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Biotic Condition and Species Composition of the Fish Community of Big Moccasin Creek, Scott and Russell Counties, Virginia

Michael J. Pinder

Aquatic Operations
Virginia Department of Game and Inland Fisheries
2206 South Main Street, Suite C
Blacksburg, Virginia 24060

Charles F. Saylor

Tennessee Valley Authority (Retired)
516 Vista Drive
Clinton, Tennessee 37716

ABSTRACT

We analyzed species composition and index of biotic integrity (IBI) of the fish assemblages of Big Moccasin Creek (BMC), Scott and Russell counties, Virginia. A total of 11,933 individuals representing 36 species was collected at 10 sites. Largescale Stoneroller (*Campostoma oligolepis*), Tennessee Shiner (*Notropis leuciodus*), and Warpaint Shiner (*Luxilus coccogenis*) were the most abundant species. Two previously known but rare species, Stonecat (*Noturus flavus*) and Blotchside Logperch (*Percina burtoni*), were found to be extant in the system. IBI scores ranged from 40 (fair) to 50 (good). With the exception of the uppermost station, the highest scores were found in the lower half of the creek. Our survey indicates that BMC is mostly in fair condition, which indicates a loss in species richness, skewed trophic structure, and lack of top carnivores. Additional restoration efforts need to be focused on this system to protect and restore its ecological health.

Key words: fish assemblage, index of biotic integrity, endemic, Holston, restoration.

INTRODUCTION

As part of the Tennessee River Basin, the Holston River originates in southwestern Virginia from three headwater tributaries - the North, Middle, and South Forks. Among these, the North Fork Holston River (NFHR) is the longest and historically supported the highest fish diversity with over 72 species. In the late 19th and early 20th centuries, industrial-related chemical spills in the upper reaches resulted in catastrophic fish kills downstream (Jenkins & Burkhead, 1994). Although there are currently less than 64 fish species known from the NFHR in Virginia, this loss could have been even greater if it were not for larger tributaries that provided unpolluted refugia during these events (Jenkins & Burkhead, 1994). Of the few, large feeders within the NFHR drainage, Big Moccasin Creek (BMC), a warm-water stream that enters at the lower section of the river, could have served this purpose. BMC is known to contain 42 native and two introduced fish species (VDGIF FWIS, 2016). Additionally, it has one of the few populations of Stonecat (*Noturus flavus*) in the NFHR drainage, and supports a relict population of Blotchside Logperch (*Percina burtoni*), a rare endemic darter.

Index of biotic integrity (IBI) monitoring is a standard methodology to assess the environmental quality of rivers and streams using structural and functional characteristics of the fish communities (Lyons, 1992). IBI can be used to assess long-term changes in the health of a river body because it is sensitive to water quality and physical habitat disturbances (Karr et al., 1986). It uses multiple metrics that reflect a range of relationships to environmental factors. Each metric is scored 1-poor, 3-intermediate, or 5-good depending on how it compares to a component of a minimally-disturbed reference fish community within the same ecoregion and similar drainage area (Karr et al., 1986). Although no single metric can be used to determine overall stream health, they can be used individually to interpret and explain results (Plafkin et al., 1989). The final score is determined by tallying all metrics to indicate the level of stream ecological health. The integrity classes include: 60-58 (Excellent), 52-48 (Good), 44-40 (Fair), 34-28 (Poor), and 22-12 (Very Poor).

The Tennessee Valley Authority (TVA) has been monitoring streams and rivers using IBI techniques in the Upper Tennessee drainage since the early 1990s (Matthews & Malone, 2016). Their IBI criteria are developed by the Tennessee Department of Health and Environmental Conservation [TDHEC] (1996), which are specifically applicable to the Upper Tennessee River drainage. The results of TVA's IBI assessment indicate BMC is an impaired system; however, this is based on sporadic and limited sampling. Between 1994 and 2007, TVA sampled four sites of which only one was sampled for more than two years. Their most consistently sampled site was at river kilometer (RKm) 6.1, which was visited in 1994, 1997, 2002, and 2007. Total IBI scores averaged 42 (fair), with a low of 38 (poor/fair) in 1997 and a high of 46 (fair/good) in 2002. The lowest scored metrics during this period were related to a decrease in sunfish, suckers, and piscivores and an increase in omnivores. These low ratings may indicate impairment to the fish community due to sedimentation in the form of siltation and excessive nutrients. Possible sources of these impairments in the BMC watershed include cattle production, forestry, and urban development.

Our main objective was to use IBI methodology to assess BMC by sampling multiple sites over one field season. The secondary objective was to provide a cursory examination of the fish distribution and composition of BMC. Information gathered would be useful as a baseline reference of stream health and for the evaluation of future restoration efforts.

MATERIALS AND METHODS

Study Area

BMC originates at Hansonville, Russell County, Virginia, and flows southwest for 88 km between Moccasin Ridge to the north and Clinch Mountain to the south before emptying into the North Fork Holston River upstream of Weber City, Scott County, Virginia. The watershed area of BMC is 245.45 km^2, which is approximately 14% of the total NFHR basin. The entire BMC watershed is within the Ridge and Valley Physiographic Province and is comprised of limestone, dolomites, and shales in the lowlands and sandstones on the mountains. Land use is 54% forest, 37% agriculture, and 7% residential (Wickham et al., 2014). The remaining 2% is open water and wetlands. Agriculture, in the form of pasture and row crops, is mostly confined to the valley and along the mainstem. Most of the mountainous regions are forested, while the residential areas are concentrated in Gate City and Weber City, Scott County, in the lower 5 km of BMC.

Fish Sampling

We sampled a total of 10 sites at base-flow conditions between 14 July and 16 September 2009 (Fig. 1; Table 1). Sites were primarily selected to be an equal distance apart from each other between the mouth and the headwaters. In order to collect representative fish diversity at each site, locations were adjusted to ensure the presence of multiple meso-habitats (i.e., pools, riffles, and runs). Landowner permission was the final criterion for site selection. The average distance between sites was 9.4 km (± 0.85 SE).

We used standardized TVA methods for conducting IBI fish sampling. For riffles and runs, we used a Smith-Root gas-powered SR-24 backpack unit and seine net (1.5 m x 3 m). Most sampling occurred 3 m upstream of the seine net that was placed perpendicular to stream flow forming a 9 m^2 quadrat. If needed, quadrat size was adjusted and noted for smaller habitat areas. Quadrats were placed at the downstream end of the habitat unit and subsequent quadrats were adjacent to or upstream of the previous sample. No quadrat was sampled more than once and the number of quadrats sampled at any particular habitat unit was a function of its size. Once a habitat was completely covered, we would move upstream to find and sample the same habitat type. While turning over substrate to dislodge benthic species, fish were collected in a single pass that covered the entire quadrat.

The goal of the TVA sampling design was to maximize fish species richness by rigorously sampling all available habitats. Three quadrats were sampled in each habitat type. If an additional species was collected, we would reset our sampling effort to zero and three additional quadrats would be sampled in the same habitat type. We would continue sampling using this technique until no additional species were found in each habitat type. Except for shoreline sampling, this method does not have a predetermined distance but is extremely intensive ensuring most habitats and fish species are represented in the sample. In all fish sampling techniques (electrofishing, seine hauling, and shoreline), fish species were identified, counted, and recorded before being released downstream of each quadrat. Fish were

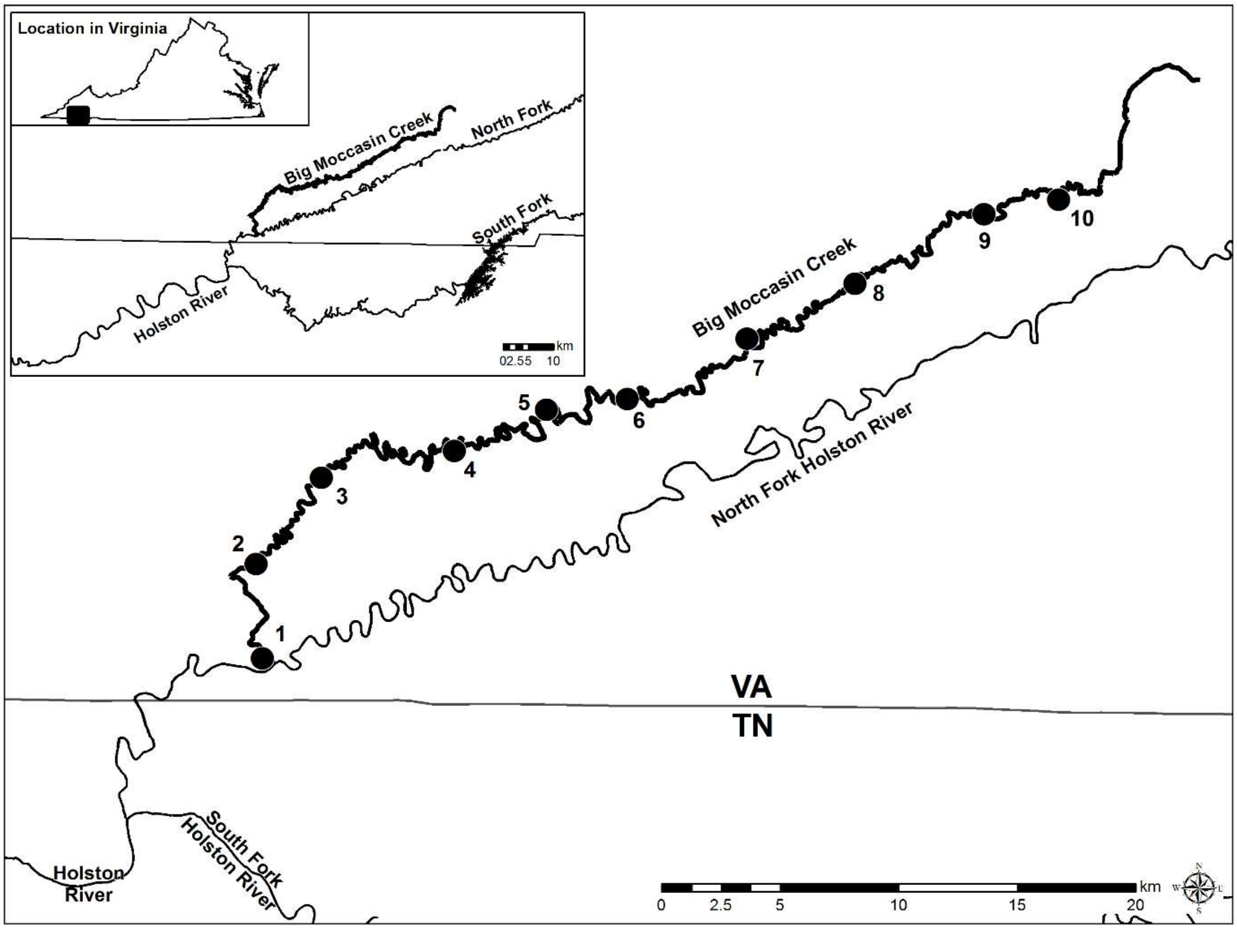

Fig. 1. Fish sampling sites on Big Moccasin Creek, Scott and Russell counties, Virginia.

also noted for disease, parasites, and hybridization. As a result of capture inefficacy and difficulty in identification, fish less than 20 mm were considered young of year and were not recorded (Karr et al., 1986).

Seine hauling was used to sample low velocity habitats such as pools, deep runs, and backwaters. The area of each quadrat sampled was determined by the length of the seine net and the distance it was hauled. Two individuals pulled an open seine (1.5 m x 3 m) while a third individual followed to free the seine net from obstacles (i.e., logs, rocks, etc.). Each haul was terminated by beaching the seine net on shore or by curling the ends and rapidly lifting it midstream.

Shoreline sampling, which often overlapped the other three habitats, was conducted last. The sample effort for shoreline sampling was 1 m from the bank edge for a distance of 46 m at each site. The beginning point typically started near the lowermost sampled habitat. Shoreline sampling consisted of a minimum of one person electroshocking and another with a dip net moving in an upstream direction to avoid turbidity caused by disturbing the stream bottom. Two 46 m sections were sampled at each site. An additional 46 m reach was sampled if a new species was captured at the site. Voucher specimens are housed at the TVA ichthyological facility, Norris, TN.

Biotic Condition

The IBI is comprised of 12 metrics that are used to reflect fish community structure and function including native species richness, taxonomic composition, trophic structure, pollution tolerance, abundance, and condition (Table 2). Most metrics are scored based on their species/drainage area relationship (Plafkin et al., 1989). The native status and ecological information detailed in Table 3 is derived from Pflieger (1975), Smith (1979), Lee et al. (1980), Etnier & Starnes (1993), and Jenkins & Burkhead (1994).

Table 1. Sampling sites on Big Moccasin Creek, Scott and Russell counties, Virginia.

Site	River Km above confluence	County	Quadrangle	Sample date	Coordinates	Basin area (km^2)
1	0.64	Scott	Kingsport	14 July 2009	36.6111 -82.5497	243.46
2	7.08	Scott	Gate City	14 July 2009	36.6476 -82.5532	206.16
3	15.93	Scott	Gate City	15 July 2009	36.6814 -82.5231	191.14
4	30.58	Scott	Hilton	15 July 2009	36.6926 -82.4605	160.32
5	40.55	Scott	Hilton	16 July 2009	36.7090 -82.4172	148.41
6	48.76	Scott	Hilton	14 Sept 2009	36.7136 -82.3791	135.71
7	58.74	Russell	Mendota	14 Sept 2009	36.7376 -82.3230	108.52
8	68.72	Russell	Moll Creek	15 Sept 2009	36.7595 -82.2723	90.13
9	79.50	Russell	Hansonville	15 Sept 2009	36.7870 -82.2118	68.89
10	85.29	Russell	Hansonville	16 Sept 2009	36.7930 -82.1766	30.04

Table 2. Metrics used in calculating Index of Biotic Integrity for sampling sites on Big Moccasin Creek, Scott and Russell counties, Virginia are based on those developed by Karr (1981) and modified by the Tennessee Department of Health and Environmental Conservation (1996) for the Tennessee River drainage. Scoring criteria for each sampling site is as a function of its drainage area.

Metric	Site	Score 1	Score 3	Score 5
Number of native fish species	1	<15	15-28	>28
	2	<14	14-27	>27
	3	14	14-26	>26
	4-5	<13	13-25	>25
	6	<13	13-24	>24
	7	<12	12-23	>23
	8	<12	12-22	>22
	9	<11	11-20	>20
	10	<9	9-16	>16
Number of native darter species	1-3	<3	3-4	>4
	4-5	<2	2-4	>4
	6-9	<2	2-3	>3
	10	<2	2	>2
Number of native sunfish species (less *Micropterus* spp.)	All	<2	2	>2
Number of native sucker species	All	<2	2	>2
Number of intolerant species	1-7	<2	2-3	>3
	8-10	<2	2	>2

Table 2 (continued).

Metric	Site	Score 1	3	5
Percentage of tolerant species	1	>27	27-13	<13
	2	>27	27-14	<14
	3	>28	28-14	<14
	4-5	>29	29-14	<14
	6	>29	29-15	<15
	7	>30	30-15	<15
	8	>31	31-16	<16
	9	>32	32-16	<16
	10	>36	36-18	<18
Percentage of individuals as omnivores and stonerollers	1	>30	30-15	<15
	2	>31	31-16	<16
	3	>32	32-16	<16
	4	>33	33-16	<16
	5	>33	33-17	<17
	6	>34	34-18	<18
	7	>35	35-18	<18
	8	>37	37-18	<18
	9	>39	39-19	<19
	10	>44	44-22	<22
Percentage of individuals as specialized insectivores	1	<25	25-50	>50
	2	<24	24-48	>48
	3	24	24-47	47
	4	23	23-46	46
	5	<23	23-45	>45
	6	<22	22-43	>43
	7	<21	21-42	>42
	8	<20	20-41	>41
	9	<19	19-39	>39
	10	<16	16-31	>31
Percentage of individuals as piscivores	All	<2	2-4	>4
Percentage of individuals as hybrids	All	>1	1-0	<0
Percentage of individual species with disease, tumors, fin damage, and other anomalies	All	>5	5-2	<2
Catch rate (average number of fish/300 ft^2 [28.7 m^2]) sampling unit	1	<15	15-29	>29
	2	<15	15-31	>31
	3	<16	16-31	>31
	4	<16	16-33	>33
	5	<17	17-33	>33
	6	<18	18-36	>36
	7	<18	18-36	>36
	8	<19	19-38	>38
	9	<21	21-41	>41
	10	<26	26-52	>52

Table 3. Fish species collected in Big Moccasin Creek, Scott and Russell counties, Virginia, with designations for native status, trophic guild, family group, and pollution tolerance for the Tennessee River drainage. Native status and ecological information are presented by Pflieger (1975), Smith (1979), Lee et al. (1980), Etnier & Starnes (1993), and Jenkins & Burkhead (1994).

Scientific name	Native	Trophic guild	Family group	Tolerance
Rhynichthys obtusus	Yes	Specialized Insectivore	Cyprinidae	----
Campostoma oligolepis	Yes	Herbivore	Cyprinidae	----
Nocomis micropogon	Yes	Omnivore	Cyprinidae	----
Phenocobius uranops	Yes	Specialized Insectivore	Cyprinidae	----
Hybopsis amblops	Yes	Specialized Insectivore	Cyprinidae	Intolerant
Cyprinella galactura	Yes	Insectivore	Cyprinidae	----
Cyprinella spiloptera	Yes	Insectivore	Cyprinidae	Tolerant
Luxilus coccogenis	Yes	Specialized Insectivore	Cyprinidae	Intolerant
Luxilus chrysocephalus	Yes	Omnivore	Cyprinidae	Tolerant
Notropis micropteryx	Yes	Specialized Insectivore	Cyprinidae	----
Notropis leuciodus	Yes	Specialized Insectivore	Cyprinidae	Intolerant
Notropis photogenis	Yes	Specialized Insectivore	Cyprinidae	----
Notropis telescopus	Yes	Specialized Insectivore	Cyprinidae	Intolerant
Notropis volucellus	Yes	Specialized Insectivore	Cyprinidae	----
Notropis sp.	Yes	Specialized Insectivore	Cyprinidae	----
Pimephales notatus	Yes	Omnivore	Cyprinidae	----
Hypentelium nigricans	Yes	Insectivore	Catostomidae	Intolerant
Catostomus commersoni	Yes	Omnivore	Catostomidae	Tolerant
Moxostoma duquesnei	Yes	Insectivore	Catostomidae	Intolerant
Moxostoma erythrurum	Yes	Insectivore	Catostomidae	----
Ameiurus natalis	Yes	Omnivore	Ictaluridae	Tolerant
Noturus flavus	Yes	Insectivore	Ictaluridae	----
Cottus baileyi	Yes	Insectivore	Cottidae	----
Cottus carolinae	Yes	Insectivore	Cottidae	----
Ambloplites rupestris	Yes	Piscivore	Centrarchidae	Intolerant
Micropterus dolomieu	Yes	Piscivore	Centrarchidae	----
MIcropterus salmoides	Yes	Piscivore	Centrarchidae	----
Lepomis auritus	No	Insectivore	Centrarchidae	----
Lepomis megalotis	Yes	Insectivore	Centrarchidae	----
Lepomis macrochirus	Yes	Insectivore	Centrarchidae	----
Percina burtoni	Yes	Specialized Insectivore	Percidae	----
Etheostoma simoterum	Yes	Specialized Insectivore	Percidae	----
Etheostoma blennioides	Yes	Specialized Insectivore	Percidae	----
Etheostoma zonale	Yes	Specialized Insectivore	Percidae	----
Etheostoma rufilineatum	Yes	Specialized Insectivore	Percidae	----
Etheostoma flabellare	Yes	Specialized Insectivore	Percidae	Intolerant

Species richness and composition metrics includes number of darter, sunfish, sucker, and intolerant species and percentage of tolerant species. Darter and sucker species are sensitive to degradation in benthic habitats where they feed and spawn. Similarly, sunfish are sensitive to impacts in pools and the lack of instream cover (Karr et al., 1986). Tolerance is related to a species' susceptibility to siltation, low dissolved oxygen, and toxins (Karr et al., 1986). In streams impacted by chemical and physical degradation, darter, sunfish, sucker, and intolerant species will decrease in number. In contrast, tolerant species, such as Green Sunfish (*Lepomis cyanellus*) and Creek Chub (*Semotilus atromaculatus*), will increase and can become dominant in disturbed systems (Plafkin et al., 1989).

Trophic structure is based on adult feeding patterns such as herbivores, omnivores, insectivores, and piscivores (Karr et al., 1986). The TDHEC (1996) metric "Percentage of individuals as omnivores and stonerollers" is a variation from Karr et al. (1986) that uses "Proportion of individuals as omnivores." Owing to their varied diet of plants and animals, omnivores are tolerant to changes in their food base caused by environmental degradation (Lyons, 1992). Stonerollers (*Campostoma* spp.) are primarily herbivores feeding on algae and sometimes detritus (Jenkins & Burkhead, 1994). A disproportionately high abundance of stone-rollers in the fish community can be an indicator of elevated algae growth caused by increased nutrients in a system (TDHEC, 1996). The TDHEC (1996) metric "Percentage of individuals as specialized insectivores" is a variation from the Karr et al. (1986) metric "Proportion of individuals as insectivorous cyprinids." Specialized insectivores, including both cyprinids and darters, respond negatively to a decrease in their invertebrate food sources because of habitat degradation (Plafkin et al., 1989). The "Percentage of individuals as piscivores" metric represents top carnivores that feed on fish and crayfish (Karr et al., 1986). These species will decline as habitat degrades, which in turn impacts their food source.

The "Catch rate" metric or as defined by Karr et al. (1986) "Number of individuals in a sample" is used to evaluate population abundance. The TDHEC (1996) metric uses number of fish/300 ft^2 or 28.7 m^2. Depending on the region and stream size, density of individuals is expected to decline as integrity decreases (Plafkin et al., 1989).

Fish condition metrics are determined by individuals that are hybrids and those with disease and other anomalies within the fish community. Karr et al. (1989) indicate that hybridization can increase in degraded systems, a result of altered reproductive isolation among species. Hybrids can be difficult to detect, especially for minnows and darters (Karr et al., 1986). Fish exhibiting an excessive amount of diseases, parasites, fin damage, and other anomalies can be indicative of environmental degradation. The most frequent and easily observed parasite in these systems is a trematode (*Neascus* sp.) infection that appears as black spots on the fins and body (Post, 1987). TVA IBI assessment protocols require more than five spots on an individual fish to have a disease diagnosis (TDHEC, 1996).

Fish data from each site are pooled and entered separately into Ssurvey, a TVA developed software program. Final data are provided in an Excel Microsoft spreadsheet. Descriptions of each IBI ranking class are detailed in Table 4.

Table 4. Biotic integrity classes used in assessing fish communities along with general descriptions of their attributes (Karr et al., 1986).

Class	Attributes	IBI 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.	40-44
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.	28-34
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.	

RESULTS

Species Composition and Distribution

A total of 11,933 specimens representing 36 species of six families was captured (Table 5). The most dominant families were Cyprinidae and Percidae with 16 and six species, respectively. The three most abundant species were Largescale Stoneroller (*Campostoma oligolepis*), Tennessee Shiner (*Notropis leucoidus*), and Warpaint Shiner (*Luxilius coccogenis*). The rarest species (three individuals or less) were Stargazing Minnow (*Phenocobius uranops*), Mimic Shiner (*Notropis volucellus*), Golden Redhorse (*Moxostoma erythrurum*), Stonecat (*Noturus flavus*), Longear Sunfish (*Lepomis megalotis*), Bluegill (*L. macrochirus*), and Blotchside Logperch (*Percina burtoni*). All species were native except Redbreast Sunfish (*L. auritus*).

The average number of species per site was 20.8 (range 18-26). Many species were found only at the lowermost station, including Stargazing Minnow, Spotfin Shiner (*Cyprinella splioptera*), Highland Shiner (*Notropis micropteryx*), Sawfin Shiner (*Notropis* sp.), Silver Shiner (*Notropis photogenis*), and Longear Sunfish. The greatest abundance was recorded at Site 8, which was dominated (50%) by Largescale Stoneroller.

Biotic Condition

Metric scores and integrity class for each site are detailed in Table 6. The most frequent metric scores for all sites was “5” (N=65), followed by “3” (N=35) and “1” (N=20). The total scores of individual metrics across all sites ranged from 14 to 50. The highest score of 50 was shared by “Percentage of tolerant species” and “Percentage of individuals as hybrids”, which scored “5” at all sites. The two lowest scores were “Number of native sunfish species” at 14 and “Percentage of individuals as omnivores and stonerollers” at 18. All other metrics ranged between 30 and 46.

IBI site scores averaged 45 (range 40-50). Of the 10 sites sampled, five were ranked “fair” and five as “good.” The “good” sites averaged 48.4 (range 48-50), while “fair” sites averaged 41.6 (range 40-46). Four of the five sites that ranked “good” were located in the lower half of BMC. In contrast, all except one “fair” site were located in the upper half. The metric scores of “5”, “3” and “1” were distributed 37, 16, and 7 for “good” sites and 27, 20, and 13 for “fair” sites, respectively.

In comparing individual metrics between the “good” and “fair” sites, “good” sites had higher scores for “Number of sucker species,” “Percentage of individuals as piscivores,” and “Percentage of individuals with disease, tumors, fin damage, and other anomalies.” There were no differences in “Number of intolerant species” and “Percentage of individuals as specialized insectivores” between sites that scored “good” and “fair.” Only a minimal difference was found between these categories for “Number of darter species.”

DISCUSSION

BMC is mostly in fair condition, which indicates loss in species richness, skewed trophic structure, and lack of top predators (Lyons, 1992). Throughout the creek, omnivores and stonerollers comprised over 45% of the total fish collected indicating a possible impairment to the food base allowing species to flourish that can live on broad diets (Lyons, 1992). Stonerollers alone comprised 32% of the total fish collected and their high abundance may be a result of elevated algal growth, a primary diet component (Jenkins & Burkhead, 1994). Cattle production is the dominant agricultural use in the BMC watershed, and is therefore the most likely source of the nitrogen and phosphorus that contributes to algal growth. The other widespread indicator of stress was the lack of native sunfish species - a possible result of degraded pool habitat and insufficient instream cover (Karr et al., 1986).

Biotic integrity generally decreased from the lower to upper reaches of BMC. The most obvious indicators of impairment in the upper reaches were the loss of suckers and piscivores. Many sucker species are long-lived and their absence may be indicative of chronic chemical and physical habitat degradation (Karr et al., 1986). Piscivores are considered top predators, and thus require a trophically-robust, diverse fish community to sustain their populations (Karr et al., 1986). If this food base is stressed, piscivore numbers will diminish as observed in BMC. Lastly, disease and other anomalies are more prevalent in the upper portions of BMC providing further evidence of an impaired system.

While BMC does show signs of stress, the system is also resilient. In particular, intolerant, specialized insectivores, and darter species had metric scores that indicate they are in good condition. All three metrics include species that are highly sensitive to poor water quality and increases in siltation and turbidity (Karr et al., 1986). Specialized insectivores, which include darters, are indirectly affected by impacts to their food base by the same perturbations (Robertson et al., 2006). The continued presence of these sensitive species may indicate that the degraded conditions in BMC are not beyond recovery.

Table 5. Distribution and abundance of fishes collected in Big Moccasin Creek, Scott and Russell counties, Virginia. Nomenclature follows Page et al. (2013).

		Site										
Common name	Scientific name	1	2	3	4	5	6	7	8	9	10	Total
W. Blacknose Dace	*Rhynichthys obtusus*	-	-	-	-	-	2	-	-	14	48	64
Largescale Stoneroller	*Campostoma oligolepis*	147	19	46	280	225	300	748	814	777	469	3825
River Chub	*Nocomis micropogon*	12	12	59	38	65	70	44	53	32	3	388
Stargazing Minnow	*Phenocobius uranops*	3	-	-	-	-	-	-	-	-	-	3
Bigeye Chub	*Hybopsis amblops*	-	-	-	2	5	11	33	4	41	1	97
Whitetail Shiner	*Cyprinella galactura*	21	11	55	38	36	69	23	28	4	29	314
Spotfin Shiner	*Cyprinella spiloptera*	28	-	-	-	-	-	-	-	-	-	28
Warpaint Shiner	*Luxilus coccogenis*	60	124	186	89	177	152	105	94	60	5	1052
Striped Shiner	*Luxilus chrysocephalus*	47	23	40	157	121	144	93	55	176	135	991
Highland Shiner	*Notropis micropteryx*	10	-	-	-	-	-	-	-	-	-	10
Tennessee Shiner	*Notropis leuciodus*	89	178	173	169	170	271	146	139	273	5	1613
Silver Shiner	*Notropis photogenis*	5	-	-	-	-	-	-	-	-	-	5
Telescope Shiner	*Notropis telescopus*	81	82	42	82	59	162	38	155	147	35	883
Mimic Shiner	*Notropis volucellus*	1	1	-	-	-	-	-	-	-	-	2
Sawfin Shiner	*Notropis sp.*	22	-	-	-	-	-	-	-	-	-	22
Bluntnose Minnnow	*Pimephales notatus*	-	-	-	37	5	7	4	11	21	119	204
Northern Hogsucker	*Hypentelium nigricans*	10	4	3	34	31	28	31	24	22	1	188
Black Redhorse	*Moxostoma duquesnei*	1	2	5	6	14	23	4	1	-	5	61
Golden Redhorse	*Moxostoma erythrurum*	-	1	-	-	-	-	-	-	-	-	1
White Sucker	*Catostomus commersoni*	-	-	-	1	-	-	-	-	-	6	7
Yellow Bullhead	*Ameiurus natalis*	-	-	2	1	-	1	-	1	1	2	8
Stonecat	*Noturus flavus*	-	-	3	-	-	-	-	-	-	-	3
Black Sculpin	*Cottus baileyi*	-	-	-	-	124	-	20	63	106	37	350
Banded Sculpin	*Cottus carolinae*	18	35	41	8	-	-	-	-	-	-	102
Rock Bass	*Ambloplites rupestris*	19	16	9	59	36	18	6	17	45	18	243
Smallmouth Bass	*Micropterus dolomieu*	9	8	12	4	5	8	6	11	6	3	72
Largemouth Bass	*Micropterus salmoides*	-	-	-	1	-	-	-	-	-	3	4
Redbreast Sunfish	*Lepomis auritus*	16	2	4	15	6	18	2	-	-	34	97
Longear Sunfish	*Lepomis megalotis*	1	-	-	-	-	-	-	-	-	-	1
Bluegill	*Lepomis macrochirus*	2	-	-	-	-	1	-	-	-	-	3
Blotchside Logperch	*Percina burtoni*	-	1	-	-	2	-	-	-	-	-	3
Snubnose Darter	*Etheostoma simoterum*	5	3	3	16	34	1	23	27	124	52	288
Greenside Darter	*Etheostoma blennioides*	15	13	3	28	38	3	21	4	7	-	132
Banded Darter	*Etheostoma zonale*	3	-	-	6	9	-	4	-	-	-	22
Redline Darter	*Etheostoma rufilineatum*	40	18	27	74	83	50	48	45	21	15	421
Fantail Darter	*Etheostoma flabellare*	1	-	-	18	41	3	28	69	97	172	429
Number of Specimens		666	553	713	1163	1286	1342	1427	1615	1971	1197	11933
Species Richness		26	19	18	23	21	21	20	19	19	22	36

Table 6. Index of biotic integrity scores on sites sampled on Big Moccasin Creek, Scott and Russell counties, Virginia. Metrics are based on those developed by Karr (1981) and modified by the Tennessee Department of Health and Environmental Conservation (1996) for the Tennessee River Drainage.

	Site									
Metrics	1	2	3	4	5	6	7	8	9	10
Number of native species	3	3	3	3	3	3	3	3	3	5
Number of darter species	5	3	3	5	5	3	5	5	5	5
Number of native sunfish species (less *Micropterus* spp.)	5	1	1	1	1	3	1	1	1	1
Number of sucker species	3	5	3	5	3	3	3	3	1	5
Number of intolerant species	5	3	3	5	5	5	5	5	5	5
Percentage of tolerant species	5	5	5	5	5	5	5	5	5	5
Percentage of individuals as omnivores and stonerollers	1	5	3	1	3	1	1	1	1	1
Percentage of individuals as specialized insectivores	5	5	5	3	5	5	3	3	5	3
Percentage of individuals as piscivores	5	5	3	5	3	1	1	1	3	3
Percentage of individuals as hybrids	5	5	5	5	5	5	5	5	5	5
Percentage of individuals with disease, tumors, fin damage, and other anomalies	5	5	5	5	5	5	3	5	1	5
Catch rate	3	3	3	5	5	5	5	5	5	5
IBI total score	50	48	42	48	48	44	40	42	40	48
Integrity class	Good	Good	Fair	Good	Good	Fair	Fair	Fair	Fair	Good

One of the most useful aspects of the IBI method is its ability to determine trends (Karr et al., 1986). Unfortunately, none of our sampling sites were located exactly at the sites selected by TVA for long-term monitoring. The closest would be their site at RKm 6.1 (Slabtown), which was one kilometer downstream of our site 2. TVA has monitored this site four times between 1994 and 2007. Their scores have ranged from 38 (poor/fair) in 1997 to 46 (fair/good) in 2007 (Matthews & Malone, 2016). Our score of 48 (good) may demonstrate a slight improvement, but during TVA sampling at their Slabtown site in 2012 the score dropped to 42 (fair), and in 2017 declined to 40 (fair) (J.M. Mollish, TVA pers. comm.), which could indicate that ecological health in this system continues to degrade.

BMC continues to contain a rich diversity of freshwater fish species despite demonstrating signs of impairment. Our survey confirmed that 36 of the 42 species previously collected in BMC are still present (Angermeier & Smoger, 1993; Jenkins & Burkhead, 1994). Species known from BMC but not collected by us are Logperch (*Percina capriodes*), Tangerine Darter (*Percina aurantiaca*), Common Carp (*Cyprinus carpio*), Black Bullhead (*Ameiurus melas*), Smallmouth Redhorse (*Moxostoma breviceps*), Green Sunfish (*Lepomis cyanellus*), Gizzard Shad (*Dorosoma cepedianum*), and Creek Chub (*Semotilus atromaculatus*). Common Carp is not native to North America.

Redbreast Sunfish is the only non-native centrarchid collected in our survey. They were first noted in BMC in 1937 by TVA (VDGIF FWIS, 2016) and now are the dominant *Lepomis* in the system. In contrast, the other sunfish species we found, Longear and Bluegill, were quite rare. Bluegill is also stocked heavily for recreational purposes and is widespread in the state (Jenkins & Burkhead, 1994). Longear Sunfish, a species native to the Tennessee River drainage, has become rare (Saylor, pers. obs.), a possible result of pollution and competition from non-native centrarchids. Longear Sunfish are also listed as a Tier IV species, in moderate need of conservation, in Virginia's Wildlife Action Plan (VDGIF, 2015).

Rare species are still extant in BMC despite its impaired nature. Blotchside Logperch is endemic to the Tennessee River drainage and listed as a Tier II species, critical need of conservation action (VDGIF, 2015). Blotchside Logperch was first discovered in BMC in 1993 by Angermeier & Smoger (1993) and our collection of this species at two locations indicates that it is still extant in the system. The Stonecat (*N. flavus*), is a Tier IV species that was first found in BMC by TVA in 1973. Our discovery of three individuals at two locations demonstrates that it is extremely rare but still persists in the system. Fragmentation caused by a lowhead dam located at RKm 7.7 may result in genetic drift and inbreeding depression that could further exacerbate the vulnerability of both species (Waples, 1990).

In 2017, TVA sampling at Slabtown yielded two species new to BMC (J.M. Mollish, TVA pers. comm.). The first was the Spotfin Chub (*Erimonax monachus*), a federally threatened species that is well known from the NFHR (VDGIF FWIS, 2016). The other was Ohio Lamprey (*Ichthyomyzon bdellium*), its nearest recorded previous collection being from the NFHR above Saltville, Smyth County. With their inclusion, the total number of native species in the BMC system is currently 44 of seven families.

Although all of BMC is in need of restoration activities, the most efficient use of limited funding and resources should be directed towards its upper reaches to restrict cattle access and establish riparian buffers along its mainstem and tributaries (VDCR, 2004). To accomplish this task, landowners will need to be informed on the importance of implementing best management practices (Weigmann, 1995). If significant restoration efforts are not focused on BMC, its continued decline will contribute to the loss of species richness and ecological integrity in a waterbody that is critically important to the North Fork Holston drainage.

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