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SOUTH FORK HOLSTON RIVER BASIN

1988 BIOMONITORING

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EXECUTIVE SUMMARY

To determine levels of environmental degradation in the headwaters of the South Fork Holston River watershed, Tennessee Valley Authority biologists sampled fish and macroinvertebrate communities from four principal headwater drainages--Middle Fork Holston River, South Fork Holston River, Watauga River, and Elk River. The index of biotic integrity was used to measure and rate fish community composition, structure, and overall health. Sites on the Middle Fork Holston, Watauga, and Elk Rivers were moderately impaired. Fish sampled from these sites produced indices of 42, 40, and 40, respectively. Each of these indices corresponded to an index of biotic integrity rating classification of "fair." Various index of biotic integrity metrics were moderately or severely impaired in species richness and composition, trophic structure, fish abundance, and condition. Fish sampled from the South Fork Holston River site produced an index of 52 and a rating classification of "good." Only three metrics were moderately impaired at this site: species composition, trophic structure, and fish condition.

Except for the Watauga River site, analysis of macroinvertebrate samples generally supported index of biotic integrity findings. Macroinvertebrate communities at the Middle Fork Holston, the South Fork Holston, and the Elk River sites were affected by losses in numbers of taxa, including some pollution-sensitive taxa. The Middle Fork Holston River site had the greatest reduction of sensitive taxa and the highest percentage of tolerant organisms. The South Fork Holston River site had

the second greatest numbers of taxa and sensitive taxa but also had a high percentage of pollution-tolerant taxa. The Watauga River site had the healthiest macroinvertebrate community, with the greatest number of sensitive taxa and a low percentage of pollution-tolerant taxa. The discrepancy between the health of fish and macroinvertebrate communities at the Watauga River site may have been due to greater tolerance or resiliency by invertebrates.

Water quality measurements for temperature, dissolved oxygen, pH, and conductivity taken during sampling did not indicate severe perturbation. Evidence of sedimentation and enrichment was visually observed at the Middle Fork Holston River and the Elk River sites.

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INTRODUCTION

There is concern over the effects of shifts in land use practices on the aquatic fauna of streams in the South Fork Holston River basin in northwestern North Carolina and southwestern Virginia. Trout reproduction has noticeably declined in the Watauga River subbasin. The Watauga River and Elk River subbasins have been subjected to commercial and resort development. The Middle Fork Holston River and the upper South Fork Holston River subbasins have been affected by agricultural and mining activities, respectively (Cox, 1986).

To aid reclamation and management of the South Fork Holston basin, Tennessee Valley Authority (TVA) biologists conducted biomonitoring--including index of biotic integrity and macroinvertebrate sampling--on the Middle Fork Holston, South Fork Holston, Watauga, and Elk Rivers to assess cumulative impairment related to changes in habitat and pollutant loading in these subbasins. Biomonitoring can detect environmental degradation, help document problem areas, and assist in development of strategies for managing water quality.

METHODS AND MATERIALS

Selection of Sampling Sites

In spring 1988, potential sampling sites were located and general observations were made on habitat, access, and sources of degradation. Selection of sampling stations was based on presence of habitat types, characteristics of Tennessee Valley streams, and land use and estimated soil loss in the watershed above each site as determined from low-altitude color infrared aerial photographic surveys in 1985 and 1986

by TVA's Remote Sensing Unit in Chattanooga, Tennessee. Each sampling site included habitats classified as riffle, run, or pool. Four sites were selected (figure 1) and sampled during late April and early May 1988. A description of each sampling site is presented with results. Drainage area at each site was based on estimates reported by the Tennessee Valley Authority (TVA, 1958). River mile, stream gradient, and stream order were determined from U.S. Geological Survey 7.5-minute topographic maps. Ecoregions were determined according to Omernik (1987).

Index of Biotic Integrity

Development of an index of biotic integrity based upon samples of fish populations is a method used for assessing general environmental quality at a site by measuring certain aspects of species richness and composition, trophic structure, and condition of individuals in the fish population. Twelve metrics (table 1) reflect the condition of the fish community. Each is scored as 1 (poor), 3 (intermediate), or 5 (the best to be expected under pristine conditions). Scores for these 12 metrics are then tabulated to produce an index for a site. The index is then classified according to the system described by Karr et al. (1986) (table 2).

Establishing scoring criteria for the 12 metrics is an integral part of index of biotic integrity. Scoring criteria were determined for each monitoring station because sampling sites varied in stream order and ecoregion. Scoring criteria for certain metrics were adjusted for each site; these adjusted criteria are presented with the results. Scoring criteria for species richness and composition (metrics 1-5) were

established according to checklists of species either occurring or expected to occur (table 3). Several sources were used to determine this information: 1974 TVA data from stream surveys of the Middle Fork Holston and South Fork Holston Rivers; 1947 TVA data from a preimpoundment study of South Holston Reservoir; miscellaneous fish collections (Jenkins and Burkhead, 1975); a report on state-managed trout streams of North Carolina (Brown, 1983); miscellaneous fish collections from the Elk River (Menhenick, personal communication); and Lee et al. (1980). Some fish species for which there is no previous record of occurrence were listed in table 3 as expected to occur because of the presence of potentially suitable habitat and proximity to the range of the species. The number of sunfish species (metric 4 of species composition) could not be used for the Elk and Watauga River sites because only one sunfish species, rock bass, was expected to occur at these sites. Consequently, the number of sunfish was replaced by the proportion of simple lithophilic spawners, fish species that deposit eggs in or on gravel or rocky substrate without preparing a nest or providing parental care. Designation of simple lithophilic species was based on index of biotic integrity methods used by Ohio Environmental Protection Agency (1987). Scoring criteria for the proportion of simple lithophils were derived from data from relatively unimpaired fourth- and fifth-order streams of the Blue Ridge Ecoregion (Fitz, 1972), and from unpublished TVA data from Snowbird Creek and Oconaluftee River (Little Tennessee River drainage) and from Laural Creek (South Fork Holston River drainage). The low number of darter species expected to occur at the Elk River site necessitated expanding the number of darter species (metric 2) to

include Cottus sp. following methods used by the Ohio Environmental Protection Agency (1987). Scoring criteria for metrics 6, 7, 8, 9, and 11 followed Saylor et al. (1988). Criteria for scoring metric 10, catch rate, varied among the four sites. Expected catch rate for the Middle Fork Holston River followed that set for other rivers of the Ridge and Valley Ecoregion (Saylor et al., 1988). Scoring criteria for catch rate in the South Fork Holston, Watauga, and Elk River sites were based on unpublished TVA data from index of biotic integrity sampling on rivers of the Blue Ridge Ecoregion (Oconaluftee River, North Carolina). Catch rate, expressed as the mean number of fish per sampling effort, was quantified by seine haul (sampling approximately 300 square feet), or by five minutes of shocking (boat or backpack). Scoring criteria for metric 12, overall fish condition, followed Karr et al. (1986).

Index of Biotic Integrity Fish Sampling

Fish were collected from all discernible habitat types within riffle, run, and pool areas (i.e., sand and gravel, rubble, bedrock, vegetation, and other forms of instream cover). Pool areas more than three feet deep were considered a single habitat regardless of substrate or cover. Predominant habitat types were sampled until a minimum of three seine hauls or 15 minutes of boat shocking had been completed without producing a new species for that habitat type. When deep pool habitat was limited, sampling with a boat shocker was repeated in areas already sampled. If duplication of effort resulted in reduced catch rate, the particular sample run was not used in calculating catch rate.

Shallow backwaters, pools, and runs were sampled with a 20- by 6-foot seine with 3/16-inch mesh net. This seine size was also used in

conjunction with backpack electrofishing to sample riffles and runs. An area approximately 20 by 15 feet was shocked in a downstream direction. Fish drifting immobilized or driven into the seine positioned stationary and across current in the river were captured in the net. Five-minute shocking runs with backpack shockers and dip nets were used to collect fish from around logs, boulders, undercut banks, and brush piles in shallow water.

Shocking with a boat-mounted, 230-volt DC generator was the primary method for sampling deeper pool areas. Each shocking run lasted 10 minutes and was made in a downstream direction to allow stunned fish to rise to the surface in front of the boat for collection. Sampling was conducted at midstream and along shorelines.

After each seine haul or shocking run, captured fish were sorted by species, counted, and recorded. Young-of-year fish (<20 mm total) can affect the accuracy of the index of biotic integrity and were omitted from the records; however, their occurrence, was noted in the comments section of the record sheet. Before fish were released, each specimen was examined for anomalies, disease, and poor condition. Occurrence of any of these conditions was recorded by species. Fish that could not be positively identified were preserved in a jar of 10 percent formalin, with an appropriate field identification label, and returned to TVA's fisheries laboratory in Norris, Tennessee, for closer examination.

Benthic Macroinvertebrate Sampling

Benthic macroinvertebrates were sampled in conjunction with index of biotic integrity fish sampling at the four sites. Benthic samples were collected before fish were sampled to avoid disrupting benthic

organisms. Five samples were taken at each site. A Surber sampler was used to take four quantitative samples along a transect across a shallow riffle area in gravel or cobble substrate. Substrate within the confines of the sampling frame down to a depth of approximately 100 mm was scraped clean, and organisms were allowed to wash into the sampler net. Additionally, a single qualitative sample was taken from the various habitats with a D-net and seine. Approximately one to two manhours was spent collecting the qualitative sample at each site. Each macroinvertebrate sample was transferred to an appropriately labeled collecting jar, preserved in 10 percent formalin, and returned to the TVA laboratory at Norris for sorting and identification. Macroinvertebrates were identified only to the family or genus level. The general condition of benthic macroinvertebrate communities was assessed on the basis of the total number of taxa; total number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa; and percentage of tolerant organisms (i.e., chironomids and oligochaets) in quantitative samples. Ratings for the level of impairment are presented in table 4. Total taxa and EPT taxa ratings were based on mean values derived from macroinvertebrate data collected from relatively unimpaired river sites in the upper Tennessee River Valley. These data include data from the Powell and Clinch Rivers (Saylor et al. 1988) and from the North Fork Holston, Powell, and Clinch Rivers, and Copper Creek (Barr et al., 1986). Ratings for the level of impairment for percentage of tolerant organisms was based on Shackleford (1987). The health of the macroinvertebrate community at each site was also assessed by examining the percentage of samples composed of major taxocenes (taxa groups).

Water Quality

In conjunction with biological sampling at each of the four sampling sites, dissolved oxygen, temperature, conductivity, and pH were measured with a Hydrolab Surveyor II, calibrated, and operated in accordance with procedures in TVA's Natural Resource Engineering Procedures Manual, Volume I.

RESULTS

Middle Fork Holston River

Site Description. Samples were collected on April 27-28, 1988, from Middle Fork Holston River miles 11.2 to 11.5 near Mock Mill (Damascus Quadrangle, Washington County, Virginia, 213-NE). Substrate at this site was predominately rubble, with smaller areas of gravel and sand and of boulder and bedrock. Substrates in eddies and shallow pools were covered with silt and heavy deposits of sediment along the shoreline of deeper pool areas. Tree canopy covered approximately 20 percent of the area over the river. The amount of instream fish cover (brush, trees, roots, boulders, etc.) appeared sufficient to support a fish community typical of free-flowing streams in the region. Stream gradient was moderate (12.2 feet per mile between Middle Fork Holston River miles 9.0 and 12.3). The Middle Fork Holston River at this site is a fifth-order stream of the Ridge and Valley Ecoregion with a drainage area of approximately 212 square miles. Flow at Middle Fork Holston River mile 13.2 on April 28, 1988, was 114 cubic feet per second (cfs). Results of water quality measurements, presented in table 5, and did not indicate any poor water quality.

Index of Biotic Integrity. Sampling effort at Middle Fork Holston River mile 11.5 consisted of 32 seine hauls (including those made in conjunction with backpack shocking) and 80 minutes of boat shocking. Table 6 shows 1,897 fish were collected, including 34 native species and 5 introduced species (common carp, northern pike, fathead minnow, redbreast sunfish, and pumpkinseed). Priority fish families were represented by six darter, two sunfish, and six sucker species. Intolerant species present included telescope shiner, northern hog sucker, and streamline chub. Tolerant species present were gizzard shad, common carp, river chub, striped shiner, spotfin shiner, creek chub, and yellow bullhead. Forty fish had parasites, injury, disease, deformities, or poor condition.

The fish fauna at Middle Fork Holston River mile 11.5 was classified as "fair," with an index of 42 (table 7). Species richness and composition showed moderate disturbance, with losses among native sunfish species and more sensitive species such as darter and intolerant species (metrics 2, 3, and 5, respectively). These losses were associated with an increased proportion of tolerant species in the population (metric 6). Furthermore, the whitetail shiner, which is at least moderately tolerant to siltation and enrichment, was abundant in eddies, constituting about 30 percent of the total catch. The numbers of native and sucker species (metrics 1 and 4) were at healthy levels.

Trophic structure reflected a shift in the food base toward organisms feeding on plant matter (algae, detritus, periphyton, etc.). The proportion of specialized insectivorous minnows and darters was unusually low (metric 7), and the proportion of omnivores in the

population (metric 8) was higher than normal. The proportion of piscivores (metric 9) was low, suggesting instability in the forage base or increased stress and mortality of large carnivores.

Metrics that usually measure degradation at severe levels (metrics 10-12) showed only slight disturbance. Catch rate (metric 10) was excellent and considered abnormally high. This increased fish abundance may be a result of nutrient and organic enrichment. No hybrids were found; absence of hybrids produced a high score for metric 11. The proportion of fish with injury, disease, or other anomalies (metric 12) was only slightly greater than expected. Fin rot and parasitic blackspot disease (Neascus sp.), were the most common maladies of fish, followed by lesions, deformities, and poor condition. Other anomalies occurring singularly were popeye disease (a parasite), blindness, white grub (a parasite), and fungal infection.

Benthic Macroinvertebrates. Disturbances in the macroinvertebrate community at the Middle Fork Holston River site generally paralleled those in the fish community. Loss of invertebrate taxa was comparable to the loss of fish species. Depressed numbers of total taxa (40) and EPT taxa (16) both rated a "fair" classification, indicating moderate impairment (tables 4 and 8). The percentage of tolerant organisms in quantitative samples was unusually high. Dipteran midge larvae (chironomids) comprised almost 45 percent of all benthic organisms in quantitative samples, the highest percentage found during this study. This indicated severe impairment. The percentage of oligochaets (1.7 percent) was within a healthy range; however, an unusually high percentage (5.6 percent) of flatworms (planariids), another pollution-tolerant group, was considered a sign of enrichment and sedimentation.

The density of planariids at Middle Fork Holston River mile 11.5 (18.75 per square foot) was the highest density found at any site during the study. Furthermore, this density was at least three times greater than the highest density reported for quantitative samples from six TVA fixed-station biomonitoring sites in the Tennessee Valley (Bear Creek and Duck, Elk, Sequatchie, Powell, and Clinch Rivers) (Saylor et al. 1988). Taxonomic groups comprising 5 percent or more of the organisms collected in quantitative samples from the Middle Fork Holston River site were:

Diptera	46.9 percent
Coleoptera	16.4 percent
Ephemeroptera	16.2 percent
Trichoptera	7.2 percent
Planariidae	5.6 percent

South Fork Holston River

Site Description. Samples were collected April 28-29, 1988, between South Fork Holston River miles 75.4 and 75.3 near Delmar (Damascus Quadrangle, Washington County, Virginia, 213-NE). Substrate at this site was predominately rubble, with deposits of sand and gravel restricted to deeper pool areas. Substrates in run, eddy, and pool habitats appeared to have only small amounts of silt. There was no evidence of heavy accumulations of silt or organic sediments in pool areas. Tree canopy covered approximately 30 percent of the area over the river. The amount of instream fish cover appeared sufficient to support a fish community typical of free-flowing rivers in the region. A limited amount of deep-pool habitat was accessible by boat, necessitating repeated sampling of some of the deeper pools. Stream gradient was steep (approximately 49.8 feet per mile between South Fork Holston River miles 75.0 and 76.3). The South Fork Holston River at this site

is a sixth-order stream in the Ridge and Valley Ecoregion. However, most of the drainage area (approximately 306 square miles) is located in the Blue Ridge Ecoregion. River flow on April 29, 1988, was moderately high (630 cfs). Results of water quality measurements during sampling (table 5) showed no signs of poor water quality.

Index of Biotic Integrity. Twenty seine hauls (including those in combination with backpack shocking) and 100 minutes of boat shocking were spent sampling fish (catch and effort for the final 60 minutes were not used in calculating catch rates because of fish depletion resulting from duplication of shocking runs). Sampling yielded 573 fish representing 31 native species and 4 introduced species (brown trout, common carp, fathead minnow, and pumpkinseed) (table 6). Priority fish families present were seven darters, two sunfish, and six suckers. Intolerant species present were telescope shiner and northern hog sucker. Tolerant species present were common carp, river chub, striped shiner, and spotfin shiner. Fourteen fish had disease or injury. The most common ailment was parasitism by Neascus sp., followed by fin rot, white grub, and sores.

Analysis of fish collections from South Fork Holston River mile 75.4 produced an index of 52 and a classification of "good" (table 9). Species richness (metric 1) was within expectations. However, two metric scores were lowered in species composition by the absences of one native sunfish and one intolerant species (metrics 3 and 5). Other metrics of species composition, metrics 2, 4, and 6 (number of darter species, number of sucker species, and proportion of individuals as tolerant species) received high scores.

Trophic structure exhibited only a mild imbalance as the proportion of specialized insectivores (metric 8) was slightly less than expected. The proportion of omnivores and piscivores (metrics 7 and 9, respectively) were healthy.

Catch rate (metric 10) was good despite some difficulty with sampling in high flows. No hybrids were found resulting in a high score for metric 11. The proportion of individuals with disease, injury, or other anomalies was somewhat greater than expected (metric 12). This was mainly the result of several mild cases of blackspot disease, which may be associated with enrichment.

Benthic Macroinvertebrates. The overall health of the benthic macroinvertebrate community sampled at South Fork Holston River mile 75.5 was mixed (tables 4 and 8). In the quantitative samples, dipteran midge larvae (chironomids) comprised a high percentage (37.5 percent) of the benthic organisms collected, an indication of severe impairment, while the percentage of oligochaets (5.5 percent) reflected only slight impairment. However, the total number of taxa (43) rated a classification of "fair" (moderate impairment), and the total EPT taxa (23) rated a classification as "good" (slight impairment). This balance in success of tolerant and intolerant taxa was also evident in the percentage composition; dipterans and ephemeropterans shared dominance. Taxonomic groups constituting 5 percent or more of the organisms collected in quantitative samples from the South Fork Holston River site were:

Ephemeroptera	42.7 percent
Diptera	39.1 percent
Coleoptera	6.3 percent
Oligochaeta	5.5 percent

The high number of pollution-sensitive EPT and dominance by sensitive ephemeropterans suggests that the increased proportion of chironomids was the result of a moderate level of enrichment affecting this site.

Watauga River

Site Description. The Watauga River was sampled on May 4, 1988, from mile 61.9 to 62.3 at U.S. Highway 321 west of Sugar Grove (Sherwood Quadrangle, Watauga County, North Carolina, 214-SE). Substrate was predominately rubble, with bedrock and boulder substrate in the area downstream from U.S. Highway 321 bridge. Small pockets of gravel were restricted to the deeper pools. Substrates in eddies and pools were also lightly covered with silt, but no heavy deposits of silt or organic sediments were observed. Tree canopy covered about 15 percent of the area over the river. The amount of fish cover appeared to be sufficient to support a fish community typical of free-flowing rivers in the region. Stream gradient at this site was moderately steep, 16.6 feet per mile from Watauga River miles 61.7 to 62.9. The river at this site is a fifth-order stream of the Blue Ridge Ecoregion with a drainage area of 93.5 square miles. Flow at Watauga River mile 54.5 on May 4, 1988, was 97 cfs. Water quality measurements presented in table 5 did not indicate poor water quality during sampling.

Index of Biotic Integrity. The Watauga River site was sampled by 24 seine hauls (including those made in conjunction with backpack shocking) and 70 minutes of boat shocking. Sampling produced 377 fish, including 11 native species and 4 introduced species: common carp, various bullhead, margined madtom, and redbreast sunfish (table 6).

Priority fish families were represented by two darter and two sucker species. Only one intolerant species, northern hog sucker, was found. Tolerant species included common carp, river chub, and various bullhead. Thirty-four cases of disease or abnormalities were reported.

An index of 40 and a classification of "fair" were derived from analysis of fish collections at Watauga River mile 62.0 (table 10). Species richness (metric 1) was below expectations since 45 percent of the anticipated species, mostly minnows and darters (metric 2), were missing. Numbers of sucker species and intolerant species (metrics 4 and 5) were also low. Despite the loss of species, some moderately intolerant species remained, including Tennessee shiner, greenfin darter, tangerine darter, northern hog sucker, and black redhorse. Interestingly, the proportion of individuals as tolerant species (metric 6) was not above normal, an indication that tolerant species have not been able to take advantage of the disturbed conditions. The proportion of simple lithophilic spawners (substituted for number of sunfish species, metric 3) was lower than expected, reflecting decreased reproductive success of species in this vulnerable breeding guild.

Trophic structure appeared to be relatively healthy at Watauga River mile 62.0, except for an unusually low proportion of specialized insectivores (metric 8). This suggested a possible problem with the macroinvertebrate population. There was no overabundance of omnivores (metric 7) that would indicate a shift toward consumption of plant matter, which may be related to increased siltation or enrichment. The proportion of piscivores (metric 9) was at a healthy level.

Additional problems were suggested by fish abundance and condition. Catch rate (metric 10) was below normal, and the proportion of diseased fish (metric 12) was unusually high. Of the 34 diseased fish, 31 had blackspot. Species not usually affected by blackspot, greenfin darter and Tennessee shiner, were also infested. Other abnormalities were fin rot and poor condition.

Benthic Macroinvertebrates. The benthic macroinvertebrate community reported from Watauga River mile 62.0 appeared less affected than the fish community. An elevated percentage (5.7 percent) of dipteran midge larvae (chironomids) in the quantitative samples indicated only slight impairment. The number of total taxa (47) rated a classification as "fair" (moderate impairment) but, pollution intolerant EPT (27) rated a classification as "excellent" (no impairment). No pollution-tolerant oligochaets were found in quantitative samples. Pollution-sensitive organisms (ephemeropterans and trichopterans) also dominated in percentage composition. Taxonomic groups comprising 5 percent or more of the organisms collected in quantitative sampling from the Watauga River site were:

Trichoptera	31.3 percent
Ephemeroptera	27.5 percent
Gastropoda	17.7 percent
Diptera	16.9 percent

The discrepancy between macroinvertebrate and fish index of biotic integrity findings suggests that the macroinvertebrate community, compared to the fish community, is either more tolerant to pollution that may periodically affect this site or more resilient.

Elk River

Site Description. An approximately 300-foot reach of the Elk River was sampled May 3, 1988, upstream from Elk River Falls at Elk River mile 15.4 (Elk Mills Quadrangle, Avery County, North Carolina, 215-NE). Stream substrate consisted mainly of rubble plus some boulder and bedrock habitat. Eddies and pools were heavily silted. Deposits of organic sediments and loose sand were so abundant in some of these areas that seine hauling was hampered by deposits filling the seine. Canopy cover had been reduced along the left bank adjacent to a small public park at this site, leaving approximately 10 percent canopy cover over the stream. The amount of fish cover appeared sufficient to support a fish community typical of small rivers in the Blue Ridge Ecoregion. Stream gradient at this site was moderately steep (25 feet per mile between Elk River miles 15.4 and 17.0). No functional U.S. Geological Survey stream gauge exists on the Elk River; however, flow at Elk River mile 15.4 was estimated at less than 100 cfs during sampling on May 3, 1988. The Elk River at Elk River mile 15.4 is a fourth-order stream in the Blue Ridge Ecoregion with a drainage area of approximately 43 square miles. Because of its small size and stream gradient, this site could not be sampled with a boat shocker. Water quality measurements presented in table 5 revealed no evidence of poor water quality during sampling.

Index of Biotic Integrity. Sampling at Elk River mile 15.4 consisted of 34 seine hauls plus sample collections with a backpack shocker. Two rainbow trout were collected by hook and line, and several others were observed but not collected. The 394 fish collected included eight native species and two introduced species, rainbow trout and

bluntnose minnow (table 6). Priority fish families were represented by one sculpin and two sucker species. Sampling produced only one intolerant species (northern hog sucker) and one tolerant species (white sucker). Five fish were found affected by disease or parasites.

The fish fauna at Elk River mile 15.4 received an index of 40, which falls in the classification of "fair" (table 11). Both species richness and species composition indicated impairment. The number of species of native fish (metric 1), darters and sculpins (metric 2), and intolerant fish (metric 4) were moderately depressed. The number of sucker species and the proportion of tolerant species (metrics 5 and 6, respectively) were normal. However, fish numbers were dominated by whitetail shiners, which are considered moderately tolerant. The proportion of simple lithophils (metric 3) was well below expectations, an indication of problems with reproductive success for species in this breeding guild.

Trophic structure exhibited disorder because the proportion of omnivores (metric 7) was greater than expected and because the proportions of specialized insectivores (metric 8) and piscivores (metric 9) were unusually low. This imbalance toward omnivores can be directly attributed to the sedimentation and enrichment observed at this site

Metrics of fish abundance and condition showed only slight disruption. Catch rates (metric 10) were moderately low, primarily because low numbers of fish were collected in run and riffle habitat. No hybrids were found that would affect metric 11. The proportion of

diseased fish (metric 12) was within expectations. Maladies included fin rot and parasitism by blackspot disease and anchor worm.

Benthic Macroinvertebrates. The macroinvertebrate community at Elk River mile 15.4 exhibited signs of a disturbed, stressed benthic community. Low numbers of total taxa (35) rated a classification as "poor" (severe impairment) and total EPT (20) rated a classification as "good" (slight impairment) (tables 4 and 8). Both classifications were one taxa from an overall rating of "fair," which suggests moderate impairment of the benthic fauna at this site. The percentage of dipteran midge larvae (chironomids) in quantitative samples (9.06 percent) indicated only slight impairment. No oligochaets were found in the quantitative samples that would indicate impairment. Furthermore, a healthy macroinvertebrate community was indicated by a dominance of intolerant taxa (ephemeropterans and trichopterans) in percentage composition of organisms. Groups of taxa comprising 5 percent or more of the organisms collected in quantitative sampling from the Elk River site were:

Ephemeroptera	56.6 percent
Trichoptera	23.3 percent
Diptera	11.7 percent

Despite physical evidence of siltation and enrichment at this site, the cause for the relatively low proportions of tolerant organisms in quantitative samples is uncertain. High stream gradient at this site limits sediment deposition in the riffle habitat where quantitative samples were taken, thus preserving a relatively healthy macroinvertebrate community in this habitat. Quantitative samples in pools or eddies might have provided a more complete assessment of impairment.

CONCLUSIONS

Biomonitoring results from sites on the Middle Fork Holston, upper South Fork Holston, Watauga, and Elk Rivers revealed that each of these streams was impaired by some level of environmental degradation (table 12). Stream quality perturbation was indicated by impairment of fish and macroinvertebrate communities and by visual observation of physical habitat.

Fish and macroinvertebrate fauna at the Middle Fork Holston River site reflected significant levels of degradation. The fish community received an index of biotic integrity of 42 and a classification of "fair." Moderate losses were seen in species richness and composition, and disturbances occurred in trophic structure and fish condition. Similar impairments were found in the macroinvertebrate community which appeared to be more affected than other macroinvertebrate communities sampled during this survey. The taxa (40) and pollution-sensitive EPT taxa (16) both rated a classification as "fair" (moderate impairment). The number of EPT taxa was the lowest found at the four survey sites. Percentage of tolerant organisms in quantitative samples was abnormally high (44.4 percent composition by dipteran midge larvae, chironomids)--the highest percentage found in this study. Additionally, flat worms, another tolerant taxa not used in rating analysis, occurred in abnormally high density. Heavy deposits of silt and organic sediments observed in the river at this site may account for much of the impairment of the fauna.

The South Fork Holston River site supported the healthiest fish community of the four sample sites. Minimal losses in fish species and

limited disorder in trophic structure and fish condition resulted in an index of biotic integrity of 52 and a classification as "good." However, the macroinvertebrate community showed signs of impairment to the benthic community. The taxa (43) rated a classification as "fair" (moderate impairment), but the pollution-sensitive EPT (23) was one class higher and ranked a classification as "good" (slight impairment). The high percentages of chironomids and oligochaets in quantitative samples indicated some degree of impairment. There was no visible evidence of heavy siltation in pools or eddies at this site, suggesting that enrichment may be the cause for increased proportions of tolerant macroinvertebrates. Apparently, these conditions are not severe enough to affect the colonization of pollution sensitive EPT at this site.

Sampling at the Watauga River site produced mixed results. The fish community at this site rated an index of biotic integrity of 40 and a classification as "fair." Losses occurred in species richness and composition, and disturbances were reported in reproduction of simple lithophilic spawners, trophic structure, fish abundance, and fish condition. In the macroinvertebrate community, the taxa (47) was rated a classification as "fair" (moderate impairment), but the pollution intolerant EPT taxa (27) was rated a classification as "excellent" (no impairment). The low percentages of tolerant organisms in quantitative samples indicated only slight impairment. This disparity between fish and macroinvertebrate communities may indicate the macroinvertebrates had greater tolerance to periodic pollution episodes or greater resiliency. There was no increase in omnivorous fish or visible evidence in the stream to suggest siltation or enrichment as problems at this site.

Sampling at Elk River mile 15.4 revealed considerable degradation in the fish and macroinvertebrate community, comparable to that found in the Middle Fork Holston River. Index of biotic integrity sampling in the Elk River produced an index of 40 and a classification of "fair." Serious problems were found in trophic structure, and moderate disorders were seen in species richness, species composition, reproduction of simple lithophilic spawners, and fish abundance. The macroinvertebrate community also reflected severe disturbances in numbers of total taxa and EPT taxa. The total taxa (35) was rated a classification as "poor" (severe impairment), and the total EPT taxa (20) was rated a classifcation as "good" (slight impairment). The number of taxa at the Elk River site was the lowest among the four sites sampled, and the "good" EPT rating for this site was only one taxa higher than a "fair" classification. Numbers of tolerant organisms were not especially high, although heavy deposits of sand and silt were observed in pools and eddies. Because of the high stream gradient at this site, the macroinvertebrate habitat in riffle areas was probably saved by the cleansing action of increased flow.

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TABLES

Table 1. Metrics Used in Calculating Index of Biotic Integrity[a]

Metric	Description
1	Number of native species
2	Number of darter species
3	Number of sunfish species (excluding *Micropterus* sp.)
4	Number of sucker species
5	Number of intolerant species
6	Proportion of individuals as tolerant species
7	Proportion of individuals as omnivores
8	Proportion of individuals as specialized insectivorous minnows and darters
9	Proportion of individuals as piscivores
10	Catch rate (average number/unit sampling effort)
11	Proportion of individuals as hybrids
12	Proportion of individuals with disease, tumors, fin damage, and other anomalies

a. Each is assigned a score as follows: 1-poor, 3-intermediate, 5-the best to be expected. The index of biotic integrity for a given site is the sum of those values.

Table 2. Biotic Integrity Classes Used in Assessing Fish Communities Along with General Descriptions of Their Attributes[a]

Class	Attributes	Index of biotic integrity range
Excellent	Comparable to the best situations without influence of man; all regionally expected species for the habitat and stream size, including the most intolerant forms, are present with full array of age and sex classes; balanced trophic structure.	58-60
Good	Species richness somewhat below expectation, especially due to loss of most intolerant forms; some species with less than optimal abundances or size distribution; trophic structure shows some signs of stress.	48-52
Fair	Signs of additional deterioration include fewer intolerant forms, more skewed trophic structure (e.g., increasing frequency of omnivores); older age classes of top predators may be rare.	39-44
Poor	Dominated by omnivores, pollution-tolerant forms, and habitat generalists; few top carnivores; growth rates and condition factors commonly depressed; hybrids and diseased fish often present.	28-35
Very Poor	Few fish present, mostly introduced or tolerant forms; hybrids common; disease, parasites, fin damage, and other anomalies regular.	12-22
No fish	Repetitive sampling fails to turn up any fish.	

a. Karr et al., 1986

Table 3. Native Fish Species Expected to Occur Under Unimpacted Conditions at Index of Biotic Integrity Sampling Sites on the Middle Fork Holston, South Fork Holston, Watauga, and Elk Rivers

Scientific name	Common name	Fd Gld[a]	Tol /Int[b]	Br Gld[c]	Sampling site: Middle Fork mile 11.5	South Fork mile 75.5	Watauga River mile 62.0	Elk River mile 15.4
Dorosoma cepedianum	Gizzard shad	Om	Tol		X	X		
Salvelinus fontinalis	Brook trout	Ps	Int					X[d]
Campostoma anomalum	Central stoneroller	Hb			X	X	X	X
Hybopsis amblops	Bigeye chub	Sp		S	X	X		
H. dissimilis	Streamline chub	Sp	Int	S	X			
H. insignis	Blotched chub	Om		S	X	X		
H. monacha	Spotfin chub	Sp			X			
Nocomis micropogon	River chub	Om	Tol		X	X	X	X[d]
Notropis ariommus	Popeye shiner	Sp	Int	S	X			
N. chrysocephalus	Striped shiner	Om	Tol	S	X	X		
N. coccogenis	Warpaint shiner	Sp		S	X	X	X	X[d]
N. galacturus	Whitetail shiner	In			X	X	X	X
N. leuciodus	Tennessee shiner	Sp		S	X	X	X	
N. photogenis	Silver shiner	Sp		S	X	X	X	
N. rubellus	Rosyface shiner	Sp		S	X[d]			
N. spectrunculus	Mirror shiner			S		X[d]	X[d]	X[d]
N. spilopterus	Spotfin shiner	In	Tol		X	X		
N. telescopus	Telescope shiner	Sp	Int	S	X	X	X[d]	
N. sp. cf. N. spectrunculus	Undescribed shiner	Sp		S	X			
Phenacobius crassilabrum	Fatlips minnow	Sp		S		X	X[d]	
P. uranops	Stargazing minnow	Sp		S	X			
Pimephales notatus	Bluntnose minnow	Om			X	X		
Rhinichthys atratulus	Blacknose dace	Sp		S				X
R. cataractae	Longnose dace	Sp		S		X	X[d]	
Semotilus atromaculatus	Creek chub	In						X
Carpiodes cyprinus	Quillback carpsucker	Om			X	X		
Catostomus commersoni	White sucker	Om	Tol	S	X	X	X	X

Table 3 (Continued)

Scientific name	Common name	Fd Gld[a]	Tol /Int[b]	Br Gld[c]	Sampling site: Middle Fork mile 11.5	South Fork mile 75.5	Watauga River mile 62.0	Elk River mile 15.4
Hypentelium nigricans	Northern hog sucker	In	Int	S	X	X	X	X
Moxostoma carinatum	River redhorse	In		S	X	X		
M. duquesnei	Black redhorse	In		S	X	X	X	
M. erythrurum	Golden redhorse	In		S	X	X		
M. macrolepidotum	Shorthead redhorse	In		S	X	X		
Ictalurus natalis	Yellow bullhead	Om	Tol		X	X[d]		
I. punctatus	Channel catfish	Om			X	X		
Noturus eleuthurus	Mountain madtom	Sp	Int		X[d]			
Pylodictis olivaris	Flathead catfish	Ps			X	X		
Ambloplites rupestris	Rock bass	Ps			X	X	X	X
Lepomis gulosus	Warmouth	Ps				X		
L. macrochirus	Bluegill	In			X	X		
L. megalotis	Longear sunfish	In			X	X[d]		
Micropterus dolomieui	Smallmouth bass	Ps			X	X	X	
M. salmoides	Largemouth bass	Ps			X	X		
Pomoxis nigromaculatus	Black crappie	Ps			X			
Etheostoma acuticeps	Sharphead darter	Sp		S		X		
E. blennioides	Greenside darter	Sp		S	X	X	X[d]	
E. camurum	Bluebreast darter	Sp	Int	S	X[d]			
E. chlorobranchium	Greenfin darter	Sp		S			X	
E. maculatum	Spotted darter	Sp			X	X		
E. rufilineatum	Redline darter	Sp		S	X	X		
E. swannanoa	Swannanoa darter	Sp		S		X	X	
E. simoterum	Tennessee snubnose darter	Sp		S	X	X		
E. zonale	Banded darter	Sp		S	X	X		
Etheostoma sp.[e]	Darter sp.			S				X

Table 3 (Continued)

Scientific name	Common name	Fd Gld[a]	Tol /Int[b]	Br Gld[c]	Sampling site: Middle Fork mile 11.5	South Fork mile 75.5	Watauga River mile 62.0	Elk River mile 15.4
Percina aurantiaca	Tangerine darter	Sp		S	X[d]	X	X	
P. evides	Gilt darter	Sp	Int	S	X[d]	X	X	
P. caprodes	Logperch	Sp		S	X	X		
Cottus bairdi	Mottled sculpin	Sp				X	X	X
Cottus carolinae	Banded sculpin	Sp			X	X		
Maximum species richness					46	44	21	12

a. Feeding guild: herbivore-Hb, insectivore-In, omnivore-Om, piscivore-Ps, specialized insectivore-Sp
b. Tolerance: tolerant-Tol, intolerant-Int
c. Breeding guild: simple lithophils-S
d. No collection records known for site; expected occurrence based on habitat present and proximity of range.
e. Either Etheostoma caeruleum, E. chlorobranchium, or E. flabellare expected to occur; no collection records found for site.

Table 4. Ratings for Levels of Impairment on Macroinvertebrate Communities

Level of impairment	Total taxa[a]	EPT taxa[a]	Percentage chironomids[b]	Percentage oligochaets[b]
None	>67	>27	<5	<5
Slight	53-67	19-26	5-10	5-10
Moderate	35-52	14-18	10-30	10-20
Severe	<35	<14	>30	>20

a. Based on Saylor et al., 1988, and Barr et al., 1986.
b. Based on Shackleford, 1987.

Table 5. Findings from Water Quality Measurements Taken at Index of Biotic Integrity and Macroinvertebrate Sampling Sites on the Middle Fork Holston, South Fork Holston, Watauga, and Elk Rivers

Parameter	Sampling site			
	Middle Fork mile 11.5	South Fork mile 75.5	Watauga River mile 62.0	Elk River mile 15.4
Temperature, °C	18.10	9.80	12.90	14.80
pH, s.u.	7.30	7.20	6.88	6.66
Conductivity, µmhos/cm	291.00	91.00	63.00	54.00
Dissolved oxygen, mg/l	9.30	9.10	10.00	8.60

Table 6. Fish Collected from Index of Biotic Integrity Sampling Sites on the Middle Fork Holston, South Fork Holston, Watauga, and Elk Rivers

Scientific name	Common name	Sampling sites: Middle Fork mile 11.5	South Fork mile 75.5	Watauga River mile 62.0	Elk River mile 15.4
Dorosoma cepedianum	Gizzard shad	10	0	0	0
Salmo gairdneri[a]	Rainbow trout	0	0	0	2
S. trutta[a]	Brown trout	0	1	0	0
Esox lucius[a]	Northern pike	1	0	0	0
Campostoma anomalum	Central stoneroller	165	110	6	50
Cyprinus carpio[a]	Common carp	34	16	2	0
Hybopsis amblops	Bigeye chub	17	8	0	0
H. dissimilis	Streamline chub	26	0	0	0
Nocomis micropogon	River chub	4	23	32	0
Notropis chrysocephalus	Striped shiner	165	1	0	0
N. coccogenis	Warpaint shiner	4	7	12	0
N. galacturus	Whitetail shiner	608	0	11	217
N. leuciodus	Tennessee shiner	0	1	17	0
N. photogenis	Silver shiner	50	2	0	0
N. spilopterus	Spotfin shiner	29	1	0	0
N. telescopus	Telescope shiner	23	28	0	0
Phenacobius crassilabrum	Fatlips minnow	0	24	0	0
P. uranops	Stargazing minnow	16	0	0	0
Pimephales notatus[a]	Bluntnose minnow	145	0	0	30
P. promelas[a]	Fathead minnow	2	1	0	0
Rhinichthys atratulus[b]	Blacknose dace	5	0	0	32
R. cataractae	Longnose dace	0	8	0	0
Semotilus atromaculatus	Creek chub	1	0	0	2
Carpiodes cyprinus	Quillback carpsucker	19	1	0	0
Catostomus commersoni	White sucker	0	0	0	19
Hypentelium nigricans	Northern hog sucker	28	12	16	37
Moxostoma carinatum	River redhorse	6	1	0	0
M. duquesnei	Black redhorse	11	21	61	0
M. erythrurum	Golden redhorse	28	9	0	0
M. macrolepidotum	Shorthead redhorse	3	3	0	0

Table 6 (Continued)

Scientific name	Common name	Sampling sites: Middle Fork mile 11.5	South Fork mile 75.5	Watauga River mile 62.0	Elk River mile 15.4
Ictalurus sp.	unidentified bullhead	0	0	1	0
I. natalis	Yellow bullhead	1	0	0	0
I. punctatus	Channel catfish	9	1	0	0
Noturus insignis[a]	Margined madtom	0	0	114	0
Ambloplites rupestris	Rock bass	4	12	51	4
Lepomis auritus[a]	Redbreast sunfish	63	0	31	0
L. gibbosus[a]	Pumpkinseed	20	2	0	0
L. gulosus	Warmouth	0	1	0	0
L. macrochirus	Bluegill	28	21	0	0
Micropterus dolomieui	Smallmouth bass	11	15	6	0
M. salmoides	Largemouth bass	3	3	0	0
Etheostoma acuticeps	Sharphead darter	0	2	0	0
E. blennioides	Greenside darter	109	19	0	0
E. chlorobranchium	Greenfin darter	0	0	16	0
E. maculatum	Spotted darter	1	40	0	0
E. rufilineatum	Redline darter	159	92	0	0
E. simoterum	Tennessee snubnose darter	13	7	0	0
E. zonale	Banded darter	68	11	0	0
Percina aurantiaca	Tangerine darter	0	0	1	0
P. caprodes	Logperch	4	7	0	0
Cottus carolinae	Banded sculpin	4	20	0	0
Cottus sp.	Undescribed sculpin	0	42	0	1

a. Introduced species
b. Species probably immigrated from tributary

Table 7. Index of Biotic Integrity Analysis for Middle Fork Holston River Mile 11.5, April 27-28, 1988

Metric	Description	Scoring	Scoring criteria 1	3	5	Observed	Maximum expected
1	Total number of native fish species	5	<15	15-30	>30	32	47
2	Number of darter species	3	<3	3- 6	>6	6	9
3	Number of sunfish species, less Micropterus	3	<2	2	>2	2	4
4	Number of sucker species	5	<3	3- 4	>4	6	7
5	Number of intolerant species	3	<3	3- 4	>4	3	7
6	Proportion of individuals as tolerant species	3	>20%	20-10	<10%	44.9%	
7	Proportion of individuals as omnivores	3	>30%	30-15	<15%	20.5%	
8	Proportion of individuals as specialized insectivores	3	<25%	25-50	>50%	26.1%	
9	Proportion of individuals as piscivores	1	<2%	2- 5	>5%	1.0%	
10	Catch rate (average No. of individuals per seine haul or five minutes of boat shocking)	5	<8	8-16	>16	39.5	
11	Proportion of individuals as hybrids	5	>1%	1-Tr[a]	0	0.0%	
12	Proportion of individuals with disease, tumors, fin damage, and other anomalies	3	>5%	5- 2	<2%	2.1%	
	Index of Biotic Integrity Value	42					

a. Tr = value <1.0 but >0.0

Table 8. Benthic Macroinvertebrate Taxa Collected at Four Index of Biotic Integrity Sampling Sites on the Middle Fork Holston, South Fork Holston, Watauga, and Elk Rivers

Taxa	Taxa at sample site, mean number/ft^2			
	Middle Fork mile 11.5	South Fork mile 75.5	Watauga River mile 62.0	Elk River mile 15.4
TURBELLARIA				
Planariidae	18.75		0.75	
NEMATODA	0.25			
OLIGOCHAETA	6.25	7.25	Q[a]	Q
CRUSTACEA				
Isopoda				
Asellidae				
Asellus sp.		0.25		
Decapoda				
Astacidae				
Cambarus sp.	0.75	Q	Q	Q
Orconectes sp.	Q	Q		
INSECTA				
Plecoptera				
Nemouridae				
Amphinemura sp.			1.00	
Pteronarcyidae				
Pteronarcys sp.				Q
Perlodidae				
Isoperla sp.		0.50	1.00	
Cultus sp.				0.25
Chloroperlidae				
Alloperla sp.	0.50		0.50	0.75
Perlidae				
Acroneuria sp.		0.75	Q	0.50
Paragnetina sp.		Q		
Perlesta sp.			0.25	
Perlinella sp.	1.00			
Phasganophora sp.	0.25			
Ephemeroptera				0.25
Baetidae			0.25	
Baetis sp.		3.25	5.75	
Pseudocloeon sp.		0.75	0.50	1.25
Heptageniidae	0.25		0.50	
Epeorus sp		1.50		3.00
Heptagenia sp.		0.75	0.25	
Rhithrogena sp.				0.50
Stenacron sp.	1.00	0.75		
Stenonema sp.	2.00	11.25	2.00	1.25

Table 8 (Continued)

Taxa	Taxa at sample site, mean number/ft^2			
	Middle Fork mile 11.5	South Fork mile 75.5	Watauga River mile 62.0	Elk River mile 15.4
Oligoneuriidae				
Isonychia sp.	0.25	1.50	2.00	Q
Siphloneuridae				
Siphlonurus sp.	Q	0.75		
Ephemeridae				
Ephemera sp.	0.25	0.25		
Hexagenia sp.				Q
Potamanthidae				
Potamanthus sp.	4.00	0.25	0.25	
Ephemerellidae				
Drunella sp.		0.25		
Ephemerella sp.	46.50	35.50	32.00	37.50
Neoephemeridae				
Neoephemera sp.				Q
Odonata				
Aeshnidae				
Boyeria sp.	Q	Q	0.25	Q
Gomphidae		0.25		
Hagenius brevistylus			0.25	
Gomphus sp.				Q
Ophiogomphus sp.				0.25
Macromiidae				
Macromia sp.	Q			
Calopterygidae				
Calopteryx sp.	Q			
Coenagrionidae				
Argia sp.		0.25	Q	
Enallagma sp.			0.25	
Megaloptera				
Corydalidae				
Corydalus sp.	0.75	0.50	0.50	Q
Nigronia sp.		Q	0.25	0.25
Trichoptera		1.75	0.75	0.25
Hydropsychidae	1.75	Q	8.75	4.75
Cheumatopsyche sp.	10.50	0.75	16.00	1.25
Hydropsyche sp.	9.00	1.00	12.00	11.25
Macronema sp.			7.25	
Polycentropodidae				
Cyrnellus fraternus			0.25	
Neureclipsis sp.		1.50	1.25	0.25
Glossosomatidae				
Glossosoma sp.	2.50		1.50	

Table 8 (Continued)

Taxa	Taxa at sample site, mean number/ft^2			
	Middle Fork mile 11.5	South Fork mile 75.5	Watauga River mile 62.0	Elk River mile 15.4
Hydroptilidae			Q	
Rhyacophilidae				
Rhyacophila sp.			0.50	
Brachycentridae	0.25			
Brachycentrus sp.			0.25	
Micrasema sp.		Q	0.50	0.25
Lepidostomatidae				
Lepidostoma sp.		0.25	0.50	
Limnephilidae				
Pycnopsyche sp.		Q		Q
Lepidoptera				
Pyralidae	0.25			
Coleoptera				
Gyrinidae				
Dineutus sp.			Q	
Hydrophilidae				
Berosus sp.	0.75			
Psephenidae				
Psephenus herricki	33.25	4.75	0.25	2.25
Dryopidae			3.00	Q
Elmidae	0.25		1.75	
Optioservus sp.	1.00		0.50	
Stenelmis sp.	19.25	3.75		
Diptera				
Tipulidae				
Antocha sp.	0.75	0.50	1.75	1.75
Eriocera sp.	1.25			
Pilaria sp.		0.25		
Tipula sp.	Q	Q	0.50	Q
Tandyderidae				
Protoplasa fitchii		0.25		
Blephariceridae				
Blepharicera sp.			0.25	
Chironomidae	148.50	50.50	9.00	7.00
Simuliidae	6.50	0.50	15.25	0.25
GASTROPODA				
Pleuroceridae				
Elimia sp.		0.25	28.00	1.75
Lymnaeidae				
Lymnaea sp	0.25			
Physidae				
Physella sp.	0.25			

Table 8 (Continued)

Taxa	Taxa at sample site, mean number/ft^2			
	Middle Fork mile 11.5	South Fork mile 75.5	Watauga River mile 62.0	Elk River mile 15.4
Ancylidae				
Ferrissia sp.	7.75	0.25		0.50
PELECYPODA				
Corbiculidae				
Corbicula fluminea	7.75	0.25		
Mean number of taxa per square foot	334.50	133.00	158.25	77.25
Number of taxa	40	43	47	35
Number of EPT taxa	16	23	27	20

a. Qualitative sample; occurrence of taxa noted.

Table 9. Index of Biotic Integrity Analysis for South Fork Holston River Mile 75.5, April 28-29, 1988

Metric	Description	Scoring	Scoring criteria 1	3	5	Observed	Maximum expected
1	Total number of native fish species	5	<14	14-27	>27	31	44
2	Number of darter species	5	<4	4- 6	>6	7	10
3	Number of sunfish species, less Micropterus	3	<2	2	>2	2	3
4	Number of sucker species	5	<3	3- 4	>4	6	7
5	Number of intolerant species	3	<2	2	>2	2	3
6	Proportion of individuals as tolerant species	5	>20%	20-10	<10%	7.2%	
7	Proportion of individuals as omnivores	5	>30%	30-15	<15%	7.5%	
8	Proportion of individuals as specialized insectivores	3	<25%	25-50	>50%	44.7%	
9	Proportion of individuals as piscivores	5	<2%	2- 5	>5%	5.4%	
10	Catch rate (average No. of individuals per seine haul or five minutes of boat shocking)	5	<7	7-13	>13	18.0	
11	Proportion of individuals as hybrids	5	>1%	1-Tr[a]	0	0.0%	
12	Proportion of individuals with disease, tumors, fin damage, and other anomalies	3	>5%	5- 2	<2%	2.4%	
	Index of Biotic Integrity Value	52					

a. Tr = Value <1.0 but >0.0

Table 10. Index of Biotic Integrity Analysis for Watauga River Mile 62.0, May 4, 1988

Metric	Description	Scoring	Scoring criteria 1	3	5	Observed	Maximum expected
1	Total number of native fish species	3	<7	7-13	>13	11	21
2	Number of darter species	3	<2	2	>2	2	4
3	Proportion of simple lithophils	3	<20%	20-39	>39%	32.6%	
4	Number of sucker species	3	<2	2	>2	2	3
5	Number of intolerant species	3	<0	1	>2	1	2
6	Proportion of individuals as tolerant species	5	>20%	20-10	<10%	7.3%	
7	Proportion of individuals as omnivores	5	>30%	30-15	<15%	9.3%	
8	Proportion of individuals as specialized insectivores	1	<25%	25-50	>50%	12.2%	
9	Proportion of individuals as piscivores	5	<2%	2- 5	>5%	15.1%	
10	Catch rate (average No. of individuals per seine haul or five minutes of boat shocking)	3	<7	7-13	>13	9.9	
11	Proportion of individuals as hybrids	5	>1%	1-Tr[a]	0	0.0%	
12	Proportion of individuals with disease, tumors, fin damage, and other anomalies	1	>5%	5- 2	<2%	9.0%	
	Index of Biotic Integrity Value	40					

a. Tr = Value <1.0 but >0.0

Table 11. Index of Biotic Integrity Analysis for Elk River Mile 15.4, May 3, 1988

Metric	Description	Scoring	Scoring criteria 1	3	5	Observed	Maximum expected
1	Total number of native fish species	3	<4	4- 8	>8	8	13
2	Number of darter species	3	<0	1	>1	1	2
3	Proportion of simple lithophils	3	<20%	21-39	>39%	22.4%	
4	Number of sucker species	5	<0	1	>1	2	2
5	Number of intolerant species	3	<0	1	>1	1	2
6	Proportion of individuals as tolerant species	5	>20%	20-10	<10%	5.4%	
7	Proportion of individuals as omnivores	3	>30%	30-10	<10%	15.3%	
8	Proportion of individuals as specialized insectivores	1	<25%	25-50	>50%	8.2%	
9	Proportion of individuals as piscivores	1	<2%	2- 5	>5%	1.3%	
10	Catch rate (average No. of individuals per seine haul or five minutes of boat shocking)	3	<7	7-13	>13	11.5	
11	Proportion of individuals as hybrids	5	>1%	i-Tr[a]	0	0.0%	
12	Proportion of individuals with disease, tumors, fin damage, and other anomalies	5	>5%	5- 2	<2%	1.3%	
	Index of Biotic Integrity Value	40					

a. Tr = Value <1.0 but >0.0

Table 12. Index of Biotic Integrity Scores and Indices for Sampling Sites on the Middle Fork Holston, South Fork Holston, Watauga, and Elk Rivers, 1988

Metric	Description	Sampling sites			
		Middle Fork Mile 11.5	South Fork mile 75.5	Watauga River mile 62.0	Elk River mile 15.4
1	Total number of native fish species	5	5	3	3
2	Number of darter species or number of darter and Cottus species	3	5	3	3
3	Number of sunfish species, less Micropterus, or proportion of simple lithophils	3	3	3	3
4	Number of sucker species	5	5	3	5
5	Number of intolerant species	3	3	3	3
6	Proportion of individuals as tolerant species	3	5	5	5
7	Proportion of individuals as omnivores	3	5	5	3
8	Proportion of individuals as specialized insectivores	3	3	1	1
9	Proportion of individuals as piscivores	1	5	5	1
10	Catch rate (average No. of individuals per seine haul or five minutes of boat shocking)	5	5	3	3
11	Proportion of individuals as hybrids	5	5	5	5
12	Proportion of individuals with disease, tumors, fin damage, and other anomalies	3	3	1	5
	Index of Biotic Integrity Value	42	52	40	40

FIGURES

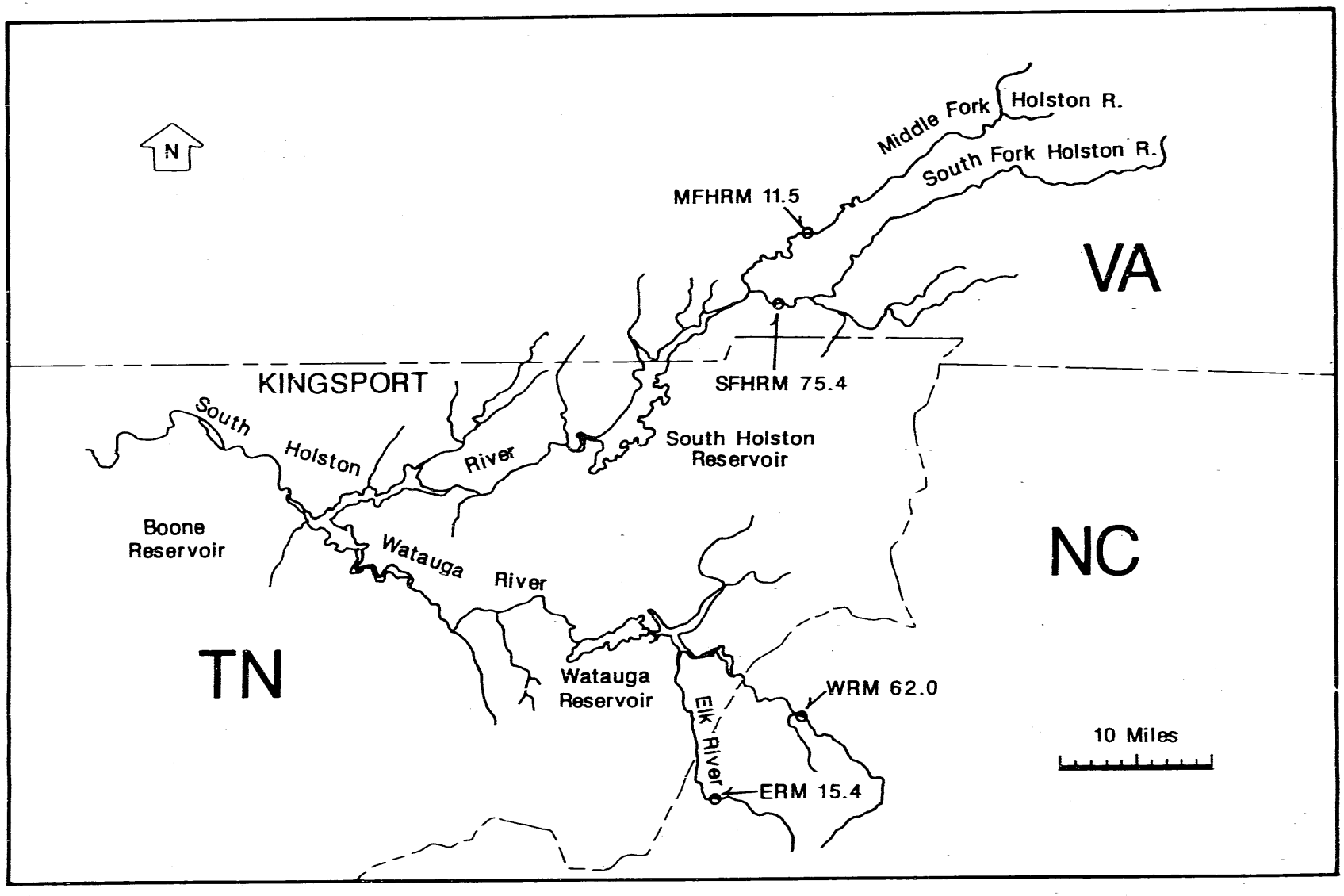

Figure 1. Four IBI and macroinvertebrate sampling sites in the South Fork Holston River Basin, North Carolina and Virginia

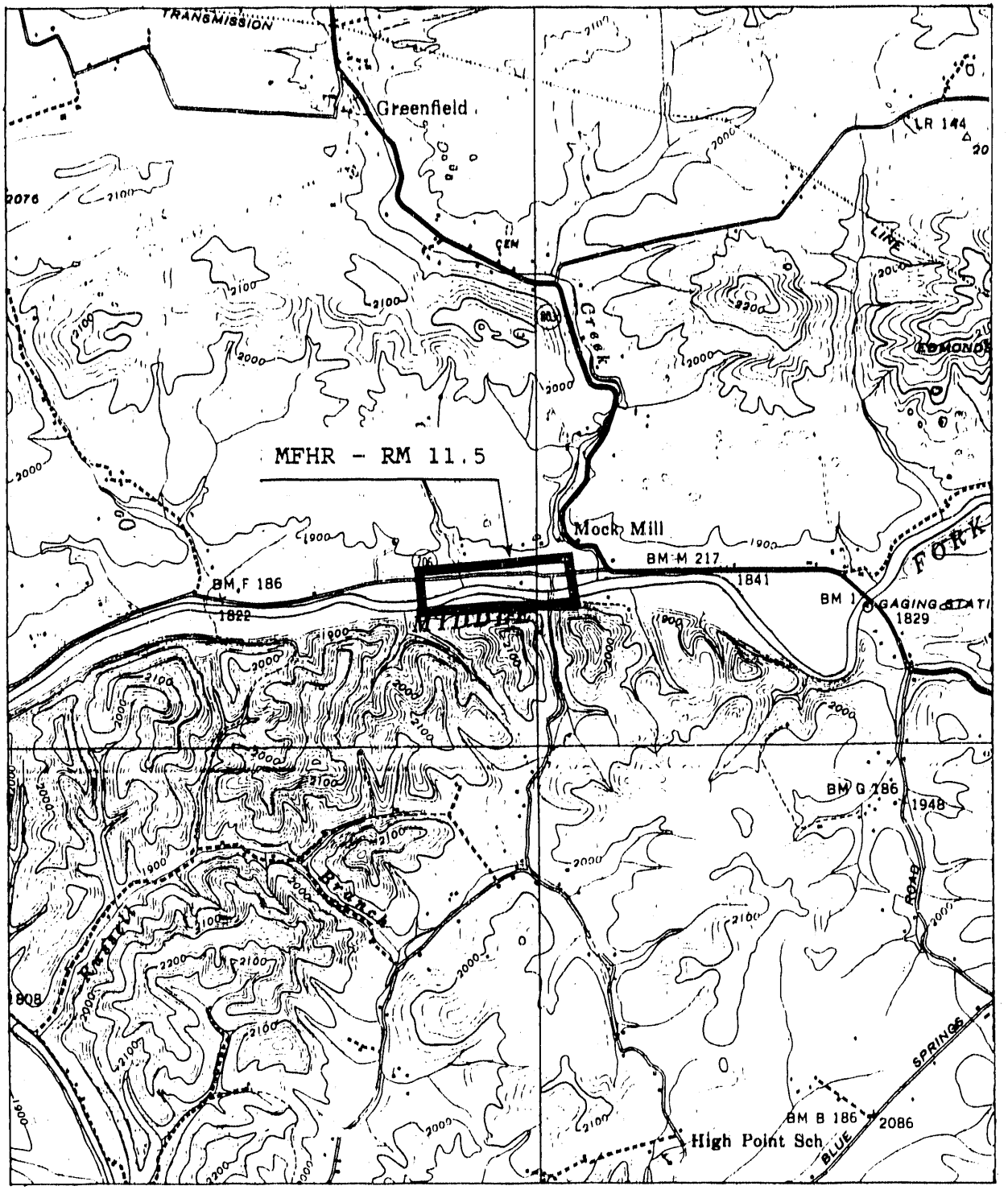

Figure 2. Map of IBI and benthic sampling site on the Middle Fork Holston River (USGS 7.5 minute topographic map, Damascus 213 NE).

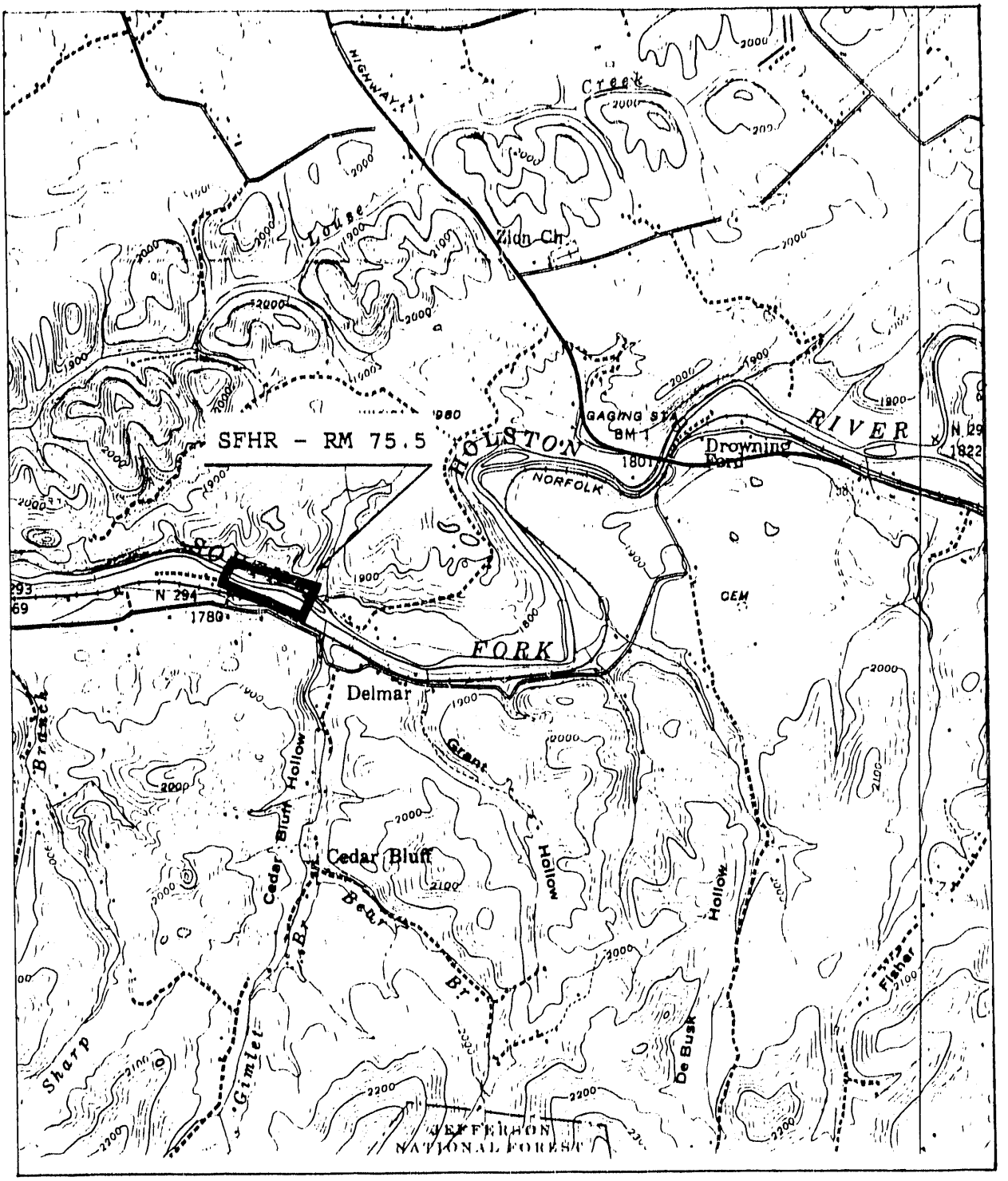

Figure 3. Map of IBI and benthic sampling site on the South Fork Holston River (USGS 7.5 minute topographic map, Damascus 213 NE).

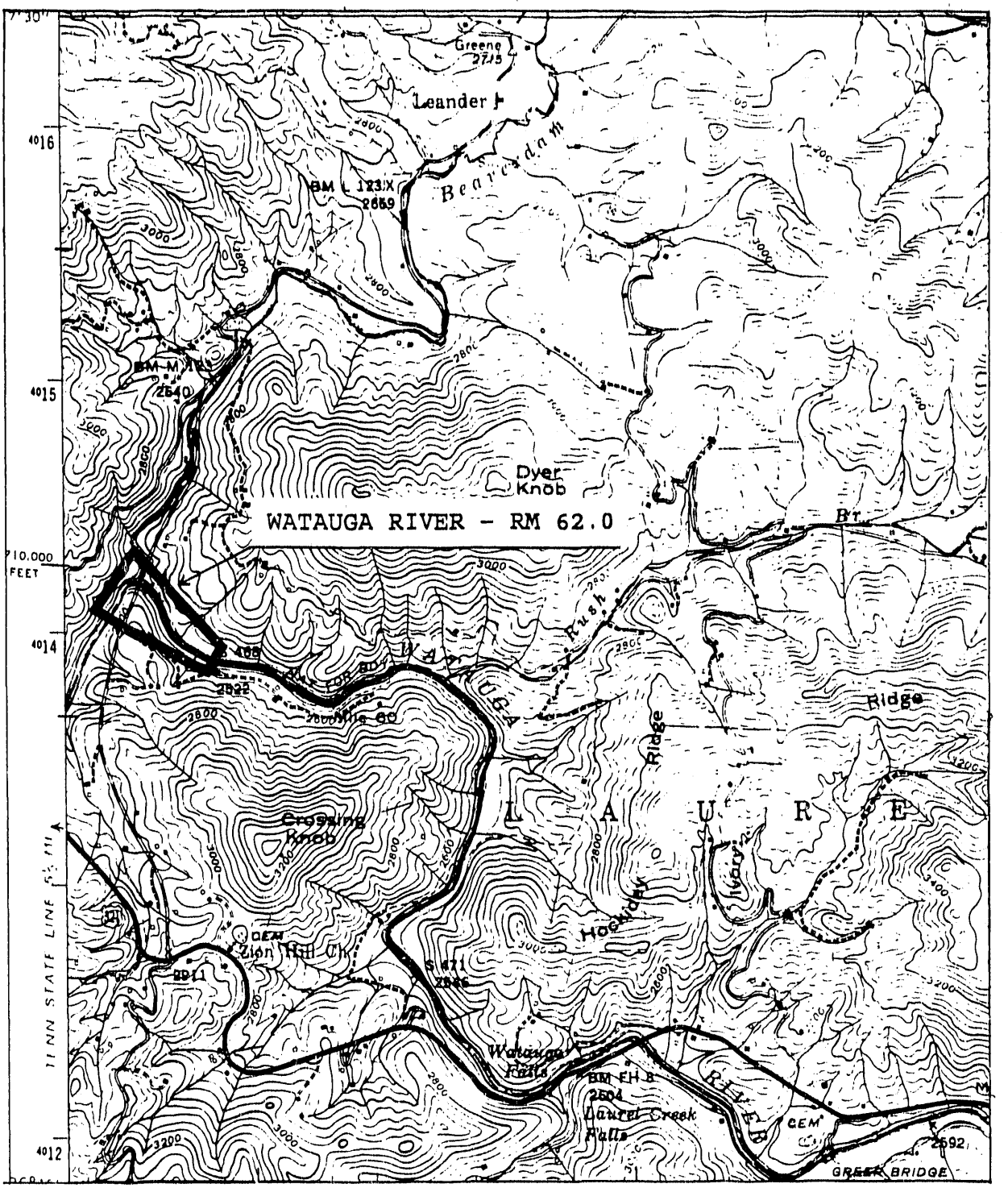

Figure 4. Map of IBI and benthic sampling site on the Watauga River (USGS 7.5 minute topographic map, Sherwood 214 SE).

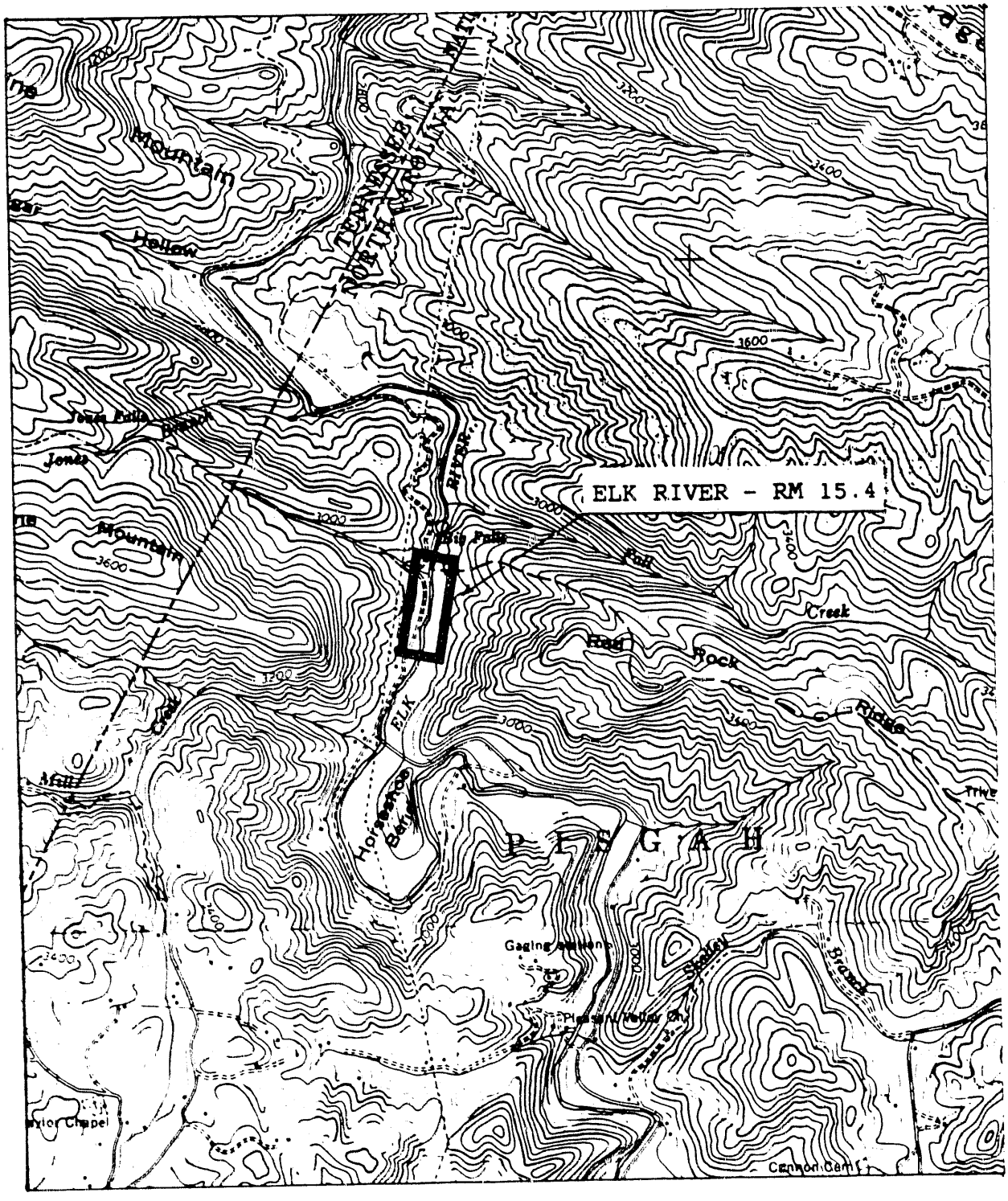

Figure 5. Map of IBI and benthic sampling site on the Elk River (USGS 7.5 minute topographic map, Elk Park 215 NW).

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