ASSESSMENT OF FISH AND IN-STREAM HABITAT RESPONSES TO DAM REMOVAL ON THE MIDDLE FORK NEW RIVER

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Abstract

Small dams are common throughout the southeastern United States. With push for increased stream connectivity dam removals are becoming popular but, little is known about the removal of small dam removals. The removal of dams on high gradient streams has not been studied often, long term studies are even less common. This study assesses a dam removal comparing data collected in 2014 to data collected in 2023. The Payne Branch Dam on the Middle Fork of the New River was deconstructed in Summer 2020, nearly 50 years after it was decommissioned. The Middle Fork New River historically supported populations of over 20 fish taxa, including several species endemic to the New River Drainage. Fish surveys in 2014, identifying 1,524 fish revealed that 15 species occurred in the Middle Fork upstream from the dam including small, localized populations of two endemics, Kanawha minnow (*Phenacobius teretulus*) and Toungetied minnow (*Exoglossum laurae*). This study evaluated the recovery of fish populations in response to the removal of this barrier. In 2023, 1,420 fish were sampled using a backpack electrofishing unit and measured habitat parameters (channel width, depth, flow and substrate composition) to assess recolonization at 4 historically- sampled sites (2 upstream and 2 downstream from the former dam site) as well as 2 new sites: the tailrace, beginning just downstream of the old dam site, and along Boone Greenway becoming the most downstream site. In the impoundment, channel depth and width decreased post-removal whereas velocity and substrate coarseness increased substantially. Habitat conditions in the tailrace and at our upstream reference sites remained largely unchanged. However, increases in fine sediment (primarily sand) and decreased depth was observed at sites further downstream in the Middle Fork. Post removal sampling in the former impoundment revealed that fish communities are composed of species associated with high-gradient habitats. Additionally, communities at

upstream reference sites appear largely unchanged following dam removal. Previous sampling shows New River endemics have not been detected upstream of the former dam since 2014. Spring 2023 sampling demonstrated that this is still true, indicating trans-locations may be needed to promote recovery of upstream communities.

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Introduction

Dams have profound effects on stream ecosystems and communities, fragmenting not only aquatic communities but also disrupting the natural flow and impacting in-stream habitat (Helms et al. 2011). The unnatural flow caused by dams leads to habitat degradation impacting the fish community. Disruption of the ratio of coarse and fine particulate matter, dams can drastically change the physical dynamics of streams (Helms et al. 2011). Damming homogenizes river flow, disrupting the heterogenous mixture of mesohabitats that once existed while decreasing stream energy. Stream impoundments are known to reduce fish community diversity, creating habitat that is conducive to the colonization of invasive species (Holcomb et al. 2015). Impeding the migration of fishes, impoundments fragment populations possibly cutting off spawning habitat (Helms et al. 2011). Homogenization of stream features leads to homogenization of fish fauna and biodiversity as there begin to be fewer niches available (Poff et al. 2007). Rheophilic species are particularly affected by habitat homogenization, as they depend on a complex habitat of shallow, fast, free-flowing water to survive (Musil et al. 2012). The increased retention of sediment by impoundments may limit sediment-intolerant taxa (Holcomb et al. 2015). Breached dams release sediment downstream smothering benthic surfaces, fish communities in these impoundments are typically dominated by tolerant cyprinids containing few sensitive species and darters (Holcomb et al. 2015).

Not all aquatic biota are negatively impacted by dam-induced changes to stream structure. Low-head dams appear to provide positive impacts among the freshwater mussel community habitat generalists and eurytopic species may benefit from the homogenization of river habitat allowing them to become the dominant species in the impoundment (Holcomb et al. 2015). Reaches below dams often have increased algal cover often supporting larger algivore populations (Helms et al. 2011). Dams are also proven to be beneficial in restricting the migration of invasive species (Gangloff, 2013). However, dams have been demonstrated to have adverse effects on aquatic ecosystems. The removal of stream impoundments is an essential part of restoration projects aiming to restore the stream to a natural system. Increasingly, conservation groups such as Trout Unlimited and American Fisheries Society have begun advocating for the removal of dams as part of stream restoration programs in hopes of restoring natural habitats and enhancing the fish community.

Dam removals and restoration projects are guided by several principles in order to conduct an effective stream restoration. These include the project being driven towards the idea of creating a healthier river, a self-sustaining system, and that the project should result in a measurable increase in stream condition (Gangloff, 2013). Haphazard removal of dams can lead to a greater adverse effect on aquatic communities, the controlled deconstruction is needed to facilitate a successful removal for restoration purposes (Gangloff, 2013). A case study of a dam removal along the Milwaukee River demonstrated that a dam removal can result in a more productive stream. The reconstruction and improvement of in-stream impoundment habitat was instrumental in increasing habitat and biotic integrity (Kanehl et al. 1997).

The New River Light and Power Payne Branch Dam on the Middle Fork of the New River was deconstructed in Summer 2020, nearly 50 years after it was decommissioned. The dam was located on a high gradient stretch of the river between Blowing Rock and Boone, NC and was constructed in 1924 to provide power for Appalachian State University (Nault and Stump, 2021). Removal of the dam was part of a much larger effort to restore, and conserve stretches of the Middle Fork New River and connect local towns of Boone and Blowing Rock with a greenway trail complex along the river (Nault and Stump, 2021). This was not solely a dam removal but instead a restoration project as over 18,000 metric tons of sediment were removed from the river and a natural stream structure could be implemented (Nault and Stump, 2021). Native shrubs and plants were planted in order to create a riparian zone and stabilize banks in the former impoundment.

The Middle Fork New River historically supported populations of > 20 fish taxa, including several drainage endemics. However, in October 2003, the Blowing Rock water filtration plant spilled 11,000 liters of Sodium Hydroxide into the Middle Fork resulting in the death of more than 14,000 fish (North Carolina DEQ, 2003). This spill significantly impacted the abundance and, more importantly, the diversity of fishes in the Middle Fork New River. The fish community has yet to recover from this event as several taxa have been unable to recolonize this reach due to the existence of Payne Branch Dam. With the dam now deconstructed there is an opportunity for re-colonization by downstream taxa.

Fish surveys in 2014 revealed that 15 species occurred in the Middle Fork upstream from the dam. More recent data collected following the removal of the dam in 2021 and 2022 indicate that there has not been any change in the fish community. However, these surveys were haphazard and not conducted using the standardized methods from 2014. The purpose of this study is to evaluate the recovery of fish populations upstream from the former dam site now that the presumptive barrier to upstream movements has been removed. The study will focus primarily on fishes endemic to the New River including *Nocomis platycephalus* (Bighead chub), *Notropis scabriceps* (New River Shiner), *Etheostoma kanawhae* (Kanawha Darter), *Phenacobius teretulus* (Kanawha Minnow) and *Exoglosum laurae* (Tonguetied minnow). These species were historically present in the upper Middle Fork but are largely extirpated from the upper river. However, they remain extant in the Middle and South Forks downstream from the former dam site. Sampling in downstream sites will confirm the presence of these species to demonstrate species are in place for migration. The reach just downstream of the former dam is a very high gradient stretch of stream and it is possible that this section may present a barrier to upstream colonization. Survey data from spring 2023 will be used to assess recovery and whether translocations may be necessary to bypass this high gradient section and re-establish populations of extirpated fishes in reaches upstream of the former dam site.

Methods

Study Design

Field data were collection in Fall 2022 and Spring 2023 in order to compare data to pre-removal collections completed in 2014. In order to stay consistent with previous data collection the sample sites chosen were the same as the 2014 study. The four sites selected consisted of two reaches upstream of the dam and two reaches downstream. The furthest upstream site is Middle Fork New River at Niley Cook, which is ~1 km upstream of the former impoundment site which corresponds to the upper reaches of the former impoundment. The first historically sampled site downstream of the dam is Jordan Cook Road. Further downstream two sites were located on the. Greenway. Two additional sites were sampled in 2023. The Tailrace reach begins at the site of the removed dam and extends for 150-meters downstream ending near the high gradient reach that separates the Tailrace from the Jordan Cook Road site. The other site is a downstream reference site in the South Fork New River, downstream of the East Fork and Middle Fork confluence (Fig. 1).

In-Stream Habitat Surveys

Habitat at five reaches that were historically studied in 2014 and 2021 was also sampled during Fall 2022. Each site consisted of a 150-meter reach containing sixteen transects spaced at 10-m intervals. At each transect, stream habitat parameters were measured at equal distant points (Pugh et al. 2018). These parameters include stream width in meters (m), depth, and velocity. These measurements were taken five times across the width of the river (distance to bank was noted (n=256 per site). Velocity (m/s) was measured from the bottom of the water column using a flow meter. Twenty-five substrate particles were also measured along each transect (n=400 per site). Walking along the width of the stream every few steps a random particle was selected based on what was at the front of our boots. Non-lithic particles were characterized as organic matter, wood, sand, silt, or bedrock (Pugh et al. 2018). Sampling was not conducted during high flow events in to avoid skewing data measurements. Data collected was analyzed across each of the three years to examine changes in stream physical habitats following dam removal and to assess the degree to which changes in instream habitat may help explain changes in fish community structure. Separating habitat parameters by site and year an analysis was ran using ANOVA (α =0.05). Percent fine sediment calculations were comprised of the percentage of sand or silt detections

Fish Sampling

Fish sampling was completed at six sites using a Smith-Root LR-20B Backpack Electrofisher. Sampling was standardized to ~100 seconds (s) per mesohabitat, which were characterized as runs, riffles or pools. Each mesohabitat type was sampled three times per reach, an additional 50s were added if a new species was identified on the last pass of that mesohabitat type. The deployment of a seine net downstream of the electrifying crew allowed for effective sampling to be completed in fast-flowing waters. The survey team began sampling at the furthest downstream section of each reach and worked upstream in order to prevent the recapture of individuals and prevent disturbance. At the end of each sampling pass the fish collected in the seine and dipnets were placed in an aerated prior to processing. All fishes were then identified to species and returned to the stream immediately. Some small *Nocomis* that were unable to be identified to species due to lack of identifiable characteristics (nuptral tubercles), were simply listed as *Nocomis* spp. in data analysis.

The data was analyzed by comparing 2014 data to the data collected in 2022. Computed community metrics include species assemblage, species richness and Shannon-Weiner diversity (H') were computed for each site and year. Sites were categorized as upstream or downstream of the former dam site, in order to analyze the occurrence of migration upstream of the former dam site. I used a 2-Way ANOVA to test for differences in habitat data among sites during pre- and post-removal surveys and paired T-tests to determine whether fish communities at individual sites differed pre and post-removal.

Results

In-Stream Habitat

Depth and median substrate size remained largely unchanged at the most upstream site since 2014. At this site velocity increased while the percent of fine sediment decreased considerably between 2014 and 2022. In 2014, percent of fine sediment was highest at the most upstream site, in 2021 it was highest in the tailrace and in 2022 it was highest at the Greenway site (Fig. 3). Depth and median substrate size both increased modestly in the former impoundment following dam removal (Fig. 3). Stream velocity decreased in both sites closest to the dam site following the removal of the dam (Fig. 3).

Species Diversity

Fish surveys reveal that there has been little change in fish community diversity withing the Middle Fork New River, following the removal of Payne Branch Dam. Shannon-Wiener diversity slightly increased but, species richness stayed the same. The upstream community remains largely unchanged; however, the downstream community improved the most. The Covered Bridge site was the most diverse site containing 6 species only found at that site (Table 2). This site is not factored into the data analysis as it belonging to the South Fork New River (Table 2).

The fish community upstream of the former dam site is largely unchanged following the dam removal. In 2023, a slightly higher H' was observed, but species richness decreased. Two endemic species (*Exoglossum laurae* and *Phenacobius teretulus*) were not detected in 2023 surveys (Table 2). Both, the Jordan Cook Road and Greenway reaches saw increases in species richness and H' (Table 2). Species richness in upstream reaches was 7 less than seen at downstream sites (Table 2). One downstream site, Jordan Cook had the most change occur in the fish community structure following the dam removal. This site saw the largest increase in species richness and H' relative to all other sites (Table 2).

Species Assemblage

In 2014 the fish community was dominated by cyprinids with 58% of all individuals sampled belonging to this family. The families Cottidae (19%) and Salmonidae (18%) were the next most frequently detected fishes. This pattern remained unchanged in 2023, with 55% of being cyprinids while 16% were Cottidae and Salmonidae (Table 3). Sampling in 2023 did see a 5% increase in family Percidae, the majority of which are fantail darters (*Etheostoma flabellare*) (Table 3). *Campostoma anomalum* and *Cottus bairdii* were the two most abundant species during both sampling periods (Fig 2a and 2b). In 2023, 81% of individuals were native species, a 9% decrease from 2014 (Table 4). Site location did not impact the native species assemblage, and there was virtually no difference between number of species found upstream and downstream. The Niley Cook and Boone Greenway sites saw the largest decreases in native individuals, Niley Cook lost 14% while Boone Greenway lost 18%. However upstream and downstream sites as a whole remained largely unchanged (Table 5). Salmonidae, specifically *Salmo trutta* and *Oncorhynchus mykiss*, were 96% of all exotic species in 2014, and 85% in 2023 (Table 4).

Post-dam removal the upstream fish assemblage has remained largely consistent since 2014. In 2023, *C. anomalum* is still the most abundant species at upstream sites followed by *Rhinichthys atratulus* instead of *Clinostomus funduloides. C. funduloides* has decreased in abundance by 6% (Fig 2c and 2d). There were stark differences between upstream and downstream fish assemblage in 2023. In 2023, *Rhinichthys atratulus* accounted for 18% of individuals in upstream sites but only 2% in downstream sites. In 2023, there was a higher abundance of *Nocomis* species and *Percidae*. Neither group was found in upstream sites (Fig. 2e and 2f).

Discussion

Small dam removals are becoming increasingly popular amongst southeastern states. However, large dams are more widely understood than small dams, the removal of small dams may have different impacts on species than larger dam removal projects (Gangloff, 2013). Small dams are associated with increased rates of exotic species and the displacement of lotic species (Thoni et al. 2014). Relict dams have been demonstrated to support no differences amongst the fish community between reaches as species are able to freely disperse (Holcomb et al. 2015). However, this was not the case in our study, each reach had different values of richness as it increased in downstream sites.

The removal of the Payne Branch Dam has not significantly impacted in-stream habitat. Both the mean particle and stream width remained largely unchanged. However, the percent of fine sediments has changed significantly; it appears fine sediments are continually being moved downstream every year. Although, there was a large increase in fine sediments at the most downstream site in 2022, this slug sediments will likely move through this section of the river. Changes to the abiotic factors will likely facilitate full re-colonization of the upstream habitat.

Since the removal of the Payne Branch Dam species have not readily migrated to colonize upstream reaches. Since the water treatment spill in 2003, the fish community upstream of the dam has not recovered and appears to remain largely unaffected by the dam removal. This rejects the hypothesis stating that an increased diversity and the recolonization of upstream habitat by the fish community will be observed in response to the removal of the dam. The Covered Bridge site contained significantly more species than other sites. Because it is the furthermost downstream site, it likely has habitat for more species compared to upstream sites. The confluence of the East Fork and Middle Fork allows for species from both streams to join in a higher order stream (Minshall et al. 1985). Species such as *Micropterus dolomieu*, *Luxilus coccogenis*, and *Ambloplites rupestris* are invasive species that will likely colonize this reach soon from downstream habitats. Also, farther upstream at Chetola Lake, *Micropterus salmoides* are present and could migrate downstream into these sites. However, native species including *Notropis photogenis* and *Notropis rubellus,* as well as two endemic species, *Phenacobius teretulus* and *Notropis scabriceps* may also naturally re-colonize this reach soon. Excluding the Covered Bridge site from the data analysis revealed little, change in species richness and Shannon-Weiner between 2014 and 2022. This demonstrates that the fish community has not drastically changed, and upstream habitat remains uncolonized.

Species richness in upstream sites has decreased as two endemic species were not detected in surveys following the dam removal. The two endemic species include *E. laurae* and *E. kanawhae*, Kanawha darters was detected in recent samples downstream leaving hope for recolonization. However, *E. laurae* has not been observed since 2014 meaning natural recolonization is unlikely in the short-term future. Species within Percidae and *Nocomis* are abundant in downstream habitats but do not occur in upstream reaches. The high gradient sections just below the dam site may be acting as a barrier to upstream migration. This is supported by the low diversity in the Tailrace site which occurs in between the former dam site and the high gradient section of river. However, I found a single *N. platyrhynchus* at the Tailrace Site in 2023. This observation is significant because it suggests *Nocomis* species are capable of traversing up the gorge section and re-colonizing reaches upstream of the former dam site. This was also the only endemic taxon observed upstream from the high gradient reach.

The observation of *N. platyrhynchus* upstream of the high gradient reach displays that this genus has ability to migrate upstream through this reach. Characterized by plunge pools and cascading falls, the section promotes a challenge for migration, especially for smaller species. This natural barrier may be partially responsible for the increase of diversity at the Jordan Cook Site. This site is directly downstream of the gorge section and species may be getting stopped at the barrier and concentrating at this site. Species such as darters in the Percidae family may have an especially difficult time moving through is section of stream. Their morphology is not ideal for migrating through the fast-flowing water and plunge-pool habitats that characterize this reach. *Etheostoma flabellare*, accounted for 14% of individuals at the Jordan Cook site but was not detected in the Middle Fork upstream from the high gradient section.

Detection of *S. fontinalis* is encouraging as the species has not been observed since prior to 2014. The reemergence of the only native trout would be a very positive sign for the ecosystem. Due to the small size and presence of parr markings on one individual these fish appeared to be wild, and not stocked individuals. With populations of *S. fontinalis* in upstream smaller order streams the failure to recolonize the habitat now available could be due to increased water temperatures caused by two upstream impoundments, Chetola and Bass lakes (North Carolina DEQ, 2017). Also, the competition with indigenous Salmonidae likely limits their population. The stocking of exotic trout species like *S. trutta* and *O. mykiss,* certainly impacts the stream ecosystem as they are the top aquatic predators preying on native fish. These species currently account for 86% of all non-native fishes in the Middle Fork New River. Despite stocking protocols requiring release of only sterile individuals, many of the individuals observed were wild indicating that trout populations are well-established in the Middle Fork and its tributaries (Rash, 2019). The removal of the dam will likely the non-indigenous species to connect populations and continue to grow (Gangloff, 2013).

Trans-location may be necessary in order to restore the stream to its natural community. For this to be done effectively individuals should be taken from populations of native species, prioritizing species that will likely have difficulty in navigating the high gradient stream naturally. *E. kanawhae*, *P. teretulus*, *N. scabriceps*, *E. flabellare*, and *S. fontinalis* are likely candidates. Spanning across three families various ecological niches will be filled. *E. kanawhae* and *E. flabellare* are benthic insectivores often found in riffles. *P. teretulus* and *N. scabriceps* represent the minnow family and are more likely to be found in runs and in the middle of the water column. Before trans-locating any individuals, records of the fish community before the dam was constructed in 1924 should be reviewed in order to prevent the introduction of species that were not historically observed in that upstream habitat. The habitat structure of the site should be considered when trans-locating fish. Wild fish that are trans-located prefer habitat common in the source site and will (Carpenter-Bundhoo et al. 2020). Translocation sites should be matched with source sites based on historical records of species as well as habitat structure similarities. Translocation is a process should be facilitated with care in order to not disrupt the existing populations in upstream habitats. Translocation is a viable option to reestablish populations of species that were once historically present in upstream habitats in order to bypass the high gradient section of river.

The removal of dams can have unintended consequences with the possible migration of invasive species into upstream habitat (Gangloff, 2013). The tradeoffs of a dam removal should be considered before removing a dam (McLaughlin et al. 2013). Some small low-head dams pose as ecological lifts for the stream system (Gangloff, 2013). Although the removal of dams is often done with the noble idea of restoring the stream to a natural system, if not done properly it can negatively impact the aquatic ecosystem (Gangloff, 2013). Demolitions and the release of entrenched sediment can cause irreparable consequences to the downstream habitat and fauna (Gangloff, 2013). The removal of another dam in Watauga County, NC, Ward's Mill Dam on the Watauga River, did not involve the excavation of excess sediment before deconstruction resulting in the sediment smothering of downstream habitat after a high flow event (Gangloff, unpublished data). Comparing the removal methods and restoration of the Payne Branch Dam to the Ward's Mill Dam removal can lead to a greater understanding of proper dam removal techniques in high gradient streams. Although the Payne Branch Dam removal has not yet resulted in upstream recolonization the total stream diversity has still increased with seemingly no drastic negative impacts. Applying similar methods to similar dam removal projects in the surrounding areas could prevent the occurrence of irreversible damage to a stream system.

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Figures and Tables

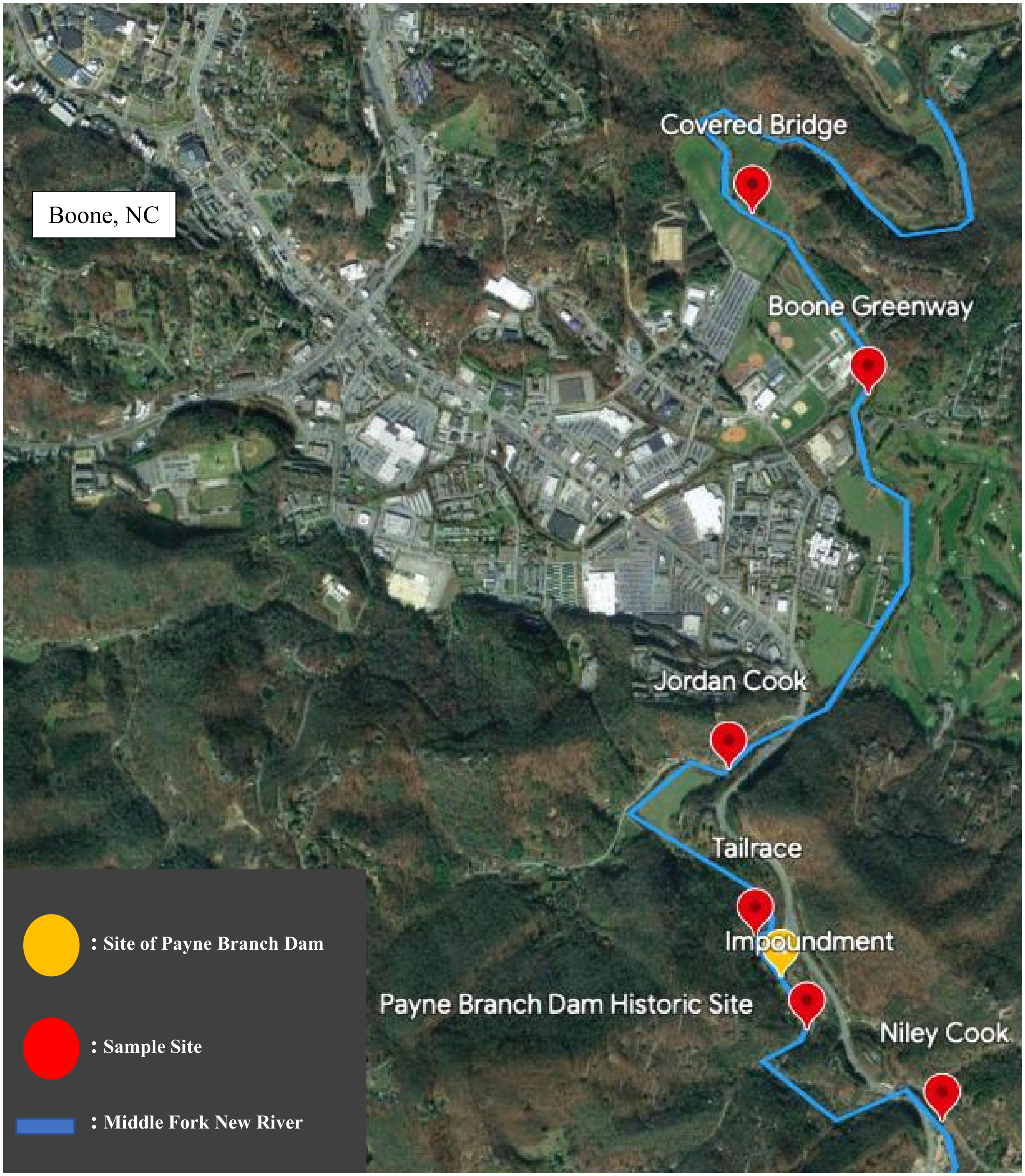

Figure 3: Map displaying each sample site, the site of the Payne Branch Dam, and the Middle Fork New River

	2014					2023						
Site	Niley Cook	Impoundment	Jordan Cook	Greenway	Total	Niley Cook	Impoundment	Tailrace	Jordan Cook	Greenway	Covered Bridge	Total
Rhinichthys atratulus	78	41	35	15	169	58	15	3	8	6	1	91
Campostoma anomalum	49	118	43	202	412	39	69	48	64	23	52	295
Salmo trutta	4	48	15	15	82	34	17	19	29	35	10	144
Cottus bairdii	39	58	83	104	284	30	24	14	42	105	12	227
Hypentelium nigricans	12	4	1	4	21	5	3	2	8	3	7	28
Oncorhynchus mykiss	9	9	50	1	69	5	13	25	19	23	0	85
Rhinichthys cataractae	0	2	0	0	2	7	1	2	2	3	0	15
Clinostomus funduloides	117	33	6	41	197	45	20	0	54	8	3	130
Lepomis auritus	1	0	0	3	4	2	1	0	0	0	0	3
Nocomis leptocephalus	16	1	17	2	36	0	0	0	3	3	3	9
Micropterus dolomieu	0	0	0	0	0	0	0	0	0	0	1	1
Etheostoma flabellare	0	0	13	28	41	0	0	0	19	45	53	117
Lepomis cyanellus	0	0	0	0	0	0	0	0	0	3	6	9
Luxilus coccogenis	0	0	0	0	0	0	0	0	0	0	18	18
Exoglossum laurae	1	0	0	1	2	0	0	0	0	0	0	0
Semotilus atromaculatus	0	1	0	0	1	2	5	0	0	1	0	8
Lepomis gibbbosus	0	0	1	0	1	0	0	0	0	0	0	0
Ambloplites rupestris	0	0	0	3	3	0	0	0	0	0	3	3
Catostomus commersonii	0	0	0	6	6	0	5	0	2	1	2	10
Phenacobius teretulus	0	2	0	0	2	0	0	0	0	0	1	1
Nocomis spp.	0	0	0	67	67	0	0	0	11	19	92	122
Salvelinus fontinalis	0	0	0	0	0	0	0	0	1	1	0	2
Etheostoma kanawhae	0	0	0	0	0	0	0	0	0	1	1	2
Salmonidae parr.	0	42	0	83	125	0	0	0	0	1	0	1
Nocomis platyrhynchus	0	0	0	0	0	0	0	1	0	0	4	5
Notropis scabriceps	0	0	0	0	0	0	0	0	0	0	61	61
Notropis photogenis	0	0	0	0	0	0	0	0	0	0	29	29
Notropis rubellus	0	0	0	0	0	0	0	0	0	0	4	4
Total	326	359	264	575	1524	227	173	114	262	281	363	1420

Table 1: Number of individuals per species at each site.

Site	Species Richness		Shannon-Weiner Index	
	2014	***2023***	**2014**	**2023**
Niley Cook Road	10	10	1.56	1.88
Impoundment	11	11	1.88	1.86
Jordan Cook Road	10	13	1.86	2.08
Boone Greenway	13	15	1.91	1.99
Tailrace		8		1.53
Covered Bridge		20		1.7
Total Stream	17	24	2.15	2.45
Total Stream (Excluding Covered Bridge)	17	17	2.15	2.17
Upstream Sites	13	11	1.88	1.90
Downstream Sites	14	18	2.10	2.12

Table 2: Species Richness and Shannon-Weiner Index of Each Site and Overall Stream. Blank values indicate that the site wasn't sampled in 2014.

2014 Family Assemblage		**2023 Family Assemblage**	
Cyprinidae	58%	Cyprinidae	55%
Cottidae	19%	Cottidae	16%
Salmonidae	18%	Salmonidae	16%
Percidae	3%	Percidae	8%
Catostomidae	2%	Catostomidae	3%
Centrarchidae	1%	Centrarchidae	1%

Table 3: Family assemblage of overall stream in 2014 and 2023.

Site	Percentage of Native Individuals		Percentage of Invasive individuals Identified as a Salmonid	
Year	*2014*	*2023*	*2014*	*2023*
Niley Cook	96%	82%	93%	95%
Impoundment	84%	82%	100%	97%
Jordan Cook	75%	82%	98%	100%
Boone Greenway	96%	78%	94%	95%
Tailrace		61%		100%
Covered Bridge		88%		26%
Upstream Sites	90%	90%	96%	96%
Downstream Sites	82%	81%	96%	80%
All Sites	90%	81%	96%	86%

Table 4: Percent of individuals that are a native species and percentage of salmonids as an invasive individual.

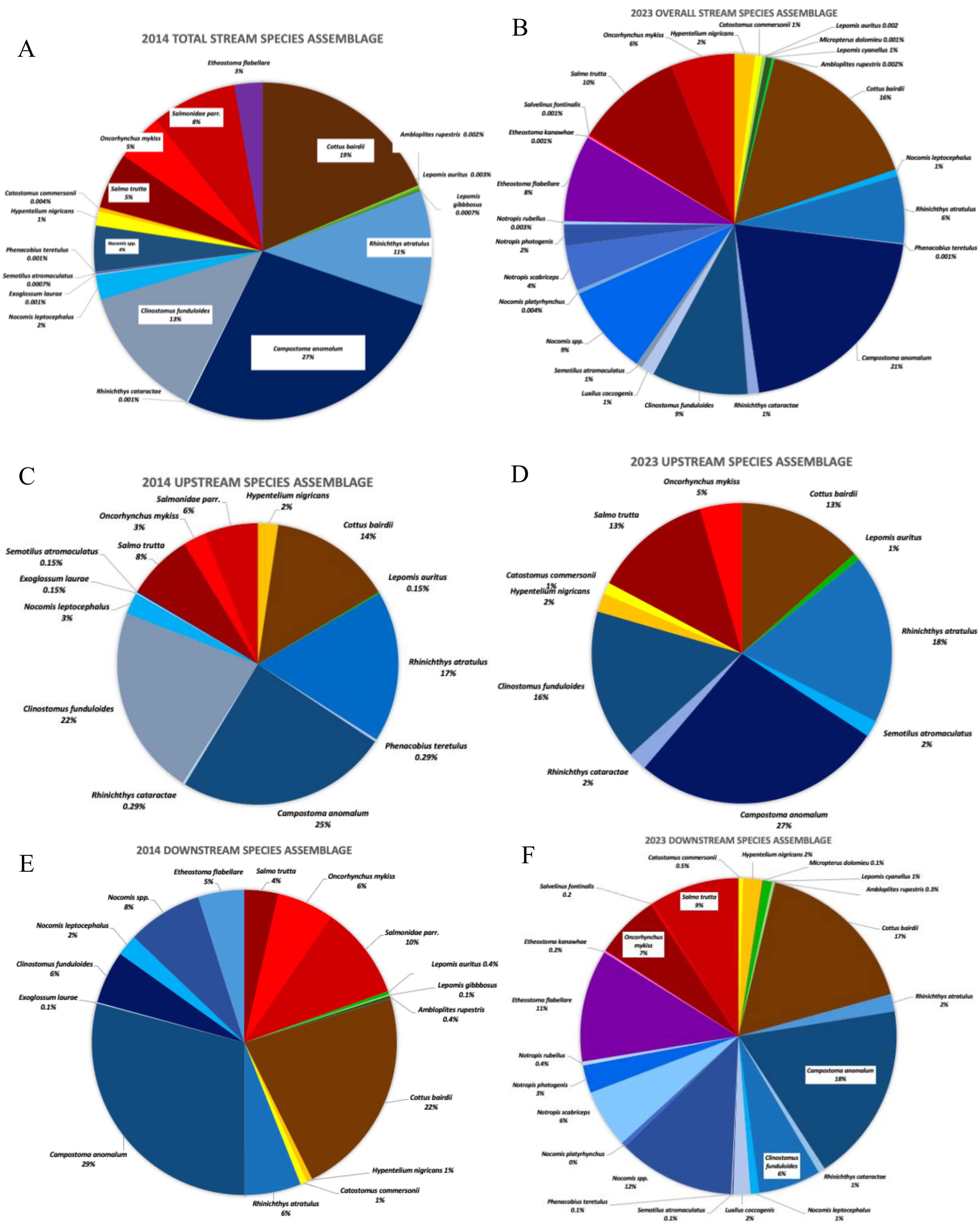

Figure 2: A) Species assemblage of total stream in 2014. B) Species assemblage of total stream in 2023. C). Upstream species assemblage in 2014. D). Upstream species assemblage in 2023. E). Species assemblage in downstream sites in 2014. F). Species assemblage in downstream sites in 2023. Color coordinated by family. Blue: Cyprinidae, Red: Salmonidae, Brown: Cottidae, Green: Centrarchidae, Yellow: Catostomidae, Purple: Percidae

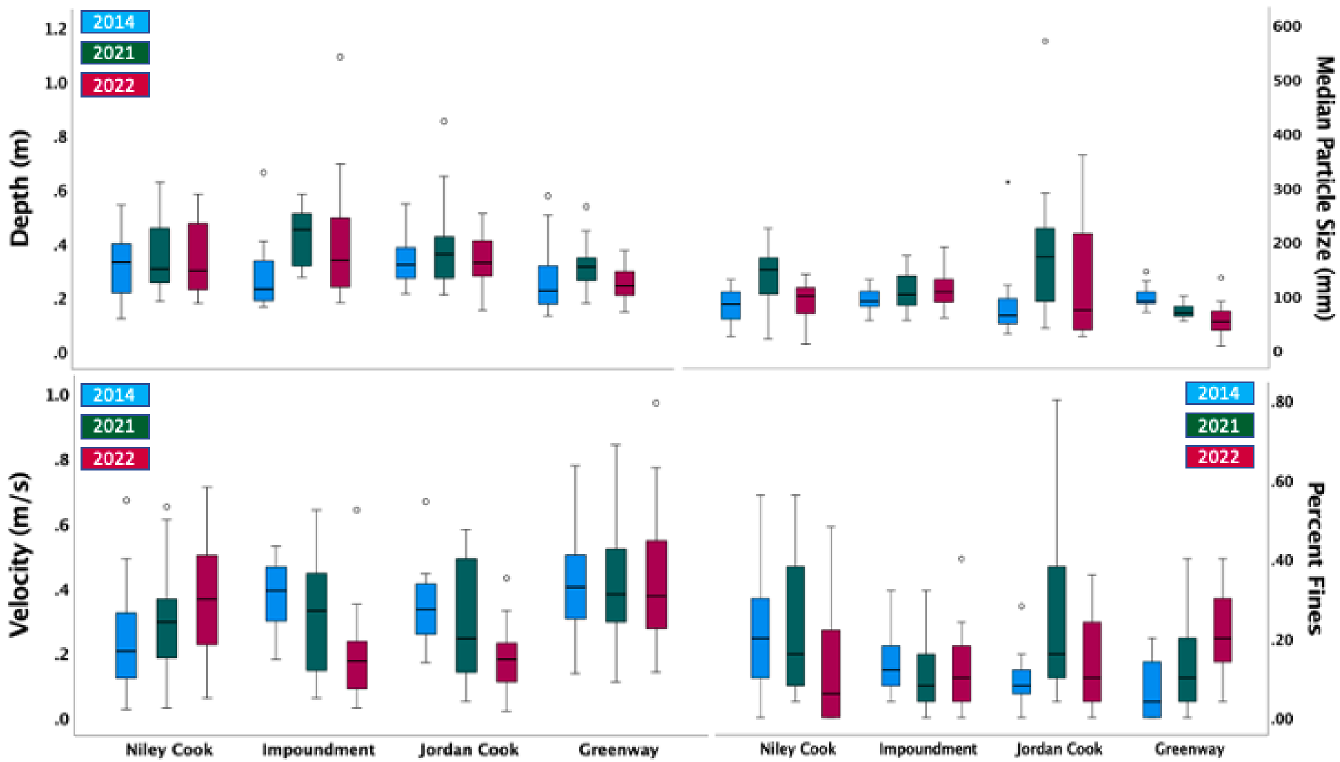

Figure 3: Changes in depth, velocity, median substrate and percent fines at four sites in the Middle Fork New River between 2014 and 2022. Sites are arranged from upstream (Niley Cook) to downstream (Greenway)