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RESEARCH ARTICLE

SPECIES COMPOSITION AND HABITAT ASSOCIATIONS OF THE FISHES OF FLAT CREEK, APPOMATTOX RIVER DRAINAGE, VIRGINIA

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ABSTRACT

Flat Creek is a tributary of the Appomattox River system, James River drainage, in central Virginia. In 2016 and 2017, we conducted a fish survey on six mainstem and four tributary sites of Flat Creek. Limited sampling in previous surveys recorded 49 species including an upland population of Bridle Shiner, *Notropis bifrenatus*, a species in critical conservation need. We collected a total of 3,112 fish of 43 species in 10 families. We noted the first records of Spottail Shiner (*Notropis hudsonius*), Spotted Bass (*Micropterus punctulatus*), and Shield Darter (*Percina peltata*) in the system. Although Bridle Shiner was not found, we did collect American Eel (*Anguilla rostrata*) and Mud Sunfish (*Acantharchus pomotis*), two species of conservation need.

Keywords: Fish survey, Bridle Shiner, habitat.

INTRODUCTION

Flat Creek is a tributary to the Appomattox River system, James River drainage, Virginia. It is 54.4 km long, beginning slightly east of the town of Burkesville, Nottoway County, and flows northeast through Prince Edward, Nottoway, and Amelia counties before joining the Appomattox River (Fig. 1). The total gradient is 1.8 m/km with elevation ranging from 152.8 m at the headwaters to 53.9 m at its mouth. The Flat Creek watershed is 36,610 ha, which comprises 10.52% of the Appomattox drainage area. Primary land uses are forested (63%), pasture (13%), and cropland (11%) (Multi-Resolution Land Characteristics Consortium, 2011). Pasture is mostly

for cattle production. Flat Creek is within the Piedmont physiographic province and specifically the Piedmont Lowland sub-province. Piedmont streams are highly entrenched with steep banks and substrates of sand, silts and clays (Jenkins & Burkhead, 1994). The low gradient produces short riffles, long runs, and medium pools. Pools are enhanced greatly by the presence of woody debris such as root wads and logs.

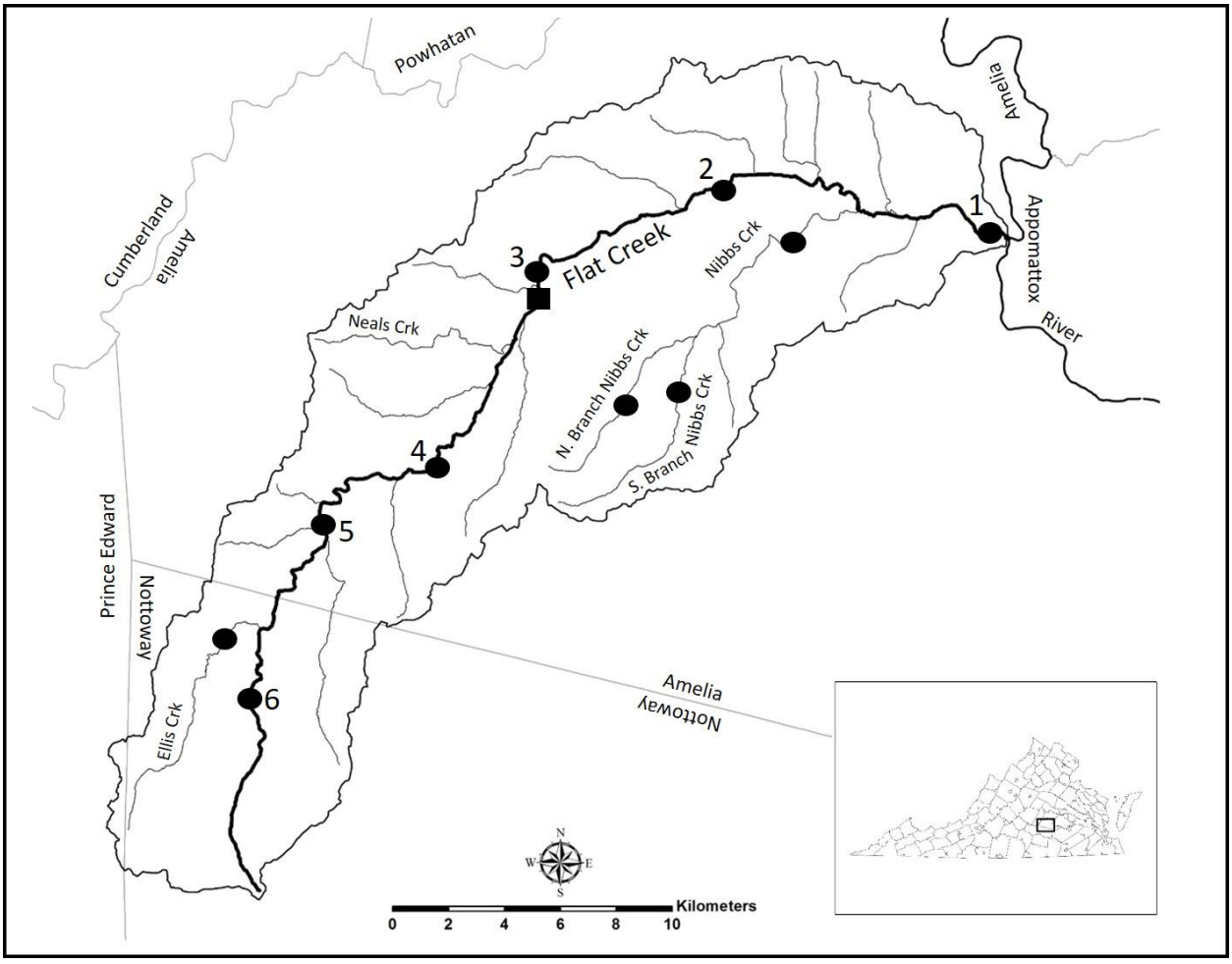

Figure 1. Locations of sampling sites (circles) in the Flat Creek watershed, Virginia. Numbered sites are located on Flat Creek mainstem while all others are on named tributaries. Square marker represents location of historic mainstem Bridle Shiner record.

Because of its smaller size, Flat Creek has only had limited investigations into its fish community. Since 1946, 49 fish species have been documented among 38 collections according to the Virginia Department of Game and Inland Fisheries' Fish and Wildlife Information database (VDGIF, 2016). Only one site was sampled prior to 1980. After 1980, multiple sites were sampled by various researchers and agencies (Table 1). The number of species collected during these surveys varied from 26 to 37. Although several surveys were conducted on both mainstem and tributary sites, sampling was sporadic and not comprehensive over its entire length.

Table 1. Fish sampling records in the Flat Creek system, Virginia. Most records are from Virginia Department of Game and Inland Fisheries' Fish and Wildlife Information Service (2016). These include Pre-1980s from various collectors, Robert Jenkins (Roanoke College), Virginia Department of Environmental Quality, and Virginia Commonwealth University data. Other records were compiled from Norman and Southwick (2014) and Starnes et al. (2016). Species are listed phylogenetically. Nomenclature follows Page et al. (2013).

Common name	Scientific name	Pre-1980	Jenkins 1983	Norman 1986-87	VDEQ 2009-13	VCU 2011	Starnes 2008-13
American Eel	*Anguilla rostrata*			X	X	X	
Gizzard Shad	*Dorosoma cepedianum*		X				
Chain Pickerel	*Esox niger*		X	X	X		X
Eastern Mudminnow	*Umbra pygmaea*			X			X
Golden Shiner	*Notemigonus crysoleucas*	X		X	X	X	X
Mountain Redbelly Dace	*Chrosomus oreas*	X		X	X	X	
Rosyside Dace	*Clinostomus funduloides*	X		X	X	X	
Blacknose Dace	*Rhynichthys atratulus*			X	X	X	
Fallfish	*Semotilus corporalis*	X	X	X		X	X
Creek Chub	*Semotilus atromaculatus*			X	X	X	
River Chub	*Nocomis micropogon*		X				
Bluehead Chub	*Nocomis leptocephalus*	X	X	X	X	X	X
Satinfin Shiner	*Cyprinella analostana*		X	X	X	X	X
Crescent Shiner	*Luxilus cerasinus*				X	X	
Common Shiner	*Luxilus cornutus*			X		X	X
Rosefin Shiner	*Lythrurus ardens*		X				X
Comely Shiner	*Notropis amoenus*			X			
Swallowtail Shiner	*Notropis procne*	X	X	X	X	X	X
Bridle Shiner	*Notropis bifrenatus*		X	X			X
Eastern Silvery Minnow	*Hybognathus regius*	X		X		X	X
Creek Chubsucker	*Erimyzon oblongus*			X	X	X	X

Table 1.
Continued

Common name	Scientific name	Pre-1980	Jenkins 1983	Norman 1986-87	VDEQ 2009-13	VCU 2011	Starnes 2008-13
Northern Hogsucker	*Hypentelium nigricans*			X			X
Torrent Sucker	*Thorburnia rhothoeca*	X		X	X	X	
Blacktip Jumprock	*Moxostoma cervinum*			X			
White Sucker	*Catostomus commersoni*		X	X	X	X	
Channel Catfish	*Ictalurus punctatus*		X				
Yellow Bullhead	*Ameirus natalis*		X	X		X	X
Brown Bullhead	*Ameirus nebulosus*			X	X		
Margined Madtom	*Noturus insignis*	X	X	X	X	X	
Pirate Perch	*Aphredoderus sayanus*	X	X	X	X	X	X
Eastern Mosquitofish	*Gambusia holbrooki*		X		X		X
Mud Sunfish	*Acantharchus pomotis*		X		X		X
Flier	*Centrarchus macropterus*			X	X		X
Bluespotted Sunfish	*Enneacanthus gloriosus*		X	X	X		X
Warmouth	*Lepomis gulosus*	X		X	X		X
Green Sunfish	*Lepomis cyanellus*				X	X	
Redbreast Sunfish	*Lepomis auritus*		X	X	X	X	X
Bluegill	*Lepomis macrochirus*	X	X	X	X	X	X
Pumpkinseed	*Lepomis gibbosus*		X	X	X	X	X
Redear Sunfish	*Lepomis microlophus*		X		X		
Yellow Perch	*Perca flavescens*				X		
Stripeback Darter	*Percina notogramma*		X	X			X
Johnny Darter	*Etheostoma nigrum*	X		X	X	X	X

Table 1.
Continued

Common name	Scientific name	Pre-1980	Jenkins 1983	Norman 1986-87	VDEQ 2009-13	VCU 2011	Starnes 2008-13
Tessellated Darter	*Etheostoma olmstedi*		X		X		X
Glassy Darter	*Etheostoma vitreum*	X	X	X	X	X	X
Fantail Darter	*Etheostoma flabellare*	X	X	X	X	X	
Swamp Darter	*Etheostoma fusiforme*	X	X	X			X
Number of Species		16	26	37	32	26	30

Among the fish species known from Flat Creek, the Bridle Shiner (*Notropis bifrenatus*), a small minnow, is of particular interest. The species was first documented in Flat Creek in 1983 (VDGIF, 2016) and most recently collected in 2013 as part of a species status survey (Starnes et al. 2014). Throughout its range from Canada to South Carolina, the Bridle Shiner has been documented to be in decline, resulting in having conservation status in eight of the 11 states in which it occurs (Margolis, 2003). In Virginia, the shiner is a Tier I species of the state's Wildlife Action Plan (VDGIF, 2015) indicating that it is in critical need of conservation action. Because of its rarity and the disjunct nature of the Flat Creek population, Starnes et al. (2014) reported that the creek should be surveyed over much of its length and tributary system to determine just how truly localized the population is and whether it can withstand removal of stock. Based on its limited sampling and presence of a rare species, we determined that a comprehensive fish survey was needed on the Flat Creek system.

MATERIALS AND METHODS

We sampled six mainstem and four tributary sites (ranging 241 m – 594 m) between July 2016 and August 2017 (Fig. 1 and Table 2). Sites were selected based on accessibility, previous Bridle Shiner records, and distribution across the Flat Creek system. Total sample length of all sites combined was 3.845 km (Table 2).

Water samples were collected and water chemistry measured before entering the stream. We used a YSI 556 MPS meter for temperature (°C), specific conductivity (µS/cm), pH, and dissolved oxygen (mg/l). Turbidity (FNU) was measured using a LaMotte 2020 Turbidity Meter. Fish were sampled using a Smith-Root LR 24 backpack electroshocker and a 3 m x 2 m (3.1 mm mesh) seine net singularly or in combination. While moving in an upstream direction, 20 samples were collected at each site. Each fish sampling effort was restricted to a specific mesohabitat type (i.e., pool, riffle, run). We sampled mesohabitats in relative proportion to those present in the sample reach. After sampling fish, we estimated average depth, dominant substrate, habitat area, and presence of woody debris (logs and root wads) at each habitat. We used a modified Wentworth

classification for substrate particles size (Cummins, 1962). Average wetted stream width (m) was determined by measuring stream width at five-equal spaced intervals along each sample reach.

Table 2. Fish sampling sites in the Flat Creek Watershed, Amelia, Nottoway and Prince Edward counties, Virginia.

Site	Stream	Adjoining Tributary	Distance above adjoining tributary (km)	Sample date	Sample Reach Coordinates Start	End	Sample Reach Distance (m)
1	Flat Creek	Appomattox River	0.0	25 July 2016	37.3920 -77.8730	37.3941 -77.8762	408
2	Flat Creek	Appomattox River	12.59	26 July 2016	37.4154 -77.9836	37.4115 -77.9876	594
3	Flat Creek	Appomattox River	21.14	26 July 2016	37.3910 -78.0623	37.3872 -78.0627	436
4	Flat Creek	Appomattox River	30.0	27 July 2016	37.3300 -78.2060	37.3273 -78.1065	383
5	Flat Creek	Appomattox River	37.50	24 Aug 2016	37.3077 -78.1548	37.3042 -78.1534	415
6	Flat Creek	Appomattox River	46.43	23 Aug 2016	37.2512 -78.1863	37.2487 -78.1855	298
EC	Ellis Creek	Flat Creek	1.09	23 Aug 2016	37.2745 -78.1899	37.2722 -78.1927	370
SBN	South Branch Nibbs Creek	Nibbs Creek	1.67	17 Aug 2017	37.3507 -78.0072	37.3481 -78.0075	292
NBN	North Branch Nibbs Creek	Nibbs Creek	4.25	17 Aug 2017	37.3407 -78.0312	37.3391 -78.0326	241
NC	Nibbs Creek	Flat Creek	2.52	16 Aug 2017	37.3982 -77.9546	37.3953 -77.9576	409

Most fish were identified, counted, and released soon after capture. A representative sample of all fish species and unidentified specimens were vouchered from each site and preserved in 10% buffered formalin. Specimens in need of further identification were processed at the Virginia Department of Game and Inland Fisheries Field Office, Blacksburg, Virginia. Assistance in identification was provided by Dr. Wayne Starnes, Fish Curator (Retired), North Carolina Museum of Natural History. All vouchers were deposited and cataloged at the Virginia Marine Institute Nunnally Ichthyological Collection, Gloucester, Virginia. Nomenclature and phylogenetic order of families follows Page et al. (2013).

For each site, water chemistry and stream habitat characteristics are summarized in Table 3. We calculated total area, average depth, and dominant substrate for each sampled mesohabitat type. Habitat association was determined by summing mesohabitat type where each species was collected and converting it into a percentage based on all habitat types. We use the terms “dominant” and “subdominant” in reference to the habitat type where the first and second highest

number of individuals of a particular species were collected, respectively. A Student T-test was used to determine difference (evaluated at $\alpha = 0.05$) in water chemistry between mainstem and tributaries. We could not normalize habitat depth so we used a non-parametric Kruskal-Wallis test to determine differences in medians. A Dunn's post hoc test (Dunn, 1964) was conducted after a significant Kruskal-Wallis test. All statistical tests were conducted using PAleontological STatistical (PAST) ver. 3.23 software.

RESULTS

Habitat

All habitat data is summarized in Table 3. Among 200 samples, pools comprised 46%, runs 38.5%, and riffles 15.5%. Pools were significantly deeper ($p < 0.001$) than runs and riffles. Runs were significantly deeper ($p < 0.001$) than riffles. Sand (79%), gravel (11.5%), silt (9%) and cobble (0.5%) comprised the dominant substrate types over all habitat types. Sand dominated 82%, 86%, and 55% of pools, runs, and riffles, respectively. The remaining pools (17%) were dominated by silt while 10.5% of runs and 41% of riffles were composed of gravel. Wood debris was present at all sites and primarily associated with pool habitat. Stream width ranged from 2.2- 9.8 ($\bar{x}$ = 5.62 m, SD = 2.18) over all sites.

Table 3. Habitat variables collected in the Flat Creek system, Virginia. Site numbers correspond to mainstem Flat Creek sites on Table 2. Tributaries are abbreviated as: EC – Ellis Creek; SBN – South Branch Nibbs Creek; NBN – North Branch Nibbs Creek; NC - Nibbs Creek.

	Site									
Variable	1	2	3	4	5	6	EC	SBN	NBN	NC
Temperature (°C)	27.8	26.9	28.8	26.3	21	21.5	22.3	23.4	23.2	23.4
pH	7.84	7.59	7.89	7.88	8.11	7.53	7.9	8.21	8.02	8.26
Specific Conductivity (µS/cm)	144	157	175	165	151	162	118	159	134	172
Dissolved Oxygen (mg/l)	7.77	5.06	8.35	5.56	7.4	7.3	7.3	7.89	4.83	6.75
Turbidity (FNU)	17.5	6.03	9.54	5.32	3.8	1.3	2.6	4.53	12.8	4.27
Avg. Stream Width (m)	8.9	7.5	8.1	4.1	6.0	5.9	2.2	3.2	4.3	6.0
% Pool	25	30	50	45	60	55	60	35	60	40
% Run	70	50	45	40	35	25	35	35	20	30
% Riffle	5	20	5	15	5	20	5	30	20	30
Pool Avg. Depth (m)	0.40	0.47	0.33	0.44	0.62	0.28	0.29	0.42	0.33	0.49
Run Avg. Depth (m)	0.27	0.24	0.24	0.19	0.31	0.10	0.16	0.10	0.14	0.22
Riffle Avg. Depth (m)	0.20	0.15	0.20	0.13	0.20	0.11	0.10	0.06	0.06	0.16
Dominant Substrate	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Gravel

Among water chemistry variables at all sites, temperature ranged from 21°C-28.78°C ($\bar{x}$ = 24.46° C, SD = 2.76), pH ranged from 7.53-8.26 ($\bar{x}$ = 7.92, SD = 0.24), specific conductivity ranged from 118 to 175 µS/cm ($\bar{x}$ = 153.7 µS/cm, SD = 17.6), dissolved oxygen ranged from 4.83 to 8.35 mg/l ($\bar{x}$ = 6.82 mg/l, SD = 1.24), and turbidity ranged from 1.3 to 17.3 FNU ($\bar{x}$ = 6.77 FNU, SD = 5.04). There were no significant differences ($p > 0.05$) when comparing water chemistry between mainstem and tributary sites.

Fish Sampling

We collected a total of 3,112 individuals of 10 families, 30 genera, and 43 species (Table 4). The most abundant species were Bluehead Chub, *Nocomis leptocephalus*, (635), Tessellated Darter, *Etheostoma olmstedi*, (248), and Satinfin Shiner, *Cyprinella analostana*, (236). In contrast, the rarest species (≤ 3 specimens) were Channel Catfish, *Ictalurus punctatus*, Spottail Shiner, *Notropis hudsonius*, Torrent Sucker, *Thoburnia rhothoeca*, Mud Sunfish, *Acantharchus pomotis*, Warmouth, *Lepomis gulosus*, Pumpkinseed, *Lepomis gibbosus*, and Redear Sunfish, *Lepomis microlophus*. Bridle Shiner was not observed during our survey.

Table 4. Distribution and abundance of fishes collected in the Flat Creek system, Virginia. Species are listed phylogenetically. Nomenclature follows Page et al., 2013. Site numbers correspond to mainstem Flat Creek sites on Table 2. Tributaries are abbreviated as: EC – Ellis Creek; SBN – South Branch Nibbs Creek; NBN – North Branch Nibbs Creek; NC - Nibbs Creek.

		Site										
Common name	Scientific name	1	2	3	4	5	6	EC	SBN	NBN	NC	Total
American Eel	*Anguilla rostrata*	5	4	4	-	1	-	-	-	-	2	16
Chain Pickerel	*Esox niger*	2	7	3	-	1	-	-	-	10	2	25
Eastern Mudminnow	*Umbra pygmaea*	-	-	2	-	-	6	2	-	21	1	32
Golden Shiner	*Notemigonus crysoleucas*	-	11	-	-	-	-	-	-	-	-	11
Mountain Redbelly Dace	*Chrosomus oreas*	-	-	-	-	-	-	13	-	-	-	13
Rosyside Dace	*Clinostomus funduloides*	-	-	-	-	8	20	63	22	-	-	113
Blacknose Dace	*Rhynichthys atratulus*	-	-	-	-	-	8	2	16	-	-	26
Fallfish	*Semotilus corporalis*	13	9	8	24	124	3	7	4	-	8	200
Creek Chub	*Semotilus atromaculatus*	-	-	-	2	2	63	70	42	2	3	184

Table 4
Continued

Common name	Scientific name	Site 1	2	3	4	5	6	EC	SBN	NBN	NC	Total
Bluehead Chub	*Nocomis leptocephalus*	5	15	4	56	65	88	219	84	1	98	635
Satinfin Shiner	*Cyprinella analostana*	91	73	10	17	31	-	-	-	-	14	236
Common Shiner	*Luxilus cornutus*	-	-	20	16	11	1	21	8	-	6	83
Rosefin Shiner	*Lythrurus ardens*	8	31	66	13	-	-	-	-	-	26	144
Comely Shiner	*Notropis amoenus*	6	3	23	9	16	-	-	-	-	-	57
Spottail Shiner	*Notropis hudsonius*	1	-	-	-	-	-	-	-	-	-	1
Swallowtail Shiner	*Notropis procne*	16	8	35	22	53	42	12	3	-	10	201
Eastern Silvery Minnow	*Hybognathus regius*	6	1	5	-	7	-	3	7	-	20	49
Eastern Creek Chubsucker	*Erimyzon oblongus*	-	1	3	-	-	-	-	-	12	1	17
Torrent Sucker	*Thorburnia rhothoeca*	-	-	-	-	-	-	-	13	-	10	23
White Sucker	*Catostomus commersoni*	-	-	4	3	6	-	13	-	-	2	28
Channel Catfish	*Ictalurus punctatus*	2	-	-	-	-	-	-	-	-	-	2
Yellow Bullhead	*Ameirus natalis*	1	-	4	-	2	5	1	5	4	-	22
Margined Madtom	*Noturus insignis*	1	7	3	3	6	5	1	7	3	4	40
Pirate Perch	*Aphredoderus sayanus*	1	5	18	1	14	15	7	1	68	15	145
Eastern Mosquitofish	*Gambusia holbrooki*	-	2	-	-	-	-	2	-	8	-	12
White Perch	*Morone Americana*	-	10	-	-	-	-	-	-	-	-	10
Mud Sunfish	*Acantharchus pomotis*	-	-	-	-	2	-	-	-	-	-	2

Table 4
Continued

Common name	Scientific name	Site 1	2	3	4	5	6	EC	SBN	NBN	NC	Total
Bluespotted Sunfish	*Enneacanthus gloriosus*	-	1	-	-	-	-	-	-	5	-	6
Spotted Bass	*Micropterus punctulatus*	-	1	1	4	1	-	-	-	-	-	7
Largemouth Bass	*Micropterus salmoides*	-	3	-	1	1	1	-	-	6	1	13
Warmouth	*Lepomis gulosus*	-	3	-	-	-	-	-	-	-	-	3
Green Sunfish	*Lepomis cyanellus*	-	-	-	2	17	17	5	-	1	1	43
Redbreast Sunfish	*Lepomis auritus*	7	5	34	16	13	6	1	2	13	5	102
Bluegill	*Lepomis macrochirus*	8	27	1	8	9	1	-	6	6	12	78
Pumpkinseed	*Lepomis gibbosus*	-	1	-	-	-	-	-	-	1	1	3
Redear Sunfish	*Lepomis microlophus*	-	-	-	-	-	-	-	-	2	1	3
Stripeback Darter	*Percina notogramma*	-	1	1	3	4	5	2	-	-	-	16
Shield Darter	*Percina peltata*	1	9	-	-	1	-	-	-	-	-	11
Tessellated Darter	*Etheostoma olmstedi*	1	2	28	11	26	37	14	33	45	51	248
Glassy Darter	*Etheostoma vitreum*	3	30	14	31	6	-	-	4	-	96	184
Fantail Darter	*Etheostoma flabellare*	1	3	2	17	4	4	6	4	-	10	51
Swamp Darter	*Etheostoma fusiforme*	-	2	-	-	-	-	-	-	2	-	4
Number of Specimens		179	276	294	266	435	327	464	261	210	400	3112
Species Richness		20	29	24	21	27	18	20	17	18	25	43

The Bluehead Chub, Margined Madtom, *Noturus insignis*, Pirate Perch, *Aphredoderus sayanus*, Redbreast Sunfish, *Lepomis auritus*, and Tessellated Darter were found at all survey sites. Species that were found at only one site were Spottail Shiner, Mountain Redbelly Dace, *Chrosomus oreas*, Golden Shiner, *Notomegnis crysoleucas*, Channel Catfish, White Perch, *Morone americana*, and Warmouth. Of the species collected, 10 were found in only mainstem sections, four in only tributary sections, and 29 in both. The average number of species per site was 21.9 (range 17-29). Site 2 yielded the most species at 29 and South Branch Nibbs Creek with the fewest at 17.

Of 43 species collected, 33 were dominant in pool, six in run, and four in riffle mesohabitats. Among pool-dominant species, seven were found only in pools, 23 were subdominant in runs, two subdominant in riffles, and one subdominant equally in runs and riffles. For species dominant in runs, one was found only in runs, five were subdominant in pools and one was subdominant in riffles. Only Blacknose Dace, *Rhynichthys atratulus*, Fantail Darter, *Etheostoma flabellare*, Glassy Darter, *Etheostoma vitreum*, and Torrent Sucker were found dominantly in riffles. The former three were subdominant in runs while the latter was subdominant in pools.

SPECIES ACCOUNTS

Family Anguillidae (Freshwater Eels)

Anguilla rostrata, American Eel: Only 16 specimens were collected at five sites. Most were found in pools (50%) and runs (44%) and infrequently with riffles (6%). The American Eel is catadromous and spends much of its adult life in freshwater streams and rivers. It is a Tier III species in the Virginia Wildlife Action Plan (VDGIF, 2015). The species was collected in several previous surveys.

Family Esocidae (Pikes and Mudminnows)

Esox niger, Chain Pickerel: We collected 25 specimens at six sites. The majority were found in pools (68%) while the remaining were in runs. The earliest record of this species was in 1983 by Dr. Robert Jenkins (VDGIF, 2016).

Umbra pygmaea, Eastern Mudminnow: A total of 32 specimens were collected at five sites. The species was most associated with pool (78%) and lesser in run (16%) and riffle (6%) habitat. The species was documented in two previous surveys.

Family Cyprinidae (Minnows)

Notemigonus crysoleucas, Golden Shiner: Eleven individuals were collected in a single pool at one mainstem site. The species was documented in several previous surveys.

Chrosomus oreas, Mountain Redbelly Dace: We found only 13 individuals in Ellis Creek. The species was associated with pool (61%) and run (39%) habitats. It was documented in several previous surveys.

Clinostomus funduloides, Rosyside Dace: We collected 113 individuals at two mainstem and two tributary sites. The species was found primarily in pools (83%), and to a lesser degree in runs (13%) and riffles (4%). It was documented in several previous surveys.

Rhinichthys atratulus, Eastern Blacknose Dace: Primarily a headwater species, it was found in one upper mainstem and two tributary sites. A total of 26 specimens were collected mostly in riffles (70%), infrequently in runs (25%) and rarely in pools (5%). The first species record was in 1986 (Norman & Southwick, 2014).

Semotilus corporalis, Fallfish: With a total of 200 specimens being found at six mainstem and three tributary sites, it was one of the most widely distributed and abundant species. The Fallfish was primarily found in pools (65%), occasionally in runs (34%), and rarely in riffles (1%). The species was documented in several previous surveys.

Semotilus artromaculatus, Creek Chub: The species was found in four upper mainstem and four tributary sites. Of the 184 individuals collected, most were in pools (85%) and infrequently in runs (11%) and riffles (4%). The first Creek Chub record was 1986 (Norman & Southwick, 2014).

Nocomis leptocephalus, Bluehead Chub: Totaling 635 specimens being found over all 10 sties, the species was the most abundant and widely distributed species. It was almost equally collected in pools (41%) and runs (38%) and infrequently in riffles (21%). The species was found in all previous surveys.

Cyprinella analostana, Satinfin Shiner: We collected Satinfin Shiner at five mainstem and one tributary site. It was the third most abundant species behind Bluehead Chub and Tesselated Darter. It was primarily found in runs (65%), uncommon in pools (32%), and rarely in riffles (3%). The species has been documented in all surveys since 1983 (VDGIF, 2016).

Luxilus cornutus, Common Shiner: The species was collected at four mainstem and three tributary sites. Of the 84 individuals collected, most were found in pools (69%), occasionally in runs (30%), and rarely in riffles (1%). The first record of Common Shiner was 1986 (Norman & Southwick, 2014).

Lythrurus ardens, Rosefin Shiner: We collected 144 individuals at the four lowest most sites and one site in Nibbs Creek. The species was slightly more prominent in pools (56%) than runs (40%) but only rarely caught in riffles (4%). The species was first collected in 1983 (VDGIF, 2016).

Notropis amoenus, Comely Shiner: The species was collected at five mainstem sites. Of the 57 specimens recorded, most were in pools (58%) and runs (42%). It was not found in riffles. The only other record of this species was in 1986 (Norman & Southwick, 2014).

Notropis hudsonius, Spottail Shiner: Only one Spottail Shiner was collected in a run at the lowest most site nearest the confluence with the Appomattox River. This is first record of the species in the Flat Creek system.

Notropis procne, Swallowtail Shiner: We collected 201 specimens at all six mainstem and three tributary sites. It was collected nearly equal in runs (48%) and pools (47%). Riffles were the least inhabited (5%). Swallowtail Shiner was documented in all previous surveys (VDGIF, 2016).

Hybognathus regius, Eastern Silvery Minnow: Although uncommon in the drainage, Eastern Silvery Minnow was distributed in four mainstem and three tributary sites. Of the 49 specimens collected, most were found in pools (78%) and infrequently in runs (20%) and rarely in riffles (2%). The species was documented before 1980 and occasionally afterwards (VDGIF, 2016).

Family Catostomidae (Suckers)

Erimyzon oblongus, Eastern Creek Chubsucker: Only 15 individuals were found from two mainstem and two tributary sites. The majority were present in pools (76%) and fewer in runs (24%). None were present in riffles. The species has been found in all surveys since 1986 (Norman and Southwick, 2014).

Hypentelium nigricans, Northern Hogsucker: The species was collected at four mainstem sites totaling 13 individuals. Most specimens were found in pools (54%) followed by runs (38%) and rarely in riffles (8%). The first documented species record was 1986 (Norman & Southwick, 2014).

Thoburnia rhothoeca, Torrent Sucker: Only 13 individuals were found in two tributary sites. Even though riffle habitat was relatively rare in our survey, it was primarily collected in riffles (77%), occasionally in pools (18%), and rarely in runs (5%). The species was documented before 1980 and occasionally afterwards (VDGIF, 2016).

Catostomus commersoni, White Sucker: Twenty-eight specimens were found at three mainstem and two tributary sites. The majority of individuals occupied pools (93%) and runs (7%) to a lesser degree. The species was first documented in 1983 (VDGIF, 2016).

Family Ictaluridae (Catfishes)

Ictalurus punctatus, Channel Catfish: Only two specimens were found in pool habitat at the most downstream site. The only other species record was an observation in 1983 (VDGIF, 2016).

Ameiurus natalis, Yellow Bullhead: Although only 22 specimens were collected, it was widely distributed across four mainstem and three tributary sites. The species was found mostly in pools (74%) and less in riffles (16%) and runs (10%). The species was first documented in 1983 (VDGIF, 2016).

Noturus insignis, Margined Madtom: Of the 40 specimens observed, the species was found at all mainstem and tributary sites. It was distributed nearly equal among pools (39%), riffles (33%), and runs (28%). The species was documented in most surveys (VDGIF, 2016).

Family Aphredoderidae (Pirate Perch)

Aphredoderus sayanus, Pirate Perch: The species was common and widely distributed in the system. A total of 145 individuals were found over all sites with nearly half being collected at North Branch Nibbs Creek. Most were collected in pools (79%) and fewer in runs (19%) and riffles (2%). The species was found in all previous collections.

Family Poeciliidae (Liverbearer)

Gambusia holbrooki, Eastern Mosquitofish: Only 12 specimens were collected at one mainstem and two tributary sites. Most were found in pools (80%) with all others in runs (10%) and riffles (10%). The species was first collected in 1983 and only occasionally afterwards (VDGIF, 2016).

Family Moronidae (Temperate Basses)

Morone americana, White Perch: A total of 10 White Perch were collected in one seine haul of a pool at a mainstem site. The species was first documented in 2011 (Starnes et al., 2014).

Family Centrarchidae (Sunfishes)

Acantharchus pomotis, Mud Sunfish: Only two individuals were found in a pool at one mainstem site. The species was occasionally collected beginning in 1983 (VDGIF, 2016). Mud Sunfish is a Tier IV species in Virginia's Wildlife Action Plan (2015).

Enneacanthus gloriosus, Bluespotted Sunfish: The species was rare in the survey and collected in one mainstem and one tributary site. Bluespotted Sunfish were mostly collected in run (80%) and to a lesser degree, pool (20%) habitat. The species was first collected in 1983 (VDGIF, 2016).

Micropterus punctulatus, Spotted Bass: A total of seven Spotted Bass were collected at four mainstem sites. Most were collected in runs (57%) followed closely by pools (43%). No previous collection record was known for Flat Creek although the species is prominent in other Appomattox River tributaries (Norman & Southwick, 2014).

Micropterus salmonoides, Largemouth Bass: We found 14 individuals in four mainstem and two tributary sites. Most were collected in pools (83%) and infrequently in runs (17%). The first documented record for the species was in 2009 in Nibbs Creek (VDGIF, 2016).

Lepomis gulosus, Warmouth: The species was very rare with only three individuals at one mainstem site in pool habitat. It was known before 1980 and collected in several surveys afterwards (VDGIF, 2016).

Lepomis cyanellus, Green Sunfish: The species was found in three mainstem and three tributary sites. Of the 43 individuals collected, most were in pools (85%) and occasionally in runs (15%). Green Sunfish was first documented in 2011 (VDGIF, 2016).

Lepomis auritus, Redbreast Sunfish: Totaling 102 individuals and found at all mainstem and tributary sites, Redbreast Sunfish was the most common and widespread Centrarchid in our survey. Most specimens were found in pools (71%), occasionally in runs (26%), and rarely in riffles (3%). The species was first discovered in 1983 and has been found in all following surveys (VDGIF, 2016).

Lepomis macrochirus, Bluegill: The species was found at all mainstem and three tributary sites. It was most frequently collected in pools (90%) and rarely in runs (8%) and riffles (2%). Bluegill was found in all previous surveys (VDGIF, 2016).

Lepomis gibbosus, Pumpkinseed: Only three Pumpkinseeds were collected at one mainstem and two tributary sites. All specimens were collected in pools. The species was collected in all surveys since 1983 (VDGIF, 2016).

Lepomis microlophus, Redear Sunfish: Only three individuals were collected in two tributary sites. Two were found in pool (67%) and one (33%) in run habitats. Redear Sunfish was first recorded in 1983 and only once afterwards (VDGIF, 2016).

Family Percidae (Perches)

Percina notogramma, Stripeback Darter: Only 16 individuals were found at five mainstem and one tributary site. Most were collected in pools (69%), infrequently in runs (25%), and rarely in riffles (6%). The species was first collected in 1983 and occasionally afterwards (VDGIF, 2016).

Percina peltata, Shield Darter: The species was found at three mainstem sites. We collected 11 individuals in both runs (55%) and riffles (45%). None were present in pools. This is the first documented record of Shield Darter in Flat Creek although it was collected in other Appomattox River tributaries (Norman & Southwick, 2014).

Etheostoma olmstedi, Tessellated Darter: Totaling 248 individuals, Tessellated Darter was the second most abundant species. Additionally, it was widely distributed being found at all mainstem and tributary sites. The species could be considered a habitat generalist with nearly equal presence in pools (38%), runs (33%), and riffles (29%). It was found in three previous surveys beginning in 1983 (VDGIF, 2016).

Etheostoma vitreum, Glassy Darter: We found 184 specimens at four mainstem and two tributary sites. Most (52%) were found at one site on Nibbs Creek. Individuals were found in riffles (47%) and runs (45%), and rarely pools (8%). The species was present in all previous surveys (VDGIF, 2016).

Etheostoma flabellare, Fantail Darter: The species was found at all mainstem and three tributary sites. Among the 51 collected, most were found in riffles (64%), occasionally in runs (30%), and rarely in pools (6%). The species has been noted in most surveys (VDGIF, 2016).

Etheostoma fusiforme, Swamp Darter: Only four individuals were found at one mainstem and one tributary site. All individuals were collected in pool habitat. The species has been found in most surveys (VDGIF, 2016).

DISCUSSION

The Flat Creek fish community is characteristic of a medium-sized Piedmont stream dominated by pool/run mesohabitat and sand substrate. Of the 10 fish families represented, the majority of species were found in Cyprinidae (32%) and Centrarchidae (23%). Besides species such as Swallowtail Shiner, Satinfin Shiner, and Glassy Darter commonly known from Virginia's Piedmont, Flat Creek also contained an interesting mix of those species found at the margins of their range and habitat limits. These include the pool-adapted Eastern Mudminnow, Swamp Darter, Mud Sunfish, and Bluespotted Sunfish that are typical of ponds and swamps of the Coastal Plain. Other species such as Fantail Darter, Blacknose Dace, and Torrent Sucker, which were found in riffle mesohabitats, are characteristic of mountainous, western regions of the state.

Our survey collected 43 species in the Flat Creek system bringing its total species to 52. Previous (post-1980) surveys averaged 30.2 (range 26-37) species. The next closest survey by species number was Norman & Southwick (2014) conducted in 1986-87 with 37 species. Similar to our survey, they sampled in both mainstem and tributary reaches, which provided a wide variety of habitats. In addition to the most species, our survey collected species not previously known in Flat Creek including Spottail Shiner, Spotted Bass, and Shield Darter. All of these species were present in mainstem sections of Flat Creek and none in tributaries. Although not collected by Norman & Southwick (2014) in Flat Creek, they did note the expansion of Spotted Bass, an introduced species, in other tributaries of the Appomattox River.

We were unable to find eight species reported in previous surveys. These include Gizzard Shad (*Dorosoma cepedianum*), River Chub (*Nocomis micropogon*), Crescent Shiner (*Luxilus cerasinus*), Bridle Shiner, Blacktip Jumprock (*Moxostoma cervinum*), Flier (*Centrarchus macropterus*), Yellow Perch (*Perca flavescens*), and Johnny Darter (*Etheostoma nigrum*). Among these species, Gizzard Shad and River Chub were only collected by Dr. Robert Jenkins (VDGIF, 2016) and Blacktip Jumprock and Yellow Perch by Norman & Southwick (2014). Multiple surveyors collected all other species. Blacktip Jumprock is native to the Roanoke River drainage and introduced in the James River drainage (Jenkins & Burkhead, 1994). The first record in the Appomattox system was four specimens in 1986 in Neal's Creek, a Flat Creek tributary (Norman & Southwick 2014). Although we did not sample this tributary, lack of Blacktip Jumprock at our sampling sites may indicate that the introduction was unsuccessful.

According to Jenkins & Burkhead (1994), all species we found were native to the James River drainage except Channel Catfish, Green Sunfish, Bluegill and Redear Sunfish. In addition, Largemouth Bass is considered introduced but possibly native and the Warmouth as native but possibly introduced. While native to the drainage, White Perch above the fall line is considered introduced. All introduced species are popular gamefish, and their presence is likely the result of stocking into local ponds and Lake Chesdin, a downstream reservoir.

Although we only recorded Tessellated Darter, both Johnny and Tessellated darters are known from previous surveys. Flat Creek occurs within an *olmstedi*/*nigrum* intergrade zone in the Chowan, James, and Roanoke drainages (Jenkins & Burkhead, 1994). In this zone, phenotypic resemblance between the two species can make identification extremely problematic. We addressed this issue by sending a subset of vouchered *E. olmstedi* specimens to the Near Laboratory at the Department of Ecology and Evolutionary Biology, Yale University to verify species identifications. Dr. Tom Near and Mr. Dan MacGuigan, PhD Candidate, are currently examining the phylogeography of the *Etheostoma nigrum* complex using mitochondrial and ddRAD data. Their examination indicated our specimens were *E. olmstedi* and possibly a distinct, geographically restricted species (D. MacGuigan, pers. comm.).

The most disappointing result of our study was not finding Bridle Shiner. The species was found in four surveys from 1983 to 2013 (Norman & Southwick, 2014; Starnes et al., 2014; VDGIF, 2016). In 1986, Norman & Southwick (2014) collected one specimen in North Branch Nibbs Creek. We sampled the same site but failed to find it. The only known mainstem Bridle Shiner site was originally sampled by Dr. Robert Jenkins in 1983 (VDGIF, 2016) and by Dr. Wayne Starnes (Starnes et al., 2014) in 2011 and 2013 (Fig. 1). We were unable to determine the number of specimens observed by Jenkins but Starnes found two and 10 specimens in 2011 and 2013, respectively.

In the early fall of 2016, accompanied by Dr. Wayne Starnes, we conducted an abbreviated survey at the known mainstem site for Bridle Shiner. No specimens were found but Dr. Starnes

indicated that submerged aquatic vegetation (SAV), microhabitat where his specimens were collected, was absent. The nearest sampling during our full survey was 1.18 km downstream of the known Bridle Shiner site. Even though we sampled over 400 m and came within 0.74 km of his collection site, we were still unsuccessful. Starnes et al. (2014) recommended that Flat Creek be 1) surveyed over much of its length and tributary system to determine just how truly localized the Bridle Shiner population is and 2) whether it can withstand removal of stock for propagation purposes. If Bridle Shiner is still present in Flat Creek, it is extremely localized and additional survey effort is necessary prior to any consideration of species removal.

Despite not finding our target species, we did record the presence of two other species on Virginia's Wildlife Action Plan, the Mud Sunfish (Tier IV) and American Eel (Tier III). The presence of American Eel is notable because this catadromous species is able to navigate through the 256 m long and 22 m high George F. Brasfield dam located on the Appomattox River approximately 55 km downstream of its confluence with Flat Creek. Eel passage may have been assisted by a fish lift that has been operational on the dam since 2004 (Martin, 2019). It is unknown whether other migratory species such as Sea Lamprey (*Petromyzon marinus*), Blueback Herring (*Alosa aestivalis*), and Alewife (*Alosa pseudoharengus*) use this lift or can traverse this barrier (VDGIF, 2016).

Our study indicates that Flat Creek still has a diverse fish assemblage with only a few notable species absences and additions. If SAV is disappearing, water quality issues should be investigated. Because we sampled less than five percent of the Flat Creek mainstem, it is premature to conclude that Bridle Shiner is gone from the system. We recommend additional mainstem sampling be concentrated in those more difficult to access reaches.

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