin shiner	0	1990		70.1 (14,56.44)	
Bigmouth chub	0	1988	32.3 (33,10.23)		88.6 (30,206.72)
				0.494 (0.1292)	
		1990		56.0 (27,79.62)	90.2 (35,66.11)
				0.376 (0.1327)	
Spottail shiner	0	1989		47.7 (17,30.10)	
		1990			83.1 (43,49.74)
Rosyface shiner	0	1988	34.8 (40,9.28)		
Northern hog sucker	0	1990			125.3 (19,441.98)

Table 7. (continued)

species	age	year	early summer	mid- summer	mid- fall
Rock bass	0	1988	23.9	46.8	85.5
			(14,9.82)	(20,64.34)	(95,188.80)
			0.676	0.471	
		1990	(0.2533)	(0.1989)	
					82.5
					(14,41.04)
	1	1988	112.5		144.9
			(13,254.10)		(13,309.91)
				0.285	
		1989	111.9		128.0
			(27,311.10)		(58,156.25)
				0.158	
		1990		(0.2119)	
					135.4
					(21,287.46)
	2	1988	158.6		191.9
			(42,127.52)		(21,166.63)
				0.292	
		1989	167.4		178.1
			(18,867.90)		(41,215.66)
				0.105	
		1990	151.8		177.4
			(52,256.54)		(34,197.04)
				0.188	
		1988	178.6		
			(15,275.11)		
				(0.1566)	
		1990	189.7		197.6
			(15,267.67)		(10,390.93)
				0.058	
Redbreast sunfish	0	1988		(0.1887)	
				39.8	68.0
				(12,85.84)	(75,199.2)
				0.353	
				(0.2110)	
	1	1988	105.1		
			(11,256.49)		

Table 7. (continued)

species	age	year	early summer	mid- summer	mid- fall
Pumpkinseed	1	1989	116.9 (10,48.54)		
Bluegill	0	1988		39.0 (35,38.15)	74.8 (113,210.08)
				0.448 (0.1969)	
		1990			69.2 (11,46.56)
	1	1989	119.2 (24,583.88)		
	2	1989	165.1 (24,323.99)		
		1990	142.1 (31,335.53)		183.1 (10,172.54)
				0.302 (0.1657)	
	3	1990	174.4 (30,108.24)		
Smallmouth bass	0	1988	40.6 (90,41.33)	76.2 (30,180.53)	133.7 (92,485.92)
			1.049 (0.4381)	0.718 (0.3227)	
		1990		67.8 (170,64.23)	115.1 (85,353.11)
				0.519 (0.2245)	
	1	1989	152.9 (27,380.21)		175.1 (127,247.15)
				0.218 (0.2456)	
	2	1990	192.6 (15,159.54)		

Table 7. (continued)

species	age	year	early summer	mid- summer	mid- fall
Spotted bass	0	1990		73.1 (11,262.29)	121.7 (12,292.06)
				0.534 (0.2587)	

Table 8. Mean weights for species collected from Bluestone Dam in the New River in 1988, 1989, and 1990. Sample sizes and variances are given in parentheses below means. Growth in weight (d^{-1}) is given in bold and is centered below corresponding samples. The standard error (also in bold) of the growth estimate is in parentheses below the growth estimate.

species	age	year	early summer	mid- summer	mid- fall
Central stoneroller	0	1988	0.6 (462,0.06)	1.8 (223,0.44)	7.7 (305,33.48)
			0.030 (0.0155)	0.018 (0.0105)	
		1989		1.8 (24,0.18)	
		1990		5.6 (28,2.65)	
Spotfin shiner	0	1990		3.5 (14,1.35)	
Bigmouth chub	0	1988	0.4 (33,0.01)		8.0 (30,16.97)
				0.027 (0.0053)	
		1990		2.2 (27,1.34)	8.0 (35,6.67)
Spottail shiner	0	1989		0.014 (0.0067)	
				0.9 (17,0.15)	
		1990			4.4 (43,2.07)
Rosyface shiner	0	1988	0.4 (40,0.01)		
Northern hog sucker	0	1990			23.0 (19,140.07)

Table 8. (continued)

species	age	year	early summer	mid- summer	mid- fall
Rock bass	0	1988	0.3 (14,0.02)	2.5 (20,1.85)	13.6 (95,49.06)
			0.060 (0.0198)	0.021 (0.0093)	
		1990			11.1 (14,6.18)
	1	1988	32.9 (13,147.58)		69.8 (13,460.31)
				0.007 (0.0042)	
		1989	31.2 (27,248.34)		42.4 (58,185.47)
				0.003 (0.0059)	
		1990			55.3 (21,518.20)
	2	1988	95.3 (42,520.47)		168.1 (21,1383.53)
				0.005 (0.0029)	
		1989	98.3 (18,1256.12)		111.2 (41,727.53)
				0.001 (0.0043)	
		1990	78.2 (51,614.03)		126.1 (33,907.27)
				0.004 (0.0029)	
Redbreast sunfish	0	1988	131.1 (15,950.21)		
			144.9 (15,1313.84)		167.7 (10,1451.12)
				0.001 (0.0025)	
				1.6 (12,0.95)	7.3 (75,16.88)
				0.019 (0.0106)	

Table 8. (continued)

species	age	year	early summer	mid- summer	mid- fall
Redbreast (cont'd)	1	1988	29.6 (11,245.05)		
Pumpkinseed	1	1989	34.9 (10,80.77)		
Bluegill	0	1988		1.1 (35,0.53)	8.3 (113,20.18)
				0.025 (0.0105)	
		1990			5.4 (11,2.87)
	1	1989	37.2 (24,413.74)		
	2	1989	87.5 (24,485.39)		
		1990	65.9 (31,725.58)		140.0 (10,1347.56)
				0.006 (0.0036)	
	3	1990	114.8 (30,599.91)		
Smallmouth bass	0	1988	1.1 (90,0.25)	7.9 (28,27.52)	35.2 (92,302.22)
			0.059 (0.0237)	0.019 (0.0103)	
		1990		4.6 (168,3.63)	20.0 (85,125.10)
				0.016 (0.0076)	
	1	1989	40.7 (28,269.93)		61.6 (127,326.63)
				0.004 (0.0049)	
	2	1990	82.3 (15,280.50)		

Table 8. (continued)

species	age	year	early summer	mid- summer	mid- fall
Spotted bass	0	1990		5.2 (11,8.50)	19.2 (12,63.24)
				0.014 (0.0077)	

Table 9. Mean lengths for fish species collected from Sandstone Falls in the New River in 1988, 1989, and 1990. Sample sizes and variances are given in parentheses below means. Growth in length (mm d⁻¹) is given in bold and centered below corresponding samples. The standard error (also in bold) of the growth estimate is given in parentheses below the growth estimate.

species	age	year	early summer	mid- summer	mid- fall
Central stoneroller	0	1988	46.9 (27,91.03)	67.0 (16,115.73)	109.5 (54,226.37)
			0.559 (0.3994)	0.488 (0.2126)	
		1989	50.2 (17,49.07)	72.9 (53,280.26)	104.8 (53,548.90)
			1.618 (1.2962)	0.390 (0.3512)	
		1990	35.8 (38,30.06)	75.7 (33,118.02)	
			0.888 (0.2704)		
<u>Luxilus</u> spp.	0	1988		59.8 (22,20.35)	92.7 (85,202.89)
				0.378 (0.1717)	
		1989	39.1 (76,18.58)	56.2 (44,36.75)	73.4 (10,200.49)
			1.228 (0.5313)	0.209 (0.1878)	
Bigmouth chub	0	1988		58.9 (22,19.61)	93.2 (105,103.64)
				0.394 (0.1276)	
		1989	43.6 (31,12.77)	61.3 (90,71.44)	79.8 (72,141.29)
			1.260 (0.6555)	0.226 (0.1779)	
		1990	28.6 (61,23.25)	53.5 (305,57.49)	84.4 (146,127.09)
			0.555 (0.1997)	0.318 (0.1401)	
Spottail shiner	0	1989	38.5 (91,25.36)	44.6 (15,12.97)	42.0 (10,126.44)
			0.432 (0.4422)	-0.032 (0.1440)	
Telescope shiner	0	1989	38.3 (306,20.46)	50.7 (95,23.62)	57.8 (16,16.43)
			0.888 (0.4742)	0.087 (0.0772)	

Table 9. (continued)

species	age	year	early summer	mid- summer	mid- fall
Northern hog sucker	0	1988	37.4 (18,11.91)		
		1989			104.5 (11,150.07)
		1990	31.0 (49,14.58)	71.2 (79,107.97)	106.3 (65,153.73)
Flathead catfish	0	1990	0.894 (0.2460)	0.361 (0.1668)	
			61.9 (15,79.12)		
Rock bass	0	1988	23.5 (12,7.91)	44.1 (18,67.58)	63.1 (129,116.58)
		1989	0.571 (0.2414)	0.219 (0.1560)	
					54.2 (42,191.64)
	0	1990		38.8 (17,16.03)	66.4 (47,91.55)
		1	87.1 (59,368.58)	0.284 (0.1069)	
					118.7 (30,234.02)
	0	1989	109.3 (50,412.39)	0.257 (0.1996)	
		1990	82.4 (19,150.91)	0.071 (0.3156)	116.2 (32,505.64)
	2	1989	156.1 (15,152.64)		
		1990	148.3 (16,1352.36)		

Table 9. (continued)

species	age	year	early summer	mid- summer	mid- fall
Redbreast sunfish	0	1988			64.0 (26,351.08)
Bluegill	0	1988	34.0 (33,17.22)		57.1 (18,67.75)
				0.188 (0.0749)	
Smallmouth bass	0	1988	40.6 (94,42.78)	69.6 (101,101.42)	102.7 (178,171.69)
			0.805 (0.3336)	0.381 (0.1900)	
		1989	62.0 (55,63.65)	82.7 (63,142.20)	106.5 (65,114.44)
			1.482 (1.0248)	0.289 (0.1954)	
		1990	33.6 (20,25.82)	68.7 (176,118.31)	94.6 (149,189.56)
			0.778 (0.2668)	0.267 (0.1809)	

Table 10. Mean weights for fish species collected from Sandstone Falls in the New River in 1988, 1989, and 1990. Samples sizes and variances are given in parentheses below means. Growth in weight (d^{-1}) is given in bold and is centered below corresponding samples. The standard error (also in bold) of the growth estimate is given in parentheses below the growth estimate.

species	age	year	early summer	mid- summer	mid- fall
Central stoneroller	0	1988	1.3 (27,0.55)	3.1 (16,2.49)	15.9 (54,53.55)
			0.025 (0.0214)	0.019 (0.0078)	
	1989		1.4 (17,0.34)	4.8 (53,10.27)	14.2 (52,81.71)
			0.090 (0.0560)	0.013 (0.0112)	
	1990		0.6 (38,0.04)	5.0 (33,5.07)	
			0.048 (0.0126)		
Luxilus spp.	0	1988		1.7 (22,0.19)	8.3 (85,16.82)
				0.018 (0.0064)	
	1989		0.6 (76,0.02)	1.6 (44,0.28)	3.8 (10,4.74)
			0.076 (0.0313)	0.011 (0.0080)	
Bigmouth chub	0	1988	0.4 (33,0.02)	2.0 (22,0.28)	9.2 (105,11.04)
			0.043 (0.0112)	0.017 (0.0052)	
	1989		0.9 (31,0.06)	2.5 (90,1.02)	5.6 (72,7.25)
			0.074 (0.0350)	0.010 (0.0077)	
	1990		0.3 (61,0.02)	1.8 (305,0.06)	6.6 (146,9.44)
			0.041 (0.0121)	0.013 (0.0050)	
Spottail shiner	0	1989	0.5 (91,0.04)	0.7 (15,0.05)	0.8 (10,0.34)
			0.019 (0.0371)	0.002 (0.0096)	
Telescope shiner	0	1989	0.5 (306,0.04)	1.1 (95,0.11)	1.5 (16,0.15)
			0.055 (0.0343)	0.004 (0.0047)	

Table 10. (continued)

species	age	year	early summer	mid- summer	mid- fall
Northern hog sucker	0	1988	0.5 (18,0.03)		
		1989			11.0 (11,13.35)
		1990	0.3 (49,0.02)	4.0 (79,2.67)	12.9 (65,25.06)
Flathead catfish	0		0.055 (0.0131)	0.012 (0.0058)	
		1990		1.3 (15,0.33)	
Rock bass	0	1988	0.3 (12,0.01)	2.0 (18,2.08)	5.6 (129,6.88)
			0.053 (0.0214)	0.012 (0.0097)	
		1989			3.6 (42,0.51)
		1990		1.3 (17,0.18)	5.8 (47,5.24)
				0.015 (0.0052)	
		1	1988	16.7 (59,107.86)	34.2 (30,182.65)
				0.006 (0.0060)	
		1989	27.0 (50,224.53)		33.1 (32,651.29)
				0.002 (0.0099)	
		1990	12.5 (19,35.94)		
		2	1989	72.2 (15,214.74)	
		1990	76.5 (16,2406.93)		

Table 10. (continued)

species	age	year	early summer	mid- summer	mid- fall
Redbreast sunfish	0	1988			7.1 (26,79.69)
Bluegill	0	1988			3.3 (18,2.43)
Smallmouth bass	0	1988	1.1 (94,0.28)	5.2 (101,8.36)	15.7 (178,44.68)
			0.043 (0.0203)	0.013 (0.0080)	
		1989	2.3 (55,2.42)	6.4 (62,7.67)	15.0 (64,17.93)
			0.074 (0.0578)	0.010 (0.0063)	
		1990		4.8 (174,7.70)	10.9 (149,25.85)
				0.008 (0.0076)	

Table 11. Mean condition factors (K) for fish species collected from Bluestone Dam in the New River in 1988, 1989, and 1990. Sample sizes and variances are given in parentheses below means.

species	age	year	early summer	mid- summer	mid- fall
Central stoneroller	0	1988	1.07 (462,0.012)	0.91 (223,0.010)	1.05 (305,0.013)
		1989		1.00 (24,0.017)	
		1990		1.13 (28,0.004)	
Spotfin shiner	0	1990		1.00 (14,0.005)	
Bigmouth chub	0	1988	1.11 (33,0.033)		1.08 (30,0.014)
		1990		1.18 (27,0.007)	1.06 (35,0.006)
Spottail shiner	0	1989		0.77 (17,0.027)	
		1990			0.74 (43,0.006)
Rosyface shiner	0	1988	0.88 (40,0.005)		
Northern hog sucker	0	1990			1.07 (19,0.005)
Rock bass	0	1988	2.33 (14,0.022)	2.27 (20,0.043)	2.09 (95,0.047)
		1990			1.95 (14,0.016)
					2.22 (13,0.034)
	1	1988	2.25 (13,0.061)		1.95 (58,0.040)
		1989	2.05 (27,0.226)		2.11 (21,0.067)
		1990			2.35 (21,0.023)
	2	1988	2.35 (42,0.029)		1.93 (41,0.014)
		1989	2.13 (18,0.391)		2.18 (33,0.031)
		1990	2.19 (51,0.027)		
	3	1988	2.27 (15,0.031)		
		1990	2.10 (15,0.037)		2.15 (10,0.061)

Table 11. (continued)

species	age	year	early summer	mid- summer	mid- fall
Redbreast sunfish	0	1988		2.08 (12,0.040)	2.09 (75,0.036)
	1	1988	2.33 (11,0.092)		
Pumpkinseed	1	1989	2.15 (10,0.143)		
Bluegill	0	1988		1.74 (35,0.049)	1.76 (113,0.038)
		1990			1.58 (11,0.021)
	1	1989	1.95 (24,0.149)		
	2	1989	1.94 (24,0.139)		
		1990	2.17 (31,0.069)		2.23 (10,0.056)
	3	1990	2.14 (30,0.073)		
Smallmouth bass	0	1988	1.51 (90,0.015)	1.56 (28,0.130)	1.35 (92,0.015)
		1990		1.40 (168,0.099)	1.20 (85,0.014)
	1	1989	1.11 (27,0.034)		1.12 (127,0.010)
	2	1990	1.18 (15,0.003)		
Spotted bass	0	1990		1.27 (11,0.093)	1.00 (12,0.004)

Table 12. Mean condition factors (K) for species collected from Sandstone Falls in the New River in 1988, 1989, and 1990. Samples sizes and variances are given in parentheses below means.

species	age	year	early summer	mid- summer	mid- fall
Central stoneroller	0	1988	1.07	0.96	1.14
			(27,0.015)	(16,0.008)	(54,0.006)
		1989	1.05	1.06	1.11
			(17,0.007)	(53,0.009)	(52,0.014)
Luxilus spp.	0	1988	1.25	1.09	
			(38,0.080)	(33,0.013)	
		1989		0.78	0.94
				(22,0.010)	(85,0.007)
Bigmouth chub	0	1988	0.91	0.86	0.85
			(76,0.016)	(44,0.006)	(10,0.004)
		1989	1.08	0.96	1.09
			(33,0.036)	(22,0.003)	(105,0.005)
Spottail shiner	0	1988	1.05	1.01	1.02
			(31,0.008)	(90,0.006)	(72,0.006)
		1989	1.20	1.12	1.03
			(61,0.386)	(305,0.011)	(146,0.005)
Telescope shiner	0	1989	0.87	0.74	1.01
			(91,0.025)	(15,0.010)	(10,0.023)
Northern hog sucker	0	1988	0.89	0.84	0.78
			(306,0.020)	(95,0.010)	(16,0.008)
		1989	0.97		
			(18,0.012)		
Flathead catfish	0	1988			0.94
					(11,0.005)
		1990	1.06	1.04	1.04
			(49,0.048)	(79,0.005)	(65,0.007)
Rock bass	0	1988	0.56		
			(15,0.083)		
		1989	2.25	2.14	2.05
			(12,0.035)	(18,0.026)	(129,0.024)
		1989			1.97
					(42,0.068)
		1990		2.21	1.90
				(17,0.189)	(47,0.122)
	1	1988	2.25		1.96
			(59,0.087)		(30,0.031)
		1989	1.88		1.85
			(50,0.047)		(32,0.019)
		1990	2.08		
			(19,0.038)		

Table 12. (continued)

species	age	year	early summer	mid- summer	mid- fall
Rock bass (cont'd)	2	1989	1.89 (15,0.040)		
		1990	2.10 (16,0.033)		
Redbreast sunfish	0	1988			2.04 (26,0.021)
Bluegill	0	1988			1.63 (18,0.015)
Smallmouth bass	0	1988	1.53 (94,0.061)	1.43 (101,0.076)	1.39 (178,0.009)
		1989	0.83 (55,0.070)	1.07 (62,0.014)	1.21 (64,0.013)
		1990		1.35 (174,0.079)	1.22 (149,0.015)

Table 13. Statistical analysis of **Total Density** among years at **Bluestone Dam** site in **Cobble/Pebble** habitat (means in parentheses). Kruskal-Wallis and Wilcoxon Rank Sum tests; $p = 0.05$; $n = 3$ (1982), 3 (1984), 10 (1988), 3 (1989), 3 (1990).

Pretreatment	x	Pretreatment	Significant?
1982 (4136)	x	1984 (2364)	No
Pretreatment	x	Treatment	Significant?
1982 (4136)	x	1988 (3170)	No
1982 (4136)	x	1989 (881)	No
1982 (4136)	x	1990 (6307)	No
1984 (2364)	x	1988 (3170)	No
1984 (2364)	x	1989 (881)	Yes
1984 (2364)	x	1990 (6307)	Yes
Treatment	x	Treatment	Significant?
1988 (3170)	x	1989 (881)	Yes
1988 (3170)	x	1990 (6307)	Yes
1989 (881)	x	1990 (6307)	Yes

Table 14. Statistical analysis of **Taxa Richness** among years at **Bluestone Dam** site in **cobble/pebble** habitat (means in parentheses). Kruskal-Wallis and Wilcoxon Rank Sum tests; $p = 0.05$; $n = 3$ (1982), 3 (1984), 10 (1988), 3 (1989), 3 (1990).

Pretreatment	x	Pretreatment	Significant?
1982 (9.7)	x	1984 (18.0)	Yes
Pretreatment	x	Treatment	Significant?
1982 (9.7)	x	1988 (18.8)	Yes
1982 (9.7)	x	1989 (19.7)	Yes
1982 (9.7)	x	1990 (21.7)	Yes
1984 (18.0)	x	1988 (18.8)	No
1984 (18.0)	x	1989 (19.7)	No
1984 (18.0)	x	1990 (21.7)	No
Treatment	x	Treatment	Significant?
1988 (18.8)	x	1989 (19.7)	No
1988 (18.8)	x	1990 (21.7)	No
1989 (19.7)	x	1990 (21.7)	No

Table 15. Statistical analysis of **EPT Index** among years at **Bluestone Dam** site in **Cobble/Pebble** habitat (means in parentheses). Kruskal-Wallis and Wilcoxon Rank Sum tests; $p = 0.05$; $n = 3$ (1982), 3 (1984), 10 (1988), 3 (1989), 3 (1990). EPT = Ephemeroptera, Plecoptera, Trichoptera.

Pretreatment	x	Pretreatment	Significant?
1982 (4.7)	x	1984 (8.3)	Yes
Pretreatment	x	Treatment	Significant?
1982 (4.7)	x	1988 (8.2)	Yes
1982 (4.7)	x	1989 (10.0)	Yes
1982 (4.7)	x	1990 (12.0)	Yes
1984 (8.3)	x	1988 (8.2)	No
1984 (8.3)	x	1989 (10.0)	No
1984 (8.3)	x	1990 (12.0)	No
Treatment	x	Treatment	Significant?
1988 (8.2)	x	1989 (10.0)	No
1988 (8.2)	x	1990 (12.0)	No
1989 (10.0)	x	1990 (12.0)	No

Table 16. Statistical analysis of **Shannon Diversity Index** among years at **Bluestone Dam** site in **Cobble/Pebble** habitat (means in parentheses). Kruskal-Wallis and Wilcoxon Rank Sum tests; $p = 0.05$; $n = 3$ (1982), 3 (1984), 10 (1988), 3 (1989), 3 (1990).

Pretreatment	x	Pretreatment	Significant?
1982 (2.06)	x	1984 (2.14)	No
Pretreatment	x	Treatment	Significant?
1982 (2.06)	x	1988 (1.57)	No
1982 (2.06)	x	1989 (2.35)	No
1982 (2.06)	x	1990 (1.46)	No
1984 (2.14)	x	1988 (1.57)	Yes
1984 (2.14)	x	1989 (2.35)	Yes
1984 (2.14)	x	1990 (1.46)	Yes
Treatment	x	Treatment	Significant?
1988 (1.57)	x	1989 (2.35)	Yes
1988 (1.57)	x	1990 (1.46)	No
1989 (2.35)	x	1990 (1.46)	Yes

Table 17. Statistical analysis of **HBI** among years at **Bluestone Dam** site in **Cobble/Pebble** habitat (means in parentheses). Kruskal-Wallis and Wilcoxon Rank Sum tests; $p = 0.05$; $n = 3$ (1982), 3 (1984), 10 (1988), 3 (1989), 3 (1990). HBI = Hilsenhoff Biotic Index.

Pretreatment	x	Pretreatment	Significant?
1982 (5.93)	x	1984 (6.03)	No
Pretreatment	x	Treatment	Significant?
1982 (5.93)	x	1988 (5.96)	No
1982 (5.93)	x	1989 (5.67)	No
1982 (5.93)	x	1990 (5.87)	No
1984 (6.03)	x	1988 (5.96)	No
1984 (6.03)	x	1989 (5.67)	No
1984 (6.03)	x	1990 (5.87)	No
Treatment	x	Treatment	Significant?
1988 (5.96)	x	1989 (5.67)	Yes
1988 (5.96)	x	1990 (5.87)	Yes
1989 (5.67)	x	1990 (5.87)	No

Table 18. Statistical analysis of **Total Density** among years at **Sandstone Falls** site in **cobble/pebble** habitat (means in parentheses). Kruskal-Wallis and Wilcoxon Rank Sum tests; $p = 0.05$; $n = 3$ (1982), 3 (1984), 5 (1988), 3 (1989), 3 (1990).

Pretreatment	x	Pretreatment	Significant?
1982 (5466)	x	1984 (318)	Yes
Pretreatment	x	Treatment	Significant?
1982 (5466)	x	1988 (647)	Yes
1982 (5466)	x	1989 (346)	Yes
1982 (5466)	x	1990 (499)	Yes
1984 (318)	x	1988 (647)	Yes
1984 (318)	x	1989 (346)	No
1984 (318)	x	1990 (499)	No
Treatment	x	Treatment	Significant?
1988 (647)	x	1989 (346)	Yes
1988 (647)	x	1990 (499)	No
1989 (346)	x	1990 (499)	No

Table 19. Statistical analysis of **Taxa Richness** among years at **Sandstone Falls** site in **cobble/pebble** habitat (means in parentheses). Kruskal-Wallis and Wilcoxon Rank Sum tests; $p = 0.05$; $n = 3$ (1982), 3 (1984), 5 (1988), 3 (1989), 3 (1990).

Pretreatment	x	Pretreatment	Significant?
1982 (12.3)	x	1984 (22.0)	Yes
Pretreatment	x	Treatment	Significant?
1982 (12.3)	x	1988 (23.4)	Yes
1982 (12.3)	x	1989 (23.7)	Yes
1982 (12.3)	x	1990 (23.0)	Yes
1984 (22.0)	x	1988 (23.4)	No
1984 (22.0)	x	1989 (23.7)	No
1984 (22.0)	x	1990 (23.0)	No
Treatment	x	Treatment	Significant?
1988 (23.4)	x	1989 (23.7)	No
1988 (23.4)	x	1990 (23.0)	No
1989 (23.7)	x	1990 (23.0)	No

Table 20. Statistical analysis of **EPT Index** among years at **Sandstone Falls** site in **cobble/pebble** habitat (means in parentheses). Kruskal-Wallis and Wilcoxon Rank Sum tests; $p = 0.05$; $n = 3$ (1982), 3 (1984), 5 (1988), 3 (1989), 3 (1990). EPT = Ephemeroptera, Plecoptera, Trichoptera.

Pretreatment	x	Pretreatment	Significant?
1982 (5.0)	x	1984 (12.0)	Yes
Pretreatment	x	Treatment	Significant?
1982 (5.0)	x	1988 (11.8)	Yes
1982 (5.0)	x	1989 (12.0)	Yes
1982 (5.0)	x	1990 (12.7)	Yes
1984 (12.0)	x	1988 (11.8)	No
1984 (12.0)	x	1989 (12.0)	No
1984 (12.0)	x	1990 (12.7)	No
Treatment	x	Treatment	Significant?
1988 (11.8)	x	1989 (12.0)	No
1988 (11.8)	x	1990 (12.7)	No
1989 (12.0)	x	1990 (12.7)	No

Table 21. Statistical analysis of **Shannon Diversity Index** among years at **Sandstone Falls** site in **cobble/pebble** habitat (means in parentheses). Kruskal-Wallis and Wilcoxon Rank Sum tests; $p = 0.05$; $n = 3$ (1982), 3 (1984), 5 (1988), 3 (1989), 3 (1990).

Pretreatment	x	Pretreatment	Significant?
1982 (2.32)	x	1984 (3.50)	Yes
Pretreatment	x	Treatment	Significant?
1982 (2.32)	x	1988 (2.98)	Yes
1982 (2.32)	x	1989 (3.11)	Yes
1982 (2.32)	x	1990 (3.04)	No
1984 (3.50)	x	1988 (2.98)	Yes
1984 (3.50)	x	1989 (3.11)	No
1984 (3.50)	x	1990 (3.04)	No
Treatment	x	Treatment	Significant?
1988 (2.98)	x	1989 (3.11)	No
1988 (2.98)	x	1990 (3.04)	No
1989 (3.11)	x	1990 (3.04)	No

Table 22. Statistical analysis of **HBI** among years at **Sandstone Falls** site in **cobble/pebble** habitat (means in parentheses). Kruskal-Wallis and Wilcoxon Rank Sum tests; $p = 0.05$; $n = 3$ (1982), 3 (1984), 5 (1988), 3 (1989), 3 (1990). HBI = Hilsenhoff Biotic Index.

Pretreatment	x	Pretreatment	Significant?
1982 (5.93)	x	1984 (4.90)	Yes
Pretreatment	x	Treatment	Significant?
1982 (5.93)	x	1988 (5.52)	No
1982 (5.93)	x	1989 (5.60)	No
1982 (5.93)	x	1990 (5.17)	No
1984 (4.90)	x	1988 (5.52)	Yes
1984 (4.90)	x	1989 (5.60)	Yes
1984 (4.90)	x	1990 (5.17)	No
Treatment	x	Treatment	Significant?
1988 (5.52)	x	1989 (5.60)	No
1988 (5.52)	x	1990 (5.17)	No
1989 (5.60)	x	1990 (5.17)	No

Table 23. Analysis of macroinvertebrate communities among years at **Bluestone Dam** site in **Cobble/Pebble** habitat by **Percent Similarity Index (PSC)**. PSC ranges from 0% (no similarity) to 100% (complete similarity). PSC is not an inferential statistical test, so there are no p values.

Pretreatment	x	Pretreatment	PSC (%)
1982	x	1984	29.1
Pretreatment	x	Treatment	PSC (%)
1982	x	1988	12.4
1982	x	1989	20.8
1982	x	1990	12.2
1984	x	1988	78.9
1984	x	1989	86.3
1984	x	1990	72.9
Treatment	x	Treatment	PSC (%)
1988	x	1989	82.0
1988	x	1990	75.5
1989	x	1990	75.8

Table 24. Analysis of macroinvertebrate communities among years at **Bluestone Dam** site in **Cobble/Pebble** habitat by **Pinkham and Pearson Similarity Index (B)**. B ranges from 0% (no similarity) to 100% (complete similarity). B is not an inferential statistical test, so there are no p values.

Pretreatment	x	Pretreatment	B (%)
1982	x	1984	7.4
Pretreatment	x	Treatment	B (%)
1982	x	1988	5.7
1982	x	1989	8.7
1982	x	1990	7.7
1984	x	1988	26.6
1984	x	1989	22.7
1984	x	1990	24.6
Treatment	x	Treatment	B (%)
1988	x	1989	20.6
1988	x	1990	20.9
1989	x	1990	22.7

Table 25. Analysis of macroinvertebrate communities among years at **Sandstone Falls** site in **Cobble/Pebble** habitat by **Percent Similarity Index (PSC)**. PSC ranges from 0% (no similarity) to 100% (complete similarity). PSC is not an inferential statistical test, so there are no p values.

Pretreatment	x	Pretreatment	PSC (%)
1982	x	1984	12.7
Pretreatment	x	Treatment	PSC (%)
1982	x	1988	11.8
1982	x	1989	6.0
1982	x	1990	13.4
1984	x	1988	42.9
1984	x	1989	31.0
1984	x	1990	35.3
Treatment	x	Treatment	PSC (%)
1988	x	1989	56.9
1988	x	1990	53.9
1989	x	1990	75.5

Table 26. Analysis of macroinvertebrate communities among years at **Sandstone Falls** site in **Cobble/Pebble** habitat by **Pinkham and Pearson Similarity Index (B)**. B ranges from 0% (no similarity) to 100% (complete similarity). B is not an inferential statistical test, so there are no p values.

Pretreatment	x	Pretreatment	B (%)
1982	x	1984	4.9
Pretreatment	x	Treatment	B (%)
1982	x	1988	6.6
1982	x	1989	2.3
1982	x	1990	5.4
1984	x	1988	18.6
1984	x	1989	20.3
1984	x	1990	21.7
Treatment	x	Treatment	B (%)
1988	x	1989	24.9
1988	x	1990	22.6
1989	x	1990	31.1

Table 27. Percentages of fish orders and families collected in mid-summer at Bluestone Dam in the New River in 1979^a, 1984^b, 1988, 1989, and 1990.

Taxon	Bluestone Dam				
	1979	1984	1988	1989	1990
Order					
Cypriniformes	47.8	41.3	63.0	38.9	25.4
Siluriformes	3.1	1.1	1.4	2.7	2.8
Atheriniformes	0.5				
Perciformes	48.6	57.6	35.6	58.4	71.8
Family					
Cyprinidae	46.9	40.8	63.0	38.7	23.7
Catostomidae	0.8	0.5		0.2	1.8
Ictaluridae	3.1	1.1	1.4	2.7	2.8
Atherinidae	0.5				
Centrarchidae	26.1	51.6	31.7	49.0	68.2
Percidae	22.5	6.0	3.9	9.4	3.6

^a Stauffer, Hocutt, and Markham (1980)

^b Lobb (1986)

Table 28. Percentages of fish orders and families collected in mid-summer at Sandstone Falls in the New River in 1979^a, 1984^b, 1988, 1989, and 1990.

Taxon	Sandstone Falls				1990
	1979	1984	1988	1989	
Order					
Cypriniformes	65.0	63.1	39.7	67.1	63.4
Siluriformes	1.0		2.8	2.2	4.0
Atheriniformes	0.6				
Perciformes	33.4	36.9	57.4	30.7	32.6
Family					
Cyprinidae	62.8	63.0	39.0	66.9	52.8
Catostomidae	2.2	0.2	0.7	0.2	10.6
Ictaluridae	1.0		2.8	2.2	4.0
Atherinidae	0.6				
Centrarchidae	20.2	32.9	55.0	27.5	27.1
Percidae	13.2	3.9	2.5	3.2	5.5

^a Stauffer, Hocutt, and Markham (1980)

^b Lobb (1986)

Table 29. Percentages of fish orders and families collected in mid-summer at Prince in the New River in 1979^a, 1984^b, 1988, 1989, and 1990.

Taxon	Prince				
	1979	1984	1988	1989	1990
Order					
Cypriniformes	83.3	86.8	22.8	24.9	31.8
Siluriformes		0.2			2.8
Perciformes	16.7	13.0	77.2	75.1	65.4
Family					
Cyprinidae	74.6	84.1	21.9	24.6	25.6
Catostomidae	8.7	2.8	0.8	0.3	6.2
Ictaluridae		0.2			2.8
Centrarchidae	5.6	9.9	38.8	69.7	45.4
Percidae	11.1	3.1	38.4	5.4	20.1

^a Stauffer, Hocutt, and Markham (1980)

^b Lobb (1986)

Table 30. Percentages of fish orders and families collected in mid-summer at Thurmond in the New River in 1979^a, 1984^b, 1988, 1989, and 1990.

Taxon	Thurmond				
	1979	1984	1988	1989	1990
Order					
Clupeiformes					0.3
Cypriniformes	62.1	84.8	43.7	54.5	59.9
Siluriformes	1.7	0.8	0.3	0.3	
Perciformes	36.2	14.4	56.0	45.2	39.8
Family					
Clupeidae					0.3
Cyprinidae	56.9	82.1	43.4	52.0	18.1
Catostomidae	5.2	2.7	0.3	2.5	41.8
Ictaluridae	1.7	0.8	0.3	0.3	
Centrarchidae	0.9	9.1	44.0	27.7	35.5
Percidae	35.3	5.3	12.0	17.5	4.3

^a Stauffer, Hocutt, and Markham (1980)

^b Lobb (1986)

Table 31. Percentages of fish orders and families collected in mid-summer at Fayette Station in the New River in 1988, 1989, and 1990.

Taxon	Fayette Station		
	1988	1989	1990
Order			
Cypriniformes	4.0	13.2	0.6
Siluriformes	7.4	3.5	1.3
Perciformes	88.6	83.3	98.1
Family			
Cyprinidae	3.4	10.5	
Catostomidae	0.7	2.6	0.6
Ictaluridae	7.4	3.5	1.3
Centrarchidae	84.6	71.1	89.7
Percidae	4.0	12.3	8.4

Table 32. (continued)

Family and Species	Bluestone Dam				
	1979	1984	1988	1989	1990
Atherinidae					
<u>Labidesthes sicculus</u> brook silverside	0.5				
Centrarchidae					
<u>Ambloplites rupestris</u> rock bass	7.6	35.3	12.0	22.2	7.4
<u>Lepomis auritus</u> redbreast sunfish		1.1	3.7	2.7	2.5
<u>Lepomis cyanellus</u> green sunfish	0.1		0.2		
<u>Lepomis gibbosus</u> pumpkinseed	0.1			0.2	
<u>Lepomis macrochirus</u> bluegill	2.2	2.7	8.3	19.3	7.1
<u>Micropterus dolomieu</u> smallmouth bass	14.9	12.0	5.7	2.9	43.8
<u>Micropterus punctulatus</u> spotted bass	0.6	0.5	1.4		2.8
<u>Micropterus salmoides</u> largemouth bass			0.4	0.9	4.3
<u>Pomoxis annularis</u> white crappie	0.4			0.4	0.3
<u>Pomoxis nigromaculatus</u> black crappie	0.2			0.2	
Percidae					
<u>Etheostoma blennioides</u> greenside darter	3.4	1.1	0.4	4.0	0.8
<u>Etheostoma caeruleum</u> rainbow darter	12.6	1.6	3.2	4.3	2.0
<u>Etheostoma flabellare</u> fantail darter	0.1				
<u>Percina caprodes</u> logperch	0.2			0.4	0.3
<u>Percina oxyrhynchus</u> sharpnose darter	2.5	3.3		0.2	
<u>Percina roanoka</u> Roanoke darter	3.6		0.4	0.4	0.5
Total number	827	184	565	445	393

^a Stauffer, Hocutt, and Markham (1980)^b Lobb (1986)

Table 33. (continued)

Family and Species	Sandstone Falls				
	1979	1984	1988	1989	1990
Atherinidae					
<u>Labidesthes sicculus</u> brook silverside	0.6				
Centrarchidae					
<u>Ambloplites rupestris</u> rock bass	6.3	12.8	16.3	14.4	3.1
<u>Lepomis auritus</u> redbreast sunfish			0.7		0.1
<u>Lepomis cyanellus</u> green sunfish					0.1
<u>Lepomis macrochirus</u> bluegill	2.9	1.9		0.4	
<u>Micropterus dolomieu</u> smallmouth bass	7.0	18.3	38.0	12.8	23.8
<u>Micropterus punctulatus</u> spotted bass	2.1				
<u>Pomoxis annularis</u> white crappie	0.3				
<u>Pomoxis nigromaculatus</u> black crappie	1.6				
Percidae					
<u>Etheostoma blennioides</u> greenside darter	3.5	0.3	2.5	1.8	4.8
<u>Etheostoma caeruleum</u> rainbow darter	5.9	1.0			0.4
<u>Perca flavescens</u> yellow perch	0.1				
<u>Percina caprodes</u> logperch		0.2			
<u>Percina oxyrhynchus</u> sharpnose darter	0.1	0.5			
<u>Percina roanoka</u> Roanoke darter	3.5	1.9		1.4	0.3
Total number	682	586	282	501	748

^a Stauffer, Hocutt, and Markham (1980)

^b Lobb (1986)

Table 34. Percentages of fish species and total number of fish collected in mid-summer at Prince in the New River in 1979a, 1984^b, 1988, 1989, and 1990.

Family and Species	Prince				
	1979	1984	1988	1989	1990
Cyprinidae					
<u>Campostoma anomalum</u>	50.8	1.1	11.0	2.1	3.4
central stoneroller					
<u>Cyprinella galactura</u>					1.9
whitetail shiner					
<u>Cyprinella spiloptera</u>		1.2	0.8	3.6	
spotfin shiner					
<u>Luxilus</u> spp.	4.0	7.9	1.3		2.5
white and/or striped shiners					
<u>Nocomis platyrhynchus</u>		2.3	6.3	5.7	8.3
bigmouth chub					
<u>Notropis hudsonius</u>		1.2		8.4	
spottail shiner					
<u>Notropis rubellus</u>	5.6				0.6
rosyface shiner					
<u>Notropis telescopus</u>	8.7	3.5	2.1	3.9	8.0
telescope shiner					
<u>Notropis volucellus</u>	0.8	59.2	0.4	0.6	
mimic shiner					
<u>Pimephales notatus</u>	3.2	7.7		0.3	0.6
bluntnose minnow					
<u>Rhinichthys cataractae</u>	1.6				0.3
longnose dace					
Catostomidae					
<u>Hypentelium nigricans</u>	8.7	2.8	0.8	0.3	6.2
northern hog sucker					
Ictaluridae					
<u>Ameiurus natalis</u>					0.3
yellow bullhead					
<u>Ictalurus punctatus</u>					0.3
channel catfish					
<u>Pylodictis olivaris</u>		0.2			2.2
flathead catfish					
Centrarchidae					
<u>Ambloplites rupestris</u>	0.8	2.6	12.7	52.0	20.1
rock bass					
<u>Lepomis auritus</u>		0.1	0.8	0.9	0.3
redbreast sunfish					
<u>Lepomis cyanellus</u>			0.4		0.3
green sunfish					

Table 34. (continued)

Family and Species	Prince				
	1979	1984	1988	1989	1990
Centrarchidae (continued)					
<u>Lepomis gibbosus</u>				1.2	0.3
pumpkinseed					
<u>Lepomis macrochirus</u>	1.6	0.1		2.7	2.5
bluegill					
<u>Lepomis megalotis</u>			0.4	0.3	
longear sunfish					
<u>Micropterus dolomieu</u>	0.8	6.7	24.5	10.8	21.3
smallmouth bass					
<u>Micropterus punctulatus</u>	2.4	0.5		1.5	
spotted bass					
<u>Micropterus salmoides</u>					0.6
largemouth bass					
<u>Pomoxis nigromaculatus</u>				0.3	
black crappie					
Percidae					
<u>Etheostoma blennioides</u>	3.2	0.9	12.7	1.5	12.3
greenside darter					
<u>Etheostoma caeruleum</u>	0.8	0.2	18.6	1.5	4.3
rainbow darter					
<u>Percina caprodes</u>		0.6	1.3	0.9	1.5
logperch					
<u>Percina gymnocephala</u> ^c	0.8				
Appalachia darter					
<u>Percina oxyrhynchus</u>	2.4	0.3	4.2	1.2	1.2
sharpnose darter					
<u>Percina roanoka</u>	4.0	1.2	1.7	0.3	0.6
Roanoke darter					
Total number	126	1634	237	333	324

^a Stauffer, Hocutt, and Markham (1980)

^b Lobb (1986)

^c reported as Percina maculata blackside darter

Table 35. Percentages of fish species and total number of fish collected in mid-summer at Thurmond in the New River in 1979^a, 1984^b, 1988, 1989, and 1990.

Family and Species	Thurmond				
	1979	1984	1988	1989	1990
Clupeidae					
<u>Dorosoma cepedianum</u> gizzard shad					0.3
Cyprinidae					
<u>Campostoma anomalum</u> central stoneroller		4.3	1.5	2.5	2.0
<u>Cyprinella galactura</u> whitetail shiner					0.3
<u>Cyprinella spiloptera</u> spotfin shiner		2.4	3.1	1.1	0.7
<u>Luxilus</u> spp. white and/or striped shiners	5.2	21.4	6.2	5.9	1.7
<u>Nocomis platyrhynchus</u> bigmouth chub	8.6	14.7	12.6	11.3	8.7
<u>Notropis hudsonius</u> spottail shiner			8.9	1.1	0.3
<u>Notropis photogenis</u> silver shiner			2.5		
<u>Notropis rubellus</u> rosyface shiner	0.9	1.1	0.3		
<u>Notropis telescopus</u> telescope shiner	41.4	11.2	0.6	4.2	3.7
<u>Notropis volucellus</u> mimic shiner	0.9	6.4	5.5	24.9	
<u>Pimephales notatus</u> bluntnose minnow		19.2	1.2	0.8	0.7
<u>Rhinichthys cataractae</u> longnose dace		1.3	0.9		
Catostomidae					
<u>Hypentelium nigricans</u> northern hog sucker	5.2	2.7	0.3	2.5	41.8
Ictaluridae					
<u>Pylodictis olivaris</u> flathead catfish	1.7	0.8	0.3	0.3	

Table 35. (continued)

Family and Species	1979	1984	Thurmond		1990
			1988	1989	
Centrarchidae					
<u>Ambloplites rupestris</u> rock bass	0.9	1.6	22.5	17.5	8.4
<u>Lepomis auritus</u> redbreast sunfish		0.3	0.3	2.5	
<u>Lepomis cyanellus</u> green sunfish		0.5			
<u>Lepomis macrochirus</u> bluegill		0.3		1.1	2.3
<u>Micropterus dolomieu</u> smallmouth bass		6.1	21.2	6.2	23.1
<u>Micropterus punctulatus</u> spotted bass		0.3		0.3	0.7
<u>Micropterus salmoides</u> largemouth bass					1.0
Percidae					
<u>Etheostoma blennioides</u> greenside darter	3.4	1.1	4.3	6.2	2.7
<u>Etheostoma caeruleum</u> rainbow darter			2.8	1.1	
<u>Percina caprodes</u> logperch		0.3		1.4	1.3
<u>Percina oxyrhynchus</u> sharpnose darter	25.9	3.0	3.1	7.1	0.3
<u>Percina roanoka</u> Roanoke darter	6.0	1.1	1.8	1.7	
Total number	116	374	325	354	299

^a Stauffer, Hocutt, and Markham (1980)

^b Lobb (1986)

Table 36. Percentages of fish species and total number of fish collected in mid-summer at Fayette Station in the New River in 1988, 1989, and 1990.

Family and Species	Fayette Station		
	1988	1989	1990
Cyprinindae			
<u>Cyprinella spiloptera</u>	2.7	0.9	
spotfin shiner			
<u>Nocomis platyrhynchus</u>		0.9	
bigmouth chub			
<u>Notropis hudsonius</u>	0.7		
spottail shiner			
<u>Notropis telescopus</u>		7.9	
telescope shiner			
<u>Notropis volucellus</u>		0.9	
mimic shiner			
Catostomidae			
<u>Hypentelium nigricans</u>	0.7	2.6	0.6
northern hog sucker			
Ictaluridae			
<u>Ameiurus natalis</u>	0.7		
yellow bullhead			
<u>Ictalurus punctatus</u>	1.3		
channel catfish			
<u>Pylodictis olivaris</u>	5.4	3.5	1.3
flathead catfish			
Centrarchidae			
<u>Ambloplites rupestris</u>	4.7	40.4	7.1
rock bass			
<u>Lepomis auritus</u>	2.7	2.6	1.9
redbreast sunfish			
<u>Lepomis cyanellus</u>	1.3	3.5	
green sunfish			
<u>Lepomis macrochirus</u>	13.4		3.2
bluegill			
<u>Lepomis megalotis</u>	20.8		1.3
longear sunfish			
<u>Micropterus dolomieu</u>	35.6	21.9	75.5
smallmouth bass			
<u>Micropterus punctulatus</u>	5.4	2.6	0.6
spotted bass			
<u>Pomoxis annularis</u>	0.7		
white crappie			

Table 36. (continued)

Family and Species	Fayette Station		
	1988	1989	1990
Percidae			
<u>Etheostoma blennioides</u> greenside darter	0.7	2.6	5.2
<u>Etheostoma caeruleum</u> rainbow darter	0.7	5.3	1.9
<u>Percina caprodes</u> logperch	2.7		
<u>Percina oxyrhynchus</u> sharpnose darter		2.6	1.3
<u>Percina roanoka</u> Roanoke darter		1.8	
Total number	149	114	155

Table 37. Numbers of species^a collected at Bluestone Dam, Sandstone Falls, Prince, Thurmond, and Fayette Station in the New River in 1979^b, 1984^c, 1988, 1989, and 1990. Total number of species collected over the sampling period is also given for each site. Number of native^d species is given in parentheses (N/A indicates collections were not available).

Collection Site	Year					total
	1979	1984	1988	1989	1990	
Bluestone Dam	32 (19)	15 (9)	14 (7)	21 (10)	20 (10)	36 (20)
Sandstone Falls	27 (15)	20 (13)	11 (7)	14 (6)	15 (9)	33 (18)
Prince	17 (11)	20 (12)	17 (11)	21 (10)	24 (14)	31 (17)
Thurmond	11 (8)	21 (12)	20 (14)	20 (12)	18 (9)	27 (16)
Fayette Station	N/A	N/A	17 (8)	15 (9)	11 (5)	22 (11)

^a presence of Luxilus spp. was counted as one species

^b collected by Stauffer, Hocutt, and Markham 1980

^c collected by Lobb 1986

^d includes native, endemic, and probably native from Appendix A

Table 38. Fish species diversity, number of darter species, number of sunfish species, number of intolerant species, number of tolerant species, percent green sunfish, percent omnivores, percent insectivorous cyprinids, percent piscivores, and average number of fish collected per ten minutes for collections at Bluestone Dam in the New River, WV in 1979^a, 1984^b, 1988, 1989, and 1990 (N/A indicates data were not available).

Metric	Bluestone Dam				
	1979	1984	1988	1989	1990
Diversity (by number)	2.54	2.01	1.47	2.34	2.15
# darter species	6	3	3	5	4
# sunfish species	3	2	3	3	2
# intolerant species	5	1	0	1	1
# tolerant species	6	1	1	0	0
% green sunfish	0.1	0.0	0.2	0.0	0.0
% omnivores	1.8	21.2	0.0	0.0	0.0
% insectivorous cyprinids	14.5	10.3	1.2	25.6	9.2
% piscivores	26.0	48.9	20.9	28.3	60.1
# of fish per 10-min	N/A	24.5	43.5	34.2	30.2

^a Stauffer, Hocutt, and Markham (1980)

^b Lobb (1986)

Table 40. Fish species diversity, number of darter species, number of sunfish species, number of intolerant species, number of tolerant species, percent green sunfish, percent omnivores, percent insectivorous cyprinids, percent piscivores, and average number of fish collected per ten minutes for collections at Prince in the New River, WV in 1979^a, 1984^b, 1988, 1989, and 1990 (N/A indicates data were not available).

Metric	Prince				
	1979	1984	1988	1989	1990
Diversity (by number)	1.91	1.64	2.18	1.88	2.43
# darter species	5	5	5	5	5
# sunfish species	1	2	3	4	4
# intolerant species	4	2	3	3	3
# tolerant species	1	1	1	1	3
% green sunfish	0.0	0.0	0.4	0.0	0.3
% omnivores	3.2	7.7	0.0	0.3	0.6
% insectivorous cyprinids	20.6	73.0	4.6	16.5	13.3
% piscivores	4.0	9.9	37.1	64.3	44.1
# of fish per 10-min	N/A	72.6	18.2	25.6	24.9

^a Stauffer, Hocutt, and Markham (1980)

^b Lobb (1986)

Table 42. Fish species diversity, number of darter species, number of sunfish species, number of intolerant species, number of tolerant species, percent green sunfish, percent omnivores, percent insectivorous cyprinids, percent piscivores, and average number of fish collected per ten minutes for collections at Fayette Station in the New River, WV in 1988, 1989, and 1990.

Metric	Fayette Station		
	1988	1989	1990
Diversity (by number)	2.03	1.96	1.05
# darter species	3	4	3
# sunfish species	4	2	3
# intolerant species	2	2	2
# tolerant species	2	1	0
% green sunfish	1.3	3.5	0.0
% omnivores	0.0	0.0	0.0
% insectivorous cyprinids	3.4	9.6	0.0
% piscivores	51.0	68.4	84.5
# of fish per 10-min	14.9	8.8	11.9

Table 42. Fish species diversity, number of darter species, number of sunfish species, number of intolerant species, number of tolerant species, percent green sunfish, percent omnivores, percent insectivorous cyprinids, percent piscivores, and average number of fish collected per ten minutes for collections at Fayette Station in the New River, WV in 1988, 1989, and 1990.

Metric	Fayette Station		
	1988	1989	1990
Diversity (by number)	2.03	1.96	1.05
# darter species	3	4	3
# sunfish species	4	2	3
# intolerant species	2	2	2
# tolerant species	2	1	0
% green sunfish	1.3	3.5	0.0
% omnivores	0.0	0.0	0.0
% insectivorous cyprinids	3.4	9.6	0.0
% piscivores	51.0	68.4	84.5
# of fish per 10-min	14.9	8.8	11.9

Table 44. Pinkham and Pearson similarity of fish species collected at Bluestone Dam, Sandstone Falls, Prince, Thurmond, and Fayette Station in the New River in 1979a, 1984b, 1988, 1989, and 1990. Mean similarity values are given in bold (Pretrt = Pretreatment, Trt = Treatment, 79 = 1979, 84 = 1984, 88 = 1988, 89 = 1989, and 90 = 1990, N/A = not available).

Site	Pretrt vs					Pretrt vs Trt					Trt vs Trt				
	Pretrt	79&84	79&88	79&89	79&90	84&88	84&89	84&90	88&89	88&90	89&90				
Bluestone Dam	23.08		12.24	23.14	20.73 20.80	21.85	23.25	23.56	24.18	31.53 29.58	33.02				
Sandstone Falls	29.23		14.05	17.10	11.36 15.28	14.05	24.46	10.64	38.14	24.55 26.88	17.95				
Prince	14.25		12.10	17.05	17.22 17.02	18.42	23.47	13.83	28.84	26.91 26.63	24.15				
Thurmond	19.81		17.77	17.07	11.00 21.08	32.33	34.22	14.11	37.84	18.16 29.57	32.71				
Fayette Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	19.11	21.97 20.41	20.16				

a Stauffer, Hocutt, and Markham (1980)

b Lobb (1986)

Table 45. Persistence (P) of fish species between collection years at Bluestone Dam, Sandstone Falls, Prince, Thurmond, and Fayette Station in the New River in 1979a, 1984b, 1988, 1989, and 1990. Numbers of extinctions (e) and colonizations (c) of fish species between sites are given in parentheses and mean persistence values are given in bold (Pretrt = Pretreatment, Trt = Treatment, N/A = not available).

Site	Pretrt vs Pretrt				Pretrt vs Trt				Trt vs Trt			
	79&84 P (e,c)	79&88 P (e,c)	79&89 P (e,c)	79&90 P (e,c)	84&88 P (e,c)	84&89 P (e,c)	84&90 P (e,c)	88&89 P (e,c)	88&90 P (e,c)	89&90 P (e,c)		
Bluestone Dam	0.596 (18,1)	0.522 (20,2)	0.679 (14,3)	0.615 (16,4)	0.759 (4,3)	0.722 (2,8)	0.686 (3,8)	0.686 (2,9)	0.765 (1,7)	0.829 (4,3)		
				0.664					0.760			
Sandstone Falls	0.809 (8,1)	0.474 (18,2)	0.585 (15,2)	0.524 (16,4)	0.452 (13,4)	0.647 (9,3)	0.571 (10,5)	0.720 (2,5)	0.769 (1,5)	0.759 (3,4)		
				0.542					0.749			
Prince	0.757 (3,6)	0.647 (6,6)	0.684 (4,8)	0.683 (3,10)	0.811 (5,2)	0.878 (2,3)	0.727 (4,8)	0.789 (2,6)	0.683 (3,10)	0.667 (6,9)		
				0.738					0.713			
Thurmond	0.688 (0,10)	0.710 (0,9)	0.645 (1,10)	0.483 (4,11)	0.829 (4,3)	0.878 (3,2)	0.718 (7,4)	0.850 (3,3)	0.632 (8,6)	0.789 (5,3)		
				0.710					0.757			
Fayette Station	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.647 (7,5)	0.733 (7,1)	0.714 (6,2)		
									0.698			

a Stauffer, Hocutt, and Markham (1980)
b Lobb (1986)

Appendix 1

Macroinvertebrate Summary 1:

Community Structure at Lowest Taxonomic Level

Site:Bluestone Year:1982 Habitat:Cobble/Pebble Method:PIBS Replicates: 3

* denotes < 0.1%

Taxa	Mean Number/sample	Lower 95% C.L.	Upper 95% C.L.	Functional Group	HBI Tolerance
PLANARIIDAE	441.0	0.0	2128.0		0
CLASS OLIGOCHAETA	2.0	0.0	10.6		0
Serratella	11.0	0.0	58.3		0
BAETIDAE	116.0	0.0	508.1		0
Stenonema	11.0	0.0	58.3		0
Isonychia	75.0	0.0	345.0		0
HYDROPTILIDAE	145.0	0.0	459.9		0
Macrostemum (=Macronemum)	5.7	0.0	30.1		0
Hydropsyche	468.0	0.0	1356.3		0
ELMIDAE	28.7	0.0	152.1		0
Antocha	10.0	0.0	48.8		0
Simulium	2329.0	0.0	9791.4		0
CHIRONOMIDAE	461.0	0.0	1629.0		0
PLANORBIDAE	16.7	0.0	88.4		0
PLEURO CERIDAE	5.7	0.0	30.1		0
Corbicula	11.0	0.0	58.3		0

Summary	Mean Value/sample	Lower 95% C.L.	Upper 95% C.L.
Density	4136.3	0.0	14897.3
Diversity Index	2.06	0.00	3.63
Taxa Richness	9.7	2.1	17.3
EPT Index	4.7	0.0	9.8
HBI	5.93	0.00	0.00
EPT/Chironomidae Abund.	2.85	0.00	9.35
% Contrib. Dom. Taxon	51.3	9.0	93.6
Scrap./(Scrap. + Filt.)	0.00	0.00	0.00
Hydropsychidae/Tot. Tricho.	0.66	0.00	1.65

Appendix 2

Macroinvertebrate Summary 1:
Community Structure at Lowest Taxonomic Level
Site:Bluestone Year:1984 Habitat:Cobble/Pebble Method:PIBS Replicates: 3
* denotes < 0.1%

Taxa	Mean Number/sample	Lower	Upper	Functional Group	HBI Tolerance
		95% C.L.	95% C.L.		
PLANARIIDAE	66.7	0.0	292.2	CG	8
CLASS OLIGOCHAETA	0.3	0.0	1.7	CG	8
Asellus	5.0	0.0	26.5	CG	8
Crangonyx	27.7	0.0	134.1	CG	6
Serratella	4.0	0.0	8.3	CG	4
Baetis	13.7	12.3	15.1	CG	4
Heterocloeon	9.3	0.0	33.4	SC	4
Pseudocloeon	7.0	0.0	31.0	SC	4
Stenonema	0.3	0.0	1.7	SC	4
Isonychia	1.0	0.0	3.5	CF	2
Corydalus	0.3	0.0	1.7	PR	5
Leucotrichia	16.7	0.0	60.1	SC	6
Hydroptila	0.7	0.0	3.6	MP	6
Hydropsyche	81.0	0.0	404.1	CF	6
Cheumatopsyche	1038.0	0.0	2280.4	CF	6
Ceraclea	3.0	0.0	12.0	CG	4
Petrophila (=Paragyractis)	31.7	0.0	103.5	SC	5
Stenelmis	3.3	0.0	11.3	SC	4
Microcylloepus	0.7	0.0	3.6	SC	4
Simulium	264.0	0.0	754.5	CF	6
CHIRONOMIDAE	726.0	0.0	1473.3	CG	6
Hemerodromia	14.0	0.0	74.2	PR	6
Physa	8.0	0.0	42.4	CG	8
Ferrissia	16.3	0.0	50.2	SC	4
Corbicula	25.3	0.0	81.3	CF	8

Summary	Mean Value/sample	Lower	Upper
		95% C.L.	95% C.L.
Density	2364.0	390.0	4338.0
Diversity Index	2.14	0.00	2.91
Taxa Richness	18.0	15.5	20.5
EPT Index	8.3	6.9	9.8
HBI	6.03	0.00	116.03
EPT/Chironomidae Abund.	1.67	0.80	2.54
% Contrib. Dom. Taxon	44.7	20.6	68.8
Scrap./(Scrap. + Filt.)	0.05	0.00	0.28
Hydropsychidae/Tot. Tricho.	0.98	0.94	1.02

Appendix 3

Macroinvertebrate Summary 1:
 Community Structure at Lowest Taxonomic Level
 Site:Bluestone Year:1988 Habitat:Cobble/Pebble Method:PIBS Replicates:10
 * denotes < 0.1%

Taxa	Mean Number/sample	Lower 95% C.L.	Upper 95% C.L.	Functional Group	HBI Tolerance
PLANARIIDAE	19.3	8.3	30.3	CG	8
CLASS OLIGOCHAETA	0.6	0.0	1.4	CG	8
CLASS HIRUDINEA	3.6	0.0	8.0	PR	8
Asellus	0.6	0.0	1.3	CG	8
Crangonyx	125.0	54.6	195.4	CG	6
Serratella	10.8	6.2	15.4	CG	4
Baetis	7.9	3.7	12.1	CG	4
Heterocloeon	0.3	0.0	0.8	SC	4
Pseudocloeon	0.7	0.0	1.5	SC	4
Tricorythodes	43.5	13.4	73.6	CG	4
Isonychia	0.9	0.3	1.5	CF	2
AESCHNIDAE	0.1	0.0	0.3	PR	3
Corydalus	0.3	0.0	0.7	PR	5
Leucotrichia	2.3	0.0	5.4	SC	6
Hydroptila	1.8	0.7	2.9	MP	6
Macrostemum (=Macronemum)	0.9	0.0	2.1	CF	6
Hydropsyche	0.2	0.0	0.7	CF	6
Cheumatopsyche	1498.0	1108.6	1887.4	CF	6
Oecetis	0.4	0.0	0.9	PR	4
Ceraclea	3.4	2.6	4.2	CG	4
Cynnellus	0.1	0.0	0.3	CF	6
Cernotina	0.1	0.0	0.3	PR	6
PYRALIDAE	2.2	0.9	3.5	SH	5
Stenelmis	2.1	0.6	3.6	SC	4
Microcylloepus	0.1	0.0	0.3	SC	4
Promoresia	0.1	0.0	0.3	SC	4
Antocha	0.2	0.0	0.7	CG	3
CHIRONOMIDAE	1383.0	1126.6	1639.4	CG	6
Hemerodromia	5.0	2.6	7.4	PR	6
ORDER ACARI (HYDRACARINA)	0.4	0.0	1.3	PR	5
Physa	10.9	1.3	20.5	CG	8
PLANORBIDAE	0.2	0.0	0.5	CG	7
Ferrissia	29.7	5.7	53.7	SC	4
Corbicula	16.1	9.0	23.2	CF	8

Summary	Mean Value/sample	Lower 95% C.L.	Upper 95% C.L.
Density	3170.2	2569.6	3770.8
Diversity Index	1.57	0.00	1.71
Taxa Richness	18.8	17.5	20.1
EPT Index	8.2	7.1	9.3
HBI	5.96	0.00	361.96
EPT/Chironomidae Abund.	1.14	0.95	1.33
% Contrib. Dom. Taxon	50.4	47.0	53.8
Scrap./(Scrap. + Filt.)	0.03	0.00	0.09
Hydropsychidae/Tot. Tricho.	1.00	0.99	1.01

Appendix 4

Macroinvertebrate Summary 1:

Community Structure at Lowest Taxonomic Level

Site:Bluestone Year:1989 Habitat:Cobble/Pebble Method:PIBS Replicates: 3

* denotes < 0.1%

Taxa	Mean Number/sample	Lower	Upper	Functional Group	HBI Tolerance
		95% C.L.	95% C.L.		
CLASS OLIGOCHAETA	2.3	0.0	6.1	CG	8
Crangonyx	27.0	0.0	87.7	CG	6
Caenis	0.7	0.0	2.1	CG	4
Serratella	3.7	0.0	10.9	CG	4
Baetis	22.3	0.0	66.1	CG	4
Heterocloeon	1.7	0.0	5.5	SC	4
Pseudocloeon	0.3	0.0	1.7	SC	4
Stenonema	19.3	0.0	44.2	SC	4
Stenacron	0.3	0.0	1.7	SC	4
Heptagenia	0.7	0.0	2.1	SC	4
Tricorythodes	5.0	0.0	15.8	CG	4
Isonychia	14.3	0.0	41.1	CF	2
Argia	0.3	0.0	1.7	PR	9
Leucotrichia	0.3	0.0	1.7	SC	6
Hydroptila	0.7	0.0	3.6	MP	6
Hydropsyche	5.3	0.0	18.1	CF	6
Cheumatopsyche	391.0	16.7	765.3	CF	6
Petrophila (=Parangyractis)	4.0	0.0	8.3	SC	5
Stenelmis	19.3	0.0	62.9	SC	4
Optioservus	0.7	0.0	3.6	SC	4
Simulium	58.3	0.0	174.0	CF	6
CHIRONOMIDAE	275.0	0.0	773.6	CG	6
Hemerodromia	1.0	0.0	3.5	PR	6
Physa	3.7	0.0	12.4	CG	8
Ferrissia	19.3	0.0	46.7	SC	4
Corbicula	4.0	0.0	19.1	CF	8

Summary	Mean Value/sample	Lower	Upper
		95% C.L.	95% C.L.
Density	881.0	51.2	1710.8
Diversity Index	2.35	0.00	3.56
Taxa Richness	19.7	12.5	26.8
EPT Index	10.0	3.4	16.6
HBI	5.67	0.00	102.47
EPT/Chironomidae Abund.	2.26	0.00	5.20
% Contrib. Dom. Taxon	44.3	39.5	49.2
Scrap./(Scrap. + Filt.)	0.14	0.00	0.73
Hydropsychidae/Tot. Tricho.	1.00	0.99	1.01

Appendix 5

Macroinvertebrate Summary 1:

Community Structure at Lowest Taxonomic Level

Site:Bluestone Year:1990 Habitat:Cobble/Pebble Method:PIBS Replicates:3

* denotes < 0.1%

Taxa	Mean Number/sample	Lower 95% C.L.	Upper 95% C.L.	Functional Group	HBI Tolerance
PLANARIIDAE	1.0	0.0	3.5	CG	8
CLASS OLIGOCHAETA	6.0	0.0	31.8	CG	8
Asellus	0.7	0.0	3.6	CG	8
Crangonyx	31.3	0.0	112.1	CG	6
Serratella	3.3	0.0	15.6	CG	4
Baetis	101.0	0.0	224.6	CG	4
Heterocloeon	83.0	0.0	382.1	SC	4
Pseudocloeon	8.7	0.0	37.5	SC	4
Stenonema	6.7	0.0	14.3	SC	4
Epeorus	0.3	0.0	1.7	CG	4
Heptagenia	0.7	0.0	2.1	SC	4
Tricorythodes	62.7	0.0	273.3	CG	4
Isonychia	32.0	0.0	96.7	CF	2
Corydalus	1.0	0.0	5.3	PR	5
Leucotrichia	1.3	0.0	7.0	SC	6
Hydroptila	0.7	0.0	3.6	MP	6
HYDROPSYCHIDAE	1.0	0.0	5.3	CF	6
Macrostemum (=Macronemum)	0.3	0.0	1.7	CF	6
Hydropsyche	2.7	0.0	12.1	CF	6
Cheumatopsyche	4188.0	1573.7	6802.3	CF	6
LEPTOCERIDAE	1.0	0.0	5.3	CG	4
Oecetis	0.7	0.0	3.6	PR	4
Ceraclea	4.7	0.0	15.0	CG	4
Petrophila (=Parargyractis)	53.7	0.0	133.5	SC	5
Stenelmis	60.0	0.0	177.9	SC	4
ORDER DIPTERA	1.7	0.0	8.9		5
CHIRONOMIDAE	1581.0	1418.5	1743.6	CG	6
Hemerodromia	3.7	0.0	11.7	PR	6
Physa	27.3	0.0	64.5	CG	8
Ferrissia	25.3	0.0	58.4	SC	4
Corbicula	16.0	0.0	60.2	CF	8

Summary	Mean Value/sample	Lower 95% C.L.	Upper 95% C.L.
Density	6307.0	3422.0	9192.0
Diversity Index	1.46	0.00	2.27
Taxa Richness	21.7	13.7	29.7
EPT Index	12.0	9.5	14.5
HBI	5.87	0.00	109.87
EPT/Chironomidae Abund.	2.83	1.41	4.25
% Contrib. Dom. Taxon	66.0	51.6	80.4
Scrap./(Scrap. + Filt.)	0.06	0.00	0.30
Hydropsychidae/Tot. Tricho.	1.00	1.00	1.00

Appendix 6

Macroinvertebrate Summary 1:

Community Structure at Lowest Taxonomic Level

Site:Sandstone Year:1982 Habitat:Cobble/Pebble Method:PIBS Replicates: 3

* denotes < 0.1%

Taxa	Mean	Lower	Upper	Functional Group	HBI
		95% C.L.	95% C.L.		
PLANARIIDAE	394.0	0.0	1284.2	CG	8
CLASS OLIGOCHAETA	11.0	0.0	58.3	CG	8
ASELLIDAE	122.0	0.0	384.5	CG	8
GAMMARIDAE	622.0	0.0	1869.8	CG	6
Serratella	167.0	0.0	600.0	CG	4
BAETIDAE	217.0	0.0	636.9	CG	4
HEPTAGENIIDAE	11.0	0.0	58.3	SC	4
Isonychia	66.7	0.0	317.9	CF	2
Helicopsyche	27.7	0.0	90.9	SC	3
Hydropsyche	261.0	0.0	536.0	CF	6
LEPTOCERIDAE	16.7	0.0	88.4	CG	4
ELMIDAE	183.0	0.0	902.1	SC	4
Simulium	2911.0	0.0	10161.0	CF	6
CHIRONOMIDAE	38.7	0.0	142.5	CG	6
PLANORBIDAE	55.7	0.0	159.5	CG	7
PLEUROCERIDAE	200.0	0.0	1024.3	SC	4
Corbicula	161.0	0.0	749.5	CF	8

Summary	Mean	Lower	Upper
		95% C.L.	95% C.L.
Density	5466.0	0.0	16375.0
Diversity Index	2.32	0.00	2.54
Taxa Richness	12.3	4.3	20.3
EPT Index	5.0	0.7	9.3
HBI	5.93	0.00	111.93
EPT/Chironomidae Abund.	8.83	0.00	30.53
% Contrib. Dom. Taxon	48.0	22.0	74.0
Scrap./(Scrap. + Filt.)	0.07	0.00	0.37
Hydropsychidae/Tot. Tricho.	0.88	0.62	1.14

Appendix 7

Macroinvertebrate Summary 1:

Community Structure at Lowest Taxonomic Level

Site:Sandstone Year:1984 Habitat:Cobble/Pebble Method:PIBS Replicates: 3

* denotes < 0.1%

Taxa	Mean Number/sample	Lower	Upper	Functional Group	HBI Tolerance
		95% C.L.	95% C.L.		
PLANARIIDAE	6.7	0.0	19.5		0
CLASS OLIGOCHAETA	4.3	0.0	14.3		0
Neoperla	0.3	0.0	1.7		0
Acroneuria	0.7	0.0	3.6		0
Caenis	0.7	0.0	2.1		0
Serratella	5.7	0.0	17.2		0
Baetis	26.0	0.0	59.4		0
Heterocloeon	2.3	0.0	6.1		0
Pseudocloeon	0.3	0.0	1.7		0
Stenonema	41.0	4.2	77.8		0
Stenacron	6.7	0.0	33.3		0
Leucrocuta	3.0	0.0	12.0		0
Heptagenia	2.0	0.0	4.5		0
Isonychia	55.7	0.0	178.0		0
Argia	9.3	0.0	25.3		0
Sialis	0.3	0.0	1.7		0
Corydalus	2.3	0.0	10.3		0
Nigronia	1.0	0.0	5.3		0
Hydroptila	0.7	0.0	3.6		0
Helicopsyche	0.3	0.0	1.7		0
Hydropsyche	2.0	0.0	4.5		0
Cheumatopsyche	52.3	0.0	142.1		0
Neophylax	0.3	0.0	1.7		0
Psephenus	14.0	2.6	25.4		0
Stenelmis	10.0	0.0	25.5		0
Ectopria	0.3	0.0	1.7		0
Simulium	9.7	0.0	30.8		0
CHIRONOMIDAE	17.3	13.5	21.1		0
VIVIPARIDAE	6.7	0.0	21.9		0
Corbicula	36.0	0.0	107.0		0
Summary	Mean Value/sample	Lower	Upper		
		95% C.L.	95% C.L.		
Density	318.0	29.3	606.7		
Diversity Index	3.50	0.00	4.07		
Taxa Richness	22.0	15.4	28.6		
EPT Index	12.0	9.5	14.5		
HBI	4.90	0.00	0.00		
EPT/Chironomidae Abund.	11.33	3.03	19.63		
% Contrib. Dom. Taxon	23.5	10.0	37.0		
Scrap./((Scrap. + Filt.))	0.00	0.00	0.00		
Hydropsychidae/Tot. Tricho.	0.94	0.76	1.12		

Appendix 8

Macroinvertebrate Summary 1:

Community Structure at Lowest Taxonomic Level

Site: Sandstone Year: 1988 Habitat: Cobble/Pebble Method: PIBS Replicates: 5

* denotes < 0.1%

Taxa	Mean Number/sample	Lower	Upper	Functional Group	HBI Tolerance
		95% C.L.	95% C.L.		
PLANARIIDAE	3.6	*	7.2	CG	8
CLASS OLIGOCHAETA	0.4	0.0	1.1	CG	8
ASELLIDAE	0.2	0.0	0.8	CG	8
Asellus	0.2	0.0	0.8	CG	8
Hyalella	117.0	0.0	242.7	CG	8
Neoperla	0.2	0.0	0.8	PR	1
Caenis	2.6	0.0	6.6	CG	4
Serratella	34.8	0.0	78.4	CG	4
Baetis	99.4	0.0	234.1	CG	4
Heterocloeon	33.2	0.0	69.9	SC	4
Pseudocloeon	0.8	0.0	2.2	SC	4
Stenonema	5.4	1.7	9.1	SC	4
Stenacron	4.0	0.0	11.3	SC	4
Heptagenia	0.2	0.0	0.8	SC	4
Tricorythodes	44.8	0.0	124.0	CG	4
Isonychia	17.8	0.2	35.4	CF	2
Argia	1.6	0.0	4.7	PR	9
Sialis	0.2	0.0	0.8	PR	4
Corydalus	2.2	0.0	4.7	PR	5
Nigronia	1.0	0.0	3.2	PR	5
Hydroptila	0.8	0.0	2.4	MP	6
Helicopsyche	1.0	0.0	2.8	SC	3
Hydropsyche	35.0	0.0	79.4	CF	6
Cheumatopsyche	120.0	27.6	212.4	CF	6
Chimarra	1.6	0.0	5.4	CF	3
Oecetis	0.4	0.0	1.5	PR	4
Neureclipsis	0.8	0.0	2.2	CF	6
Polycentropus	3.2	0.0	8.6	PR	6
Psephenus	3.8	0.6	7.0	SC	4
Stenelmis	11.8	0.0	25.7	SC	4
Microcylloepus	1.2	0.0	3.4	SC	4
Optioservus	0.8	0.0	1.8	SC	4
Antocha	0.2	0.0	0.8	CG	3
Simulium	0.4	0.0	1.1	CF	6
CHIRONOMIDAE	87.4	21.5	153.3	CG	6
CERATOPOGONIDAE	0.2	0.0	0.8	PR	6
Physa	1.0	0.0	2.8	CG	8
Ferrissia	0.8	0.0	1.8	SC	4
PLEUROCERIDAE	1.6	0.0	4.8	SC	4
Corbicula	6.4	0.0	13.4	CF	8

Summary	Mean Value/sample	Lower	Upper
		95% C.L.	95% C.L.
Density	647.4	408.0	886.8
Diversity Index	2.98	0.00	3.05
Taxa Richness	23.4	17.8	29.0
EPT Index	11.8	8.4	15.2
HBI	5.52	0.00	158.52
EPT/Chironomidae Abund.	5.82	2.27	9.37
% Contrib. Dom. Taxon	30.4	24.1	36.7
Scrap./(Scrap. + Filt.)	0.29	0.00	1.10
Hydropsychidae/Tot. Tricho.	0.91	0.78	1.04

Appendix 9

Macroinvertebrate Summary 1:

Community Structure at Lowest Taxonomic Level

Site:Sandstone Year:1989 Habitat:Cobble/Pebble Method:PIBS Replicates: 3

* denotes < 0.1%

Taxa	Mean Number/sample	Lower 95% C.L.	Upper 95% C.L.	Functional Group	HBI Tolerance
CLASS OLIGOCHAETA	11.3	0.0	36.3	CG	8
Asellus	8.0	0.0	30.8	CG	8
Hyalella	48.7	0.0	236.9	CG	8
Crangonyx	5.3	0.0	21.8	CG	6
CAMBARIDAE	0.3	0.0	1.7		5
Caenis	0.3	0.0	1.7	CG	4
Serratella	31.3	0.0	84.7	CG	4
Baetis	9.3	0.0	21.6	CG	4
Heterocloeon	2.0	0.0	10.6	SC	4
Stenonema	7.3	0.0	21.0	SC	4
Stenacron	12.0	0.0	31.9	SC	4
Heptagenia	3.3	0.0	7.1	SC	4
Tricorythodes	19.0	0.0	66.2	CG	4
Isonychia	11.3	0.0	47.2	CF	2
Argia	2.7	1.3	4.1	PR	9
Sialis	0.3	0.0	1.7	PR	4
Corydalus	1.0	0.0	3.5	PR	5
Nigronia	2.7	0.0	5.6	PR	5
Hydroptila	1.3	0.0	5.1	MP	6
Hydropsyche	3.0	0.0	10.5	CF	6
Cheumatopsyche	21.0	0.0	57.8	CF	6
Decetis	0.7	0.0	2.1	PR	4
Neureclipsis	1.3	0.0	2.7	CF	6
Polycentropus	0.3	0.0	1.7	PR	6
Psephenus	2.0	0.0	8.6	SC	4
Stenelmis	6.7	0.0	16.7	SC	4
Microcylloepus	1.0	0.0	3.5	SC	4
CHIRONOMIDAE	128.0	0.0	318.6	CG	6
Hemerodromia	2.0	0.0	8.6	PR	6
Ferrissia	1.7	0.0	6.9	SC	4
Summary	Mean Value/sample	Lower 95% C.L.	Upper 95% C.L.		
Density	345.7	12.8	678.6		
Diversity Index	3.11	0.00	4.29		
Taxa Richness	23.7	16.1	31.3		
EPT Index	12.0	7.7	16.3		
HBI	5.60	0.00	101.00		
EPT/Chironomidae Abund.	1.35	0.00	3.75		
% Contrib. Dom. Taxon	34.7	6.2	63.2		
Scrap./(Scrap. + Filt.)	0.54	0.00	2.88		
Hydropsychidae/Tot. Tricho.	0.77	0.16	1.38		

Appendix 10

Macroinvertebrate Summary 1:
 Community Structure at Lowest Taxonomic Level
 Site: Sandstone Year: 1990 Habitat: Cobble/Pebble Method: PIBS Replicates: 3
 * denotes < 0.1%

Taxa	Mean Number/sample	Lower 95% C.L.	Upper 95% C.L.	Functional Group	HBI Tolerance
CLASS OLIGOCHAETA	12.3	0.0	42.3	CG	8
Asellus	1.7	0.0	5.5	CG	8
Hyalella	45.7	0.0	242.2	CG	8
CAMBARIDAE	0.3	0.0	1.7		5
PERLIDAE	0.3	0.0	1.7	PR	1
Agnetina (=Phasganophora)	0.3	0.0	1.7	PR	1
Acroneuria	0.7	0.0	2.1	PR	1
CHLOROPERLIDAE	0.3	0.0	1.7	PR	1
Caenis	1.7	0.0	6.9	CG	4
Serratella	28.7	0.0	90.1	CG	4
Baetis	18.0	0.0	45.3	CG	4
Heterocloeon	3.3	0.0	15.6	SC	4
Stenonema	6.0	0.0	19.8	SC	4
Stenacron	2.7	0.0	14.2	SC	4
Leucrocuta	1.3	0.0	4.2	SC	4
Tricorythodes	12.3	0.0	61.1	CG	4
Isonychia	30.0	0.0	79.9	CF	2
Argia	0.7	0.0	3.6	PR	9
Rhagovelia	0.3	0.0	1.7	PR	6
Sialis	0.7	0.0	3.6	PR	4
Corydalis	4.7	0.0	9.9	PR	5
Nigronia	1.7	0.0	5.5	PR	5
Hydroptila	2.0	0.0	4.5	MP	6
Hydropsyche	39.3	0.0	189.3	CF	6
Cheumatopsyche	23.7	1.4	46.0	CF	6
Chimarra	2.3	0.0	7.5	CF	3
Polycentropus	0.7	0.0	3.6	PR	6
Psephenus	18.0	7.2	28.8	SC	4
Stenelmis	24.3	0.0	53.0	SC	4
Dubiraphia	0.3	0.0	1.7	SC	4
Antocha	0.7	0.0	3.6	CG	3
CHIRONOMIDAE	195.0	0.0	720.3	CG	6
Ferrissia	1.3	0.0	7.0	SC	4
PLEUROCIDAE	15.3	0.0	48.7	SC	4
Corbicula	2.0	0.0	8.6	CF	8

Summary	Mean Value/sample	Lower 95% C.L.	Upper 95% C.L.
Density	498.7	0.0	1113.4
Diversity Index	3.04	0.00	4.46
Taxa Richness	23.0	15.6	30.5
EPT Index	12.7	6.9	18.4
HBI	5.17	0.00	86.67
EPT/Chironomidae Abund.	1.95	0.00	5.62
% Contrib. Dom. Taxon	34.7	0.0	81.9
Scrap./(Scrap. + Filt.)	0.49	0.00	2.58
Hydropsychidae/Tot. Tricho.	0.90	0.80	1.00

Appendix 11

Taxon	Name	Trophic Group	Origin	Tolerance
G	PHYLLUM CHORDATA			
G0	CLASS OSTEICHTHYES			
G00	ORDER ACIPENSERIFORMES			
G01	ORDER LEPISOSTEIFORMES			
G02	ORDER AMIIFORMES			
G03	ORDER OSTEOGLOSSIFORMES			
G04	ORDER ANGUILLIFORMES			
G05	ORDER CLUPEIFORMES			
G050	CLUPEIDAE			
G0500	Alosa			
G05000	Alosa pseudoharengus	INV	I	F
G0501	Dorosoma			
G05010	Dorosoma cepedianum	CMN	I	F
G06	ORDER CYPRINIFORMES			
G060	CYPRINIDAE			
G0600	Campostoma			
G06000	Campostoma anomalum	HER	N	F
G0601	Carassius			
G06010	Carassius auratus	CMN	I	T
G0602	Cyprinus			
G06020	Cyprinus carpio	CMN	I	T
G0603	Cyprinella			
G06031	Cyprinella galactura	INS	IP	F
G06032	Cyprinella spiloptera	INS	N	F
G0604	Luxilus			
G06041	Luxilus albeolus	INS	NI	F
G06042	Luxilus chrysocephalus	INS	NI	F
G0605	Nocomis			
G06050	Nocomis platyrhynchus	ENV	E	F
G0606	Notemigonus			
G06060	Notemigonus crysoleucas	CMN	I	T
G0607	Notropis			
G06070	Notropis hudsonius	INS	IP	F
G06071	Notropis photogenis	INS	N	I
G06072	Notropis rubellus	INS	N	I
G06073	Notropis scabriceps	INS	E	F
G06074	Notropis stramineus	INS	N	F
G06075	Notropis telescopus	INS	IP	F
G06076	Notropis volucellus	INS	N	I
G0608	Phoxinus			
G06080	Phoxinus phoxinus	HER	N	F
G0609	Pimephales			
G06090	Pimephales notatus	CMN	NI	T
G060A	Rhinichthys			
G060A0	Rhinichthys atratulus	CMN	N	T
G060A1	Rhinichthys cataractae	INS	N	I
G060B	Scardinius			
G060B0	Scardinius erythrophthalmus	CMN	I	F
G060C	Senotilus			
G060C0	Senotilus acromaculatus	CMN	N	T
G060H			H	
G061	CATOSTOMIDAE			
G0610	Catostomus			
G06100	Catostomus commersoni	CMN	N	T
G0611	Hypentelium			
G06110	Hypentelium nigricans	INS	N	I

Appendix 11 continued

Taxon	Name	Trophic Group	Origin	Tolerance
G07	ORDER SILURIFORMES			
G070	ICTALURIDAE			
G0700	Ameiurus			
G07000	Ameiurus natalis	INS	IP	T
G07001	Ameiurus nebulosus	INS	IP	T
G0701	Ictalurus			
G07010	Ictalurus punctatus	INV	N	F
G0702	Pylodictis			
G07020	Pylodictis olivaris	PIS	N	F
G08	ORDER SALMONIFORMES			
G080	ESOCIDAE			
G0800	Esox			
G08000	Esox masquinongy	PIS	I	F
G09	ORDER PERCOPSIFORMES			
G0A	ORDER ATHERINIFORMES			
G0A0	ATHERINIDAE			
G0A00	Labidesthes			
G0A000	Labidesthes sicculus	INS	I	F
G0B	ORDER GASTEROSTEIFORMES			
G0C	ORDER SCORPAENIFORMES			
G0D	ORDER PERCIFORMES			
G0D0	PERCICHTHYIDAE			
G0D00	Morone			
G0D000	Morone chrysops	PIS	I	F
G0D001	Morone saxatilis	PIS	I	F
G0D00H	M. chrysops x M. saxatilis			
G0D1	CENTRARCHIDAE			
G0D10	Ambloplites			
G0D100	Ambloplites rupestris	PIS	I	F
G0D11	Lepomis			
G0D110	Lepomis auritus	INS	I	F
G0D111	Lepomis cyanellus	INV	N	T
G0D112	Lepomis gibbosus	INS	I	F
G0D113	Lepomis macrochirus	INS	I	F
G0D114	Lepomis megalotis	INS	I	I
G0D11H			H	
G0D12	Micropterus			
G0D120	Micropterus dolomieu	PIS	I	F
G0D121	Micropterus punctulatus	PIS	I	F
G0D122	Micropterus salmoides	PIS	I	F
G0D13	Pomoxis			
G0D130	Pomoxis annularis	INV	I	F
G0D131	Pomoxis nigromaculatus	INV	I	F
G0D2	PERCIDAE			
G0D20	Etheostoma			
G0D200	Etheostoma blennioides	INS	N	F
G0D201	Etheostoma caeruleum	INS	NI	F
G0D202	Etheostoma flabellare	INS	N	F
G0D21	Perca			
G0D210	Perca flavescens	PIS	I	F
G0D22	Percina			
G0D220	Percina caprodes	INS	N	F
G0D221	Percina gymnocephala	INS	E	F
G0D222	Percina oxyrhynchus	INS	N	F
G0D223	Percina roanoka	INS	IP	F
G0D23	Stizostedion			

Appendix 11 continued

Taxon	Name	Trophic Group	Origin	Tolerance
G00230	Stizostedion vitreum	PIS	I	F