Rivanna River Watershed 2019 Fish Survey

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INTRODUCTION

In 2019, the Rivanna Conservation Alliance (RCA) and the Virginia Department of Wildlife Resources (DWR) surveyed fish living in the Rivanna River watershed. The Rivanna has been regarded as one of the finest remaining freshwater systems in the Piedmont of Virginia (Rivanna River Basin Commission, 2012). However, the area upstream and downstream of Woolen Mills had been significantly impacted by a 19th century dam, which was located on the Rivanna River approximately 56 km (35 miles) upstream of the confluence with the James River, and removed in 2007. The purpose of this survey was to collect fish assemblage data in the Rivanna River and its tributaries and to explore the longer-term impact of the Woolen Mills Dam removal on migratory fish species.

Researchers found that the Rivanna currently supports a diverse stream fish assemblage and offers a robust recreational fishery. The river surrounding the former site of the Woolen Mills Dam has transformed dramatically since barrier removal in 2007. It is now a free-flowing stretch of river providing refuge and habitat for a wide variety of species. Although barriers to fish movement remain in the watershed, removal of the Woolen Mills Dam restored connectivity to over 228 miles of upstream fish habitat for migratory fishes (Chesapeake Aquatic Barrier Prioritization Tool; http://maps.freshwaternetwork.org/chesapeake/#).

Results of this survey provide valuable insights into the long-term impacts and benefits of dam removal and offer important information on fish community structure at 24 sites on the Rivanna River and tributary streams. These data contribute important information toward understanding overall stream health in the Rivanna River watershed.

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METHODS

Researchers conducted the survey during low-flow conditions from July 22 through October 11, 2019, sampling a total of 24 locations. Eight sites were sampled on the mainstem Rivanna River and 16 sites were sampled on tributary streams (Figure 1). Site selection was based on accessibility and overlap with RCA's long-term Benthic Monitoring Program and previous DWR fish community data collection efforts (Table 1). Surveyors used electrofishing gear to collect fish, following methods detailed in Copeland, Chappell, and Woodward (2001). Site habitat characteristics including stream width and depth determined the sample reach length and the equipment used (backpack, tow barge, or boat) (Table 2). At each sample location, fish were identified and counted. Bulk-weight measurements were taken for non-game species, and all game fish were measured to the nearest millimeter and weighed to the nearest gram. When necessary, voucher specimens were collected for laboratory identification.

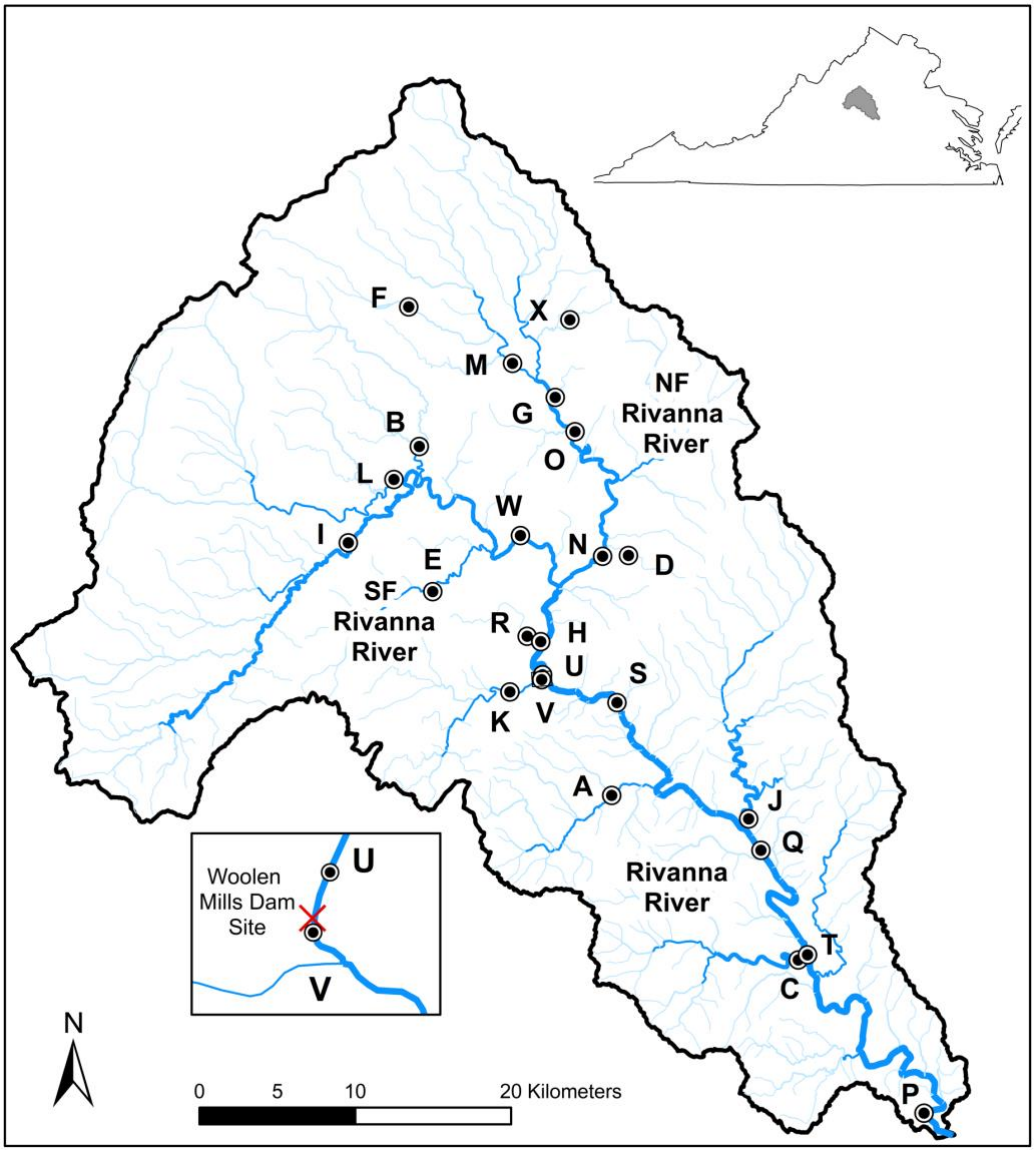

Figure 1. Map of the Rivanna River Watershed with fish sampling locations. Letters correspond to location codes in Tables 1, 2, and 4-6.

RESULTS AND DISCUSSION

Species Composition

Species Richness, Diversity, and Evenness

The diversity of fish species in the Rivanna River is considered exceptional (Harris, 2011). In this 2019 study, researchers collected a total of 56 different species representing 11 families (Table 3). This is fairly speciose, given that 109 species occur in the larger James River watershed, including 73 native, 26 introduced, and 10 estuarine or diadromous species (Jenkins and Burkhead, 1994). Of the 56 species collected in this study, 44 were native, 12 were introduced, and two were diadromous.

An average of 26 different species were collected across the 24 sampling locations. The North Fork Rivanna River at Forks of Rivanna (location "O") yielded the highest species richness, with a total of 34 different species collected. Foster Branch (location "D"), which is a smaller order stream, yielded the lowest species richness, with 11 species collected (Table 2).

Both the Shannon-Diversity Index (H') (Barnes et. al., 1998) and the Simpson Diversity Index (D') (Simpson, 1949) were used to evaluate diversity at each of the 24 locations. Diversity scores for both indices are reported in Table 2. The commonly used Shannon-Diversity Index combines both species richness and their relative abundance. Scores typically range from 1.5 to 3.5 (Gaines et. al., 1999), with higher scores representing higher diversity. In this study, H' ranged from 1.8995 to 2.9140 with an average of 2.4764 (Table 2).

The Simpson Diversity Index (D') ranges from zero to one, with zero representing no diversity and one representing infinite diversity. This metric gives higher weight to more abundant species. The average D' in this study was 0.8737 with a range of 0.7340 to 0.9301 (Table 2).

Species evenness was also calculated for each site and scores are provided in Table 2. This metric indicates how evenly distributed the population is across the species within a given area. Evenness ranges from zero to one, with higher values indicating a more even distribution. The average score across the 24 locations for species evenness was 0.7713. Calculated scores ranged from 0.5641 to 0.8421 (Table 2).

Consistently low scores for diversity and evenness were observed at the sampling location just below the South Fork Rivanna Reservoir Dam, providing evidence that the Dam has a negative influence on the downstream fish community in this section of the South Fork Rivanna River.

Most Abundant Families and Species

The most abundant families collected in the survey were Cyprinidae ("minnows"; 67.61%), Catostomidae ("suckers"; 12.58%), Centrarchidae ("sunfishes"; 9.88%), and Percidae ("perches"; 7.72%) (Table 3). The Cyprinidae family was represented by 22 species, the most abundant of which were the Bull Chub, Central Stoneroller, Bluehead Chub, Spottail Shiner, and the Common Shiner. The relatively high number of these small minnow species in the survey catch is a good indication of an abundant

forage base for larger organisms (Harris, 2011). Seven species represented the Catostomid family; the most abundant species were the Torrent Sucker, Blacktip Jumprock, and Northern Hog Sucker. The Centrarchid family was represented by eight species, the most abundant of which were the Redbreast Sunfish, Smallmouth Bass, and Bluegill. The fourth most abundant family, Percidae, was represented by eight species. The most abundant of which were the Roanoke Darter, Fantail Darter, and the Johnny Darter.

All species collected in the Rivanna River and its tributaries in this study are listed in Table 3, along with their abundance relative to the entire community (abundant, common, uncommon, and rare), and status (native or introduced).

Diadromous Species

Two migratory species (American Eel and Sea Lamprey) were collected in the survey. These species are "diadromous," meaning they migrate between salt and freshwater systems and need unimpeded access to upstream habitat during their life cycle. Both of these species have access to the Rivanna River drainage through the James River and their migration through the Boshers Dam vertical slot fishway (Weaver et al., 2003). The Woolen Mills Dam formerly impeded the upstream movement of these two species in the Rivanna as well as other fishes. The Dam was constructed on the mainstem Rivanna just upstream of its confluence with Moores Creek in the early 1800's. In 2003, the Rivanna Conservation Society (now RCA) and several partners, including DWR, began assessing the feasibility of removing the Woolen Mills Dam to restore fish habitat and improve recreational safety. After four years of planning, the removal process began in August 2007 and took less than three weeks. When completed, this portion of the Rivanna ran free for the first time in nearly 200 years.

In 2006, one year prior to the Dam's removal, research scientists at the University of Virginia, RCA, and DWR, conducted fish sampling both downstream and upstream of the Dam to assess the fish assemblage before dam removal (Doucette 2009). At that time, no Sea Lampreys were found in the two locations sampled upstream of the Woolen Mills Dam. In 2019, RCA and DWR researchers found a total of 22 Sea Lampreys at these same upstream locations, indicating that connectivity has improved within the watershed since the Dam's removal in 2007 (Table 4).

American Eels were found at 21 of 24 sites in this study, even above barriers including the Advance Mills Dam on the North Fork Rivanna River and the South Fork Rivanna Reservoir Dam (Table 4 and Figure 1). Eels can sometimes work their way over barriers if they are made of rough, textured surfaces and remain wetted (Alan Weaver, personal communication, December 2, 2020). However, study results provide evidence that these dams are limiting the passage of eels. Two of the three sites where no American Eels were collected are located above the South Fork Rivanna River Reservoir Dam: Buck Mountain Creek (Location "B") and the Moormans River (Location "L"). The other sampling sites above these two dams had relatively low abundances of eels; two individuals were collected in Ivy Creek (Location "E"), two in the Mechums River (Location "I"), and one in the North Fork Rivanna River above the Advance Mills Dam (Location "N"). Additionally, sampling just below the South Fork Rivanna

Reservoir Dam found an unusually high number of American Eels (138 individuals of varying size classes), suggesting that they had become trapped at the base of this barrier.

Sea Lampreys were found at twelve of the 24 sites in this study (Table 4.). No Sea Lampreys were collected above the Advance Mills Dam or the South Fork Rivanna Reservoir Dam, evidence that these barriers are likely inhibiting movement of this species into the upper reaches of both the North and South Forks of the Rivanna River. However, future sampling at smaller tributary streams to the North and South Fork Rivanna may reveal presence.

The Woolen Mills Dam removal had the potential to encourage the return of seasonal migrations of the anadromous and historically important American Shad to the Rivanna River. Unfortunately, no sampling efforts have recorded the return of American Shad to the watershed. While some American Shad migrate past Boshers Dam in the James River (Weaver et al., 2003), the population size remains very low compared to potential levels (ASMFC, 2020) and suggests their path to recovery faces several challenges that extend well beyond the Rivanna, including isssues related to overfishing, passage efficiency, and predation, among others (Pipkin, 2020). Although American Shad are not currently on a recovery trajectory, the removal of the Woolen Mills Dam restored aquatic connectivity for other migratory fishes and several other fish species.

Recreational Catch

Though this survey was not designed to fully characterize the sportfish potential of the Rivanna River and its tributaries, sample collections indicate that the Rivanna is an ecosystem that supports a wide variety of sportfish, including the popular Smallmouth Bass. Biomass estimates and length-class measurements are not provided in this report due to the limitations of the sampling techniques in evaluating important aspects of game fish populations. The methods employed in this study skew towards sampling smaller specimens from shallower water. They tend to under-sample the larger-sized fish favored by anglers that are more likely present in the deeper pool sections. The most abundant game fish collected in this study were the Redbreast Sunfish, Smallmouth Bass, Bluegill, Largemouth Bass, and Rock Bass, followed by the less-abundant Green Sunfish and Redear Sunfish (Table 3).

Intolerant Species and Keystone Species

The percentage of “intolerant” individuals (those fish sensitive to poor environmental conditions) was calculated for each site using the classifications listed in the Virginia Department of Environmental Quality’s (DEQ) fish community database (Ecological Data Application System, ‘EDAS’, Microsoft Access, Version 2.0) (Table 2). A higher percentage of intolerant fish is indicative of a healthier stream.

Intolerant species collected in this study included the Cutlips Minnow, Longnose Dace, Northern Hogsucker, Rosyside Dace, Shield Darter, Stripeback Darter, and Torrent Sucker. Foster Branch (Location “D”) and Lynch River (Location “F”) had the highest percentage of intolerant individuals (29.52% and 29.41%, respectively). This is not surprising, given that they are smaller tributaries in the upstream reaches of the watershed and are generally less-disturbed than other sites surveyed in 2019. Smaller

streams also tend to contain fewer species and individuals relative to larger streams (Jenkins & Burkhead, 1994).

The sampling site just below the South Fork Rivanna Reservoir Dam (Location "W") contained the lowest percentage of intolerant fish (1.62%). This is possibly due to the proximity of the Dam and influences on downstream habitat. Surface water releases from dams can create large temperature fluctuations and turbid conditions downstream, which are inhospitable to intolerant fish species. Researchers observed high levels of turbidity when sampling at this location following surface water release.

Other sensitive species were also collected in this study, including Bluehead Chub, Glassy Darter, Mountain Redbelly Dace, and Mottled Sculpin. While these species are not listed as being "intolerant" in DEQ's fish database, they are regarded as being sensitive to excessive sediment and warming temperatures (Jenkins and Burkhead, 1994; J. Harris, personal communication, December 17, 2020).

Mountain Redbelly Dace and Bluehead Chub are also considered keystone species. They both build nest mounds of rocks that are used by numerous other fish species and they both play an important role in the life cycle of the James spinymussel, a federally-listed endangered species found in the Rivanna watershed. Their presence is considered a sign of "good community health" (Chappell and Woodward, 1998). These species are also indicators of better water quality as their populations can be harmed or eradicated by excess sediment that interferes with nesting.

Water Chemistry and Habitat

During the survey, RCA staff collected basic water quality parameters including temperature, dissolved oxygen (DO), pH, and conductivity (measured as specific conductance), using a YSI 600 XL Multiparameter Probe. The average temperature was 22.48°C, ranging from 16.72 to 27.70°C. The average DO was 8.85 mg/L (6.55-10.95 mg/L). The average pH was 7.33 (6.08-8.05). The average conductivity of these sample reaches was 113 µS/cm (59-257 µS/cm). These ranges are considered to be suitable for most freshwater stream fish (Behar, 1996). Detailed results are provided in Table 5.

In conjunction with the fish samples, researchers also measured and recorded habitat characteristics at ten third- and fourth-order streams in the study following the Basinwide Visual Estimation Technique (BVET) (Hankin and Reeves, 1998). Habitat was not assessed at the fourth-order Moormans River location due to its larger stream width. Detailed results are provided in Table 6. RCA plans to investigate the relationship between fish community, water chemistry, and habitat assessment data in the future.

CONCLUSIONS

Results from this survey indicate that the Rivanna currently supports a wide diversity of fishes, including several intolerant, sensitive, and keystone species, as well as important migratory species including the American Eel and Sea Lamprey. Although barriers to fish movement still remain, aquatic connectivity in the Rivanna River watershed has improved since the removal of the Woolen Mills Dam in 2007. Data collected from this survey will be used to guide future efforts to assess other potential barriers and identify projects that could improve fish passage in the watershed.

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Data Reporting and Availability

Fish collection data are available upon request. They have also been entered into the Virginia Department of Wildlife Resources (DWR) Statewide Warm Water Stream Survey Database. American Eel data collected from this survey were submitted to the Atlantic States Marine Fisheries Commission (ASMFC) for their American Eel 2020 Benchmark Stock Assessment. An interactive StoryMap webpage displaying results from this survey is available at: http://www.rivannariver.org/fish/.

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Table 1. Sites surveyed by the Rivanna Conservation Alliance (RCA) and the Virginia Department of Wildlife Resources (DWR) in 2019.

Stream Name (map letter)[a]	RCA Benthic Monitoring Locations[b]	Previous DWR Survey Locations				Pre- and Post- Woolen Mills Dam Removal Survey Sites (2006-2008)[c]
		2017	2012	2010	1998	
Buck Island Creek (A)	X		X			
Buck Mountain Creek (B)	X				X	
Cunningham Creek (C)	X				X	
Foster Branch (D)					X	
Ivy Creek (E)	X	X				X
Lynch River (F)	X				X	
Marsh Run (G)	X				X	
Meadow Creek (H)					X	
Mechums River (I)			X		X	
Mechunk Creek (J)			X		X	
Moores Creek (K)	X		X			
Moormans River (L)	X					
North Fork Rivanna - upstream of Advanced Mills Dam (M)						
North Fork Rivanna River - downstream of Advance Mills Dam (N)	X				X	
North Fork Rivanna River - Forks of Rivanna (O)					X	
Rivanna River at Columbia (P)				X	X	
Rivanna River at Crofton (Q)	X			X	X	
Rivanna River at Darden Towe (R)	X			X		X
Rivanna River at Milton (S)	X			X	X	
Rivanna River at Palmyra (T)				X		
Rivanna River at Riverview (U)				X		X
Rivanna River at Woolen Mills (V)				X		X
South Fork Rivanna River - downstream of Reservoir Dam (W)				X	X	
Welsh Run (X)					X	

[a] Corresponds to map letters in Figure 1.

[b] Sites are located in close proximity to RCA's benthic sites.

[c] Refers to study conducted by Doucette (2009).

Table 2. Summary of fish collection information for sites surveyed by the Rivanna Conservation Alliance (RCA) and the Virginia Department of Wildlife Resources (DWR) in 2019.

Stream Name (map letter)	Stream Order	Collection Date	Reach (m)	Equipment Used	# Species	# Individuals	Simpson Diversity Index (D')	Shannon Diversity Index (H')	Evenness	% Intolerant
Buck Island Creek (A)	4	7/22/19	160	Backpack EF	28	437	0.9092	2.6887	0.8069	23.34
Buck Mountain Creek (B)	4	8/29/19	151	Backpack EF	20	515	0.8540	2.3237	0.7757	15.73
Cunningham Creek (C)	4	9/11/19	177	Backpack EF	31	881	0.9112	2.7373	0.7971	4.99
Foster Branch (D)	3	9/3/19	163	Backpack EF	11	315	0.8273	1.9574	0.8163	29.52
Ivy Creek (E)	4	7/22/19	160	Backpack EF	22	363	0.8611	2.3872	0.7723	21.49
Lynch River (F)	3	9/12/19	159	Backpack EF	16	918	0.8296	1.9744	0.7121	29.41
Marsh Run (G)	3	9/3/19	158	Backpack EF	20	456	0.8879	2.4124	0.8053	16.01
Meadow Creek (H)	3	7/10/19	163	Backpack EF	21	375	0.8612	2.3998	0.7882	12.27
Mechums River (I)	5	10/7/19	190	Tow barge EF	26	1083	0.9268	2.7437	0.8421	7.94
Mechunk Creek (J)	5	9/24/19	224	Tow barge EF	32	992	0.9301	2.9140	0.8408	6.65
Moores Creek (K)	5	8/29/19	200	Backpack EF	29	653	0.9146	2.7390	0.8134	11.18
Moormans River (L)	4	10/7/19	282	Tow barge EF	27	2093	0.9093	2.6623	0.8078	6.21
North Fork Rivanna - upstream of Advanced Mills Dam (M)	5	9/27/19	170	Tow barge EF	25	1921	0.8742	2.4279	0.7543	7.60
North Fork Rivanna River - downstream of Advance Mills Dam (N)	5	9/25/19	220	Tow barge EF	29	1914	0.8284	2.3771	0.7059	9.46
North Fork Rivanna River - Forks of Rivanna (O)	5	9/25/19	362	Tow barge EF	34	785	0.9169	2.8376	0.8047	8.66
Rivanna River at Columbia (P)	6	10/10/19	380	Tow barge EF	31	1027	0.9058	2.7358	0.7967	4.09
Rivanna River at Crofton (Q)	6	9/18/19	273	Tow barge EF	27	1378	0.8308	2.2192	0.6733	4.35
Rivanna River at Darden Towe (R)	6	10/11/19	125	Boat EF	26	303	0.8911	2.6677	0.8188	5.94
Rivanna River at Milton (S)	6	9/24/19	280	Tow barge EF	24	730	0.8436	2.3188	0.7296	6.03
Rivanna River at Palmyra (T)	6	9/18/19	163	Tow barge EF	28	910	0.8996	2.6246	0.7877	7.47
Rivanna River at Riverview (U)	6	9/23/19	220	Tow barge EF	32	1169	0.8614	2.5074	0.7235	6.07
Rivanna River at Woolen Mills (V)	6	9/23/19	200	Tow barge EF	28	1005	0.8774	2.4639	0.7394	6.77
South Fork Rivanna River - downstream of Reservoir Dam (W)	6	9/27/19	172	Tow barge EF	29	2535	0.7340	1.8995	0.5641	1.62
Welsh Run (X)	3	9/16/19	170	Backpack EF	18	387	0.8829	2.4130	0.8348	19.38
Average of All Sample Locations					*26*	*964*	*0.8737*	*2.4764*	*0.7713*	*11.34*

[a] Corresponds to map letters in Figure 1.

[b] EF = "Electrofisher".

Table 3. Rivanna fish community characteristics as indicated from the Rivanna Conservation Alliance (RCA) and Virginia Department of Wildlife Resources (DWR) 2019 survey.

FAMILY *Genus species*	Common Name	Number	Designation[a]	Status[b]
ANGUILLIDAE	FRESHWATER EELS	324	common	
Anguilla rostrata	American Eel	324	common	native
APHREDODERIDAE	PIRATE PERCH	9	rare	
Aphredoderus sayanus	Pirate Perch	9	rare	native
CATOSTOMIDAE	SUCKERS	2909	abundant	
Carpiodes cyprinus	Quillback	4	rare	native
Catostomus commersonii	White Sucker	175	uncommon	native
Erimyzon oblongus	Creek Chubsucker	3	rare	native
Hypentelium nigricans	Northern Hog Sucker	827	common	native
Moxostoma cervinum	Black Jumprock	865	common	native
Moxostoma macrolepidotum	Shorthead Redhorse	164	uncommon	native
Thoburnia rhothoeca	Torrent Sucker	871	common	native
CENTRARCHIDAE	SUNFISHES	2284	abundant	
Ambloplites rupestris	Rock Bass	123	uncommon	introduced
Lepomis auritus	Redbreast Sunfish	1261	abundant	native
Lepomis cyanellus	Green Sunfish	47	uncommon	introduced
Lepomis macrochirus	Bluegill	289	common	introduced
Lepomis microlophus	Redear Sunfish	14	uncommon	introduced
Micropterus dolomieu	Smallmouth Bass	412	common	introduced
Micropterus salmoides	Largemouth Bass	137	uncommon	introduced
Pomoxis nigromaculatus	Black Crappie	1	rare	native
CLUPEIDAE	HERRINGS	29	uncommon	
Dorosoma cepedianum	Gizzard Shad	29	uncommon	native
COTTIDAE	SCULPINS	2	rare	
Cottus bairdii	Mottled Sculpin	2	rare	native
CYPRINIDAE	MINNOWS	15635	abundant	
Campostoma anomalum	Central Stoneroller	2289	abundant	native
Chrosomus oreas	Mountain Redbelly Dace	88	uncommon	native
Clinostomus funduloides	Rosyside Dace	137	uncommon	native
Cyprinella analostana	Satinfin Shiner	797	common	native
Exoglossum maxillingua	Cutlip Minnow	7	rare	native
Hybognathus regius	Eastern Silvery Minnow	3	rare	native
Luxilus cornutus	Common Shiner	1227	abundant	native
Lythrurus ardens	Rosefin Shiner	1058	common	native
Nocomis leptocephalus	Bluehead Chub	1403	abundant	native
Nocomis micropogon	River Chub	119	uncommon	native
Nocomis raneyi	Bull Chub	3554	abundant	native

Table 3 (continued). Rivanna fish community characteristics as indicated from the Rivanna Conservation Alliance (RCA) and Virginia Department of Wildlife Resources (DWR) 2019 survey.

FAMILY *Genus species*	Common Name	Number	Designation[a]	Status[b]
Notemigonus crysoleucas	Golden Shiner	1	rare	native
Notropis amoenus	Comely Shiner	89	uncommon	native
Notropis hudsonius	Spottail Shiner	1297	abundant	native
Notropis procne	Swallowtail Shiner	410	common	native
Notropis rubellus	Rosyface Shiner	817	common	native
Notropis telescopus	Telescope Shiner	318	common	introduced
Pimephales notatus	Bluntnose Minnow	224	uncommon	introduced
Rhinichthys atratulus	Blacknose Dace	343	common	native
Rhinichthys cataractae	Longnose Dace	60	uncommon	native
Semotilus atromaculatus	Creek Chub	39	uncommon	native
Semotilus corporalis	Fallfish	792	common	native
ICTALURIDAE	N. AMERICAN CATFISHES	25	uncommon	
Ameiurus natalis	Yellow Bullhead	5	rare	native
Ameiurus nebulosus	Brown Bullhead	1	rare	native
Ictalurus punctatus	Channel Catfish	11	rare	introduced
Noturus insignis	Margined Madtom	563	common	native
Pylodictis olivaris	Flathead Catfish	8	rare	introduced
LEPISOSTEIDAE	GARS	11	rare	
Lepisosteus osseus	Longnose Gar	11	rare	native
PERCIDAE	PERCHES	1786	abundant	
Sander vitreus	Walleye	2	rare	introduced
Etheostoma flabellare	Fantail Darter	559	common	native
Etheostoma longimanum	Longfin Darter	3	rare	native
Etheostoma nigrum	Johnny Darter	220	uncommon	native
Etheostoma vitreum	Glassy Darter	42	uncommon	native
Percina notogramma	Stripeback Darter	39	uncommon	native
Percina peltata	Shield Darter	77	uncommon	native
Percina roanoka	Roanoke Darter	844	common	introduced
PETROMYZONIDAE	LAMPREYS	111	uncommon	
Petromyzon marinus	Sea Lamprey	111	uncommon	native

[a] Abundance designations are based on percentage of total catch: abundant (>5%), common (1-5%), uncommon (0.1-1%), and rare (<0.1%).

[b] Jenkins and Burkhead (1994).

Table 4. Species counts by site from the Rivanna Conservation Alliance (RCA) and Virginia Department of Wildlife Resources (DWR) 2019 survey. Letters correspond to those in Figure 1 and Tables 1, 2, 5, and 6.

Common Name	A	B	C	D	E	F	G	H	I	J	K	L
American Eel	3		2		2	1	4	2	2	5	14	
Bluehead Chub	65	157	90	40	99	142	71	21	79	13	116	363
Blacknose Dace	1			91		209	4				1	
Black Crappie												
Bluegill	2	3	1		9		3	4	2	8	63	76
Black Jumprock	3		15					2		18	12	
Bluntnose Minnow									49			149
Brown Bullhead												
Bull Chub										85		23
Channel Catfish									1			
Creek Chubsucker			1									
Central Stoneroller	3	12	110	16	15	93	71	113	4	24	78	57
Common Shiner	33	52	95	2	62	20	60	51	99	3	4	236
Creek Chub				32		1						
Cutlips Minnow						1						
Comely Shiner			12						1	21		3
Eastern Silvery Minnow										3		
Fantail Darter	7	22	11	3	9	69	14	15	40	5	2	75
Fallfish	15	66	101	13	12	1	69	6	59	119	32	109
Flathead Catfish												
Glassy Darter			8		1				6			
Golden Shiner									1			
Green Sunfish	3	2	2		3		2	5		11	1	1
Gizzard Shad												2
Johnny Darter	6	17	20		2	1	17	29	30	14	3	1
Longfin Darter												
Longnose Dace		9			15	2	13	2			3	5
Largemouth Bass	4		7		6		1	2	4	11	3	13
Longnose Gar										1		
Margined Madtom	18	20	13	2	24	44	23	5	51	1	38	55
Mountain Redbelly Dace				23		65						
Mottled Sculpin						2						
Northern Hog Sucker	1	3	27						81	63	20	81
Pirate Perch	1				6					2		
Quillback												
Redbreast Sunfish	33	26	24		5		10	16	108	43	72	205
Redear Sunfish									3			8
Rosefin Shiner	35	17	150		7		7	15	88	75	26	294
Rock Bass	3	7	2				1		23	2	1	35

Table 4 (continued). Species counts by site from the Rivanna Conservation Alliance (RCA) and Virginia Department of Wildlife Resources (DWR) 2019 survey. Letters correspond to those in Figure 1 and Tables 1, 2, 5, and 6.

Common Name	A	B	C	D	E	F	G	H	I	J	K	L
Roanoke Darter	10		15					5		23	14	
River Chub									119			
Rosyside Dace	17		1	71		22						
Rosyface Shiner	29									53	36	
Stripeback Darter	6	1	7							3	7	
Sea Lamprey	2		10							34	1	
Shorthead Redhorse			6							15		
Shield Darter												
Smallmouth Bass		17	3		2		3	13	31	7	8	120
Satinfin Shiner	2	8	29		11		9	11	81	104	16	63
Spottail Shiner		5			8				107	117		26
Swallowtail Shiner	3		35		3			10	9	26	5	46
Telescope Shiner	44	3	38							24	24	
Torrent Sucker	78	68	9	22	57	245	60	44	5		43	44
Walleye												
White Sucker	10		36		5		14	4		39	9	1
Yellow Bullhead			1								1	2

Table 4 (continued). Species counts by site from the Rivanna Conservation Alliance (RCA) and Virginia Department of Wildlife Resources (DWR) 2019 survey. Letters correspond to those in Figure 1 and Tables 1, 2, 5, and 6.

Common Name	M	N	O	P	Q	R	S	T	U	V	W	X
American Eel	1	10	17	19	41	2	13	26	7	12	138	3
Bluehead Chub		50	7								1	89
Blacknose Dace												37
Black Crappie						1						
Bluegill	4	1	10	44	3	5		2	3	3	43	
Black Jumprock	36	108	22	4	247	20	51	124	84	109	10	
Bluntnose Minnow				26								
Brown Bullhead		1										
Bull Chub	388	235	118	21	439	84	230	192	356	246	1137	
Channel Catfish			2	2	2		2	1	1			
Creek Chubsucker			1								1	
Central Stoneroller	427	709	134	30	17	8	18	28	52	132	137	1
Common Shiner	205	86	32	17	7	7	5	42	17	13	15	64
Creek Chub												6
Cutlips Minnow	1											5
Comely Shiner		5	8	10	10	7			4		8	
Eastern Silvery Minnow												
Fantail Darter	35	35	8	2	62		45	23	15	48	4	10
Fallfish	110	16	25								26	13
Flathead Catfish				4					1	2	1	
Glassy Darter	4		4	15				1	3			
Golden Shiner												
Green Sunfish			2	6		1			3		5	
Gizzard Shad				8		16				3		
Johnny Darter	42	1	2		4				7	1	16	7
Longfin Darter												3
Longnose Dace	1	2	1				2	2	1		2	
Largemouth Bass	8	10	3	14	2	5		3	2	5	12	22
Longnose Gar				2	5		1	1		1		
Margined Madtom	23	32	5		50		16	16	19	31	62	15
Mountain Redbelly Dace												
Mottled Sculpin												
Northern Hog Sucker	53	137	58	39	50	17	27	54	53	52	11	
Pirate Perch												
Quillback						1		3				
Redbreast Sunfish	219	110	41	26	26	20	58	11	56	34	107	11
Redear Sunfish						3						
Rosefin Shiner		59	75	75	4	12	1	20	16	61	21	
Rock Bass	6	4		6	4	1	6	6	8	6	2	

Table 4 (continued). Species counts by site from the Rivanna Conservation Alliance (RCA) and Virginia Department of Wildlife Resources (DWR) 2019 survey. Letters correspond to those in Figure 1 and Tables 1, 2, 5, and 6.

Common Name	M	N	O	P	Q	R	S	T	U	V	W	X
Roanoke Darter		29	27	20	208		136	69	117	148	23	
River Chub												
Rosyside Dace												26
Rosyface Shiner			56	194	109	6	45	67	168		54	
Stripeback Darter	8		1	2	2	1	1					
Sea Lamprey		13	4	10	2	3		11	19	2		
Shorthead Redhorse	16	56	11	3	1	11	5	14	18	8		
Shield Darter			2	1	8		9	11	13	5	28	
Smallmouth Bass	25	28	20	38	24	20	10	10	13	17	3	
Satinfin Shiner	44	5	40	164	8	17	15	61	43	23	37	6
Spottail Shiner	101	58	10	109		24	6	103	23	4	596	
Swallowtail Shiner	38	59	13	90	32	4			6	1	5	25
Telescope Shiner			18	26	11	7	23	8	36	26	30	
Torrent Sucker	83	42	6				5	1	4	11		44
Walleye									1	1		
White Sucker	43	12	2									
Yellow Bullhead		1										

Table 5. Water quality measurements from sites surveyed by the Rivanna Conservation Alliance (RCA) and the Virginia Department of Wildlife Resources (DWR) in 2019.

Stream Name (map letter)	Temp. (°C)	Dissolved Oxygen (mg/L)	pH	Conductivity (µS/cm)
Buck Island Creek (A)	25.49	7.20	7.33	106
Buck Mountain Creek (B)	20.00	9.24	7.24	61
Cunningham Creek (C)	22.20	7.76	7.56	59
Foster Branch (D)	21.80	-	-	140
Ivy Creek (E)	25.78	8.52	7.32	88
Lynch River (F)	27.70	-	-	-
Marsh Run (G)	23.90	-	-	67
Meadow Creek (H)	24.88	8.75	7.51	257
Mechums River (I)	20.44	10.76	7.55	89
Mechunk Creek (J)	20.66	6.55	6.39	87
Moores Creek (K)	23.88	8.95	7.56	172
Moormans River (L)	19.62	9.14	7.97	59
North Fork Rivanna - upstream of Advanced Mills Dam (M)	21.33	8.32	7.80	66
North Fork Rivanna River - downstream of Advance Mills Dam (N)	23.05	9.20	7.04	67
North Fork Rivanna River - Forks of Rivanna (O)	18.21	8.69	6.08	84
Rivanna River at Columbia (P)	17.79	9.84	7.80	229
Rivanna River at Crofton (Q)	24.55	10.95	8.05	139
Rivanna River at Darden Towe (R)	16.72	9.44	7.61	106
Rivanna River at Milton (S)	26.23	10.33	6.95	199
Rivanna River at Palmyra (T)	23.06	9.08	6.99	137
Rivanna River at Riverview (U)	23.28	8.09	6.66	99
Rivanna River at Woolen Mills (V)	-	-	-	-
South Fork Rivanna River - downstream of Reservoir Dam (W)	24.53	7.34	7.80	111
Welsh Run (X)	22.00	-	7.33	62
Average of All Sample Locations	*22.48*	*8.85*	*7.33*	*113*

[a] Corresponds to map letters in Figure 1.

Table 6. Habitat measurements from sites surveyed by the Rivanna Conservation Alliance (RCA) and the Virginia Department of Wildlife Resources (DWR) in 2019.

	Pool				Riffle				Run			
Stream Name (map letter)[a]	Avg. Length (m)	Avg. Width (m)	Max. depth (cm)	Dominant Substrate	Avg. Length (m)	Avg. Width (m)	Max. depth (cm)	Dominant Substrate	Avg. Length (m)	Avg. Width (m)	Max. depth (cm)	Dominant Substrate
Buck Island Creek (A)	18.38	8.35	68.00	large gravel	14.87	6.57	29.00	bedrock	20.20	7.65	30.00	bedrock
Buck Mountain Creek (B)	27.20	6.85	50.50	sand	15.83	6.07	34.00	cobble	24.55	7.70	35.00	sand
Cunningham Creek (C)	35.26	6.50	50.00	sand	4.32	7.50	15.00	small gravel	16.70	5.30	27.00	sand
Foster Branch (D)	8.23	2.22	87.00	silt	5.98	1.89	10.00	large gravel	3.85	1.60	8.00	large gravel
Ivy Creek (E)	14.47	6.30	101.00	silt	22.10	6.80	25.00	silt	21.13	8.10	61.00	silt
Lynch River (F)	11.95	3.72	50.00	silt	11.17	3.35	18.00	cobble	8.20	2.60	20.00	sand
Marsh Run (G)	15.90	4.99	85.00	silt	5.66	4.80	30.00	large cobble	5.60	4.25	30.00	sand
Meadow Creek (H)	26.20	9.50	115.00	silt	12.10	6.60	25.00	large gravel	17.80	7.40	28.00	sand
Moores Creek (K)	84.30	8.23	90.00	sand	15.70	10.45	22.00	cobble	-	-	-	-
Welsh Run (X)	21.78	4.34	22.00	sand	12.22	3.74	11.00	cobble	-	-	-	-

[a] Corresponds to map letters in Figure 1.