



**Linville River, Gill State Forest, Restoration Investigation**

Avery County, North Carolina, 15 September 2021

North Carolina Department of Environmental Quality

Division of Water Resources

Water Sciences Section

Biological Assessment Branch

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## BENTHIC MACROINVERTEBRATE ASSESSMENT SUMMARY

On 15 September 2021, the North Carolina Biological Assessment Branch (NCBAB) sampled the Linville River at Gill State Forest to assess the efficacy of a restoration. Two stream reaches were sampled using the EPT method. The EPT method is an abbreviated version of the Full Scale method and is used to quickly determine between-site differences in water quality. It is particularly useful for watershed or basin assessment studies with large numbers of sites, or emergency sampling where it is desirable to rapidly assess the effect of spills, unusual discharges, etc. The collection and analysis time for the EPT method has been decreased from the Full Scale method in two ways. First, collections focus solely on a subset of the benthic community composed of taxa in the taxonomic orders Ephemeroptera, Plecoptera, and Trichoptera. These orders usually include the most intolerant species among benthic invertebrates. Field notes also are made concerning the abundance of other groups, especially any pollution indicator species. Secondly, the number of collections is decreased from 13 to six: one riffle-kick, one sweep, one leaf-pack, and three visuals.

The two stream reaches were located on either side of Harmon Bridge (SR 1536). The downstream site (CB416; 36.011180, -81.931490) was the restored reach and the upstream site (CB417; 36.015770, -81.930260) was the reference reach. Both reaches rated good. The restoration reach had 32 EPT, which put it solidly in the good category. The reference reach had 35 EPT, as such it was right on the edge of receiving an excellent bioclassification, which requires 36+ EPT. Overall, water quality in the restored reach was comparable to the upstream reference. Biotic index scores, which are a measure the relative tolerance of a system to stress were similar between the two locations as well (CB416 = 3.06; CB417 = 2.89), indicating both EPT communities are generally composed of intolerant taxa.

The primary difference between the two sites in terms of EPT taxa were that more Beatidae, Ephemerellidae and Neoephemeridae were found upstream compared to the restored reach. I believe this is primarily due to the lack of Podostemum, an aquatic plant that provides excellent refuge for invertebrates and seems to be especially important to Ephemerellidae and Neoephemeridae. Podostemum will probably establish itself in the restored area in time as it present in the reference reach. Another habitat type that was lacking in the restored reach was snag habitat (i.e. large woody debris). Snags and the roots from riparian vegetation catch leaves and provide important refuge for other species like Pteronarcys spp., which we did not recover from either reach. NCBAB is planning to add the restored reach to the list of basinwide monitoring sites that are sampled every five years (the Catawba Basin is scheduled for 2022), so we can continue to assess the effects of the restoration.

Waterbody	Location	Station ID	Date	Bioclassification
Linville River	BE Harmon Bridge	CB416	09/15/21	Good

County	8 digit HUC	Latitude	Longitude	Elevation (ft)
Avery	00305101	36.011180	-81.931490	3280

Level IV Ecoregion	Drainage Area (mi2)	Stream Width (m)	Stream Depth (m)
Southern Crystalline Ridges and Mountains	30	12	0.7

Upstream NPDES Dischargers (≥ 1 MGD or < 1 MGD and within 1 mile)	NPDES Number	Volume (MGD)
Crossnore WWTP	NC0026654	< 1MDG

Landuse (%)	Forest	Developed	Impervious	Cultivation	Grass/Herb/Shrub	Wetland	Water	Barren
1992	90.4	4.9	N/A	3.8	N/A	0.0	0.6	0.2
2001	70.6	18.4	1.5	6.6	3.5	0.2	5.0	0.2
2006	70.6	18.5	1.5	6.5	3.5	0.2	0.5	0.2
2011	70.5	18.5	1.5	6.5	3.6	0.2	0.5	0.2

Water Quality Parameters	2021
Temperature (°C)	17.7
Dissolved Oxygen (mg/L)	8.7
Specific Conductance (µS/cm)	55
pH (s.u.)	6.3

Site Photograph



Habitat Assessment Scores (max score)	2021
Channel Modification (5)	4
Instream Habitat (20)	16
Bottom Substrate (15)	15
Pool Variety (10)	8
Riffle Habitat (16)	14
Bank Erosion (7)	7
Bank Vegetation (7)	6
Light Penetration (10)	2
Left Riparian Score (5)	3
Right Riparian Score (5)	3
Total Habitat Score (100)	78

<b>Substrate (%)</b>	boulder (35), cobble (30), gravel (20), sand (10), bedrock (10)	<b>Water Clarity</b>	clear
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Sample Date	Sample ID	Method	ST	EPT	BI	EPT BI	Bioclassification
09/15/21	12769	EPT	32	32	3.06	3.06	Good

**Data Analysis**

Linville River below Harmon Bridge received a Good Bioclassification in 2021. The reach had 32 EPT, which put it solidly in the Good category. For reference, an Excellent sample would have 36+ EPT. The EPT BI was 3.06, which indicates the taxa present are mostly intolerant. Overall, the restoration that occurred in this reach appears to have been successful. However, there were several habitat types that were lacking in this reach including root mats, popdostemum and snag habitat /leaf packs. The lack of root mats were possibly a limiting factor for taxa like Oecetis spp., Pycnopsyche spp., Nectopsyche spp. and Triaenodes spp. In the current sample Pycnopsyche and Nectopsyche were absent, while Oecetis and Triaenodes were rare. Podostemum, which was absent in the reach, but present upstream, is an aquatic plant which grows on rocky substrates and provides important habitat for many aquatic species including Ephemerellidae. These include Ephemerella spp. and notably Neophemera spp., which were both absent. Snag habitats (ie. large woody debris) which help to hold leaf packs were also absent in the reach. Snags and the leaves they catch provide important refuge for other species like Pteronarcys spp., which was conspicuously absent from the reach. Overall, water quality in the restored reach was comparable to the upstream reference reach. Future sampling of this location is recommended to further assess the efficacy of the restoration.

Waterbody	Location	Station ID	Date	Bioclassification
Linville River	AB Harmon Bridge	CB417	09/15/21	Good

County	8 digit HUC	Latitude	Longitude	Elevation (ft)
Avery	00305101	36.015770	-81.930260	3290

Level IV Ecoregion	Drainage Area (mi2)	Stream Width (m)	Stream Depth (m)
Southern Crystalline Ridges and Mountains	30	14	0.5

Upstream NPDES Dischargers (≥ 1 MGD or < 1 MGD and within 1 mile)	NPDES Number	Volume (MGD)
Crossnore WWTP	NC0026654	< 1MGD

Landuse (%)	Forest	Developed	Impervious	Cultivation	Grass/Herb/Shrub	Wetland	Water	Barren
1992	90.4	4.9	N/A	3.8	N/A	0.0	0.6	0.2
2001	70.8	18.3	1.5	6.6	3.5	0.2	0.5	0.2
2006	70.7	18.4	1.5	6.5	3.4	0.2	0.5	0.2
2011	70.6	18.4	1.5	6.5	3.5	0.2	0.5	0.2

Water Quality Parameters	2021
Temperature (°C)	18.3
Dissolved Oxygen (mg/L)	8.7
Specific Conductance (µS/cm)	55
pH (s.u.)	6.0

Site Photograph



Habitat Assessment Scores (max score)	2021
Channel Modification (5)	5
Instream Habitat (20)	16
Bottom Substrate (15)	15
Pool Variety (10)	10
Riffle Habitat (16)	14
Bank Erosion (7)	7
Bank Vegetation (7)	7
Light Penetration (10)	7
Left Riparian Score (5)	5
Right Riparian Score (5)	3
Total Habitat Score (100)	89

<b>Substrate (%)</b>	boulder (30), cobble (20), gravel (10), sand (20), bedrock (20)	<b>Water Clarity</b>	clear
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Sample Date	Sample ID	Method	ST	EPT	BI	EPT BI	Bioclassification
09/15/21	12770	EPT	35	35	2.89	2.89	Good

**Data Analysis**

Linville River above Harmon Bridge received a Good Bioclassification with 35 EPT in 2021. This reach served as the reference to assess the efficacy of a downstream restoration. This reach narrowly missed rating excellent, which would have required a total of 36 EPT taxa. The EPT BI was 2.89, which indicates the EPT community is generally intolerant. Compared to the restored reach, the reference reach had a higher gradient, more shade and many boulders covered with podostemum, which were absent downstream. The presence of podostemum likely contributed to the presence of Neophemera, which was absent downstream. Notably we also found Hydropsyche carolina in this reach, which is very uncommonly collected. Similar to the downstream reach, root mats and leaf packs were rare, which were possibly limiting factors for taxa like Oecetis spp., Pycnopsyche spp., Nectopsyche spp. and Triaenodes spp. all which were absent. Recent high flows likely contributed to the rarity of leaf packs, but just like the restored reach, snags that catch leaf packs were uncommon. Future sampling of this location is recommended to further assess the efficacy of the downstream restoration.

**Appendix 1.** Taxa collected from benthic sites sampled at Linville River on 15 September 2021. Categorical abundances are also shown (R = 1 or 2 specimens collected; C = 3 to 9 specimens collected; A = 10 or more specimens collected).

Order	Family	Taxon	CB416 Linville R.	CB417 Linville R.
			BE Harmon Bridge Avery County 15 Sep 2021	AB Harmon Bridge Avery County 15 Sep 2021
<b>Ephemeroptera</b>	Baetidae	Acentrella barbarae		R
		Acentrella nadineae		R
		Acentrella turbida gr	A	C
		Baetis flavistriga	C	C
		Baetis intercalaris	A	A
		Baetis pluto	A	A
		Baetis tricaudatus	R	
		Heterocloeon curiosum	R	C
		Plauditus dubius gr	A	C
	Caenidae	Caenis spp	C	C
	Ephemerellidae	Drunella conestee	R	
		Serratella serratoides		C
		Teloganopsis deficiens	R	C
	Heptageniidae	Epeorus vitreus	A	C
		Heptagenia marginalis gr		R
		Leucrocuta spp	A	C
		Maccaffertium ithaca	C	
		Maccaffertium modestum	A	
		Maccaffertium spp		A
	Isonychiidae	Isonychia spp	A	A
	Neoephemeridae	Neoephemera purpurea		R
<b>Plecoptera</b>	Leuctridae	Leuctra spp		R
	Peltoperlidae	Tallaperla spp	R	R
	Perlidae	Acroneuria abnormis	A	A
		Paragnetina immarginata	C	A
<b>Trichoptera</b>	Glossosomatidae	Glossosoma nigrior	R	
	Hydropsychidae	Cheumatopsyche spp	A	A
		Diplectrona modesta	R	R
		Hydropsyche (C.) bronta	A	A
		Hydropsyche (C.) morosa	R	
		Hydropsyche (C.) sparna	A	A
		Hydropsyche (H.) carolina		R
	Leptoceridae	Ceraclea ancylus		C
		Oecetis spp	R	
		Triaenodes taenius	R	
	Limnephilidae	Hydatophylax argus	C	R
		Pycnopsyche spp		
Philopotamidae	Chimarra spp	R	A	
	Dolophilodes spp	A	A	

Appendix 1 continued

Order	Family	Taxon	CB416 Linville R.	CB417 Linville R.
			BE Harmon Bridge Avery County 15 Sep 2021	AB Harmon Bridge Avery County 15 Sep 2021
Trichoptera	Phryganeidae	Ptilostomis spp		R
	Polycentropodidae	Nyctiophylax spp		C
		Polycentropodidae		R
		Polycentropus sensu lato spp	C	
	Rhyacophilidae	Rhyacophila fuscula	C	A
<b>Total taxa</b>			<b>32</b>	<b>35</b>

Report continues on next page...

## FISH COMMUNITY ASSESSMENT SUMMARY

On 15 September 2021, the NCBAB sampled the Linville River at Gill State Forest to assess the efficacy of a habitat restoration project. In addition to sampling for benthic macroinvertebrates in the restored and control reaches using the EPT method described above, two 300 foot stream lengths were measured within the same designated reaches and sampled for fish using the NCIBI assessment method. Two backpack electrofishing units and two fish netters (total of 4 people) collected all available fish within each sample reach using a two-pass-depletion technique. Using this standard method, each two-person team shocked either the left or right edge of the wetted channel moving upstream, then returned downstream through the channel thalweg as a group. An attempt was made to collect all stunned adult fish for identification and enumeration, followed by their release back into the river.

The two stream reaches were located on either side of Harmon Bridge (SR 1536). The downstream site (CF113; 36.011180, -81.931490) was the restored reach and the upstream site (CF114; 36.015770, -81.930260) was the reference reach. Both reaches rated Good-Fair with the NCIBI (summary of 12 scored metrics designed to evaluate the structure and condition of a fish community). The upstream reference site produced a total of 308 individuals representing 11 fish species. The downstream restoration reach produced a total of 448 fish representing 13 species. Between both sample reaches, a total of 15 fish species were collected (see Appendix 2). Both fish sampling reaches received NCIBI scores of 42, at the lower end of a Good-Fair bioclassification, due to skewed trophic structures favoring herbivores and omnivores. Both NCIBI scores (and potential bioclassifications) would have likely improved with the collection of additional insectivorous fish, including the Carolina Fantail Darter (*Etheostoma brevispinum*). Overall, water quality in the restored reach was comparable to the upstream reference reach, like the benthos assessment results. Except for two metrics (number of sucker species and percent species with multiple ages) individual metric scores (8) were identical between the two fish collection reaches. Total NCIBI scores were also identical between the control and restored sites (42 out of 60 max points), indicating comparable fish structures and overall health.

The main difference between the two fish community samples was the number of Central Stoneroller (*Campostoma anomalum*) collected in each reach (88 individuals in the control reach vs. 234 in the restored reach, a 2.7-fold difference). This variation in abundance over a relatively short distance of river is likely related to the difference in canopy shading between the two sample reaches (light penetration = 7 in the control reach vs. 2 in the restored reach). As the banks of the restored reach heal and create additional tree shading over time, distributions of this benthos grazing species may also equilibrate between sample reaches. In addition, the lack of woody substrates in the restored reach is also likely contributing to the slight differences in fish assemblages seen in this initial assessment. Over time, woody substrates should also become established within the restored reach, offering additional biological refugia to aquatic species of all kinds.

Waterbody	Location	Station ID	Date	Bioclassification
LINVILLE RIVER	BE Harmon Bridge	CF113	09/15/21	Good-Fair

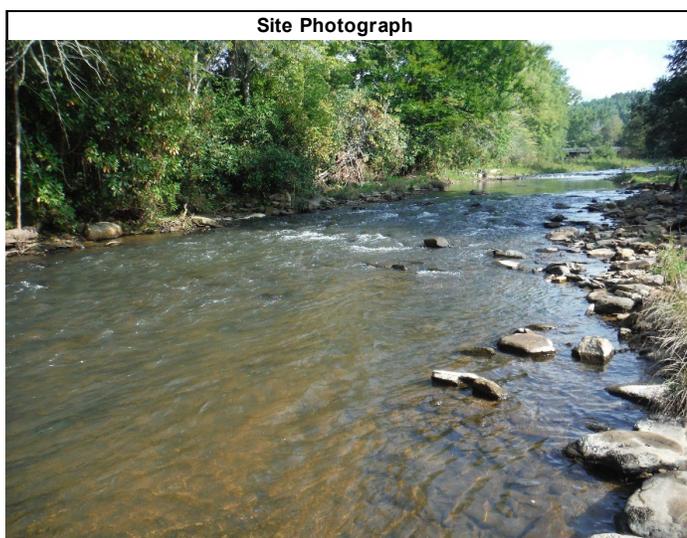
County	8 digit HUC	Latitude	Longitude	Elevation (ft)	Reference Site
AVERY	03050101	36.011180	-81.931490	3283	No

Level IV Ecoregion	Drainage Area (mi <sup>2</sup> )	Stream Width (m)	Stream Depth (m)
Southern Crystalline Ridges and Mountains	30.4	12	0.8

Upstream NPDES Dischargers (≥ 1 MGD or < 1 MGD and within 1 mile)	NPDES Number	Volume (MGD)
Crossnore WWTP	NC0026654	< 1MGD

Landuse (%)	Forest	Developed	Impervious	Cultivation	Grass/Herb/Shrub	Wetland	Water	Barren
1992	90.4	4.9	0.0	3.8	0.0	0.0	0.6	0.2
2001	70.6	18.4	1.5	6.6	3.5	0.2	0.5	0.2
2006	70.6	18.5	1.5	6.5	3.5	0.2	0.5	0.2
2011	70.5	18.5	1.5	6.5	3.6	0.2	0.5	0.2

Water Quality Parameters	2021
Temperature (°C)	17.8
Dissolved Oxygen (mg/L)	8.7
Specific Conductance (µS/cm)	55
pH (s.u.)	6.3



Habitat Assessment Scores (max score)	2021
Channel Modification (5)	4
Instream Habitat (20)	16
Bottom Substrate (15)	15
Pool Variety (10)	8
Riffle Habitat (16)	14
Bank Erosion (7)	7
Bank Vegetation (7)	6
Light Penetration (10)	2
Left Riparian Score (5)	3
Right Riparian Score (5)	3
Total Habitat Score (100)	78

<b>Water Clarity</b>	Clear	<b>Substrates</b>	boulder (35%), cobble (30%), gravel (20%), sand (10%), bedrock (10)
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Sample Date	Sample ID	Species Total	NCIBI Score	NCIBI Rating
09/15/21	2021-19	11	42	Good-Fair

**Data Analysis**

The fish community survey within the restored reach of the Linville River below the AB Harmon bridge produced a Good-Fair bioclassification using the NCIBI. A relatively abundant fish assemblage (n=448) with moderate species richness for a watershed of this size including 2 intolerant top predators [Rock Bass (*Ambloplites rupestris*), and Smallmouth Bass (*Micropterus dolomieu*)]. The NCIBI score of 42 is on the low end of the Good-Fair fish rating, mostly due to the trophic imbalance of collected taxa favoring herbivores and omnivores. The relatively open canopy here is likely influencing the overall dominance of the herbivorous Central Stoneroller (*Camptostoma anomalum*). However, the metric %Piscivores received a maximum score. Expected but unencountered insectivores include Rosyside Dace (*Clinostomus funduloides*), Creek Chub (*Semotilus atromaculatus*), Western Blacknose Dace (*Rhinichthys obtusus*), Longnose Dace (*Rhinichthys cataractae*), Rainbow Trout (*Oncorhynchus mykiss*), Striped Jumprock (*Moxostoma rupiscartes*), and most notably Carolina Fantail Darter (*Etheostoma brevispinum*). Surprisingly, no darters were collected in this restored reach. A more balanced assemblage may return over time as the restored banks become more vegetated and allow additional shading to the stream bed. Natural variation of the fish community within the Linville River may also be influencing the observed trophic structure at this location. A follow up assessment may be justified to verify these results.

<b>Most Abundant Sp.</b>	Central Stoneroller (n=234, 52%), River Chub (n=118, 26%)	<b>Non-Native Sp.</b>	Rock Bass (n=10), Green Sunfish (n=6), Smallmouth Bass (n=4), Brown Trout (n=10)
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**Species Change Since Last Cycle**

Does not apply, this was the first fish community assessment at this location.

Waterbody	Location	Station ID	Date	Bioclassification
LINVILLE RIVER	AB Harmon Bridge	CF114	09/15/21	Good-Fair

County	8 digit HUC	Latitude	Longitude	Elevation (ft)	Reference Site
AVERY	3050101	36.015770	-81.930260	3296	No

Level IV Ecoregion	Drainage Area (mi <sup>2</sup> )	Stream Width (m)	Stream Depth (m)
Southern Crystalline Ridges and Mountains	30.2	14	0.5

Upstream NPDES Dischargers (≥ 1 MGD or < 1 MGD and within 1 mile)	NPDES Number	Volume (MGD)
Crossnore WWTP	NC0026654	< 1MGD

Landuse (%)	Forest	Developed	Impervious	Cultivation	Grass/Herb/Shrub	Wetland	Water	Barren
1992	90.4	4.9	0.0	3.8	0.0	0.0	0.6	0.2
2001	70.8	18.3	1.5	6.6	3.5	0.2	0.5	0.2
2006	70.7	18.4	1.5	6.5	3.4	0.2	0.5	0.2
2011	70.6	18.4	1.5	6.5	3.5	0.2	0.5	0.2

Water Quality Parameters	2021
Temperature (°C)	18.3
Dissolved Oxygen (mg/L)	8.7
Specific Conductance (µS/cm)	55
pH (s.u.)	6.0

Habitat Assessment Scores (max score)	2021
Channel Modification (5)	5
Instream Habitat (20)	16
Bottom Substrate (15)	15
Pool Variety (10)	10
Riffle Habitat (16)	14
Bank Erosion (7)	7
Bank Vegetation (7)	7
Light Penetration (10)	7
Left Riparian Score (5)	5
Right Riparian Score (5)	3
Total Habitat Score (100)	89



<b>Water Clarity</b>	Clear	<b>Substrates</b>	boulder (30%), cobble (20%), gravel (10%), sand (20%), bedrock (20%)
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Sample Date	Sample ID	Species Total	NCIBI Score	NCIBI Rating
09/15/21	2021-20	13	42	Good-Fair

**Data Analysis**

The fish community survey within the unrestored reach of the Linville River above the AB Harmon bridge (control site) received a Good-Fair bioclassification using the North Carolina Index of Biotic Integrity (NCIBI). Good abundance (n=308) and moderate species richness (2 more taxa collected than below the bridge in the restored reach) for a watershed of this size, including 1 pollution intolerant species (Rock Bass, *Ambloplites rupestris*). The NCIBI score of 42 puts this survey on the low end of the Good-Fair bioclassification, primarily due to the skewed trophic structure in favor of herbivores (Central Stoneroller, *Camptostoma anomalum*) and omnivores (River Chub, *Nocomis micropogon*). Additional canopy shading here compared to the restored reach below the bridge (see above, Light Penetration in Habitat Assessment Scores) is likely the reason for the moderate increase in insectivores present (32% vs. 16% in the restored reach). However, matching metric scores for all 3 trophic metrics were assigned (1 out of 5 for %Omni+Herb and %Insectivores, and 5 out of 5 for %Piscivores) for both Linville River sites, highlighting the overall trophic similarities between these proximal sample reaches. Similar to the restored site, expected but unencountered insectivores include Rosyside Dace (*Clinostomus funduloides*), Creek Chub (*Semotilus atromaculatus*), Western Blacknose Dace (*Rhinichthys obtusus*), Rainbow Trout (*Oncorhynchus mykiss*), Striped Jumprock (*Moxostoma rupiscartes*), and most notably Carolina Fantail Darter (*Etheostoma brevispinum*). No darters were collected in this control reach. As may be the case in the restored reach, natural variation of the fish community may also be influencing the trophic structure here. A follow up assessment may be justified to verify these results.

<b>Most Abundant Sp.</b>	River Chub (n=94, 31%), Central Stoneroller (n=88, 29%)	<b>Non-Native Sp.</b>	Rock Bass (n=12), Green Sunfish (n=4), Brown Trout (n=14)
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**Species Change Since Last Sample**  
Does not apply, this was the first fish community assessment at this location.

**Appendix 2.** Taxa collected from fish community sites sampled at Linville River on 15 September 2021.

Family	Genus Species	Common Name	Tolerance Rating	Trophic Guild of Adults	Linville River BE Harmon Bridge (restored) Avery County 15 Sep 2021	Linville River AB Harmon Bridge (control) Avery County 15 Sep 2021
Catostomidae	<i>Catostomus commersonii</i>	White Sucker	Tolerant	Omnivore		2
	<i>Hypentelium nigricans</i>	Northern Hog Sucker	Intermediate	Insectivore	10	44
Centrarchidae	<i>Ambloplites rupestris</i>	Rock Bass	Intolerant	Piscivore	10	12
	<i>Lepomis auritus</i>	Redbreast Sunfish	Tolerant	Insectivore	2	8
	<i>Lepomis cyanellus</i>	Green Sunfish	Tolerant	Insectivore	6	4
	<i>Lepomis macrochirus</i>	Bluegill	Intermediate	Insectivore		2
	<i>Micropterus dolomieu</i>	Smallmouth Bass	Intolerant	Piscivore	4	
Cyprinidae	<i>Campostoma anomalum</i>	Central Stoneroller	Intermediate	Herbivore	234	88
	<i>Cyprinella galactura</i>	Whitetail Shiner	Intermediate	Insectivore		22
	<i>Luxilus coccogenis</i>	Warpaint Shiner	Intermediate	Insectivore	24	14
	<i>Nocomis micropogon</i>	River Chub	Intermediate	Omnivore	118	94
	<i>Notropis rubricroceus</i>	Saffron Shiner	Intermediate	Insectivore	18	2
	<i>Notropis spectrunculus</i>	Mirror Shiner	Intermediate	Insectivore		2
	<i>Rhinichthys cataractae</i>	Longnose Dace	Intermediate	Insectivore	12	
Salmonidae	<i>Salmo trutta</i>	Brown Trout	Intermediate	Piscivore	10	14
<b>Total Species</b>					<b>11</b>	<b>13</b>
<b>Total Sample Count x 2 (300 ft sample reach)</b>					<b>448</b>	<b>308</b>

