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Assessment of Stream Habitat and the Fish Community in Stony Creek in and near the Glen Alton Tract, Giles County, Virginia

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Instructor
T. J. Newcomb, Ph.D.

Participants
M. R. Anderson, J. L. Boyles, A. Braccia, S. Burm, A. K. Graves, A. K. Hunter, J. M. Kilpatrick, T. Lenger, B. C. Lockard, J. W. Persinger, J. M. Rash, J. H. Roberts, Y. Shen, D. M. Sianez, T. L. Smith, D. K. Spraker, A. C. Walker, C. C. Williams, and L. A. Williams

Community Partners
U.S. Forest Service: D. Kirk, J. Overcash
Virginia Department of Game and Inland Fisheries: M. Pinder

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Preface

This document contains baseline information regarding the fishery resources, instream habitat, and riparian conditions found in Stony Creek above and within the Glen Alton Tract in the Washington-Jefferson National Forest in Giles County, Virginia. Students in the graduate course, Stream Habitat Assessment and Management, conducted the work and a symposium was held in December 2001 to present their findings.

Additionally, the symposium featured invited keynote speakers:

- Jesse Overcash (U.S. Forest Service) spoke on the Glen Alton Tract, past and present,
- Dawn Kirk (U.S. Forest Service) gave a presentation on USFS restoration projects occurring in the Washington-Jefferson National Forests,
- Mike Pinder (Virginia Department of Game and Inland Fisheries) gave a presentation (complete with video) on the candy darter (*Etheostoma osburni*), a species of special concern in Stony Creek, and
- Mike Fisher (Natural Resource Conservation Service) gave a very practical and greatly appreciated overview of applied stream restoration principles and techniques

We extend our thanks and appreciation to these individuals for taking the time to participate in this event.

A diverse audience attended the symposium with over 50 people attending, including undergraduates, graduate students, and faculty from several departments. Additionally, we were joined by several personnel from the Virginia Department of Game and Inland Fisheries.

Acknowledgements

I thank the Camp Yount Foundation for providing funding and support for the field work, symposium, and publication of these proceedings. The Service Learning Program at Virginia Polytechnic Institute and State University provided guidance and a platform for making this work possible. Special thanks go to Marcy Anderson for the initial report compilation and editing. Finally, my sincerest appreciation is extended to Mike Pinder and Dawn Kirk for making this collaborative learning venture possible, productive, and fun.

T. J. Newcomb

Virginia Tech Department of Fisheries and Wildlife Sciences

Service Learning Center at Virginia Tech

Abstract

In August 2001, Virginia Tech graduate students enrolled in FIW 5814, Stream Habitat Management and Assessment, embarked upon a semester-long service learning project with the U.S. Forest Service (USFS) and the Virginia Department of Game and Inland Fisheries (VDGIF). Students focused on Stony Creek in Giles County on and near the recently acquired (USFS) Glen Alton Tract. Students conducted surveys of the fish community at 2 sites in each of three reaches (upstream control, middle impacted, downstream recovery/impacted), measured water quality parameters, assessed riparian condition, and evaluated instream habitat for fish. We found that while over 95% of the watershed was forested, large deforested areas occurred in the 600 m and 60 m riparian corridor in the middle and lower reaches. Water quality parameters were all within acceptable limits with dissolved oxygen > 8 ppm and pH values that ranged from 6.4 to 7.6. Instream habitat was compromised at downstream locations by large amounts of sediment and a lack of habitat diversity. Stream temperature was found to vary greatly between upstream and downstream locations. The month of July exhibited the largest difference between upstream and downstream with a mean monthly difference of 2.3°C. Furthermore, mean monthly maximum temperatures approached 20°C in the middle reach and were often above this temperature in the downstream reach on a daily basis. During April through October 2001, water temperatures rose above 20°C (DEQ water quality standard for wild trout stream) only once in the upper reach, 46 days in the middle reach, and 77 days in the downstream reach. Seventeen species of fish representing 6 families were found in the 6 Stony Creek sites. In general, large declines in abundance were noted for most all species between 2000 and 2001. The most abundant species at sites 1-4 (downstream and middle) were mountain redbelly dace *Phoxinus oreas*, rosyside dace *Clinostomus funduloides*, central stoneroller *Campostoma anomalum*, creek chub *Semotilus atromaculatus*, and bluehead chub *Nocomis leptocephalus*. A single candy darter *Etheostoma osburni* was found in the most downstream site in 2000, but not in 2001. At sites 5 and 6 (upstream), mottled sculpin *Cottus bairdi* and fantail darter *Etheostoma flabellare* were most abundant and these sites were the only sites where brown trout *Salmo trutta* were present in abundance and sites 5 and 6 were the only locations where we found brook trout *Salvelinus fontinalis* and rainbow trout *Oncorhynchus mykiss*. Several management options were evaluated for the future, and the class recommended two different management approaches. Both recommendations include restoring GAT to its pre-agricultural condition, with the focus on habitat restoration. Habitat restoration, whether nature dictated or initiated from managers, is key for enhancement of the fish community. The primary management activities that we recommend aim to enhance both riparian and instream habitat.

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Overview of Stony Creek and the Glen Alton Tract

The Glen Alton Tract (GAT), located in Giles County Virginia, is a 123 ha (304 acre) property surrounded by the Washington-Jefferson National Forest. The property includes an 81 ha (200 acre) bottomland farm, numerous wetlands and forested areas. Approximately 2.4 km of Stony Creek meanders between the property boundaries. Prior to the U.S. Forest Service (USFS) purchasing GAT in 1999, cattle had unrestricted access to the stream throughout the riparian areas. Large riparian sections of Stony Creek in this area are deforested, and the tree stands present along the stream possess very little understory vegetation.

Since its acquisition, suggestions for use of the property have ranged from little development to large concession, intensive land use. Proposals for the stream in particular range from development into a special regulation trout stream to a traditional put-and-take fishery. Because of past land use activities and the current state of the stream and its streambanks, the USFS has proposed and received funding for stream restoration activities. However, before implementing instream activities, both USFS and the Virginia Department of Game and Inland Fisheries (VDGIF) desired to obtain more information on the fish community, instream habitat, and stream channel conditions in Stony Creek. Unfortunately, limited funding precluded the agencies from conducting this work, but it posed a tremendous opportunity for a long-term service learning (SL) project for students of streams.

Service Learning

Practical skill experiences in college courses are often limited to individual techniques in a weekly module format and many times field experiences are limited. However, college students responding to surveys about effective teaching state that the most important experiences in their learning were those that involved hands-on activities. In implementing the SL approach in the sciences, instructors must thoughtfully organize activities to provide effective SL experiences that meet actual community needs while simultaneously integrating those experiences into the academic curriculum. Service learning is different from volunteerism or community service where the primary beneficiary is the community or organization and the learning component is usually minimized (e.g. picking up trash along a stream for a municipality). Internships focus on integrating the student into a working environment, where learning may occur, but the experience is usually one of employer and employee (e.g. internships with Disney®). Field education provides hands on experience, but the product is usually one that reflects assessment of classroom learning rather than producing a product for the community. Service learning unites teaching, learning, and community service in a mutually beneficial approach.

In FIW 5814, Stream Habitat Assessment and Management, we used the SL approach to benefit our community partners (VDGIF and USFS) by collecting and analyzing baseline information on which to make future decisions regarding GAT. The activity was integrated into the classroom with weekly discussions focused on the GAT project and field activities were reflective of material covered in class lecture. Multiple trips to the site allowed the class to focus on methods for fish collection and sampling in one week followed by instream habitat assessment the next. A final public symposium and this report integrated the learned material, and they are tangible products of this SL effort. Student reflections on the activities, professional skills acquired, and the effect that this

experience will have on their future involvement in aquatic resources represent the intangible benefits of this experience.

Study Objectives

The objectives of our study were to 1) quantify and describe physical (riparian zones, watershed land use, instream habitat, water quality) and biological properties (fish community) of Stony Creek in and above the GAT, and 2) propose stream habitat and fishery management alternatives for the GAT section of Stony Creek.

Methods

Based on physical properties and riparian conditions, 3 distinct sections of stream were identified on Stony Creek and labeled reach A, B, and C (Figure 1). Reach C, identified as the "control" or no-impact reach, is upstream but immediately adjacent to the GAT. Reach C is characterized by a forested riparian with substantial canopy cover and stable banks. Reach B travels through open canopy and pastureland where cattle had previously used the stream as a water source. Reach A, the most downstream reach, has a moderately forested riparian area that is more open than Reach C but possesses relatively well preserved riparian zones. In this assessment, we include results of the previous fish survey (Pinder 2000) to add support to our findings and conclusions regarding management alternatives.

Watershed Land Use/Cover Type Classification

Watershed boundaries were delineated from the most recent Digital Elevation Model (DEM) available from the U.S. Geological Survey's National Elevation Dataset (http://edcnts12.cr.usgs.gov/ned/). The DEM contours were smoothed in Arc/INFO using 2 passes with a low-frequency filter. Watersheds were delineated from reach boundaries in ArcView 3.2 using a script, wshed_point.ave (Schmidt 2000), available from the ESRI ArcScripts website (http://gis.esri.com/arcscripts/index.cfm). Land use/cover type proportions were quantified using land cover data from interpretations of 1990s satellite imagery, which have a pixel resolution of 30 square meters (Scott Klopfer, VT Conservation Management Institute, personal communication; Virginia Gap Analysis Project VAGAP, http://fwie.fw.vt.edu/WWW/vagap/frames.html). Land cover in riparian zones was quantified in ArcView 3.2 using the Spatial Analyst extension. For each reach, riparian land cover was quantified in the 600 m and 60 m corridors (300 m and 30 m respectively on each side of the stream).

Riparian Assessment

Riparian areas for each reach were assessed using a point and plot method. Parallel transects were established 30 m from the bank on both sides of the stream and divided into blocks 30 m wide. At each 30 m location, basal area was measured with a 10-factor prism and recorded as trees per acre (converted to trees per hectare TPHA), and dominant species were recorded. Canopy cover was measured for each bank at corresponding 30 m intervals. Canopy cover was also measured in the center of the stream directly over the delineated channel units. Mean TPHA numbers were calculated and reported for each reach.

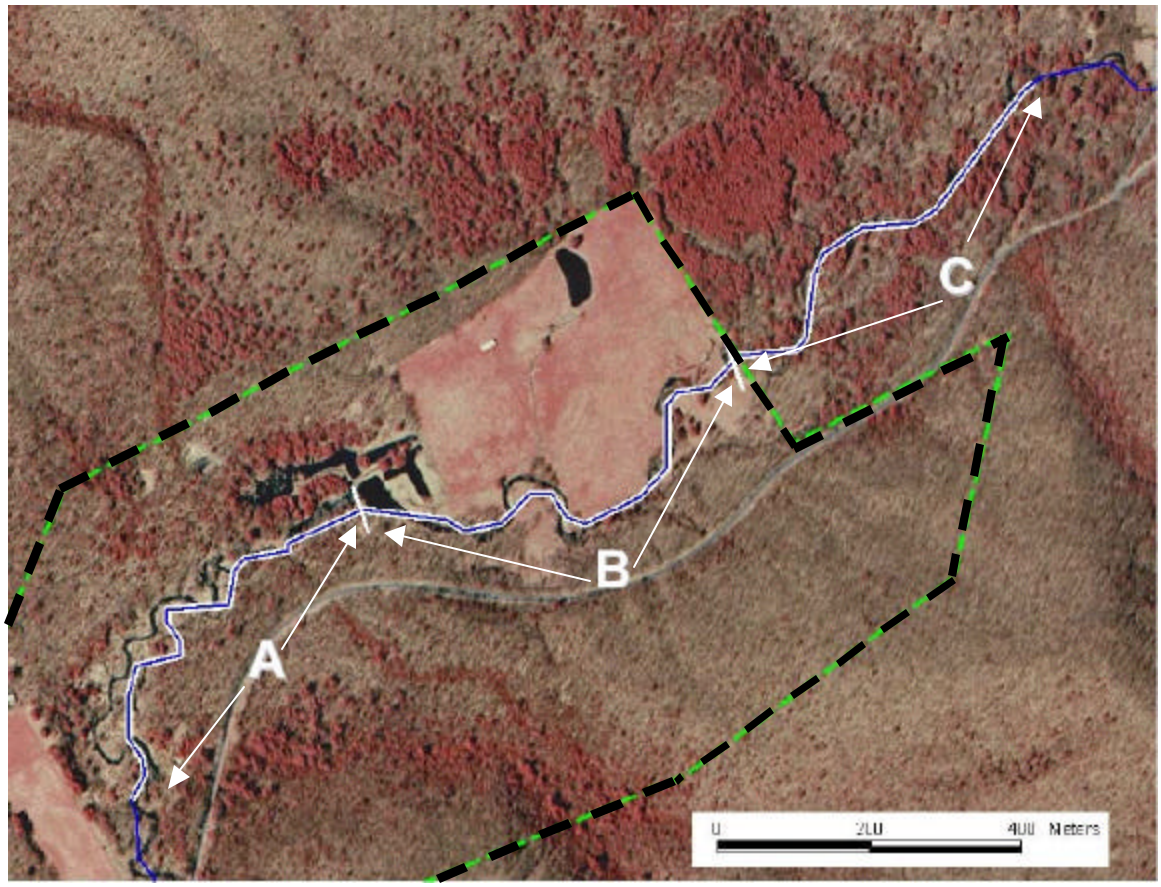

Figure 1. Infra-red aerial photo of the Glen Alton Tract (boundary shown by the dashed lines) and the 3 study reaches on Stony Creek. Aerial photo from 1997; obtained from the Virginia Economic Development Partnership website (http://gis.vedp.org).

For each 30 x 30 m block of riparian area, percent woody stems and percent ground cover were estimated. Woody stems included herbaceous cover 1 m or taller and percent ground cover included herbaceous cover < 1 m and leaf litter. Ground cover was recorded as the total percentage of soil covered in each block and then sub-classified into two categories, the percent covered by large woody debris (LWD) and percent covered by regeneration of tree species. Dominant herbaceous cover for each block was identified and recorded as well.

Water Quality

Water quality parameters were measured at the top and bottom of each reach resulting in 4 water samples from Stony Creek. Conductivity, pH, and total dissolved solids were measured using Orion® field meters, and dissolved oxygen was measured with a YSI® (Model 95) meter. Hardness, turbidity, phosphate, and ammonia-nitrogen were all measured with LaMotte® field kits. Results were compared with standards for stream water quality (DEQ 1997).

Stream Temperature

Water temperature was recorded at 15-minute intervals by StowAway Tidbit Temperature Loggers (Onset Computer Corporation, Bourne, MA) from April through October, 2001. Temperature loggers were located at downstream locations of all reaches. Downloaded temperature data was summarized into daily mean and maximum temperatures and compared between reaches. Temperature data (°C) was converted to an absolute Kelvin scale and a coefficient of variation (CV) was calculated to capture diel variability between reaches.

Stream Habitat

Stream habitat was assessed in all 6 sites. Each site was delineated into riffle, run, and pool habitat units from which a pool:riffle ratio was determined. Each habitat unit was measured for length, width, and wetted width, and a width-to-depth ratio was determined for each reach. For characterization of microhabitat variables such as depth, velocity, substrate and cover, each habitat unit was divided into 4 quadrants (upper left, upper right, lower left, and lower right). Dominant and subdominant substrate (Table 1) and embeddedness (Table 2) were visually classified. The percent occurrence of each category was calculated for each site. Cover types (Table 3) were classified for each quadrant in each habitat type.

Discharge was measured at 4 locations (top and bottom of each reach) using a pygmy flow meter and wading rod. Locations for discharge measurement had flowing water bank to bank. Each transect for measurement was divided into evenly spaced cells, with a minimum of 10 cells per transect. Depth was recorded at each cell, and velocity was measured at 60% of the depth. Stream depth, width, and velocity for each cell were multiplied together to obtain a cell discharge, and all cell discharges were summed for a total stream discharge at each transect.

Table 1. Substrate categories used to determine dominant and subdominant substrates in Stony Creek, Virginia, during fall 2001.

Substrate description	Size (cm)
Organic detritus	
Vegetation	
Silt	<0.006
Sand	0.006-0.19
Small gravel	0.2-0.8
Medium gravel	0.9-2.5
Large gravel	2.6-5.1
Small cobble	5.2-12.8
Large cobble	12.9-25.6
Small boulder	25.7-51.2
Large boulder	>51.2
Bedrock-flat	
Bedrock-tilted	

Table 2. Description of embeddedness categories used on Stony Creek, Virginia, during fall 2001.

Percent Embeddedness	Description
0-25	Very few fines visible or only present in large pore spaces.
25-50	Fines present, filling large pore spaces with few fines in smaller pore spaces.
50-75	Small particle pore spaces completely filled. Indistinct large particle boundaries.
75-100	Large and small materials nearly submerged in fines. Appears as sand bed with a few big rocks.

Table 3. Cover categories used to classify cover types found in Stony Creek, Virginia, in fall 2001.

Description and function of cover
No cover
Small velocity shelter (13 - 26 cm)
Medium velocity shelter (26 - 51 cm)
Large velocity shelter > 51 cm
Dense cluster of small sticks
Undercut boulder or log that provides overhead cover
Log jam
Root wad
8 -25 cm logs
Weedbed or submerged aquatic vegetation
Bedrock formation

Fish Community Characteristics

Two sites, 100 m each (previously established, Pinder 2000) within the reaches were used to survey the fish community using multiple-pass depletion electrofishing methods. Block nets were placed at the upper and lower ends of the sections to prevent fish movement into and out of the site. Two pulsed DC backpack electrofishers equipped with Honda® 350 generators were used to collect fish by moving simultaneously up each site. All fish collected were identified and counted. All trout, suckers, and other game fish were measured to the nearest mm total length and weighed to the nearest g. All other fish species were weighed in aggregate to determine fish biomass for each site. Population estimates and 95% confidence intervals were calculated for each species using maximum-likelihood population estimates with Microfish 3.0 (Van Deventer and Platts 1983).

Relative weight (W_r; Wege and Anderson 1978) was used to assess condition of brown trout *Salmo trutta* and white sucker *Catostomus commersoni*i in Big Stony Creek. Relative weight of the fish was calculated by the formula:

$$W_r = (W/W_s) \times 100$$

where W is the weight of the individual fish and W_s is the length-specific standard weight of the fish (Wege and Anderson 1978). The standard weight (W_s) equation used for trout was proposed by Milewski and Brown (1994) and is:

$$\log_{10} W_s \text{ (g)} = -4.867 + 2.960 \log_{10} \text{TL}$$

and the W_s equation for white sucker was proposed by Bister et al. (2000) and is:

$$\log_{10} W_s \text{ (g)} = -4.755 + 2.940 \log_{10} \text{TL}$$

where W_s is the standard weight in grams and TL is the total length of the fish in mm.

Statistical analyses on W_r were conducted in SAS Version 8.0 (SAS Institute, Cary, NC). A Kruskal-Wallis test, the nonparametric equivalent of the one-way analysis of variance, was used to test for significant differences in relative weight of brown trout between reaches. A Wilcoxon rank sum test, the nonparametric equivalent of the two-sample *t*-test, was used to test for significant differences in relative weight of brown trout and white sucker between years and for differences in white sucker relative weight between reaches. All statistical analyses were considered significant at á=0.05.

Measures of Stream Biotic Integrity and Assemblage Structure

A modified Index of Biotic Integrity (IBI) was used to assess the ecological condition of the 6 sites where fish were sampled. The metric criteria of Karr et al. (1986) and Leonard and Orth (1986) were used as templates, although several modifications were made to account for stream-size and drainage basin differences between Stony Creek and the Midwestern streams on which the original IBI was developed (Table 4). The following metrics were removed: number and identity of sunfish species, number and identity of sucker species, proportion of individuals as green sunfish *Lepomis cyanellus*, and proportion of individuals as hybrids. The proportion sunfish and sucker metrics were

Table 4. Index of Biotic Integrity (IBI) scoring criteria used in the study on Stony Creek, Virginia, on the Glen Alton Tract in September 2001.

Metric	IBI Score and Scoring Criteria		
	5	3	1
Native Species Richness	> 8	4-8	< 4
# Darter and Sculpin Species	> 2	1-2	0
# Intolerant	> 2	1-2	0
% Tolerant	< 20%	20-50%	> 50%
% Native Invaders	< 12%	12-25%	> 25%
% Omnivores	< 20%	20-45%	> 45%
% Piscivores	> 5%	1-5%	< 1%
% Insectivores	> 50%	25-50%	< 25%
% Simple Lithophilic Spawners	> 50%	25-50%	< 25%
% with Anomalies	< 2%	2-3%	> 3%

removed because of the naturally low diversity of these taxa in the New River drainage (Leonard and Orth 1986). The green sunfish metric was removed because this species would not be expected in a low-order coldwater stream such as Stony Creek. Hybrids were unidentifiable in the field, so that metric was not used. Several metrics were added to compensate for the above losses and included: sculpin were added to the number of darter species metric, and proportion of individuals as tolerant species, proportion of individuals as native invader species, and proportion of individuals as simple lithophilic spawners. Sculpin were added to darters because of their ecological similarity to each other. Proportion tolerant was added to account for an increase in sediment-tolerant individuals following a disturbance. Proportion of native invaders, defined as cosmopolitan species capable of exploiting disturbed stream conditions (Scott and Helfman 2001), was added to reflect similar changes from both temperature and sediment increases. Finally, the proportion of simple lithophilic spawners metric was added to account for loss of such individuals following increased sedimentation.

Population estimates generated from Microfish 3.0 were used for all metrics except proportion with anomalies; in which case we used capture data. Cutoffs were assigned for the species richness metric based on a Maximum Species Richness Line for streams in the New River watershed of Virginia (P. Angermeier, unpublished data). No relationship between proportion native invaders and level of disturbance has been established in this area, so assigned criteria for this metric at levels were those deemed reasonable. Because the original IBI had 12 metrics, and a maximum score of 60, and the current index had only 10 metrics, and a maximum score of 50, we adjusted the overall integrity class criteria to reflect this difference (Table 5).

To assess whether the assemblage structures of our sites were more similar within reaches than between reaches, we calculated the Bray-Curtis similarity coefficient (BC) for every combination of 2 sites (Bray and Curtis 1957). A BC value of 0 represents completely dissimilar assemblages, whereas a BC of 1 represents identical assemblages. We analyzed the results of this test for trends in the magnitude of BC.

Evaluating Management Options

We used a simple thought exercise for the future management of the GAT. Five possible management approaches for GAT were defined and each option was ranked for each of 4 management considerations including: 1) cost, 2) time spent in the approach, 3) risk, and 4) long-term sustainability. Each management option was ranked 1 through 5 with 1 being the “best” or most desirable conditions and 5 the “worst” or least desirable conditions. Scores for each management option were summed and then ranked to determine the best options on the basis of our chosen metrics.

Results

Watershed Land Use

The study area in the Stony Creek watershed drained approximately 25 square km (10 mi^2) upstream of the bottom of reach A. The watershed land cover is composed of approximately 75% upland hardwoods and 25% evergreens and other bottomland hardwoods (Figure 2).

Table 5. Index of Biotic Integrity (IBI) total scores, integrity classes, and the attributes of those classes (modified from Karr 1986).

Total IBI Score (sum of the 10 metric ratings)	Integrity Class	Attributes
47-50	Excellent	Comparable to the best situations without human disturbance.
38-42	Good	Species richness below expectation, due to loss of intolerant forms.
29-33	Fair	Signs of additional impact include skewed trophic structure.
20-25	Poor	Dominated by omnivores, tolerant forms, and habitat generalists.
10-16	Very Poor	Few fish present, mostly introduced or tolerant forms; anomalies regular.

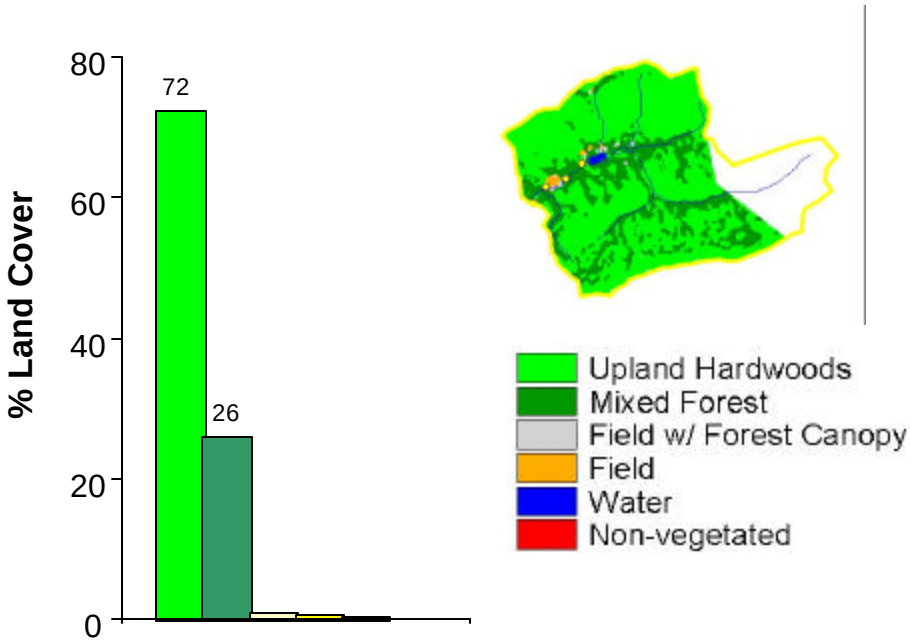

Figure 2. Land cover types associated with the watershed above and including the Stony Creek study area, Glen Alton Tract, Giles County, Virginia. Spatial data derived from Virginia Gap Analysis Project (VT-CMI).

Differences in land cover were found within the riparian corridor relative to the entire watershed. The 600 m corridor in reach A and C were both > 90% forested; however, reach B was only 67% forest with 22% open field (Figure 3). Further inspection of the 60 m corridor shows that 100% of reach C and 98% of reach A as forested, but reach B is only 50% forested at this level (Figure 3).

Riparian Qualities

Reach A: In site 1 the riparian area on the right bank (looking downstream) transitioned from open field, characterized by sparse trees and thick herbaceous cover, to a mixed-oak stand with an open understory. The average height of the stand was 24.3 m with an average diameter at breast height (DBH) of 25.4 cm. The average basal area was 99 TPHA. Species present included white oak *Quercus alba*, Northern red oak *Quercus rubra*, shagbark hickory *Carya ovata*, black cherry *Prunus serotina*, red maple *Acer rubrum*, Eastern hemlock *Tsuga canadensis*, and Eastern white pine *Pinus strobus*. Ground cover was estimated at 90% and included leaf litter, debris, and herbaceous plants. The dominant herbaceous plants were greenbrier *Smilax rotundifloria*, deerberry *Vaccinium caesium*, multiflora rose *Rosa multiflora* and various grasses and ferns. The woody stems averaged 5% and consisted of rhododendrons *Rhododendron maximum* and St. Johnswort *Hypericum* spp. There was an estimated 5% regeneration of Eastern white pine and 5% coverage by LWD at this site. Canopy cover on this bank was estimated at only 15%. Canopy cover measured in the center of the stream averaged 19%. The riparian area on the left bank was also an open, herbaceous area with few trees. The area transitioned into a mixed-oak stand at least 15 m away from the stream, with an average basal area of 148 TPHA. The average height of the stand was 24.4 m with an average DBH of 25.4 cm. Species present included white oak, Northern red oak, shagbark hickory, black cherry, red maple, Eastern hemlock, and Eastern white pine. Ground cover was 100%, consisting of leaf litter, woody debris, regenerating stems, and herbaceous plants and grasses. Estimated regeneration was higher on this bank (20%) and was observed for Eastern white pine and Eastern hemlock. There were fewer woody stems on this bank (1%) which was mostly mountain laurel *Kalmia latifolia*, however, the amount of LWD cover increased to 10%. The left bank canopy cover was 20%.

In site 2 the riparian area on the right bank was open field with a mixed stand outside the delineated riparian corridor. This site had smaller trees with an average tree height of only 15.2 m. The average DBH was 20.3 cm and the basal area was 99 TPHA. Red maple and Eastern hemlock were the only tree species present. The ground was covered (100%) with grasses, herbaceous plants, ferns, greenbrier, and leaf litter. Woody stems were very abundant at this site (70%), most of which was St. Johnswort, with mountain laurel also present. Eastern hemlock comprised the only regeneration present (1%) and there was an abundance of LWD on the ground averaging 45% of the cover. The average canopy cover was 30% on the right bank, and the canopy cover taken from the center of the stream averaged 14%.

The left bank was similar to the right, with open field habitat transitioning into mixed forest. Again, the trees averaged 15 m tall and had an average DBH of 20.3 cm. Basal area was slightly higher at 124 TPHA, but held similar species (red maple and Eastern hemlock). The ground was 100% covered with herbaceous plants, ferns, greenbrier, grasses, multiflora rose, and leaf litter. St. Johnswort dominated the woody stem estimate of 50%, with hemlock comprising the only regeneration present (1% cover). LWD was estimated at 40%, and the average canopy cover was 25% on the left bank.

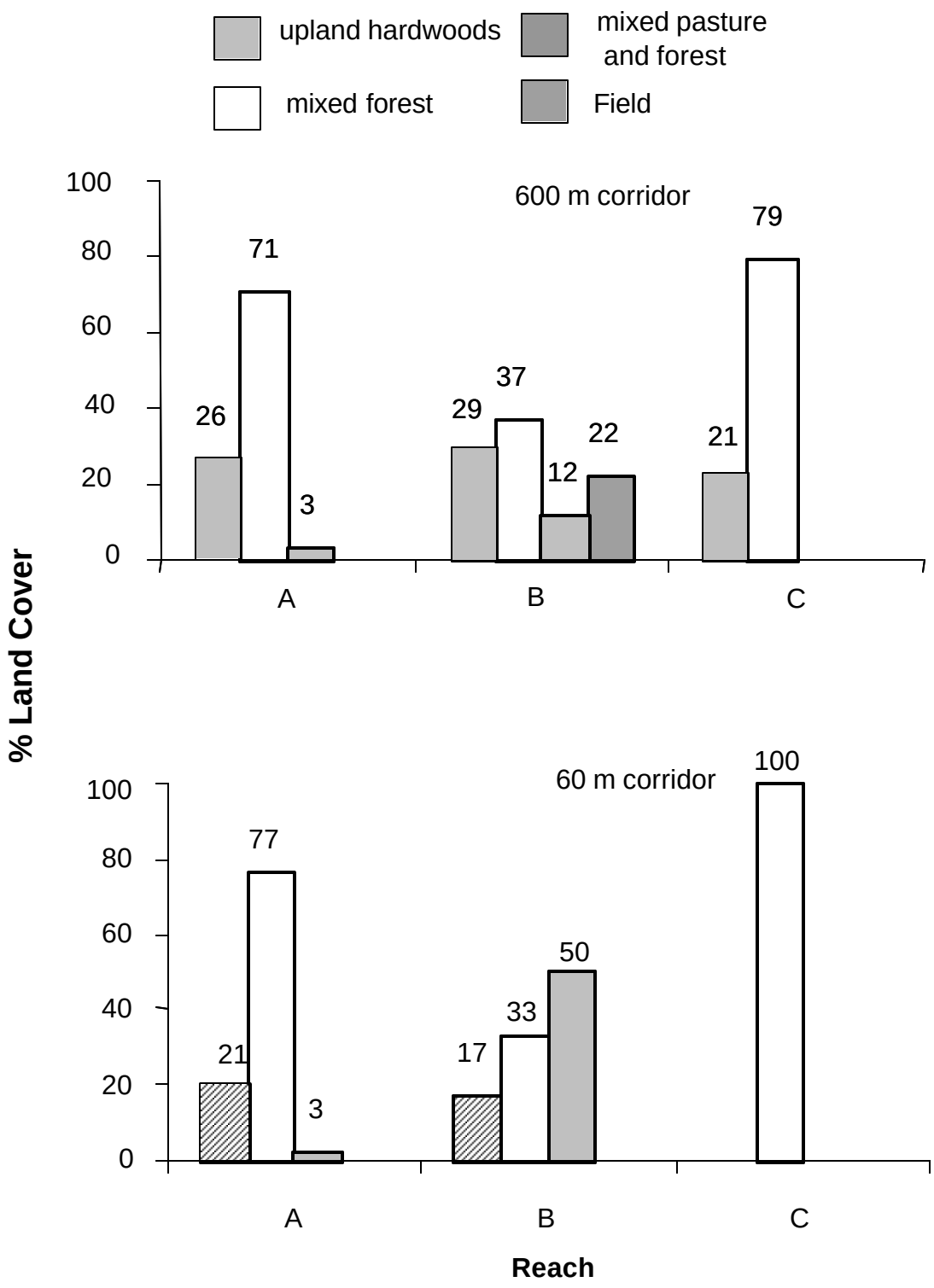

Figure 3. Land cover type classification for the 600 m and 60 m riparian corridor along Stony Creek, Glen Alton Tract, Giles County, Virginia.

Reach B: In Site 3 the right bank was forested with mixed hardwoods with an understory of pasture grass. The average basal area was 210 TPHA; however, this was influenced by the lack of trees near the end of the transect at this site. A portion of the site had only a few wolf trees whereas the forested area had an average basal area of 279 TPHA. The average height was 24.4 m and the average DBH 35.6 cm. The species present included white oak, black oak *Quercus velutina*, shagbark hickory, mockernut hickory *Carya tomentosa*, tulip poplar *Liriodendron tulipifera*, red maple, black cherry, and ironwood *Carpinus caroliniana*. The ground was covered (100%) by grasses and herbs with a layer of fallen leaves overtop. There was no regeneration found within the blocks. The amount of LWD on the ground increased on this side of the stream ranging from 0 to10%. The canopy cover for the bank in the forested section ranged from 40-60% with an average of 50%; the average canopy cover for the entire site was only 26%. The canopy cover for the center of the stream was 25%. The riparian area on the left was a pasture with a few trees directly on the bank and an average basal area of 74 TPHA. The ground was completely covered by pasture grasses except for a small patch showing signs of disturbance and the grasses were approximately 1 m tall except for areas that had been grazed or harvested. The trees consisted mainly of white oak, black oak, a hemlock, a table mountain pine, and an eastern white pine. There was no regeneration present and very little LWD (1%) on the ground. Canopy cover was sparse at 26% and ranged widely from 0 to 80%. The average was similar to that for the center of the stream due to overhanging trees. Some of the trees were beginning to lean into the stream due to bank erosion and some trees had already fallen into the stream.

In site 4 the right bank was different than the mixed hardwood stand found at Site 3. The average basal area was lower, 161 TPHA, but the understory was more pronounced with the presence of rhododendrons about 2.1 m tall. This stand was uneven-aged ranging from small poles to a DBH of 91.4 cm. The species composition was very different with a large component of Eastern hemlock; other species present included black oak, white oak, red maple, Eastern white pine, green ash *Fraxinus pennsylvanica*, black cherry, and tulip poplar. The ground was not covered with grass at this site; instead, the ground cover consisted mostly of needles and leaves from the canopy or moss. Regeneration never reached more than 5 % but was present for hemlock and eastern white pine. There were also a large number of small seedlings and saplings growing on the bank's edge including rhododendron. A significant amount of LWD was present on the ground for site 4 (40%, ranging from 10 to 50%). The canopy cover for the bank ranged from 0-100% with an average of 50%. The center of the stream averaged 29% for canopy cover. The left bank of this site was similar to Site 3 but with fewer trees and less than 2.5 TPHA. The ground was completely covered by pasture grasses. The trees present were white oak, black oak, black cherry, and a red maple. There was no regeneration present, and LWD was only present in one block (20%). The average canopy cover for the bank was very low (16%).

Reach C: In site 5 the right bank riparian area was covered with bottomland hardwoods. On average the trees were 64 m tall and had a DBH of 45.7 cm with a few very large trees (86-91 cm DBH). Basal area was 235 TPHA, and species present included white oak, shagbark hickory, buckeye *Aesculus octandra*, blackgum *Nyssa sylvatica*, musclewood, and Eastern hemlock. The ground cover consisted mainly of leaf litter, woody debris, and herbaceous plants (100%). Various ferns, grasses, greenbrier, and deerberry constituted the herbaceous layer. Regeneration was small (5%) but included a variety of species such as white oak, black cherry, and Eastern hemlock. There were

very few woody stems (3%) consisting of rhododendrons and common spicebush *Lindera benzoin*; the rhododendrons grew mainly along the banks. There was very little LWD, 6%. The right bank average canopy cover was 80%, and the canopy cover measured at the center of the stream averaged 50%. The left bank riparian area was a similar mixed forest stand sharing many of the same characteristics. At this site the stream divided and created a small island. The stand on the island had an average tree height of 25.9 m, DBH of 55.9 cm, and basal area of 272 TPHA. Species present included Northern red oak, yellow birch *Betula lutea*, and Eastern hemlock. The ground was 100% covered with leaf litter, debris, and herbaceous plants, mostly greenbrier and ferns. Woody stems were more abundant (25%), and included rhododendron, mountain laurel, and spicebush. Regeneration consisted of Eastern hemlock (1%), and LWD made up 15% of the cover. Left bank average canopy cover was 65%.

In site 6 the right bank riparian area was a mixed stand with a large Eastern hemlock component. Trees were larger than at many of the other sites; average height was 27.4 m, and average DBH was 50.8 cm with a lower basal area of 173 TPHA. Tree species present included white oak, red maple, and Eastern hemlock, and 0% regeneration was observed. The ground was 85% covered with leaf litter or debris with very few herbaceous plants. Woody stem coverage was 40%, consisting primarily of rhododendron. Cover by LWD was 15%. Canopy cover averaged 35% for the right bank and averaged 67% over the center of the stream. The left bank riparian area was very similar to the right bank in composition. Average height was 27.4 m, average DBH 50.8 cm, and basal area 173 TPHA. Eastern Hemlock was the dominant species on this side. The ground was again mostly covered with leaf litter and debris. Rhododendrons made up the woody stems component (50%) and created a thick mid-story; regeneration was estimated at 3% for Eastern hemlock only. There was 10% coverage by LWD. The left bank average canopy cover was 40%.

Water Quality

Total dissolved solids, conductivity, turbidity, phosphate, and ammonia-nitrogen were consistent among all of the sampling locations (Table 6). Phosphate and nitrogen were low and nondetectable with our methods. Alkalinity and hardness varied widely among the sampling locations (Table 6) and may have been due to sampling errors. Dissolved oxygen levels were similar among the reaches with the highest value found at the farthest upstream sampling location above Reach C (Table 6). Dissolved oxygen levels at each location were adequate for aquatic organisms. The only variable to show a longitudinal trend was pH, which ranged from 7.6 to 6.4 and was lowest at downstream locations; however the reason for the decrease is unknown.

Stream Temperature

Water temperature varied considerably over this very short stream reach. Mean monthly temperatures were consistently the coolest in the upstream reach C and warmest in the downstream reach A (Figure 4). The month of July exhibited the largest difference between upstream and downstream with a mean monthly difference of 2.3°C. Furthermore, mean monthly maximum temperatures approached 20°C (water quality standard for wild trout stream, DEQ 1997) in reach B (Figure 5) and were often above this temperature in reach A on a daily basis. During April through October 2001, water

Table 6. Water quality parameters measured in a single day at sites located in the Glen Alton Tract, Stony Creek, Giles County, Virginia, 20 October 2001.

Measurement	Station			
	1[a]	2[b]	3[c]	4[d]
Alkalinity (ppm)	44	61	28	60
Hardness (ppm)	31	62	10	88
Dissolved Oxygen (mg/L)	10.29	10.40	9.83	10.69
pH	6.4	7.2	7.4	7.6
Total Dissolved Solids (ppm)	30	30	30	30
Conductivity (µs)	70	70	70	70
Turbidity (JTU)	0	0	0	0
Phosphate (ppm)	ND	ND	ND	ND
Ammonia-Nitrogen (ppm)	ND	ND	ND	ND
Temperature (°C)	6.6	7.2	8.0	7.5

[a] Lower boundary of reach A, [b] Between reach A and reach B, [c] Between reach B and reach C, [d] Upper boundary of reach C, and ND = nondetectable

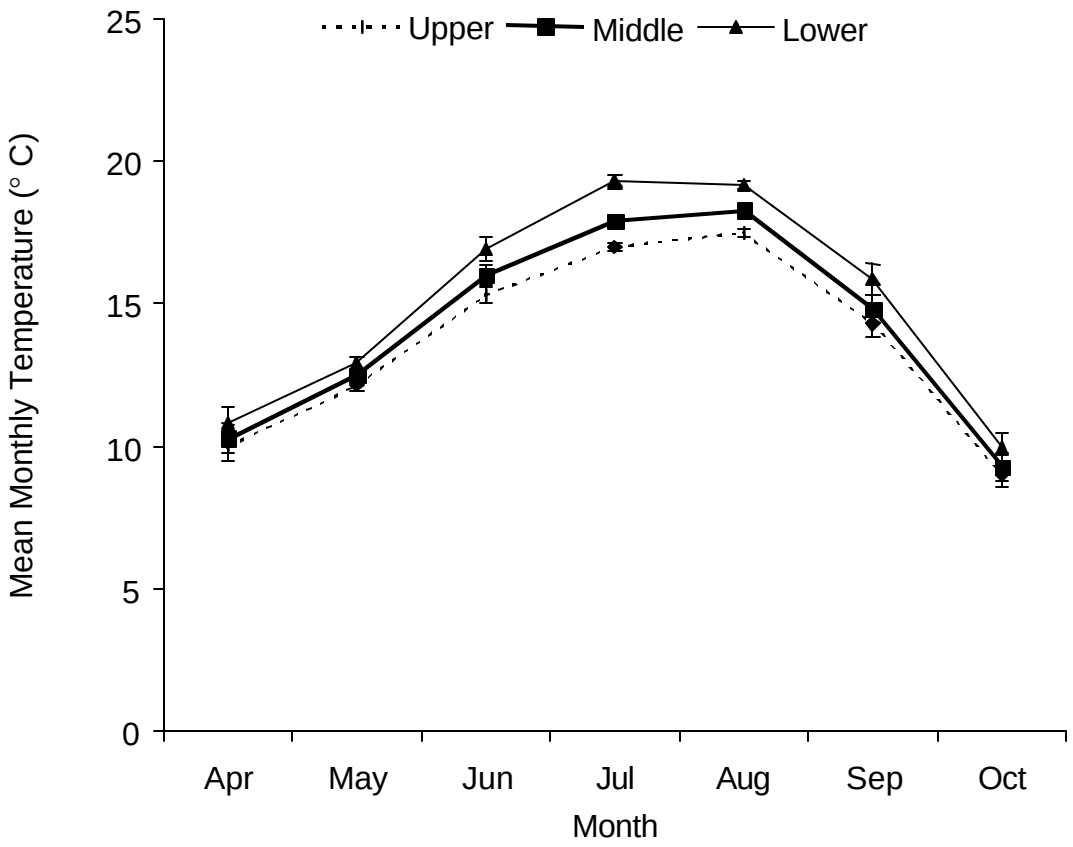

Figure 4. Mean monthly temperature (± 1SE) measured in 2001, reach A (lower), B (middle), and C (upper) in Stony Creek, Glen Alton Tract, Giles County, Virginia.

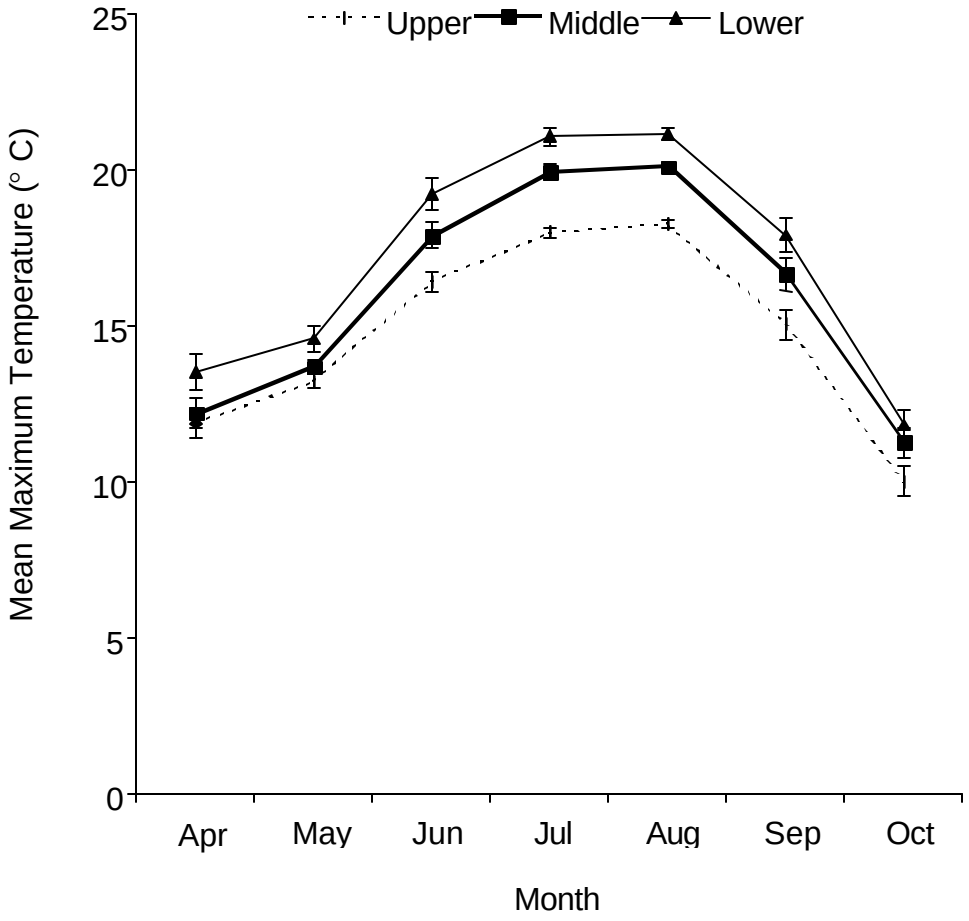

Figure 5. Mean monthly maximum temperature (± 1SE) measured in 2001, reach A (lower), B (middle), and C (upper) in Stony Creek, Glen Alton Tract, Giles County, Virginia.

temperatures rose above 20°C only once in reach C, 46 days in reach B, and 77 days in reach A. The highest measured temperature was in reach A (24°C).

The coefficient of variation (CV) was used to compare differences in daily temperature variation among the reaches. Reach C exhibited the lowest variation with CV values ranging from around 20% during the summer months to 42% during the spring transition. The lower reach A consistently exhibited the greatest amount of variation with valuations ranging from 37% to 58% (Figure 6). Reach B was most similar to upstream reach C early in the summer and then most similar to downstream reach A in late summer, early fall. Inspection of the diurnal temperature patterns in each reach revealed interesting patterns for this temperature variability. Using July 15 as an example of the thermal patterns, Figure 6 illustrates that reach B cools to colder temperatures than reach C in the early morning hours and then warms quickly throughout the day. Although reach A warms to the highest temperatures, Figure 7 illustrates how much quicker reach B warms during the day and cools in the evening.

Stream Habitat

Habitat Units: The composition of habitat units was similar between sites 1 and 2 (Reach A). Runs (42-50%) and pools (34-41%) were the dominant habitat type, and riffles were less dominant (15-16%) (Figure 8). Habitat composition differed between sites 3 and 4 (Reach B). While pool habitat was dominant at both sites (50-70%), riffles were absent at site 4 but present at site 3 and were 24% of the total site length (Figure 8). Sites 5 and 6 (Reach C) were similar, dominated by pool (58% and 48%) and riffle (29-40%) habitat. Overall, reach A was characterized by pools and runs, reach B by pools, and reach C by pools and riffles.

Width-to-depth ratios: Width-to-depth ratios were similar among all sites in 2000, except for site 5 which was noticeably wider. During 2000 ratios ranged between 23.7 and 45.3, and in 2001 ratios ranged from 18.6 to 30.8 (Table 7).

Embeddedness: Embeddedness was greater at downstream sites 1 and 2 than at the upstream sites (5 and 6) (Table 8 and Figure 9). The middle sites (3 and 4) were moderately embedded.

Substrate: Dominant substrate types at the most upstream sites (5 and 6) were small and large cobble, while the middle sites (3 and 4) were dominated by small gravel. The most downstream sites (1 and 2) were dominated by silt and small gravel (Table 8 and Figure 10). Dominant substrate size decreases downstream.

Instream Cover: The amount and type of instream cover measured in 2001 varied greatly between the reaches. In reach A 62% of the habitat cells examined contained cover, while 89% of cells in reach B and 94% of cells in reach C had cover (Figure 11). The types of cover that were most often found in reach A were logs (8.0-25.0 cm) and undercut boulders and logs, which occur in 37% and 32% of the cells respectively (Figure 10). In reach B the most common cover types were small velocity shelters (12.9-25.6 cm), medium velocity shelters (25.7-51.2 cm), and undercut boulders and logs, which occur in 89%, 44%, and 25% of the cells respectively (Figure 11). In reach C the most common cover types were small velocity shelters (12.9-25.6 cm) and undercut boulders and logs that occurred in 62% and 54% of the cells respectively. In addition to differences in the types of cover found in each reach, there were also differences in the

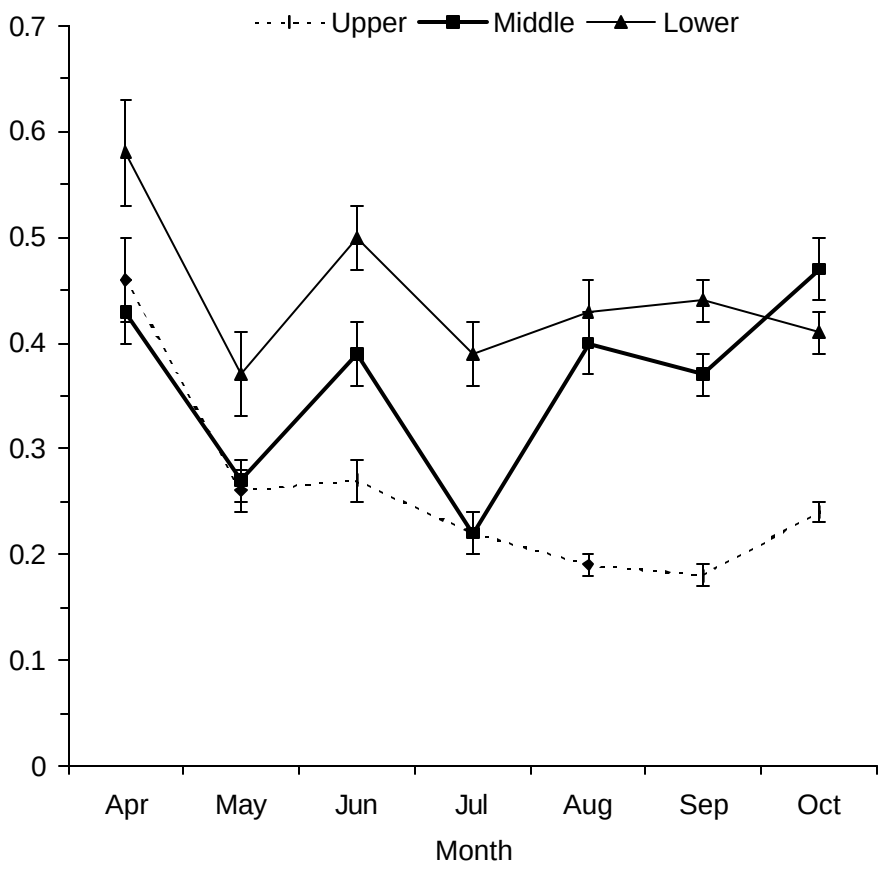

Figure 6. Mean coefficient of variation (± 1SE) for daily stream temperatures measured in 2001, reach A (lower), B (middle), and C (upper) in Stony Creek, Glen Alton Tract, Virginia.

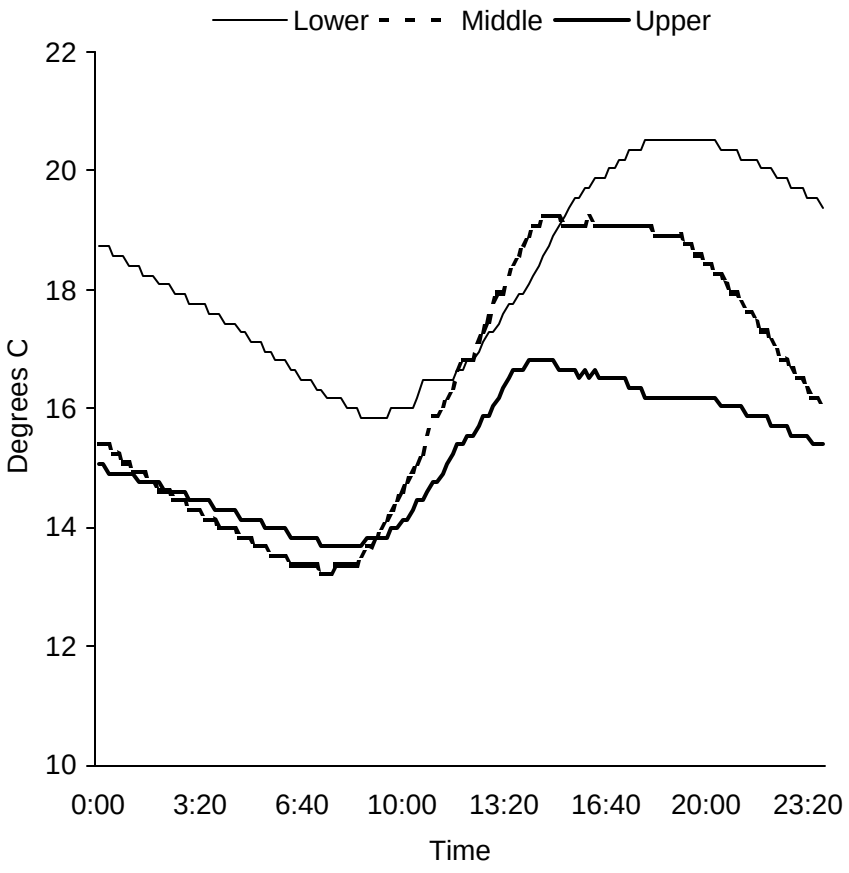

Figure 7. Diurnal temperature patterns exhibited in Stony Creek, Glen Alton Tract Virginia. Temperatures are shown for reach A (lower), B (middle), and C (upper) on 15 July 2001.

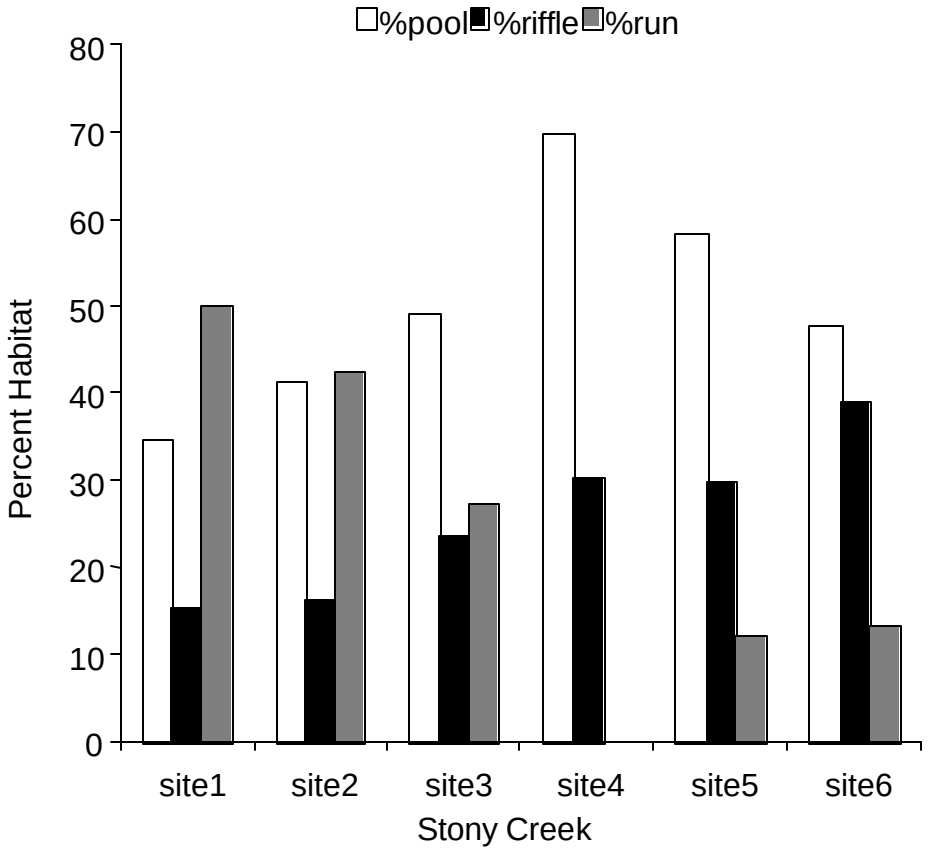

Figure 8. Percent stream habitat unit based on habitat sampling for 2001, in Stony Creek, Glen Alton Tract , Giles County, Virginia.

Table 7. Width to depth ratios from stream habitat sampling for 2000 and 2001 in Stony Creek, Glen Alton Tract, Giles County, Virginia.

Year	Site1	Site 2	Site 3	Site 4	Site 5	Site 6
2000	23.4	26.5	23.7	24.1	45.3	26.2
2001	28.4	28.3	24.5	18.6	28.5	30.8

Table 8. Characteristics of instream habitat measured in Stony Creek at sites in the Glen Alton Tract, Giles County, Virginia, September-October, 2001.

Habitat Attribute	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Length (m)	104	109	105	118	103	94
Pool:Riffle Ratio	2.3:1	2.5:1	2.1:1	2.3:1	2.0:1	1.2:1
Mean Wetted Width (m)	5.1	7.4	5.4	7.1	9.7	9.7
Mean Bankfull Width (m)	12.7	12	14.2	12.1	12.3	11.5
Cover types per habitat unit	1.1	2.8	2.0	4.1	1.7	1.8
Dominant Substrate	small gravel	silt	small gravel	small gravel	small cobble	large cobble
Sub-dominant Substrate	sand	large gravel	medium gravel	medium gravel	large cobble	small cobble
Dominant Embeddedness	25-50%	75-100%	0 - 50%	25 - 75%	50-75%	25-50%

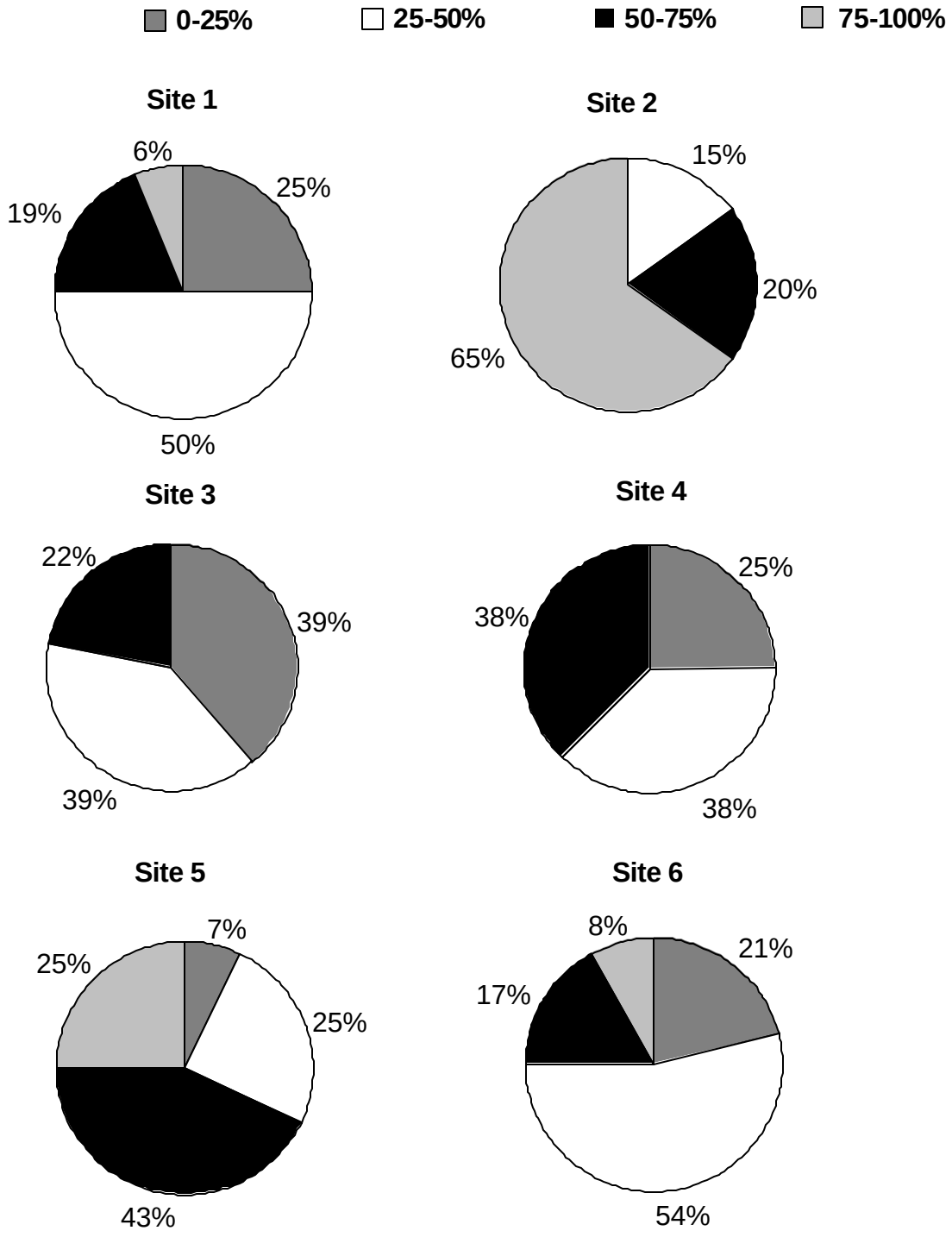

Figure 9. Percent embeddedness of substrate at 6 sites on Stony Creek, Glen Alton Tract, Giles County, Virginia, fall 2001.

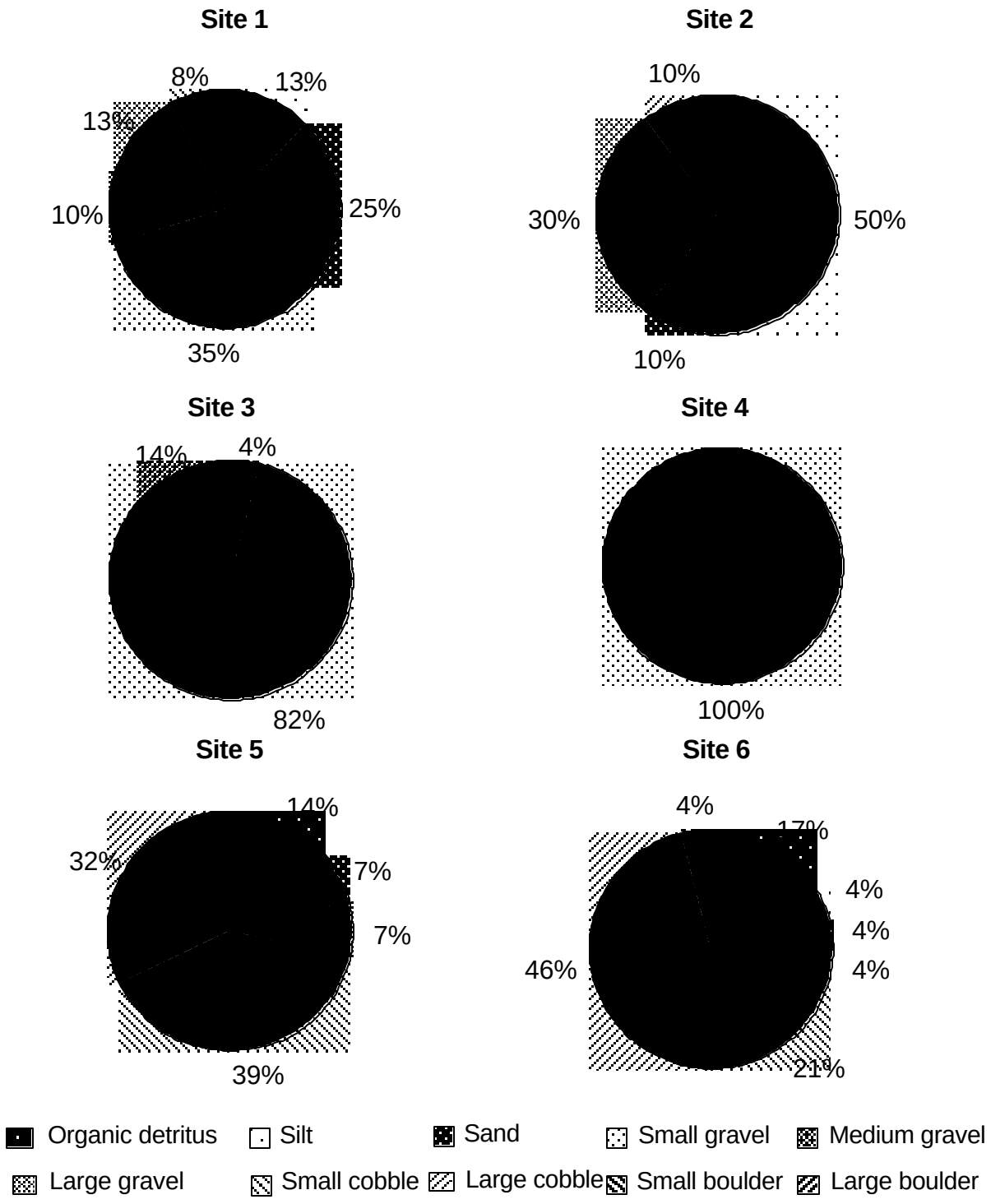

Figure 10. Percent dominant substrate type measured in 6 sites on Stony Creek, Glen Alton Tract, Giles County, Virginia, Fall 2001.

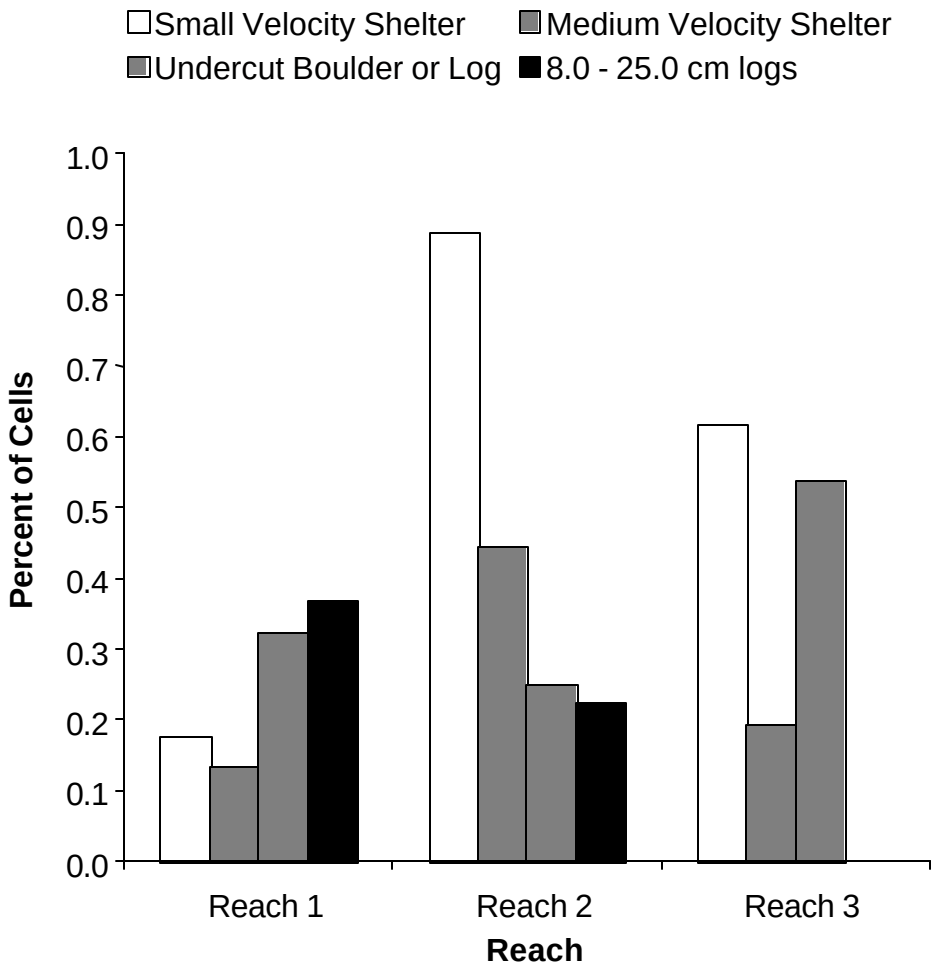

Figure 11. Percent of cells occupied by the 4 most common cover types in each study reach in Stony Creek, Glen Alton Tract, Giles County, Virginia.

diversity of cover in the reaches. Cover diversity varied between the sites in reach A and reach B. In reach A there were 1.1 cover types in each habitat unit in site 1 and 2.8 types at site 2 (Table 8). In reach B there were 2.0 types in site 3 and 4.1 in site 4 (Table 8).

Lateral inflow was low (approximately 0.5 cfs) at this time of year between the top and bottom of the entire study reach. Discharges measured at 4 locations on a single day in October 2001 were 1.87 cfs at the downstream end of reach A, 1.82 cfs at the top of reach A, 1.76 at the top of reach B, and 1.37 at the top of reach C. While discharge was not measured for the fall 2000 fish sampling effort, investigators present for both years estimated that the flow in 2001 was greatly reduced and approximately 25% of the flow present in 2000.

Fish Community Characteristics

Population Estimates: Seventeen species of fish representing 6 families were found in the 6 Stony Creek sites. In general, large declines in abundance were noted for most all species between 2000 and 2001 (Table 9). The most abundant species at sites 1-4 were mountain redbelly dace, rosyside dace, central stonerollers, creek chubs, and bluehead chubs (Table 9). At sites 5 and 6, mottled sculpin and fantail darters were most abundant, and these sites were the only sites where brown trout were present in abundance. Additionally, site 5 was the only site in which we found brook trout (Table 9).

Total fish biomass by site: Total fish biomass showed a decreasing trend between 2000 and 2001 with the exception of Site 3 (Figure 12). Because the number of fish decreased by 2,371 fish between 2000 and 2001 at Site 3, the increase in biomass for the 2001 sample can be attributed to larger fish caught in 2001. Site 1 and Site 2 showed the most drastic decreases in total fish biomass between 2000 and 2001.

Trophic Guilds: The trophic guilds were used to delineate food specializations for fish species sampled in Big Stony Creek (Table 10). The following trophic guilds were identified: DAH (detritivore, algivore, herbivore), AHI (algivore, herbivore, invertivore), INV (invertivore), and IP (invertivore, piscivore). Trophic guilds varied between reaches (Figure 13). Reach A had both the lowest and highest proportion of IP, with the lowest occurring in Site 2 directly below the agricultural land use area. Reach B (sites 3 and 4) had a higher proportion of DAH than the other reaches. Reach C (sites 5 and 6) had the highest proportion of invertivores, dominating over half of the fish present in these sites. The invertivores represent the trophic guild with the highest diversity, including seven species.

Trout: *Brown trout, rainbow trout, and brook trout were collected on Big Stony Creek in September 2000 and 2001. Brown trout was the dominant salmonid species, while the catch of brook trout and rainbow trout was sparse. In 2000, population estimates for brown trout were greatest at site 5 and 6 (Figure 14), while sites 1 and 2 had the lowest population estimates. In 2001 population estimates for brown trout decreased significantly from the 2000 estimates at all sampling locations (Figure 14). As in 2000, the highest population estimates occurred at sites 5 and 6, while the lowest estimates occurred at sites 1, 2, and 4.*

Table 9. Population estimate comparison of fish collected in sites 1-6, Stony Creek, Virginia, on the Glen Alton Tract, in fall 2000 and fall 200. A * indicates a significant difference in abundance for the species at the site between years.

	Site 1				Site 2				Site 3				Site 4				Site 5				Site 6			
Species	2000		2001		2000		2001		2000		2001		2000		2001		2000		2001		2000		2001	
Common Name/ Scientific Name	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI
Mtn. redbelly dace *Phoxinus oreas*	174	165-183	62*	59-68	429	409-449	296*	280-312	1722	515-3140	583	570-597	264	219-309	710	142-2487	94	87-103	105	92-120	79	73-88	47	33-76
Rosyside dace *Clinostomus funduloides*	146	137-156	126*	120-134	107	107-108	51*	44-63	255	51-1317	89	82-98	160	154-167	84*	66-109	93	85-103	64*	55-78	90	85-98	101	71-142
Blacknose dace *Rhinichthys atratulus*	22	20-28	4*	4-5	6	6-8	4	4-6	112	50-260	38	18-116	150	143-158	49*	48-52	89	79-102	83	68-103	106	97-117	44*	41-51
Central stoneroller *Campostoma anomalum*	43	39-51	31	29-36	160	159-163	75*	64-90	433	310-556	132*	129-137	11	11-13	85*	17-726	52	52-53	14*	14-17	0	0	0	0
Creek chub *Semotilus atromaculatus*	130	107-154	231*	75-638	141	136-148	98*	85-114	305	258-352	267	240-294	396	382-410	236*	198-274	76	75-79	85	70-105	110	101-121	52*	43-68
Bluehead chub *Nocomis leptocephalus*	911	857-965	269*	249-289	590	574-606	268*	234-302	302	258-345	198*	188-208	179	166-191	96*	86-108	174	163-185	78*	75-83	97	91-105	44*	43-48
Cresent shiner *Luxilus cerasinus*	490	474-506	154*	135-173	349	346-353	248*	237-259	10	8-21	0*	0	0	0	0	0	3	3-9	15*	3-312	0	0	0	0
Northern hogsucker *Hypentelium nigricans*	41	40-44	34	23-63	48	48-49	16*	15-21	0	0	1	0	29	22-47	3*	3-6	11	11-12	16*	14-24	0	0	6*	6-8
White sucker *Catostomus commersoni*	11	11-12	19*	18-24	0	0	7*	7-8	38	37-42	81*	79-85	90	85-97	70*	65-78	77	76-80	62*	55-73	65	61-72	15*	15-17
Brook trout *Salvelinus fontinalis*	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3*	3-8	0	0	0	0

Table 9 *(continued)*. Population estimate comparison of fish collected in sites 1-6, Stony Creek, Virginia, on the Glen Alton Tract, in fall 2000 and fall 200. A * indicates a significant difference in abundance for the species at the site between years.

Species	Site 1				Site 2				Site 3				Site 4				Site 5				Site 6			
	2000		2001		2000		2001		2000		2001		2000		2001		2000		2001		2000		2001	
Common Name/ Scientific Name	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI
Brown trout *Salmo trutta*	2	2-7	1	0	0	0	1	0	11	11-13	5*	5-7	25	25-26	1*	0	53	53-55	20*	20-21	59	57-63	23*	22-27
Rainbow trout *Oncorhynchus mykiss*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2-15.0
Mottled sculpin *Cottus bairdi*	14	13-19	7*	7-8	56	55-60	24*	24-26	407	133-940	216	205-227	377	320-434	135*	116-154	478	312-643	192*	131-254	383	200-569	82*	73-94
Rock bass *Ambloplites rupestris*	71	65-80	15*	14-20	28	28-29	11	7-35	8	8-10	17*	17-18	0	0	0	0	0	0	0	0	0	0	0	0
Bluegill *Lepomis macrochirus*	0	0	0	0	0	0	0	0	30	6-423	0*	0	0	0	1	0	0	0	0	0	0	0	0	0
Candy darter *Etheostoma osburni*	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fantail darter *Etheostoma flabellare*	154	84-261	31*	28-38	112	110-116	85*	72-102	630	126-2260	266	258-274	217	182-251	131*	94-174	203	99-364	88*	53-151	90	67-122	59	48-77

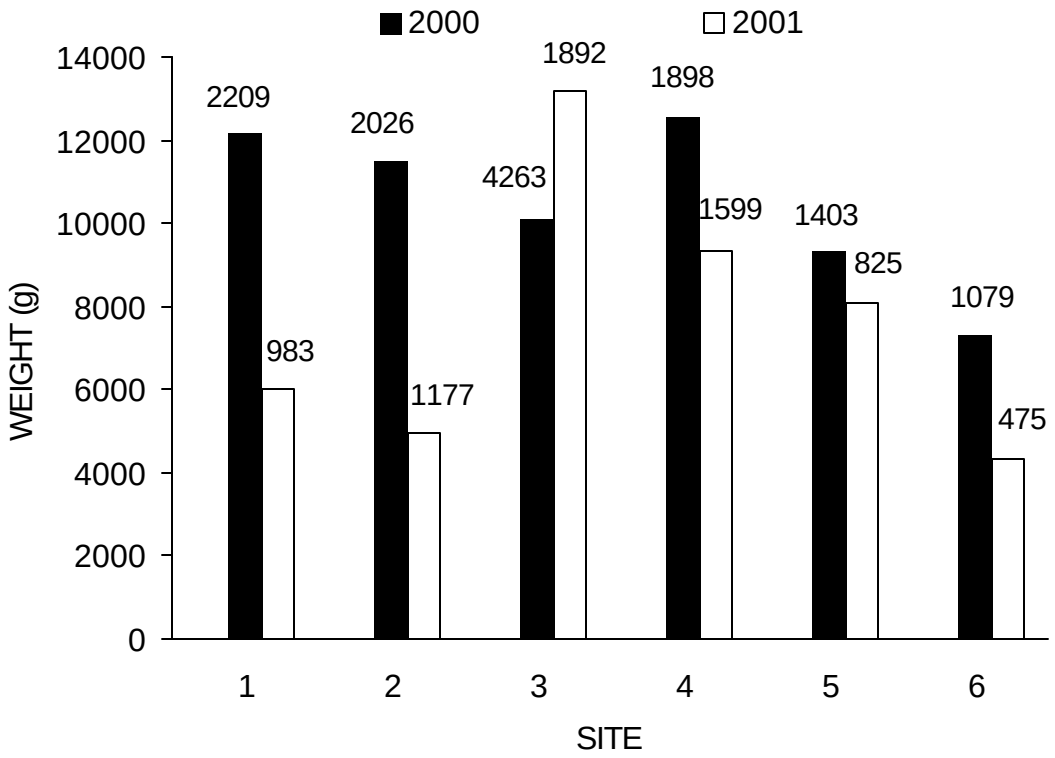

Figure 12. Total biomass for both game and nongame species over all sites in 2000 and 2001. Sample size by site is depicted above each bar.

Table 10. Native status, trophic guild and family classification of fish species collected in Stony Creek, Glen Alton, George Washington and Jefferson National Forest, Giles County, Virginia 2001.

Common name	Scientific name	Native	Trophic group	Family
Mountain redbelly dace	*Phoxinus oreas*	Yes	DAH	Cyprinidae
Rosyside dace	*Clinostomus funduloides*	Yes	INV	Cyprinidae
Blacknose dace	*Rhinichthys atratulus*	Yes	INV	Cyprinidae
Central stoneroller	*Campostoma anomalum*	Yes	DAH	Cyprinidae
Creek chub	*Semotilus atromaculatus*	Yes	IP	Cyprinidae
Bluehead chub	*Nocomis leptocephalus*	Yes	AHI	Cyprinidae
Cresent shiner	*Luxilus cerasinus*	No	INV	Cyprinidae
Northern hogsucker	*Hypentelium nigricans*	Yes	INV	Catostomidae
White sucker	*Catostomus commersoni*	Yes	AHI	Catostomidae
Brook trout	*Salvelinus fontinalis*	Yes	IP	Salmonidae
Brown trout	*Salmo trutta*	No	IP	Salmonidae
Rainbow trout	*Oncorhynchus mykiss*	No	IP	Salmonidae
Mottled sculpin	*Cottus bairdi*	Yes	INV	Cottidae
Rock bass	*Ambloplites rupestris*	No	IP	Centrarchidae
Bluegill	*Lepomis macrochirus*	No	INV	Centrarchidae
Candy darter	*Etheostoma osburni*	Yes	INV	Percidae
Fantail darter	*Etheostoma flabellare*	Yes	INV	Percidae

Note: Trophic groups are: DAH = detritivore/algivore/herbivore, AHI = algivore/herbivore/invertivore, INV = invertivore, IP = invertivore/piscivore

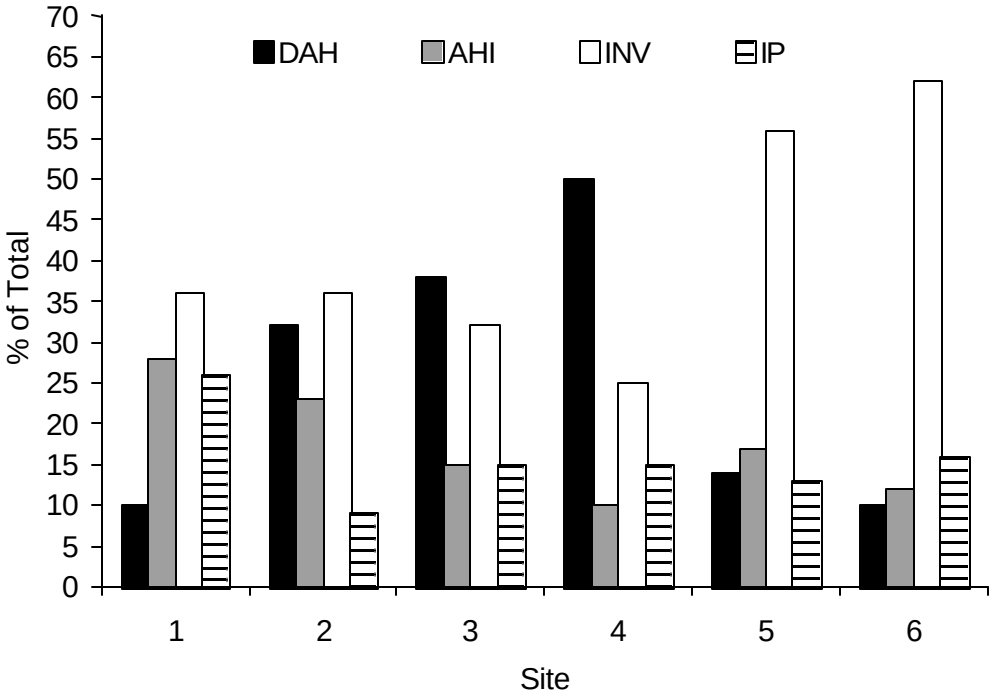

Figure 13. Percent representation of trophic guilds for fish species captured in Stony Creek, Glen Alton Tract, Giles County, Virginia. DAH = detritivor/algivore/herbivore, , AHI = algivore/herbivore/invertivore, INV = invertivore, and IP = invertivore/piscivore.

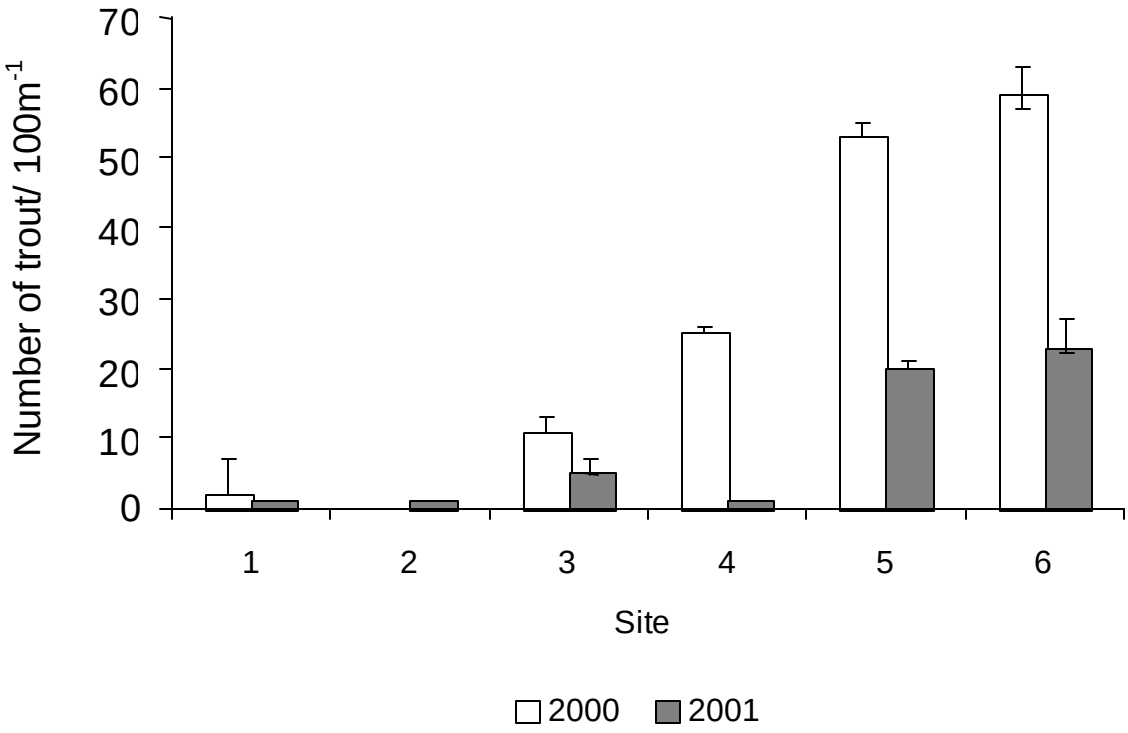

Figure 14. Population estimates for brown trout in Stony Creek, Virginia, on the Glen Alton Tract collected by three-pass depletion electrofishing in fall 2000 and 2001.

In 2000, brown trout biomass, was similar in reach A and reach B, 1858 g and 1963 g, respectively (Figure 15). Although the biomass estimates were similar, the population estimates were significantly different between reach A and reach B. Similarity in biomass despite the different population estimates was explained by a single large brown trout (1350 g) that was captured in reach A and accounted for approximately 73% of the total biomass in the reach. The trout biomass in reach C (4227 g) was over 2 times the biomass at reach A and reach B, which was a result of increased trout abundances in reach C.

In 2001, trout biomass decreased in Reach A to approximately 14% of the biomass that was present in 2000; however, if the large trout is removed from the analysis in 2000, biomass did not decrease as dramatically between years, 508 g in 2000 and 260 g in 2001 (Figure 15). In Reach B, biomass was similar between 2000 and 2001 despite the number of trout in 2001 being half of that in 2000, suggesting that the number of larger brown trout increased in 2001 (Figure 16). In Reach C, the biomass decreased in 2001 (2480 g) compared to 2000 (4227 g); however, the number of brown trout also decreased between the two years. As mentioned previously, biomass can be influenced by fish size. Length-frequency histograms indicated that although the number of brown trout decreased between the 2 years, the distribution did not change (Figure 16).

Relative Weight: Relative weight of brown trout decreased at all sites between 2000 and 2001. The Kruskal-Wallis test indicated that the W_r values were not significantly different between reaches (P=0.8722). Because W_r did not vary significantly and Reach A had low numbers of trout (N=7), reaches were combined prior to the Wilcoxon rank sum test to test for differences between years. The results of the Wilcoxon test showed a significant difference in the W_r values between years (P<0.0001), with significantly higher values in 2000 than in 2001 (Figure 17).

Relative weights of white suckers also decreased at all sites between 2000 and 2001. Due to field identification inadequacies, white suckers from Reach B were excluded from statistical analyses. The Wilcoxon rank sum test failed to show a significant difference in relative weights between Reach A and Reach C (P=0.1835), so the reaches were combined to test for differences in W_r between years. The Wilcoxon test showed a significant difference in W_r between years for white sucker (P<0.0001), with the values being significantly reduced in 2001 (Figure 18).

Although it is unknown what the exact causal mechanism was for the reduction in relative weights of both brown trout and white sucker between years, it may have been a result of the reduction in flow between 2000 and 2001. The decreased flow likely contributed to a decrease in the amount of useable area for trout. In addition, a reduction in food availability may have occurred in 2001, thus accounting for a reduction in W_r.

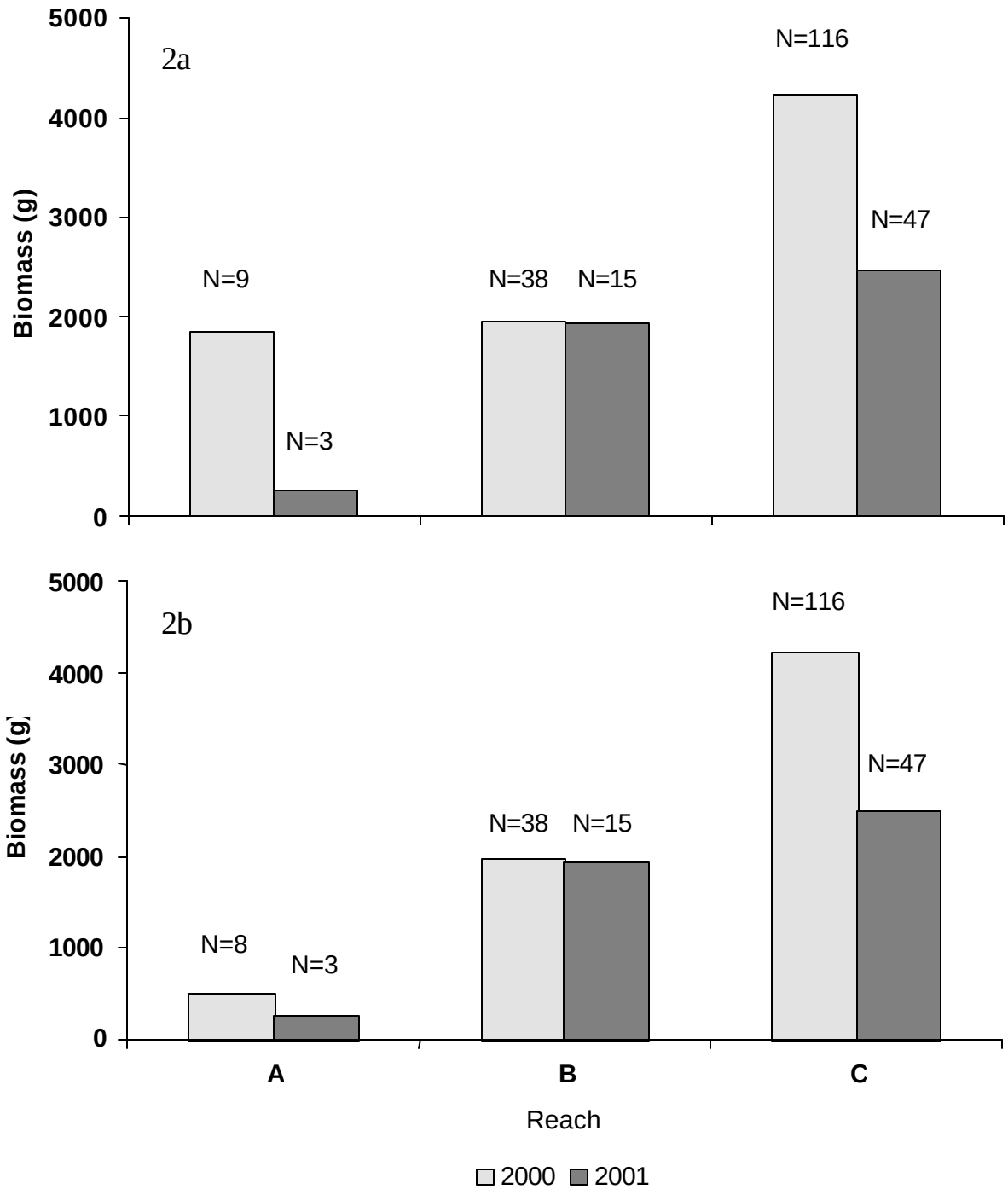

Figure 15. Brown trout biomass data for Stony Creek, Virginia, from 3 reaches on the Glen Alton Tract collected during fall 2000 and 2001. The top figure (2a) includes all trout collected, and the bottom figure (2b) excludes the large brown trout collected from Reach A in 2000.

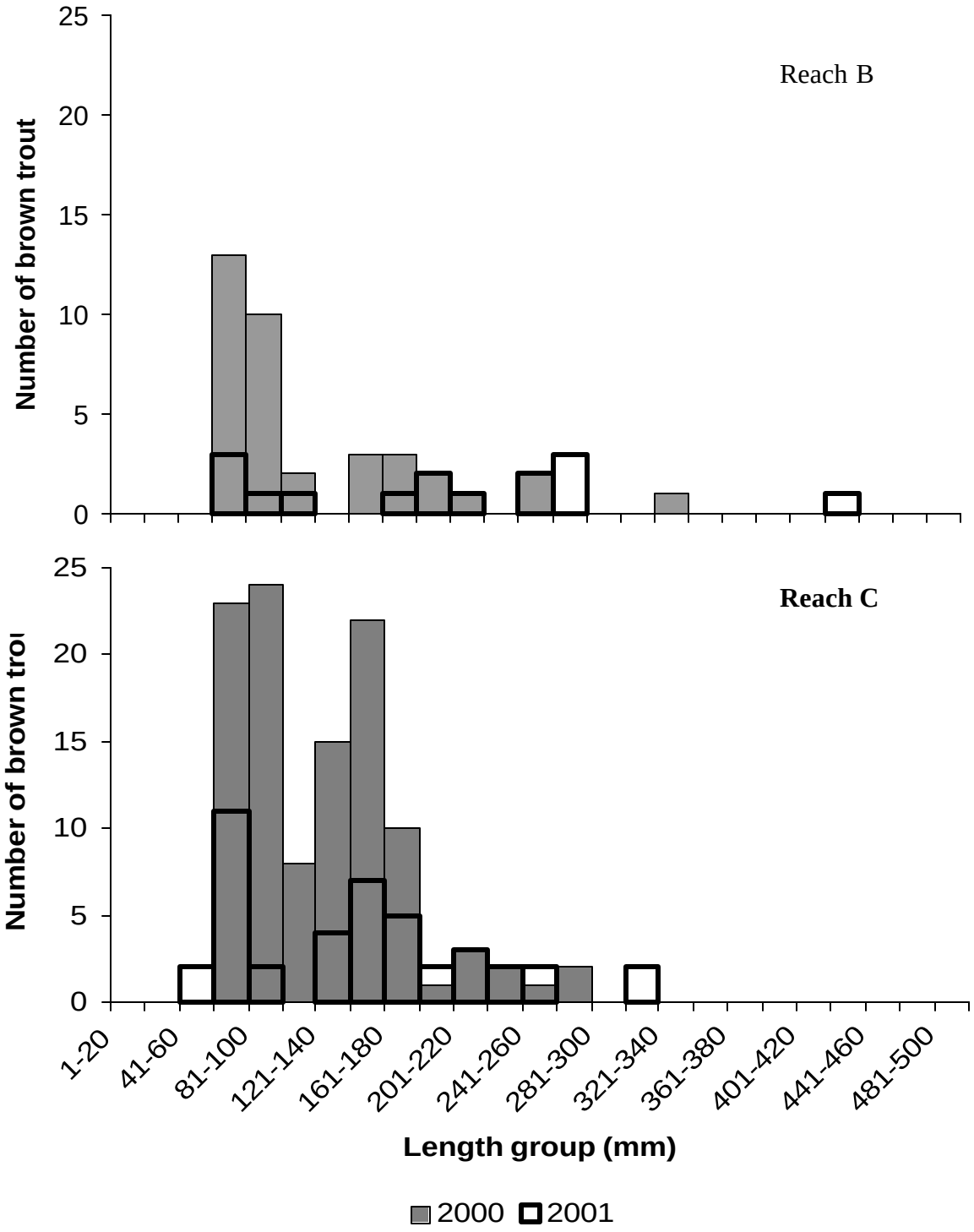

Figure 16. Length-frequency histograms for brown trout collected from Reaches B and C on Stony Creek, Virginia, on the Glen Alton Tract.

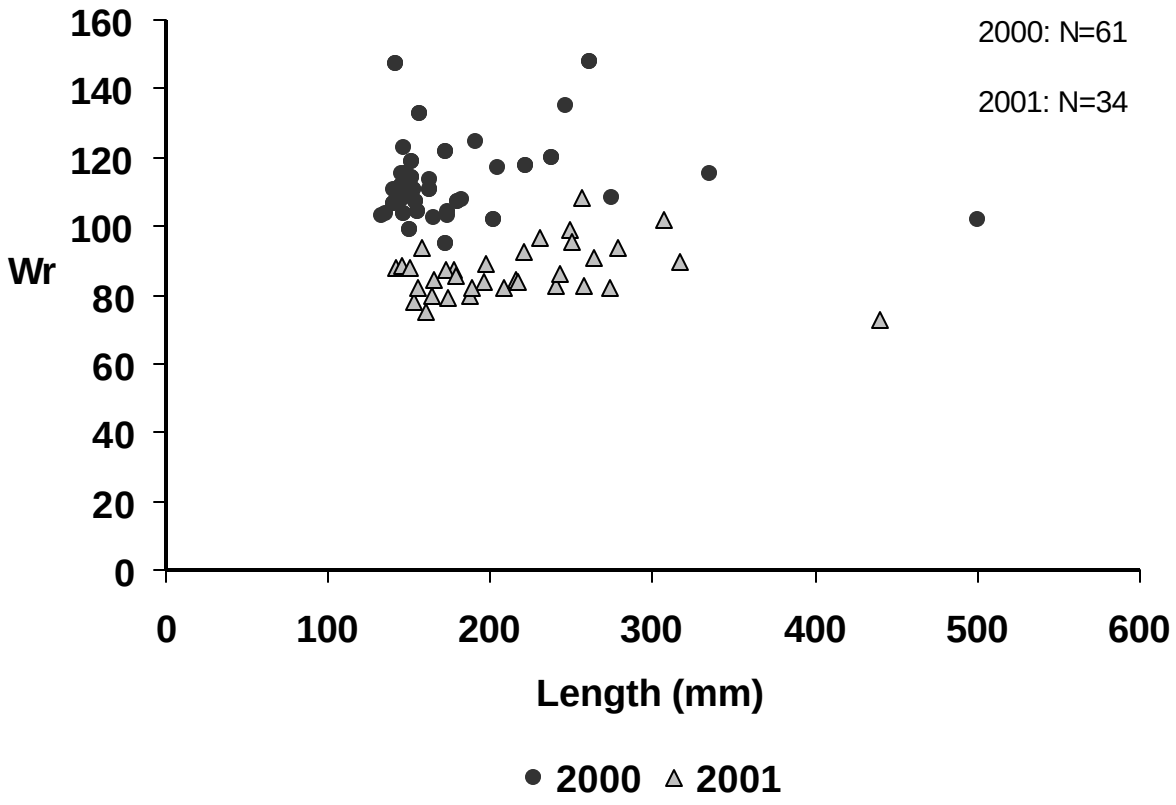

Figure 17. Relative weight of brown trout collected from Stony Creek, Virginia, during fall 2000 (dark circle) and 2001 (light triangle). Statistical analyses indicated that Wr values were significantly greater in 2000 than in 2001 (P<0.0001).

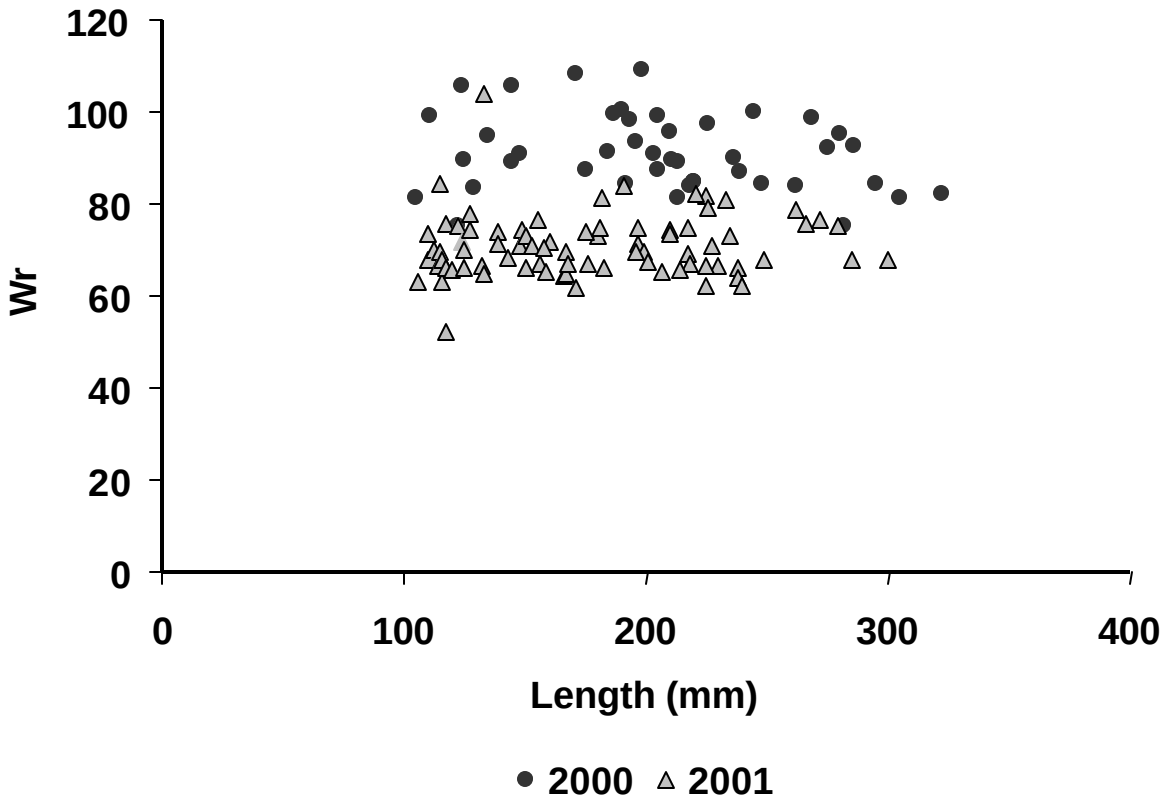

Figure 18. Relative weight of white sucker collected from two reaches on Stony Creek, Virginia, during fall 2000 (dark circle) and 2001 (light triangle). Statistical analyses indicated that Wr values were significantly greater in 2000 than in 2001 (P<0.0001).

Measures of Stream Integrity and Assemblage Structure

Application of the IBI to the 6 sites resulted in somewhat low integrity scores that differed little among sites. Sites 2, 3, 5, and 6 obtained scores of 32, 30, 30, and 34, respectively, indicating "fair" conditions (Table 11). Sites 1 and 4 both obtained scores of 28, indicating conditions between "fair" and "poor" in each case. There was no detectable integrity trend along either the longitudinal gradient or the perceived disturbance gradient of our sites. There are 3 potential reasons why the 6 sites showed little difference in detectable integrity: 1) The IBI was developed to separate stream segments of truly different integrities, of which there is a broad range in any geographic region (Karr et al 1986); our sites may have thus exhibited only relatively small differences, 2) Our sites are in close proximity to one another, providing opportunity for frequent species exchange and migration between sites, and 3) Many of the metrics we used have not been calibrated for Virginia coldwater small-order streams, so our cutoff points could have been erroneously derived. The low integrity values obtained for our 6 sites should not be construed as necessarily representative of the actual status in the Glen Alton reach. We believe that features inherent in a small, cool- to cold-water stream in the New River drainage, (e.g. low functional diversity, few native predators, low diversity of intolerant species) biased our IBI scores downward. The value of this first attempt at an IBI for Big Stony Creek lies more in its illustration of similar levels of ecological integrity across sites.

Six of the 10 chosen metrics did detect some difference between sites, allowing us to interpret possible species and habitat differences between sites at a finer scale than possible using the total IBI scores. Proportion of tolerant individuals was lower at site 2 than the other sites, a difference that was influenced largely by low abundances of white sucker, creek chub, and blacknose dace at that site (Table 11). Proportion of native invaders was highest at sites 1 and 2, indicating a potential artifact caused by these sites being downstream of the other 4 sites. Proportion of omnivores was lowest at site 6, indicating potential upstream limits to the ranges of the chub and sucker species. This site also exhibited low numbers of mountain redbelly dace, compared to the other 5 sites. Proportion of piscivores was lowest at site 4, possibly resulting from the lack of suitable pool cover there. Proportion of insectivores was lowest at site 4 and highest at site 6; the low ranking at site 4 was due to a very large proportion of omnivores at the site, whereas the high ranking at site 6 was due to a relatively high abundance of brown trout. Proportion of simple lithophilic spawners was highest at sites 2 and 4; this metric was heavily influenced by the abundance of mountain redbelly dace at site 4, and by the abundance of an exotic species, the crescent shiner, at site 2. Overall, it was difficult to attribute between-site differences in individual metric scores solely to reduced habitat quality. Rather, many such differences could be attributed to shifts in species composition due to longitudinal changes (e.g. temperature and productivity) in the stream. This inseparability highlights the difficulty of assessing ecological integrity using biological organisms at a transitional zone in the stream network, such as the point where cold-water and cool-water faunas meet (Lyons et al. 1996), as they do at the Glen Alton Property.

Although the IBI failed to separate sites in the manner we had expected, the Bray Curtis similarity coefficient (BC) calculations afforded some evidence that our grouping of sites into 3 distinct reaches was biologically meaningful. Results of the BC calculation between every combination of 2 sites revealed that site assemblages were more similar within reaches (e.g. sites 1 and 2), than between reaches (e.g. sites 1 and 3; Table 12).

Table 11. Index of Biotic Integrity (IBI) computed actual values (V) and resultant scores (S) for the 6 sites sampled on Stony Creek, Glen Alton Tract, Giles County, Virginia, sampled in September 2001.

	Site 1		Site 2		Site 3		Site 4		Site 5		Site 6	
Metric	V	S	V	S	V	S	V	S	V	S	V	S
			10	5	10	5	10	5	11	5	10	5
Native Spp. Richness	11	5										
# Darter and Sculpin Species	2	3	2	3	2	3	2	3	2	3	2	3
# Intolerant	0	1	0	1	0	1	0	1	0	1	0	1
% Tolerant	29%	3	16%	5	27%	3	27%	3	30%	3	23%	3
% Native Invaders	36%	1	31%	1	22%	3	16%	3	21%	3	14%	3
% Omnivores	63%	1	58%	1	62%	1	73%	1	52%	1	44%	3
% Piscivores	2%	3	1%	3	1%	3	0%	1	3%	3	5%	3
% Insectivores	32%	3	34%	3	30%	3	22%	1	44%	3	51%	5
% Simple Lithophilic Spawners	41%	3	53%	5	42%	3	57%	5	42%	3	45%	3
% with Anomalies	1%	5	1%	5	1%	5	1%	5	1%	5	1%	5
IBI Score		28		32		30		28		30		34
Integrity Class		Fair/Poor		Fair		Fair		Fair/poor		Fair		Fair

Table 12. Bray-Curtis Similarity Coefficients of fish assemblage structure for the 6 sites sampled on Stony Creek, Glen Alton Tract, Giles County, Virginia, September 2001.

Site	1	2	3	4	5	6
1	*	**0.68**	0.48	0.45	0.46	0.66
2		*	0.55	0.54	0.50	0.67
3			*	**0.85**	0.55	0.38
4				*	0.57	0.42
5					*	**0.7**
6						*

Mean similarity (BC) between sites was higher within reaches (mean = 74%; SD = 9%) than between reaches (mean = 52%; SD = 9%). This finding was significant because of our implicit hypothesis that the 3 reaches contained differing qualities and amounts of habitat owing to the contrasting land uses surrounding the reaches. Thus, each "treatment" (reach) of our sampling design had 2 reasonably good "replicates" (sites), and the treatments differed from each other, although this difference could not be evaluated for significance.

Future Management Alternatives

There are several management options for the GAT, 5 of which are presented (Table 13) that range from "do nothing" to a labor intensive put and take trout fishery. Pros and cons are present for each approach. Because the property was acquired in the previously discussed agricultural state, it presents an excellent learning opportunity for students and scientists who will be able to monitor and document the impacts of the management scheme that the USFS and VDGIF enact.

<u>"Do Nothing" Approach</u>

The simplest management approach would be to do nothing and let the system come to its own state of equilibrium. Because the stream is not in a state of equilibrium (as evidenced by channel incision and highly eroding stream banks), any modification may be somewhat of a risk. For instance, if time and money are spent on a stream bank stability project, such as rip-rapping unstable or eroding banks, the stream may still incise a considerable amount. If further incising occurs, the stability project may be rendered useless or even cause further damage. Although simple, this approach will only be useful if annual monitoring is conducted to assess trends within the fish community.

Benefits of the "do nothing" approach would include low effort requirements and subsequent low costs. Before money is invested in the recovery of the property, the stream community may begin to recover itself. The agricultural field, for instance, will eventually establish a tree community. With increased vegetation in the riparian, less sediment will be deposited in the stream, and the existing sediment will wash out of the area. This approach would also allow an opportunity for VDGIF to document the recovery succession of the property and use it as a learning and educational tool for future recovery projects.

This type of "laissez faire" approach, however, does have some drawbacks. One obvious drawback is that the results are unknown and unpredictable. Due to environmental uncertainties, this unpredictability is typically the case with any restoration project. Another risk with this approach is the formation of negative public perception. Also, without any form of management or enhancement, there exists the potential for overexploitation of the fish stock in the middle and lower stretches of the stream. Finally, this recovery process would take a long time. A stream will eventually come to quasi-equilibrium with its environment, but it could, in fact, get worse before it gets better. An example would be a vertical stream bank from an incised channel. The position of the bank would prevent establishment of vegetation, and the bank position, coupled with the undercutting power from the streams, would eventually lead to bank sections sloughing off. This would add yet another source of sediment to the already impacted stream.

Table 13. Management option matrix for Stony Creek, Giles County, Virginia, for the Glen Alton Tract. Rankings shown 1-5 where 1 = most desirable, 5 = least desirable.

	Requirements				
Management Approach	Cost[a]	Time spent[b]	Risk[c]	Long term sustainability[d]	Score[e]
Do nothing	1	1	4	3	9
Trout-intensive	5	5	5	5	20
Trout-Less intensive	3	2	3	4	12
Native fish assemblage	2	4	2	2	10
Stream bank restoration	4	3	1	1	9

[a.] Cost is monetary cost , [b.] Time spent is person hours required, [c.] Risk is environmental risk, [d.] Long term sustainability is ability of fish community to sustain itself, [e.] Score is the total of the 4 rankings.

Trout Fishery

Another management option would be to manage for a trout fishery. There are many different ways to do this, but we propose 2. One would be an intensive trout fishery, and the other would be to manage for naturalized trout populations. Although both schemes ultimately manage for a trout fishery, they have different components, and both approaches possess potentially different outcomes.

Intensive Trout Fishery

Under an intensive management approach, a put-and-take fishery could be established through weekly or monthly stocking. Because suitable habitat is found only the upper reach, instream modification would be desired in the middle and lower reaches. This type of modification would require extensive labor and equipment to create pool areas that would hold fish.

The benefit of this approach would be the creation of fishing opportunities with large numbers of fish to catch. However, we feel that there are far more potential pitfalls with this management idea. A high monetary cost would be incurred through the continual stocking of trout and habitat improvements. There would also be negative effects upon native fish assemblages that require riffle habitat. The creation of pool habitat could prove devastating to downstream fish communities by creating large amounts of sediment, in particular is the likely negative impact upon the endemic population of candy darters *Etheostoma osburni*, which are a species of special concern to the state. Also, because sediment is a concern, any pool habitat would need to be periodically cleaned out, creating a whole new suite of problems. The pool areas that have trout in them would lead to many anglers going to and from these areas. Further erosion to already fragile streambanks could result due to increased traffic. Because there is already a popular put and take fishery in the downstream areas of Big Stony, the GAT is not needed as an additional put and take fishery. We feel taking an intensive trout approach would waste an opportunity for stream restoration and monitoring the effects thereof.

Less Intensive Trout Fishery

A less intensive trout management plan could also be enacted. Through the less intensive approach, there would be less stocking or possibly no stocking at all. Management emphasis would be placed on restrictive limits or catch and release. An alternate approach could be a seasonal catch-and-release management program, with harvest available only in the summer months.

This method would be less expensive than the intensive management approach, while still providing anglers with fishing opportunities. Although it would not require extensive habitat modifications, slight modifications could be made, resulting in better conditions as the downstream reaches progress through the recovery succession. Because an abundance of places near GAT for put-and-take trout fishing exists, anglers may value the opportunity to catch naturalized trout in GAT. Because trout would occupy a broader range of habitats, angler effort would not necessarily be focused on a few fishing holes, as in a put-and-take situation, but angler impact would be diluted throughout the GAT.

Although not as expensive as intensive management, the effort to provide enhanced fishing could induce significant costs. Stocking is a cost, but instream habitat modifications that would be advantageous to the fishery, create costs as well. Addition of lunker structures or the simple addition of woody debris would provide trout habitat. Further stream bank modifications, such as encouraging riparian development, would also help provide woody debris input, shade the stream, and stablize the eroding banks. Another limitation to this management approach is that not as many fish will be available for harvest, which may result in failure to satisfy the harvest-oriented constituents. Also, fish stocking will have some impact upon native fish assemblages, with the candy darter being of premium concern.

Native Fish Assemblage

Management could be directed toward the enhancement of a native fish assemblage. This management approach would especially benefit the candy darter. The clean water required for the candy darter would additionally benefit the entire GAT aquatic community. More information is needed to assess the impact of predatory exotics, such as the brown trout, on the candy darter. If the impact is deemed biologically significant, then some measure of keeping trout out of certain "sanctuaries" could be developed. Something like a fish screen could work, although this would be an obvious temporary approach that would require routine cleaning and maintenance.

The existence of a native fish community could also be used as an education tool for students of all ages. If a diverse fish community continues to exist and is enhanced, many learning opportunities may be created. Although fishing is often the focus of management, the candy darter could be an excellent "charasmatic microfauna" to direct the public's attention to the value of nongame species. A "snorkeling park" could be established to take advantage of this resource. Instream viewers or other tools could also be used for people to actually see, and hopefully gain an appreciation for fish other than just trout.

A drawback to encouraging people to get out into the streams to view fish is the impact to the fish, fish cover, and benthic populations due to people walking in the streams. This increased local impact could easily be offset if we foster the appreciation of the sensitivity to these animals. Increased community awareness of the inhabitants of GAT will help VDGIF gain support in future management endeavors (i.e., if people don't know what something is, then they won't care about it). Another drawback to this management approach would be the failure to satisfy some anglers due to the lack of large numbers of trout. Also, the native sport fish that were observed through sampling were not extremely large, which would probably not provide a satisfactory angling experience to most anglers. However, as we discussed, this native fish assemblage could be of high value to educational programs.

Streambank Restoration

Although we have discussed several fish management schemes, another approach is to aim toward habitat restoration and let the fish community respond as it may. Several habitat restoration measures could be utilized. Instream habitat structures could be placed throughout the stream, including large boulders, woody debris, and lunker structures. Because the stream has incised and there exists some vertical, undercut, or highly alluvial banks, bank stabilization measures will be important to prevent further

stream widening and inputs of sediment. An approach already used in some areas at the GAT is the pulling back of stream banks to an approximate 45° angle. We also propose planting vegetation in the riparian zone, such as willow trees *Salix spp.* In addition to providing not only stabilization, riparian vegetation would shade the stream, reduce the overall temperature of the stream, and reduce the daily temperature variations that now occur through the middle and lower unshaded reaches.

In addition to direct instream or riparian restoration, several other management opportunities exist. A nature trail, with pathways to fishing locations, could be developed to prevent excessive environmental degradation. Beaver *Castor canadensis* are of some concern on the GAT. In high gradient streams, periodic pulsing rain events carry sufficient power to blow out beaver dams, but in low gradient streams, such as the stretch of Big Stony through the GAT, beaver dams can persist through most rain events. The presence of beavers coupled with the fact that we have not had any severe rain events in the area for some time, means there is a larger potential for impact from the dams. The dams create depositional areas for the stream. With the high degree of sediment found in the stream already, most benthic areas are completely silted in, and the interstitial spaces necessary for a healthy fish food base of invertebrates are absent. The dams also create movement barriers and prevent the recolonization of fish to areas that experience small scale disturbances or even very localized extirpations. On the other hand, dams could also be constructed to establish large pools; however, the problems inherent with beaver dams would be present with any artificial structures as well. Many habitat restoration measures are available; which, if any, are appropriate, depends upon the desired management goal.

Management Recommendations

We recommend 2 different management approaches for the GAT (Table 13). Both recommendations include restoring GAT to its preagricultural condition, with the central idea focus on habitat restoration and monitoring how the fish community responds. Habitat restoration, whether nature dictated or initiated from managers, is key for enhancement of the fish community. The primary management activities that we recommend are to enhance both riparian and instream habitat. This would entail the development of stable stream banks and the establishment of trees in the riparian zone. We recommend planting willows due to their ease of planting and rapid growth. Because of their ease of planting, this could serve as an important outreach project to the community, with volunteers being used to plant the non-vegetated banks. The increased tree canopy will provide many benefits, including habitat for birds and mammals, shading for the stream, and the addition of woody debris for fish cover. Bank stabilization will also aid in the reduction of sediment inputs into the stream and prevent stream channel widening.

In addition to bank stabilization, instream boulders should be placed to create complex currents and fish refuge areas. Lunker structures should be placed outside bends and run areas to establish additional instream cover. These lunker structures could also be established with the help of volunteers or service learning projects, helping out the state, the anglers, and the students. Beavers should be removed to prevent their dams from impeding fish movement and creating large sediment depositional areas detrimental to fish and invertebrates alike. Although this approach would work toward restoring the native fish community to a possible pre-agricultural condition, the naturalized trout populations would likely respond in a positive manner as well. For example, reduced

sediment loading would not only provide an increased invertebrate forage base but would also allow for more salmonid spawning areas.

We believe that more intensive management approaches would not be appropriate for the GAT, as good trout fishing already exists both above and below the property. Perhaps recovery will leave the GAT useful as an educational tool for the candy darter in the future, utilizing the property for a more diverse interest base than just a trout fishery.

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