RATTLESNAKE CREEK DAM REMOVAL MONITORING

2021 REPORT

PREPARED BY TROUT UNLIMITED, WATERSHED EDUCATION NETWORK AND

MONTANA FISH, WILDLIFE & PARKS FISHERIES DIVISION

WITH SUPPORT FROM THE RESOURCES LEGACY FUND

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Introduction

The Rattlesnake Creek Dam Removal project, completed in summer 2020 in Missoula, Montana, aimed to enhance fish and wildlife habitat and connectivity, improve public safety, restore natural ecological processes to the watershed, and increase recreational and cultural resources. Monitoring the project's success in meeting these project goals is critical to adaptive management, outreach and education concerning the project's benefits, as well as the continued evolution of dam removal projects in the region. For this reason, early in the dam removal planning phase, Trout Unlimited and partners initiated a dam removal monitoring program. This report presents a summary of results for one year post-dam removal.

Rattlesnake Creek flows from the Rattlesnake Wilderness and National Recreation Area into the heart of downtown Missoula, Montana. Because of its proximity to town and to the University of Montana, as well as the stream's importance for Fisheries and Natural Resource managers, substantial monitoring and research efforts were already underway when the dam removal project was proposed. Trout Unlimited (TU), therefore, assumed the role of coordinating dam removal monitoring efforts by identifying the key metrics that should be monitored, data already being collected, and data gaps that should be filled to quantify the impact of dam removal. To this end, we developed a monitoring plan in coordination with our partners to outline the questions, methods, and timelines related to monitoring the impacts of Rattlesnake Creek dam removal. The overarching aim for this monitoring program was to:

1) Understand the impact of dam removal on natural resources and stream processes through collaboration with agency, academic, and non-profit partners; and
2) Engage the public through citizen science and outreach.

Monitoring Goals and Monitoring Questions:

Our goals for monitoring, and associated monitoring questions, were developed based on several overarching factors:

1. Dam removal impacts will likely occur across a *range of spatial scales*, from the immediate dam removal site to the broader watershed. Our monitoring plan aims to document changes across this range of scales. Goal 1 focuses on impacts at and immediately below the dam site while Goal 2 aims to document broader ecosystem trends and patterns. We recognize that we likely will not be able to document watershed-scale responses to dam removal; to do so would require a much more intensive and expensive research effort over a long period of time (below). Collecting baseline watershed health data, however, helps us understand the context, and relative influence, of dam removal on the ecosystem.
2. Dam removal impacts will occur over a *range of temporal scales*. Some impacts may be evident in the year following removal and restoration, while others may not be clear for decades. This report, one-year post-dam removal, represents a summary of results to-date, and presents opportunities for long-term monitoring.

Based on these considerations, we developed the following monitoring goals and associated monitoring questions.

Goal 1: Evaluate the impact of dam removal on stream and floodplain conditions at and below the dam site.

a. Did dam removal improve fish passage?
b. What was the impact of dam removal and site restoration on aquatic and riparian habitat at, and below, the dam site?
c. What was the impact of dam removal on sediment transport and channel form at and below the dam site?
d. What was the impact of dam removal on streamflow (flood peaks and baseflow)?

Goal 2. Collect baseline data to assess watershed health and impairments.

a. How have human activities impacted Rattlesnake Creek over the last century?
b. What are the spatial patterns of native fish abundance and reproduction throughout Rattlesnake Creek?
c. How do habitat variables such as temperature, wood and pool density and groundwater inflows vary throughout the Rattlesnake?

Partners

Partnerships were essential to this monitoring effort. Partners not only offer efficiency and expertise in data collection, but also completeness in our monitoring perspective, integrating data from land use, fisheries, hydrology and other disciplines.

Field Monitoring and Analysis Partners:

Field monitoring partners engaged in the data collection and analysis described in this report. These groups and individuals have collected data on Rattlesnake Creek historically, engaged in the plan for dam removal monitoring, shared their data and shifted their methods to answer specific questions about dam removal impacts. They include:

- **Montana Fish Wildlife and Parks, Fisheries Division (MFWP)** – Ladd Knotek, Ruben Frey
- **River Design Group (RDG) -** Matt Daniels, John Muhlfeld, and Selita Ammondt
- **Trout Unlimited (TU)** – Christine Brissette & Rob Roberts
- **University of Montana (UM)** – Chris Miller (land use assessment); Ben Colman & Sam Turner (macroinvertebrate analysis)
- **Watershed Education Network, Citizen Science Program (WEN)** – Aissa Wise, Stephie Novak, David Cole and WEN Stream Team citizen science volunteers.

Citizen Science Volunteers:

Integrating citizen science was a key goal and major accomplishment in this monitoring effort. While the dam removal, restoration and the monitoring of its effects was the focus of this project, increasing public awareness and involvement through Citizen Science was integral to overall project success.

The majority of sampling efforts performed by Watershed Education Network involved volunteers and engagement only grew as awareness of the project increased. Through this effort, WEN involved approximately 117 citizen scientists who volunteered over 1200 hours between 2019 - 2021. There was a substantial increase in volunteer hours, 346 volunteer hours in 2019 to 499 volunteer hours in 2021.

MFWP and TU also engaged 30+ citizen science in the Missoula Trout Tag Study. This recapture data involved local anglers and engaged the public on movement of individual fish. Figure 2 presents a map of monitoring activity, and highlights activities that relied on citizen science with and asterisk.

Guidance Partners

Guidance Partners are individuals with technical expertise who guided the development of the Rattlesnake Dam monitoring plan and/or specific methods therein. They include:

- Dan Brewer, USFWS (Fisheries monitoring)
- Terry Carlson (Citizen Science monitoring plans and stream survey methods)
- David Cole (WEN Citizen Science Advisor)
- Craig Groves (Dam removal monitoring plan development)
- Shane Hendrickson, Lolo National Forest (Habitat monitoring)
- Ladd Knotek, MFWP (Habitat monitoring)
- Sean Sullivan & Rennie Winkelman, Rhithron Associates, Inc. (Macroinvertebrate sampling and analysis)
- UC Davis Center for Community and Citizen Science

Background: Rattlesnake Creek Dam Removal & Restoration

The defunct Rattlesnake Creek Dam was located 3.5 miles upstream from the city of Missoula, Montana. It spanned 60 feet wide, 10 feet high, and 15 feet thick at the base. Constructed in 1901, the dam historically provided municipal water for the city of Missoula by impounding 3 million gallons of water in an adjacent reservoir. When Missoula switched to groundwater for their drinking water in 1983 due to giardia concerns, the reservoir became a backup water supply. High water damaged the dam in 1998, and since then various parts of the structure have been removed or buttressed. By 2011, the dam had ceased functioning even as a backup water supply. After a long legal battle with Mountain Water Supply, the city of Missoula, in June 2017, assumed ownership of the dam and associated infrastructure, including the derelict reservoir upstream. In July 2017, the city agreed to work with Trout Unlimited to develop a plan for removing the dam.

In 2020, TU broke ground on the dam removal project along with partners City of Missoula and Montana Fish, Wildlife and Parks. TU contracted Aquaterra Restoration Inc to complete the construction contract for the Rattlesnake Dam Removal project and equipment was mobilized to the site during the second week of June 2020. That summer, Aquaterra began excavating the dam embankment, screening material for boulder and cobble salvage, and beginning construction of the bypass channel for future dam and concrete removal activity. Rattlesnake Creek was dewatered in late July 2020 for dam removal activity. The stream was rebuilt using large boulders and cobble from the site and includes four logjams for overhead cover and pool development. Streambanks were rebuilt with a mix of gravel, logs and brush to provide short term stability.

The dam demolition and stream channel reconstruction were completed by October 15, 2020 according to design and specifications. In total, more than 1,000 linear feet of stream were reconstructed, incorporating 10,000 willow cuttings and 6,000 containerized plants. Four wetland cells were created, with the restoration of 5 acres of floodplain. Temporary fencing units were installed to protect sensitive areas and planting areas. Weed treatment, plant watering and other maintenance activities were continued by TU and the City of Missoula in 2021. Figure 1 presents the topographic changes that occurred on the dam site, specifically the removal of the dam, reservoir and embankment, construction of a new channel, and regrading of the floodplain, including wetland cells and a side channel. Appendix 1 presents pre and post-construction photopoints throughout the site.

For more details on project funding, design alternatives and a summary of public comment, visit the City of Missoula's Rattlesnake Reservoir website: https://www.ci.missoula.mt.us/2384/Rattlesnake-Reservoir

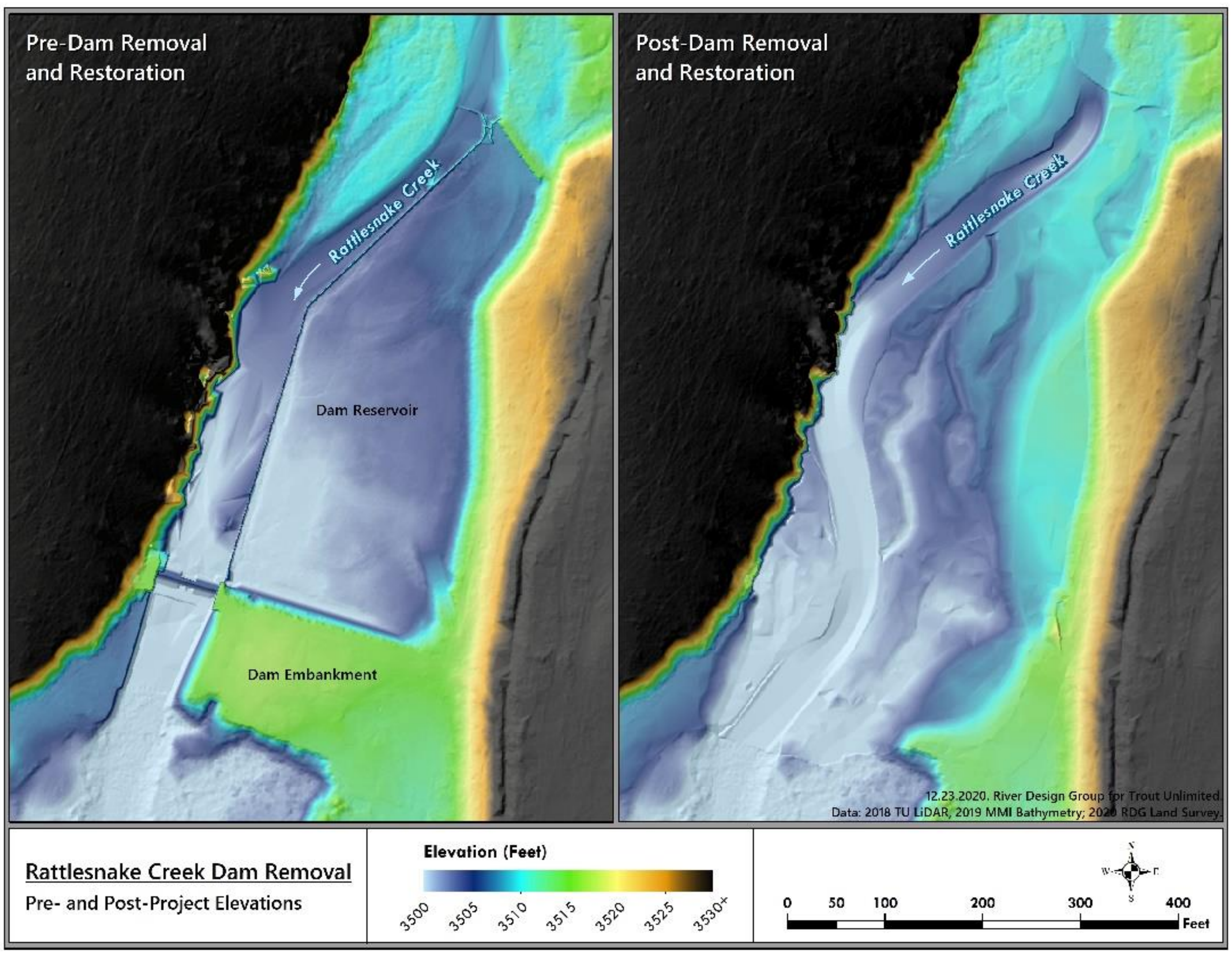


Figure 1. Surface elevations of the Rattlesnake Creek Dam site before (left) and after (right) dam removal and restoration illustrate the major topographic chances that occurred, namely the removal of the dam, dam embankment and reservoir and construction of a meandering channel and adjacent floodplain. Figure by River Design Group.

Monitoring Dam Removal: Activities and Results

This section will outline data collection and initial results for all monitoring activities within the Rattlesnake dam removal monitoring program, 1-year post dam-removal. This report is written as a broad overview of activities and dam removal impacts, summarizing work by numerous partners. **As such, we have not included detailed methods and results, but instead describe highlights and list the key entities that led each monitoring effort. If a reader would like further details on anything related to this work, please reach out to the associated contact or Trout Unlimited**.

Monitoring took place across a large portion of the Rattlesnake watershed. Figure 2 summarizes all monitoring activities that are presented in this report and their spatial organization in the Rattlesnake Creek watershed.

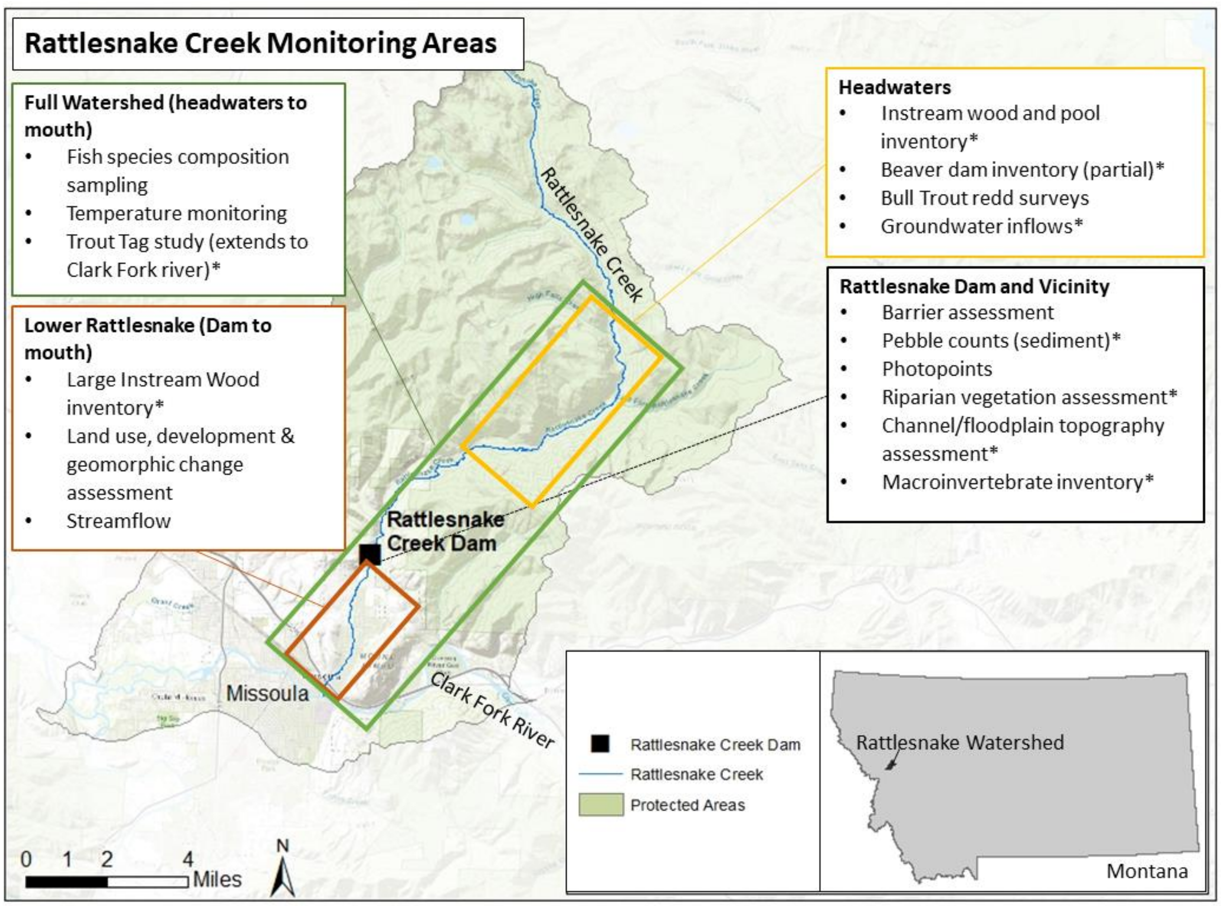


Figure 2. Monitoring activates occurred at the dam removal site (black box), the lower Rattlesnake (red box), the headwaters (yellow box) or from headwaters to mouth (green box). Activities marked with an asterisk (*) involved citizen science volunteers.

Monitoring At or Near the Dam Removal Project Site

The Rattlesnake Creek dam removal was designed to have several immediate and substantial impacts including the removal of a barrier to aquatic organisms and substantial changes in channel and floodplain form through channel re-alignment and restoration. Restoration projects can also have unintended consequences, both good and bad, such as channel downcutting or aggradation outside of the project site, changes to local hydrology impacting existing vegetation or residual effects of construction on aquatic or terrestrial habitat that may take years to re-establish. This section focuses on monitoring at and immediately adjacent to the project site, documenting changes to aquatic organisms, habitat and ecosystem function directly related to dam removal and restoration.

Fisheries

Rattlesnake Creek is a major tributary to the Clark Fork River in Missoula, MT. It supports native species, including westslope cutthroat trout (*Oncorhynchus clarkii lewisi*), bull trout (Salvelinus confluentus), sculpin *(Cottus* spp.), longnose dace (*Rhinichthys cataractae*), and mountain whitefish (*Prosopium williamsoni*). Other fish species, including longnose sucker *(Catostomus catostomus),* largescale sucker *Catostomus macrocheilus),* and northern pikeminnow *(Ptychocheilus oregonensis),* are observed sporadically near the stream mouth. Non-native, wild trout species include brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*) and brook trout (*Salvelinus fontinalis*).

Summary: Fisheries

- Dam removal in 2020 resulted in year-round passage of all aquatic species for the first time since dam construction in 1901.

- Ongoing monitoring by MFWP will provide the long-term dataset needed to assess the impact of dam removal on species composition and distribution, though other variables (e.g. temperature, non-native competition, historic partial passage) may make it difficult to precisely quantify the direct and cumulative impacts of the dam and its removal.

Several native and introduced trout species exhibit migratory life forms. As such, the Rattlesnake contributes to the overall Clark Fork River fishery, with native and non-native trout migrating into Rattlesnake Creek to spawn, before returning to the Clark Fork River.

The factors limiting the Rattlesnake Creek native trout fishery are numerous and likely cumulative, including temperature, hybridization and competition with non-native species and habitat loss. The "Basin-wide Monitoring" section of this report provides further context in understanding the impact of these factors on the Rattlesnake fishery. This section will, instead, focus on one of the identified limiting factors that has been mitigated - fish passage related to the Rattlesnake Dam.

Fish Passage (MFWP)

Introduction

While the impacts of environmental factors like temperature are difficult to evaluate, the Rattlesnake Creek dam, which has posed a seasonal or full barrier to fish movement for over 100 years, was an obvious and solvable problem. "This structure likely impact[ed] all species and life stages of fish. However, the greatest impacts [were] likely to native fluvial fish (e.g., bull trout and westslope cutthroat trout) that cannot access preferred spawning areas and thermal refugia." (Knotek et al., 2004). Since 2001, MFWP has led a range of efforts to aid fish in bypassing the dam, including manual, selective transport and the construction of a fish ladder. In 2020, with the removal of the Rattlesnake Dam, 12 miles of main stem Rattlesnake Creek were fully reconnected for the first time since 1901.

Methods and Results

No direct monitoring was conducted to assess the impact of dam removal on fish passage. It is reasonable to assume that, with all obstructions removed, fish are able to move freely through the newly restored site. This section, instead, presents the results of previous fish passage monitoring at the dam site, providing context for a fully reconnected system.

Table 1 Timeline of barrier status for upstream aquatic movement at the Rattlesnake Creek dam site

Years	Barrier Level	Description
1901 – 2000 (102 years)	Full barrier	Rattlesnake Dam was constructed in 1901.
2001-2003*	Full barrier	MFWP initiates manual, selective passage program for adult migratory trout
2003-2012 (9 years)	Partial barrier	Fish Ladder installed. Estimated 50-90% passage efficiency (Knotek et al. 2004) – efficiency variable temporally and among species.
2012-2020 (8 years)	Partial barrier	Dam sluice gates permanently opened. MFWP runs selective transport program through the fish ladder for Spring migrants (cutthroat/rainbow trout). No barrier for fall fluvial migrants (bull trout, mountain whitefish, brown trout) and resident fish.
2020- present	No barrier	Rattlesnake Dam removed summer 2020 – upstream fish passage fully open year-round for all species

* MFWP's selective passage program continued until the Rattlesnake Dam was removed.

Rattlesnake dam posed a complete barrier to upstream fish passage for over 100 years, from its construction in 1901 until the construction of the Rattlesnake dam fish ladder in 2003. In 2001 and 2002 MFWP initiated a manual passage program, capturing migratory adult trout below the dam, and releasing them above. As part of this effort, and to study the impact of the dam on fish passage, MFWP used a combination of snorkel surveys, Floy tags radio telemetry and electrofishing to evaluate impacts and passage efficiency. Knotek et al. (2004) provides a detailed overview of this effort. Electrofishing by MFWP prior to the fish ladder construction indicated that species composition (presence/absence) was similar above and below the dam, with the exception of mountain whitefish found only below (Knotek et al., 2004). However, the dam was preventing movement between these two reaches from below, and undoubtedly affecting all migratory fish species. For instance, impacts to mountain whitefish and sculpin were recognized, but never quantified. Figure 3 from Knotek et al. (2004) presents the number of manually transported fish along with MFWP's estimates of the number of fish staged below the dam. Based on these numbers, MFWP's manual passage program transported 48-66% of Westslope cutthroat trout (total of 118 fish over 2 years) and 65-93% of bull trout (total of 54 fish over 2 years). Immediately following the installation of the fish ladder at Rattlesnake dam in 2003, MFWP estimated that 80-90%

(n=63) of Westslope Cutthroat and Rainbow trout and >50% of Bull Trout (n=13) passed the fish ladder successfully (Knotek et al., 2004) based on a trap set up in the dam and snorkel surveys below the dam.

Table 2 Fish observed and transpoted over the Rattlesnake Creek dam in spring/summer 2001-2001. From Knotek et al. (2004)

SPECIES (ADULTS)	TIMING[a]	ESTIMATED # AT DAM[b]	# MOVED OVER DAM	SIZE RANGE[c]
2001				
Rainbow Trout	~3/15 – 5/22	130-150	14	330-474 mm
W. Cutthroat Trout	~5/1 – 6/23	90-120	60	256-489 mm
Bull Trout	~ 6/23 – 8/4	30-40	26[d]	358-818 mm
Brown Trout	-	10-20	0	-
Brook Trout	-	<10	0	-
Mtn Whitefish	-	30-60	0	-
2002				
Rainbow Trout	~4/1 - 5/31	130-150	0	340-504 mm
W. Cutthroat Trout	~ 5/5 – 6/20	90-120	58	285-460 mm
Bull Trout	~ 6/19-8/20	30-40	28*	350-810 mm
Brown Trout	-	10-20	0	-
Brook Trout	-	<10	0	-
Mtn Whitefish	-	30-60	0	-

[a] Timing = the period when adult fluvial trout species congregated at the dam
[b] Estimated # at Dam = total estimated number of adults and sub-adults observed (while snorkeling) in tailrace
[c] Size range includes only those fish captured and measured
[d] Radio transmitters were implanted in 6 adult bull trout at the dam in 2001 & 2002

The fish ladder operated as designed for 9 years until 2012 when the dam sluice gates were permanently opened. The open gates likely allowed full fish passage at moderate to low flow levels, including during the adult bull trout summer migration period. At high flows, however, the constricted opening at the sluice gates increased velocities enough to prohibit fish passage. While the fish ladder was still used, the open sluice gates significantly altered hydraulics around the spillway and fish ladder, likely confusing migrating fish and reducing the efficiency of the ladder. This disproportionally impacted spring migrants, including Westslope cutthroat trout, rainbow trout and their hybrids. A portion of migrating trout successfully ascended the fish ladder, though an unknown portion likely did not (Knotek, personal communication, 1/10/22), as the number passing through the ladder was much lower than previously observed immediately after ladder installation.

Discussion and Future Monitoring

Ultimately, the removal of the Rattlesnake Dam resulted in complete reconnection of habitat from the Clark Fork River to the upper reaches of Rattlesnake Creek. It is reasonable to assume that, with the barrier gone, fish will move freely along the lower ~12 miles of the main stem. Ongoing, basin-wide monitoring by MFWP (described in the Basin-wide Monitoring section) will provide the long-term dataset needed to assess passage impacts to the Rattlesnake Creek fishery, such as changes in the relative abundance of species like Westslope cutthroat, rainbow trout, and their hybrids that were disproportionately affected by the dam in recent years. However, the history of partial passage, scale of the system, and confounding environmental variables may make it difficult to quantify the direct and cumulative impacts of dam removal.

Aquatic Habitat

Complex habitat – pools, overhead cover, side channels, well-sorted substrate patches – are well recognized as important to sustaining healthy aquatic ecosystems, providing the range of habitat allowing a diversity of species to persist, including finding refuge during extreme conditions such as floods or high temperatures. The lower 5 miles of Rattlesnake Creek, as it enters the low-gradient Missoula valley, was historically braided, providing complex and ever-changing habitat. However, in an effort to accommodate and protect residential and commercial use, the creek along this reach has been straightened and leveed. Side channels used for spawning or high flow refuge are infrequent, as are large wood structures that provide cover and create habitat complexity that support robust aquatic ecosystems. Removal of the Rattlesnake Dam, therefore, provided a unique opportunity to improve aquatic habitat across the 850-foot reach impacted by dam removal construction. Monitoring partners employed several methods to assess changes in habitat quality at, or adjacent to, the project area, as described below.

Summary: Aquatic Habitat

- Channel restoration resulted in a decrease in overall pool frequency, but an increase in deep pools (pools >1 ft depth)

- Dam removal did not result in a detectable increase in fine sediment below the dam, but a short-lived (2020 only) increase in sediment-tolerant aquatic macroinvertebrates.

- Macroinvertebrate sampling indicate minimal impact at or below the dam removal site. In 2021, the restored sight had slightly lower species diversity and richness, but supported many of the species indicative of high water quality.

Topographic Survey (TU, WEN)

Introduction

Aquatic habitat complexity is often evaluated in terms of the channel-bed's topography, including features such as pools or riffles, as well as measures of channel incision and sinuosity. For this reason, tracking changes in the channel topography before and after a major restoration project provides insight into changes in habitat complexity.

Figure 3. Two trout, one with a Floy tag from the Missoula Trout Tag study, sit in a newly built pool at the Rattlesnake Creek restoration site. Photo by Jason Jaacks

Methods and Results

Four channel cross-sections and a longitudinal profile were collected within the dam removal project area in 2017 by River Design Group using a total station. These were replicated with a laser level in fall 2020, soon after dam removal, and again in summer 2021 by Trout Unlimited to evaluate changes in bed topography after the project's first flood event. It is important to note that because restoration excavated and built an entirely new channel, pre-restoration longitudinal profiles (2017) were not collected at the same locations as post-restoration longitudinal profiles (2020, 2021). Appendix 2 presents a map of the two channel alignments. Longitudinal profiles were evaluated to determine stream channel slope, stream length, pool frequency and residual pool depth (maximum pool depth minus pool tail-out depth). Pool frequency decreased with restoration from 1.05 to 0.66 pools/100 feet of stream, though the overall count of deep pools (>1-foot residual pool depth) increased from 2 to 6 post-restoration. Pools post-restoration were generally deeper with a 2.63-foot mean residual pool depth, compared to 0.90 pre-restoration. Stream slope decreased slightly; from 0.18 to 0.15 ft/ft. Figure 4 and Table 3 summarize these data.

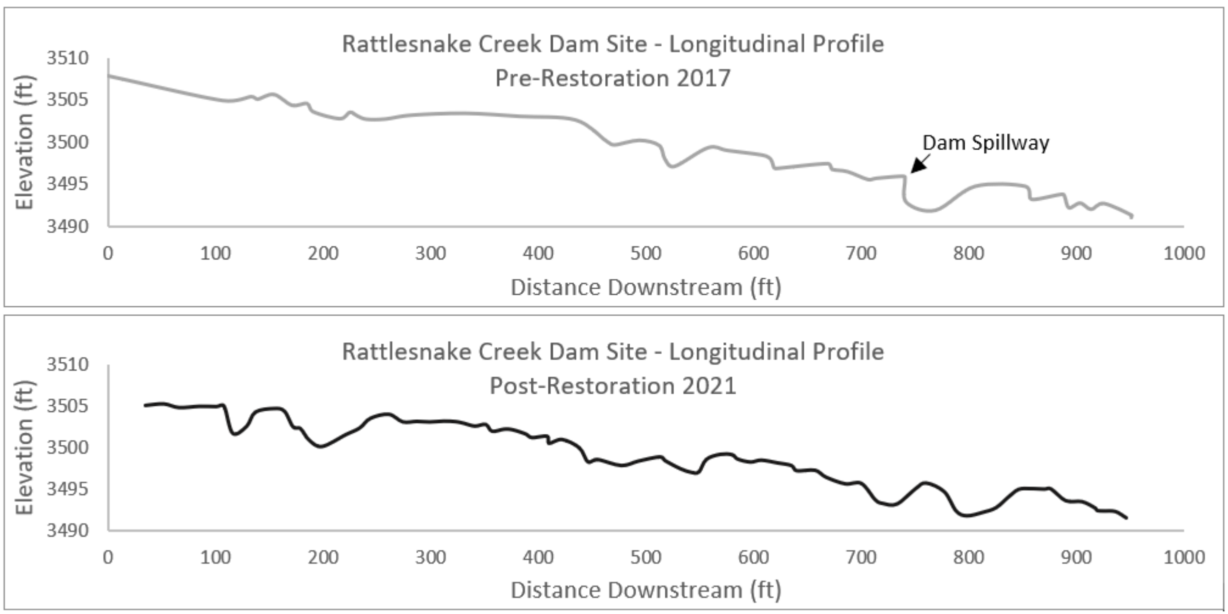


Figure 4. Longitudinal profiles pre- and post-dam removal and restoration show overall change in bedform. The restored site had fewer, but deeper pools when compared to pre-restoration conditions

Table 3. Summary of habitat characteristics within the dam removal project site pre and post restoration.

	Pre-Restoration (2017)	***Post-restoration (2021)***	***Change***
Pool Count 0.5-1 ft residual depth	*8*	*0*	*-8*
Pool Count >1 ft residual depth	*2*	*6*	*+4*
Total Pool count	*10*	*6*	*-4*
Pool Frequency (pools /100 ft stream)	*1.05*	*0.66*	*-0.39*
Mean Residual Pool Depth (ft)	*0.90*	*2.63*	*+1.73*
Surveyed Stream length (ft)	*911*	*950*	*N/A*
Stream Slope (ft/ft)	*0.018*	*0.015*	*-0.003*

In an effort to evaluate potential downstream effects of dam-removal, Watershed Education Network also established permanent cross-sections above and below the dam removal site. Upstream sites were considered controls, while sites below were selected to detect major changes in bedform downstream of the project site post-restoration. The downstream sites were surveyed from 2019-2021, and the sites above the dam removal site were surveyed during 2019 and 2020. These cross-sections were surveyed using a hand level and a stadia rod. The surveyor with the hand level remained in one location, aside from turning points, while the individual with the stadia rod moved across the stream at two-foot intervals. Additional measurements were taken at major feature changes in the river, such as the bankfull mark and the edge of water and were repeated at those locations each year. A map of cross-section locations and the figures from WEN, TU, and River Design Group cross-section data can be found in Appendix 2.

The dam-removal site cross-sections completed by TU and RDG show substantial changes between pre (2017) and post-restoration (2020). All project-area cross-sections (Sites 3-6) show the removal of the retaining wall separating the creek and former reservoir, the lateral shift of the newly constructed meandering creek, and re-sloped stream banks and floodplain to allow for overbanking in spring floods. Profiles changed slightly (<1-foot aggradation or deposition) between 2020 and 2021 surveys, as the channel adjusted to its first flood event. Sites below the project area (sites 1 and 2) showed little, if any, change between pre and post-restoration surveys. The sites above the project also saw little to no change across the two years surveyed (both pre-restoration).

Discussion and Future Monitoring

Changes within the project site, as shown in Figure 5 and Appendix 2, illustrate improvements to instream habitat and channel form from dam removal and restoration, specifically deeper pools, a more complex channel bed and increased stream-floodplain connectivity. They also clearly demonstrate the project withstood its first flood event with only small, expected adjustments in channel elevation. Finally, the lack of change above and below the project site indicates that project impacts were limited to the project site, as intended.

Sediment

Introduction

Dams can have a substantial impact on sediment transport regimes, accumulating fine sediment above the dam and limiting its transport downstream, as well as affecting the peak flow events that dictate sediment transport and distribution. The fine sediment trapped behind the Rattlesnake Creek dam, along with the construction activities in the stream channel, could have resulted in an increase in the fine sediments below the construction site post-dam removal. Substrate plays a highly important role in fish spawning and is an important habitat component for macroinvertebrate communities. An increase in fine sediments below the dam restoration site could, therefore, impact macroinvertebrate and fish communities.

Methods and Results

Pebble counts were performed at one site below and one site above the dam removal site in 2018 and 2019 (both pre-dam removal) as well as 2020 and 2021 (post-dam removal). Each survey was conducted in the fall, with the 2020 surveys being done after the dam was removed, but before the high spring flows of the following spring. For each pebble count WEN used a modified Wolman Pebble Count procedure (Archer, 2016) to sample a minimum of 100 particles (i.e., rocks) from the substrate within the bankfull channel. This technique required surveyors to measure sizes of random particles using a gravelometer that classified each particle by size. These size classes ranged from less than 4 mm to greater than 300 mm.

Below the dam site, the proportion of fine sediment after dam removal, in 2020 and 2021, was lower than in 2018 but higher than in 2019 as shown in Figure 5. This suggests that there was no pronounced increase in fine sediment after removal of the dam.

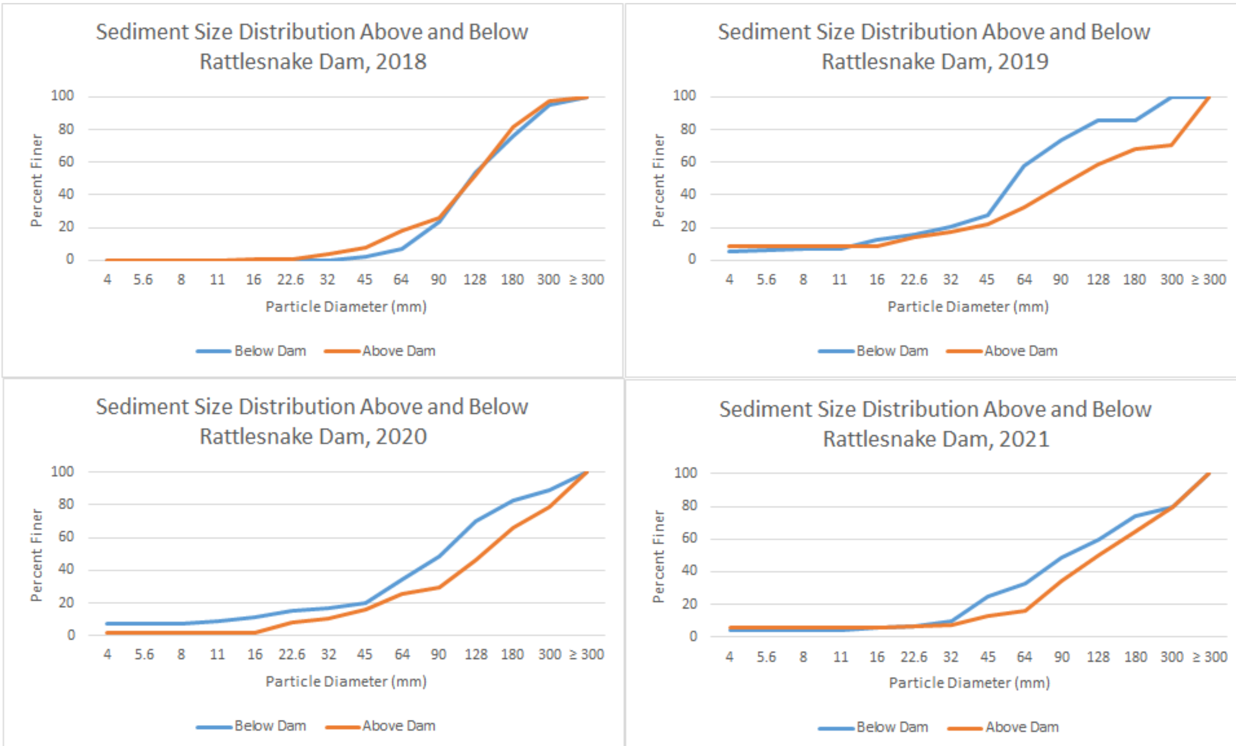


Figure 5. Sediment size distribution above and below the dam site, 2018-2021. Data and figure by WEN.

Discussion and Future Monitoring

The lack of an increase in fine sediments below the dam restoration site indicates that there was not a large influx of fine sediment immediately after the dam removal (2020) or after one flood event (2021). This may be the result of a successful design strategy, which included a controlled breach of the dam, full reconstruction of the stream channel and floodplain to minimize potential bedload and fine sediment transport. However, while Wolman pebble counts with the sample size used are commonly used in monitoring efforts, this method is known to have relatively high error unless prohibitively large sample sizes are used. The difference noted between the 2019 sample below the dam is likely a reflection of sampling error rather than a real difference from other years. This is also apparent as the 2018 data from below the dam also do not show the difference noted in 2019. Ongoing monitoring over a longer timescale will help to determine if there are any changes that can only be seen after several flood events occur.

Macroinvertebrate Inventory (WEN, UM)

Introduction

Aquatic macroinvertebrates are a valuable bioindicator of overall stream health. They are commonly used to assess water quality due to the tolerance or intolerance of certain taxa on specific sediment conditions, temperatures, pollution levels, and many other water quality characteristics.

Macroinvertebrates are also a critical food source for native trout populations and are a key piece of river ecosystems. Due to their relative ease of collection combined with the wide variety of specific habitat characteristics that they require, macroinvertebrates allow for straight forward assessment of the recovery of the site after construction, as well as impacts of construction to downstream habitat.

Methods and Results

Macroinvertebrates were sampled at three sites above, three sites below, and three sites within the dam removal site. These locations were compared as the downstream, upstream, and restored sites respectively. Each sample was a combined collection from three subsamples taken near the left bank, right bank, and middle of the stream channel. Sampling was done using a Surber Sampler, which allowed for the sampling of exactly one square foot of stream bed. A timed sample was collected from this area as the sampling area was manually disturbed and the macroinvertebrates flowed into the Surber Sampler's net. The sample was then transferred to a sampling container containing ethanol before being sent to Rhithron Associates Inc. to be counted and professionally identified to the smallest possible taxonomic level.

56 different community-based metrics were received from Rhithron and were compared across site and year by Sam Turner with guidance from Ben Colman, both at the University of Montana. This comparison was done using generalized linear models and ANOVA testing in the statistical software R. Out of the various metrics calculated, several were chosen for further analysis based on the metrics that are used in the MT DEQ multi-metric index as well as the current literature on small dam removals (Barbour et al. 1999; MT DEQ, 2006).

The upstream and downstream sites display relatively little variation over time, including pre and post-dam removal. However, there was a slight increase in the percentage of sediment tolerant species downstream during the year of the dam removal as shown in Figure 6. Additional graphs can be found in Appendix 3.

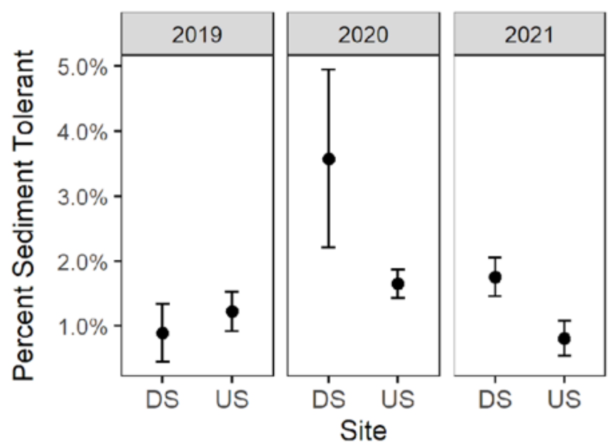


Figure 6. Percent sediment tolerant macroinvertebrate species by site (DS=downstream, US = Upstream) and year. Data by WEN. Analysis by Rhithron Lab and Sam Turner, UM.

Turner also compared results from samples taken upstream, downstream and within the restored site in 2021, post-dam removal. The restored site had a lower number of species present (Taxa Richness, Figure 7, left), though the difference was minimal. It also had lower overall diversity (see additional graphs in Appendix 3). However, the restored reach also had a higher percentage of EPT species (Mayflies, Stoneflies, Caddisflies), often associated with high water quality, as well as a higher percentage of scraper and shredder species (Figure 7, middle and right).

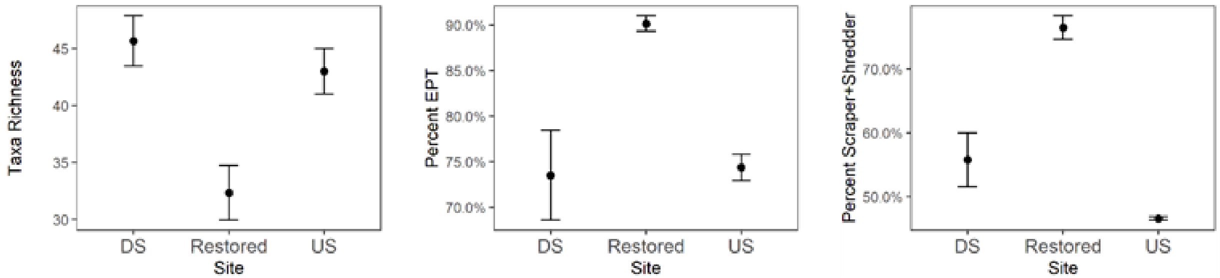


Figure 7. Macroinvertebrate Taxa Richness, Percent EPT, and Percent Scraper + Shredder species by reach (DS= downstream, US= upstream. All data were collected in 2021, post-restoration. Data collected by WEN, analysis by Rhithron Lab and Sam Turner, UM

Discussion and Future Monitoring

The lack of change in the macroinvertebrate communities above and below the restoration site indicates that there was likely little change in the water quality characteristics due to the dam removal. The increase in percent sediment tolerant species downstream in 2020 may be due to the short-term influence of the restoration efforts, as sediment plumes often occur during this process primarily when the stream channel was switched to and from the bypass channel to allow for access to the dam. However, the decrease in 2021 to approximately pre-dam removal levels may indicate a return to baseline conditions following the temporary pulse disturbance.

During the removal of the dam, an entirely new stream channel was constructed. We can assume that any macroinvertebrates found in the restored area in the year after the dam was removed had re-colonized the area from either above or below the restoration site. This re-colonization process may explain the lower diversity and richness found in the restored site, though it should be noted that these differences were minor. Other variations between sites in 2021 (such as percent EPT) is likely influenced by differences in the functional feeding groups present as macroinvertebrates returned to the restored reach. With less riparian stream cover, greater amounts of sunlight may increase algal growth, resulting in a shift in macroinvertebrate community composition as a result of changes in food/resource availability. While further monitoring efforts are needed to draw stronger inferences, the preliminary findings here point to minimal change in the macroinvertebrate communities of Rattlesnake Creek.

Wetland and Riparian Habitat

Wetlands and riparian areas are among the most biologically diverse ecological communities on Earth (Cherry, 2011) and also among the most imperiled. While these systems represent only 6% of the Earth's surface, they support disproportionately high number of ecosystem services such as flood mitigation, water quality improvement, carbon sequestration and groundwater recharge. However, a 1990 study by the U.S Fish and Wildlife Service estimates that over half of the 221 million acres of wetlands that existed in the continental U.S. in the late 1700's have been lost to development, agriculture, and other threats (Dahl and Johnson, 1991). While dam removal typically focuses on aquatic benefits such as reinstating fish passage, the restoration associated with dam removal has high potential to improve wetland and riparian ecosystems by reinstating natural hydrology, inundation regimes and connection between the stream and floodplain corridor.

Summary: Wetland and Riparian Habitat

- Restoration post-dam removal resulted in an almost 2000% increase in wetland and riparian area at the dam removal site and the establishment of a 200-foot side channel.

- Despite major changes to project-site topography and hydrology, the monitoring transects just downstream of the project site showed no detectable change in vegetation.

Introduction

Wetland and riparian communities are often characterized by their vegetation, hydrology and soil type. These same features often define the break between wetland and upland communities, following gradients in soil-moisture dictated by changes in elevation. Wetland and riparian habitat types are highly elevation-dependent, with small changes in elevation (e.g., 6-inches) controlling the duration of saturation as well as soil type, and thus the plants that inhabit that area. For this reason, floodplain and channel regrading through restoration sets the stage for development of wetland and riparian vegetation communities.

Wetland Delineation (TU, River Design Group)

Methods and Results

As part of the dam removal design and permitting process, River Design Group collected LiDAR data of the project site and conducted a wetland delineation following US Army Corps of Engineers protocol (USACE, 1987) and regional supplement (2010), identifying and quantifying acreage of all wetlands on site using vegetation, soil and hydrologic indicators. In fall 2020, after dam removal construction and restoration, River Design Group completed an as-built survey using a Total Station, documenting the surface and channel elevations of the restored project site. This gridded data was interpolated into a surface layer in ArcGIS, creating a detailed map of the restored surface topography. This layer provides clear visualization of wetland cells, side channels and upland areas. For this reason, River Design Group was able to use the as-built survey data and their prior knowledge of wetlands on the site to create a post-project map of wetland, riparian and upland areas, and calculate changes in wetland and upland communities as compared to the 2017 wetland delineation (Figure 8). Because nearly all vegetation on site was planted and soils heavily disturbed by construction, this approach provides a more accurate delineation of wetland and riparian types than the vegetation and soils-based approach used for the pre-construction survey.

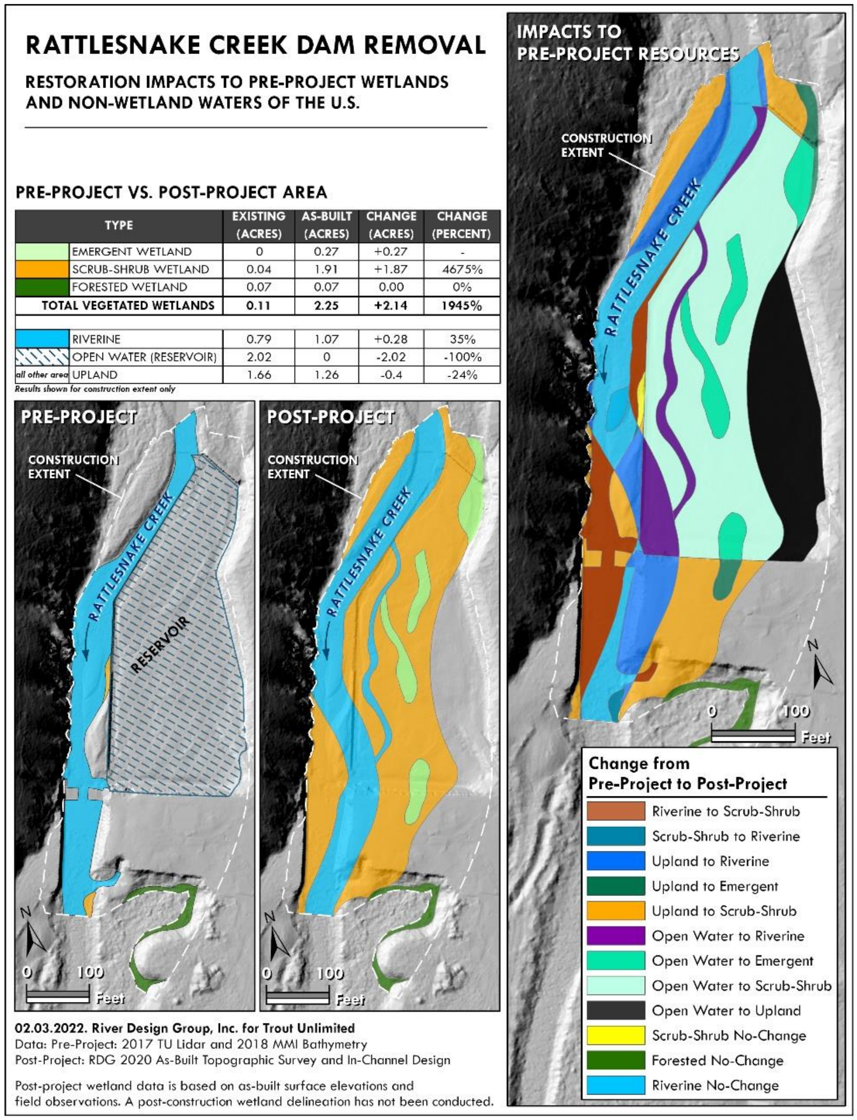


Figure 8. Changes to wetland, riparian and upland communities between pre (2017) and post (2020) dam removal and restoration

Through restoration, the majority of the Rattlesnake dam reservoir and upland areas were converted to wetland and riparian habitats. The post-restoration project site represents a 1945% increase in vegetated wetland area, increasing from only 0.11 acres pre-project to 2.25 acres post-project. Scrubshrub and emergent wetlands were the two wetland types identified based on elevation. Additionally, the post-project site supports a 200-foot side-channel that will be activated in moderate to high-flow events, providing lower velocity, protected habitat for aquatic organisms.

Discussion and Future Monitoring

The establishment of over 2-acres of new wetland and riparian area, as well as side-channel habitat, counter many of the habitat losses in Rattlesnake Creek from development and channel manipulation (see Figure 11 in Basin-wide impacts). Future monitoring of the plant communities, soils and hydrology will be necessary to verify plant establishment and ecosystem function. The University of Montana's Ecosystem Restoration Program has initiated data collection at several reference sites for the lower Rattlesnake that could be used to assess the variables such as species composition, vegetated cover, weeds, litter, and soil organic matter. Because the pre-restoration dam site was so highly manipulated, this "Reference Model" approach allows us to document site recovery towards reference conditions, rather than just simply changes pre and post.

Vegetation Monitoring (WEN)

Introduction

Dam removal can impact riparian vegetation, with both immediate and delayed responses. For example, substantial changes in the topography and hydrology of the dam and reservoir site from restoration could alter surface water or groundwater outside of the project site. This in turn impacts vegetation communities. The goal of vegetation surveys is to characterize riparian vegetation by sampling vegetation monitoring stations along permanent transects. It follows, in modified format, the suggestions of Collins et al. 2007.

Methods and Results

In June of 2020 and 2021, Watershed Education Network and Scientific Advisor, David Cole, conducted baseline riparian vegetation surveys upstream and downstream of the dam removal project area. Eight transects were established–four upstream and four downstream of the dam site. Along each transect, ground cover, shrub and saplings and trees were surveyed. To characterize groundcover, we estimated the percent cover of the bare soil, plant litter (dead plant material) and ground cover vegetation, which included all non-woody plants as well as woody plants that are usually <3 feet in height. Percent cover of abundant species was also estimated. The shrub and sapling layer consisted of all live woody stemmed plants that are greater than 2 feet tall, but not taller than 20 feet. For this layer we estimated total percent cover and cover of individual species. The tree layer was defined as all live woody plants that are taller than 20 feet and have a diameter at breast height (DBH) greater than 2 inches. Trees were identified and counted by species, with each individual tree being counted in a size class based on its diameter.

Differences between the transects above and below the dam site were modest, suggesting that the upstream sites provide adequate control for assessing the effect of dam removal on sites below the dam site. All transects, both upstream and downstream of the dam site, are in a forest of ponderosa pine

(*Pinus ponderosa*) and Douglas fir (*Pseudotsuga menziesii*), with a groundcover dominated by snowberry (*Symphoricarpos albus*). Litter cover was more abundant in the upstream sites while groundcover vegetation was more abundant below the dam site (Figure 9). Tree density was also somewhat greater above the dam site (Figure 10). It is likely that the increased tree and litter cover upstream versus downstream may be related. As most of the trees found in both areas were coniferous, there would be more needles/litter dropped with the increase in trees. There was no difference in shrub and sapling cover across the sites, or over time. The most abundant groundcover species upstream of the project area (in order of percent cover) were Snowberry (*Symphoricarpos albus*), unidentified graminoid species, White Spiraea (*Spiraea betulifolia*), Western Sweet-Cicely (*Osmorhiza occidentalis*), Heartleaf Arnica (*Arnica cordifolia*) and Starry False Solomon's Seal (*Smilacina stellata*). The most abundant species downstream of the project area were Snowberry (Symphoricarpos albus), Western Meadow Rue (Thalictrum occidentale), Starry False Solomon's Seal (*Smilacina stellata*), Clematis (*Clematis columbiana*), unidentified graminoid species, and Fragrant Bedstraw (*Galium triflorum*). Between 2020 and 2021, there were no pronounced changes within the ground cover, shrub-sapling or tree layers.

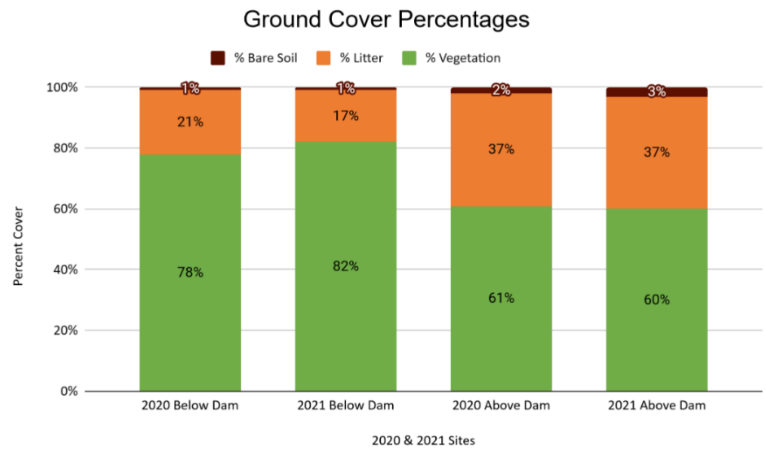


Figure 9. Ground cover above and below the dam pre and post restoration

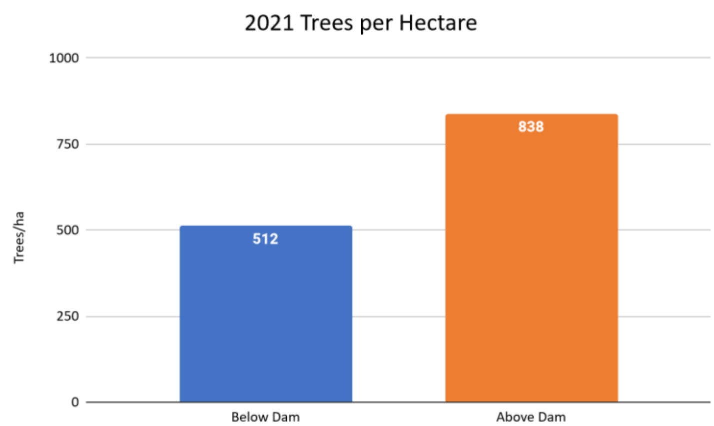


Figure 10. Tree density upstream and downstream of the dam removal site in 2021

Discussion and Future Monitoring

Lack of short-term change in the riparian zone downstream of the dam site is not surprising. Even long-term changes are not expected given the small size of the dam that was removed. To ensure that these results were due to topographic and land use rather than impacts of the dam, WEN, volunteers and project partners will continue to survey the riparian vegetation on Rattlesnake Creek at approximately 5-year intervals. The long timescale needed for plant growth indicates that it may be several years before changes, if any occur, may be seen.

Basin-wide Baseline Monitoring

The Rattlesnake Creek dam removal project was intended to address not only local conditions at the dam site, but the ecosystem-scale problem of a barrier to aquatic organism passage that has been in place for over a century. Understanding the spatial and temporal impact of this barrier would require an intensive research effort outside the scope of this monitoring program. However, describing the baseline and historic conditions in the watershed provides context for understanding the many variables that affect watershed health, and the relative influence of dam removal on the ecosystem.

Land Use and Development

(Chris Miller, University of Montana)

Introduction

The majority of the Rattlesnake Creek watershed falls under the jurisdiction of Lolo National Forest and the Rattlesnake Creek National Wilderness and Recreation Area. For this reason, little development has been permitted in the upper basin (see protected areas highlighted in Figure 2). Lower Rattlesnake Creek, however, flows through the residential lower Rattlesnake neighborhood, under Interstate 90, and through a dense area of commercial development near its mouth. As such, the Rattlesnake has a long history of manipulation (e.g., straightening, confining for flood hazard reduction, removal of side channels) to allow for, and protect, residential and commercial development. This analysis of land use and geomorphic change in the lower Rattlesnake was completed by Chris Miller in 2019 as a Graduate Student Thesis in the Environmental Studies department of the University of Montana.

Summary: Land Use and Development

- Channel sinuosity on lower Rattlesnake Creek in both 1929 and 2015 was much lower than natural conditions indicating that channel straightening occurred prior to 1929

- Land use has changed dramatically, with a 51% increase in developed land, primarily grassland conversion to residential

- While the riparian corridor along Rattlesnake Creek has narrowed, it has persisted throughout almost the entire length of the study area.

Methods and Results

Analysis of land use and geomorphic change focused on the lower 4-miles of Rattlesnake Creek below Rattlesnake Dam. Changes in channel form and land use were assessed using five overlapping aerial photos form 1929, and aerial imagery from 2015, with the primary channel and land use manually digitized. Once digitized, channel features such as channel length and sinuosity were calculated, as well as land use classification.

Both the 1929 and 2015 channel alignments (Figure 11, left) exhibit low sinuosity (1.15 and 1.13 respectively). These values are typical of a cascading step-pool system in a steep valley, not a low-gradient meandering channel that would naturally be expected in the study area (sinuosity of 1.3-3 based on Rosgen 1996). While the digitized photos exhibit some lateral movement around stream mile 2-3, this movement is more likely a natural alternation between primary and secondary channels, common in low-gradient systems, rather than processes of erosion or avulsion causing the creek to migrate laterally. The channel along the lower 1-mile appears artificially straightened in both time periods, indicating that channel manipulation occurred prior to 1929.

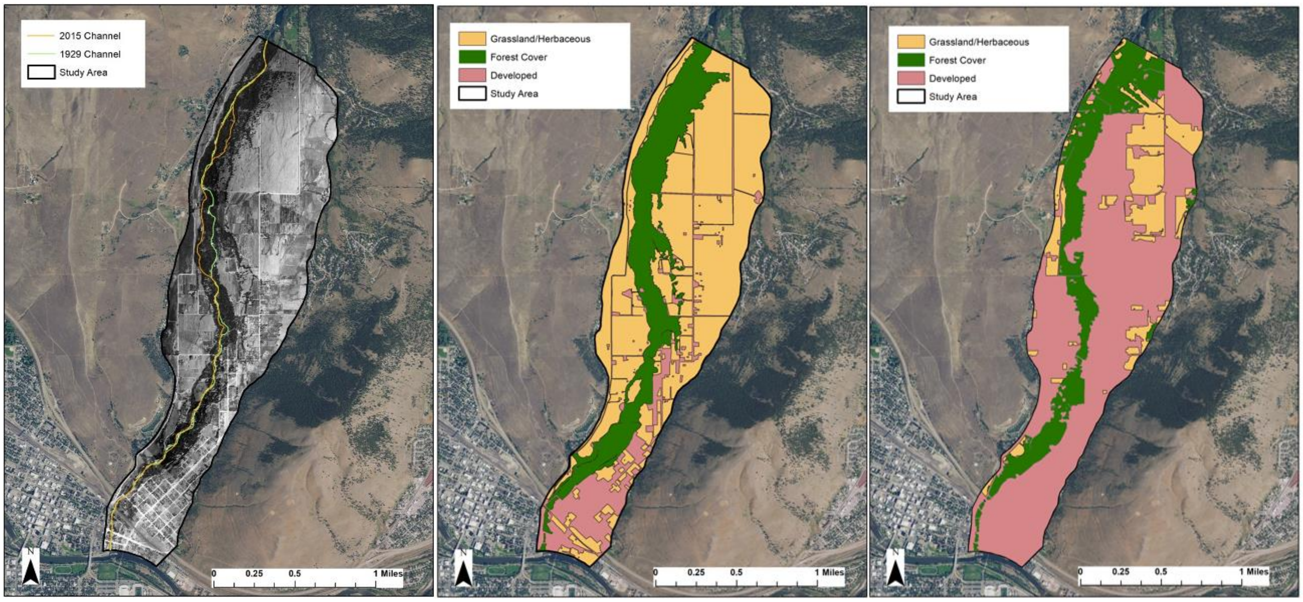


Figure 11. Rattlesnake Creek channel alignment (left) in 1929 (yellow line) and 2015 (green line). Land use change in the lower Rattlesnake between 1929 (center) and 2015 (right). Figures from Miller (2019).

Land use changed dramatically over this 85-year period (Figure 11, center and right). Overall, an increase in development (pink) and decrease in grassland/herbaceous (includes agriculture) is the most notable change in land cover within the study area, as the lower Rattlesnake residential neighborhoods expanded by 51%, becoming the dominant land-use. This change corresponds to an increase in impervious surfaces, and a decrease in riparian corridor (Forest Cover) width throughout much of the study area. Despite this, Forest cover was maintained along the full extent of the creek and expanded at the upper end of the study are, near the Rattlesnake dam, resulting in a net loss of only 3% Forest cover.

Discussion and Future Monitoring

The low sinuosity present in the lower Rattlesnake over 90 years ago underscores the fact that Rattlesnake Creek habitat and ecosystems have long been impacted in subtle (e.g., channel confinement) and not-subtle (e.g., dam construction) ways that are likely compounding. While the riparian forest corridor has narrowed since 1929, it has, generally, been maintained. Approximately half of this riparian corridor is currently owned by the City of Missoula, so it is at low risk for future development.

Streamflow

Analysis of historic streamflow (TU)

Introduction

Depending on their scale, dams can have a substantial impact on streamflow, limiting flood intensities during typical high-water periods, and releasing stored water, increasing streamflow during typically low-water periods. The Rattlesnake dam reservoir had little capacity to store or regulate streamflow, so it was unlikely that dam removal would have an impact on streamflow. However, increased flood risk was one of the chief concerns raised by the public during dam removal planning (City of Missoula, 2018). Additionally, Rattlesnake Creek is a south-facing drainage, generally making it more susceptible to climate change-driven shifts in the hydrograph resulting from less snowpack and earlier snowmelt timing (Barnett et al. 2005; Green et al. 2011; Huntington and Niswonger, 2012; IPCC, 2014). Rattlesnake Creek is, however, fed by roughly 45 high elevation Wilderness lakes, 10 of which are dam-regulated. Currently, an effort is underway to determine which of these dams could be removed and which, if any, could be improved and managed for increased streamflow.

Summary: Streamflow

- Streamflow in 2021, post dam removal, fell within the historic 25th-75th percentile during spring floods indicating no increased flood risk.

- July 2021 flows reached historic lows, while August 2021 reached historic highs. This pattern occurred throughout Western Montana and is not likely related to dam removal.

Methods and Results

The Rattlesnake Creek gage site (USGS #12341000), downstream of the dam removal project area, provides limited but informative historical context of flow regimes over a 120-year timeframe. Mean daily discharge was recorded in 1899 and continuously from 1958-1967. The gage was reinstated in January 2018 and is now managed by Montana Department of Natural Resource Conservation, with data hosted on the Montana Bureau of Mines and Geology website. Historic streamflow data were downloaded and used by River Design Group to prepare a mean annual

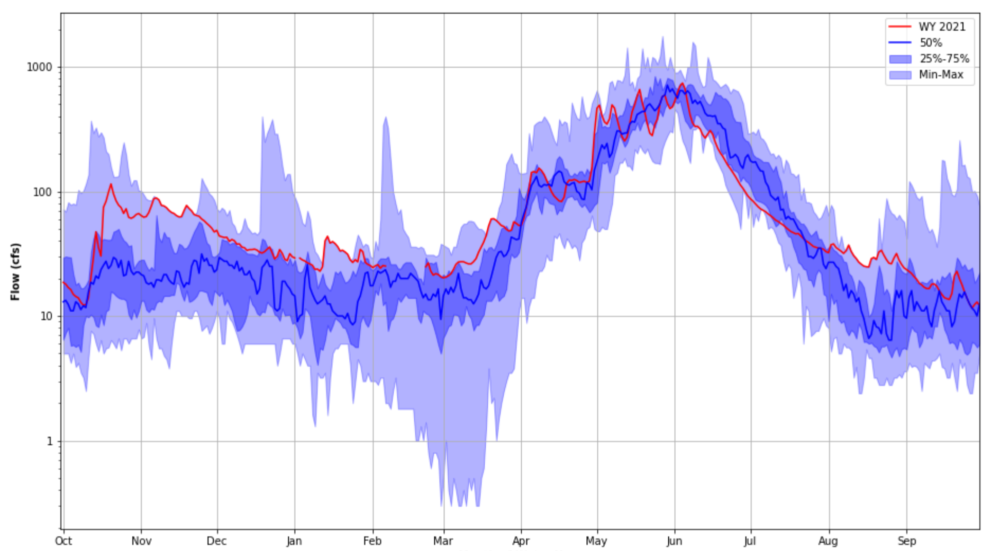


Figure 12. Historic streamflow on Rattlesnake Creek with the 2021 water year in red. Light purple indicates historic maximum and minimums, dark purple the 25th-75th percentile, and blue line the median. Figure by River Design Group

hydrograph for the period of record before dam removal, including the 25th and 75th percentiles of the mean, and minimum and maximum flows. The hydrograph for the first water year post-dam removal (October 2020-October 2021) is shown in red against the historic data (Figure 12).

Post-dam removal peak flow volume and timing (mid-May to mid-June) fell within the 25-75th percentile, indicating that the dam removal had no substantial impact on flow peak. The early receding limb (late June to early July) shows the creek within the lowest range flows on record, while the late summer flows (August) are among the highest. However, these patterns were seen across Western Montana which faced critically low flows in nearly all creeks and rivers in early summer 2021 (Montana DNRC).

Discussion and Future Monitoring

Trout Unlimited and partners will continue to monitor the flow regime on Rattlesnake Creek through the DNRC gage. As a south-facing drainage, Rattlesnake Creek's vulnerability to climate change impacts could also be evaluated once a longer period of record has been established since the new gage's launching. Finally, gage data are available to evaluate the impact of projects to remove or manage Rattlesnake Wilderness dams in the future.

Fisheries

Species Composition and Distribution (MFWP)

Introduction

Prior to the arrival of western settlers, Rattlesnake Creek supported three native salmonid species - bull trout (*Salvelinus confluentus*), westslope cutthroat trout (*Oncorhynchus clarkii lewisi*), and mountain whitefish (*Prosopium williamsoni*). Bull trout provided such a valuable food source that native Salish tribe referred to the confluence of Rattlesnake Creek and the Clark Fork River as "*Nɫʔay*" or "Place of the Small Bull Trout" (Smith, 2010). Although all three species still inhabit the creek today, the fishery has undergone many changes over the past century, most notably with the introduction of several non-native trout species and the physical impediment imposed by the dam. Non-native fish compete with native trout where they overlap. They also readily hybridize with native species (brook trout with bull trout; rainbow trout with westslope cutthroat or Yellowstone cutthroat), which can lead to loss of distinctive genetic traits, localized extinctions and reduced fitness for wild populations (Muhlfeld et al. 2009).

> *Summary: Fisheries*
>
> *- Dam removal fully reconnected 12-miles of Rattlesnake Creek habitat to the Clark Fork River for the first time in 100+ years*
>
> *- Ongoing monitoring by MFWP will provide the longterm dataset needed to assess the impact of barrier of dam removal on species composition and*
>
> *- The Missoula Trout Tag Study confirmed the importance of Rattlesnake Creek in supporting the broader Clark Fork Fishery*

Beginning in the 1930s, fish stocking programs introduced non-native trout species to local streams and rivers. The Clark Fork River basin was stocked with approximately 4.5 million rainbow trout, 1.1 million brown trout (*Salmo trutta*) along with smaller introductions of brook trout. Though stocking in Rattlesnake Creek itself was limited to a nine-year period between 1931 and 1940, records indicate that over 54,000 rainbow trout and 320,000 cutthroat trout (species unknown) were stocked in Rattlesnake Creek (MFWP). Finally, mountain lakes in the upper drainage were stocked with a variety of trout species that included Yellowstone cutthroat trout, rainbow trout, and westslope cutthroat trout. Trout stocked in headwater lakes provide a continual source of out-migrants to stream reaches below. While the original stocking programs were discontinued in Rattlesnake Basin lakes by the 1970s, their influence is long-lasting. Rainbow trout, brown trout, and brook trout are now well-established in the Rattlesnake and Clark Fork River systems and are central to the wild trout-based recreational fishery.

Methods and Results

Montana FWP maintains a database that describes fisheries sampling in Rattlesnake Creek since 1960. Currently, the agency monitors fish species composition, genetics, and relative abundance over time using a variety of metrics. These include six permanent sampling locations from the mouth of Rattlesnake Creek to the headwaters that are sampled every 3 years. Samples are collected along 200-meter representative reaches using backpack-mounted electrofishing units. All fish captured are anesthetized, identified to species, and measured before being returned to the stream. These data provide a snapshot of the distribution and relative abundance of fish species longitudinally along the stream's length over time.

Historic MFWP records (1960-1980) describe the lower Rattlesnake Creek main stem (below the former dam site) as dominated by rainbow trout, cutthroat trout and their hybrids, as well as brook trout, sculpin and other native fish species, with native bull trout still present. In the 20-year period between 2001 and 2021, lower reaches have experienced significant increases in brown trout and a decline in bull trout. As indicated in Figure 13 below, the fish species composition has changed at this site over time and at other sampling locations along the length of Rattlesnake Creek below Franklin Bridge. The distribution and relative abundance of different fish species will likely continue to change in these sections, now facilitated and accelerated by unobstructed fish passage at the former dam site.

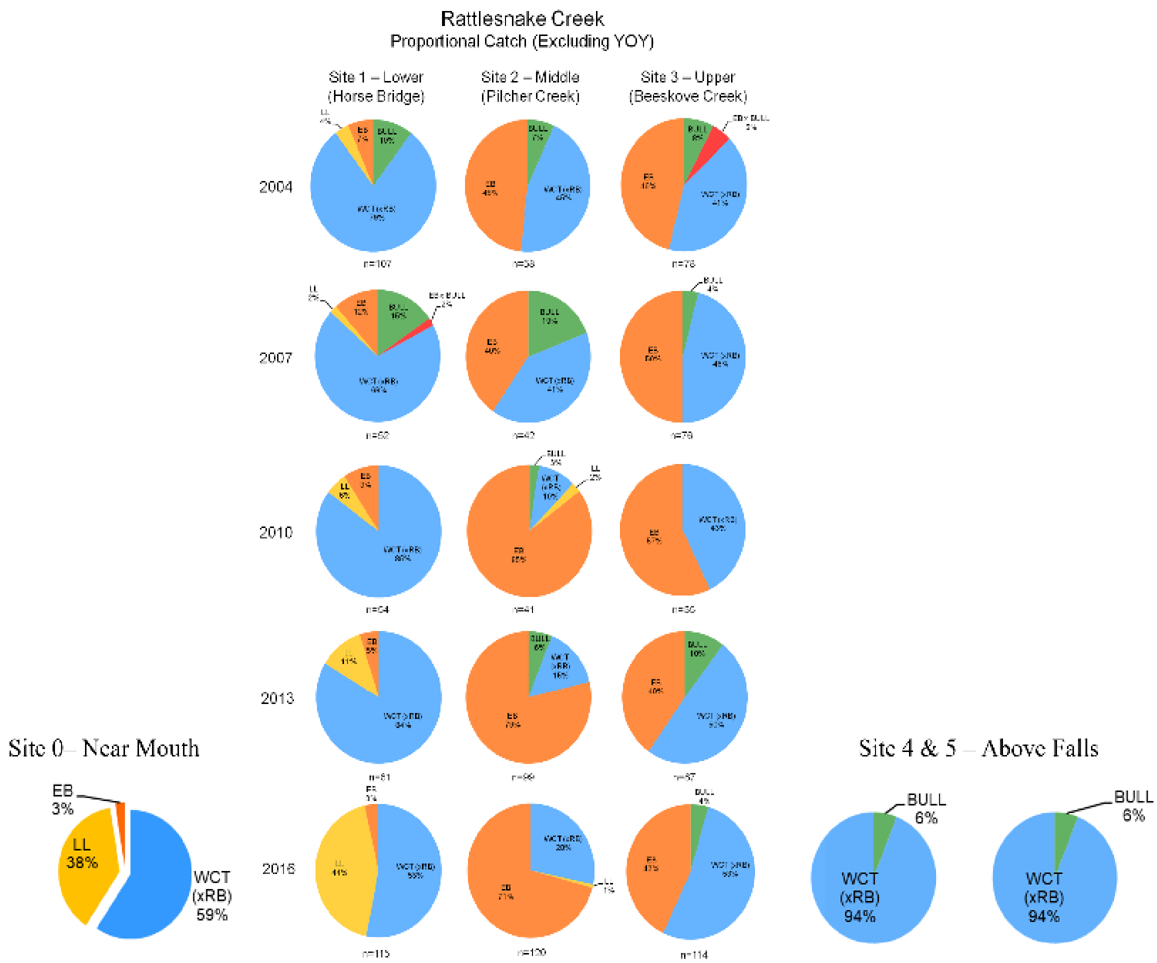


Figure 13 Rattlesnake Creek Species Composition over time. Blue: Westslope cutthroat (x rainbow); Green: bull trout; Orange : Eastern brook trout; Yellow: Brown trout. Data collected by MFWP. Figure from Knotek (2020)

Discussion and Future Monitoring

Future sampling by MFPW will continue to evaluate whether fish passage improvements contribute to ongoing changes for fish populations above the dam site. Specifically, MFWP biologists will look for evidence of increased spawning success, recruitment, and abundance for migratory cutthroat trout and rainbow x cutthroat hybrids that spawn in middle reaches of the stream system. (Knotek, personal communication 1/10/22). However, fish passage is only one of many factors influencing species distribution in the creek. Competition and hybridization with non-natives, loss of habitat, angling pressure and environmental stresses from warm water and low flows all may affect the make-up of the Rattlesnake fishery over time, making direct determination of dam removal impacts difficult.

Bull trout spawning escapement (MFWP)

Introduction

Monitoring bull trout spawning escapement – the number of adult fish returning to their natal stream to spawn – allows fisheries managers to track the health of the population and make inferences into its response to fish passage upgrades like fish ladders, fish screens and dam removal (Knotek et al., 2004). Redd counts are a common method in which a surveyor counts the number of redds, or nests, excavated by spawning females. These counts serve as an index of spawning adult abundance and the level of spawning activity, as well as providing insight into recruitment of the subsequent generation (Knotek et al., 2004). Adult, migratory trout are generally larger than resident trout and excavate a proportionally large redd. However, in larger tributary systems, the size range of stream-resident adults and their redds may overlap with those of migratory fish, so redd count indices in Rattlesnake Creek may include a small proportion of stream-resident bull trout redds.

Methods and Results

According to Knotek et al., 2004, MFWP conducted basin-wide redd counts in 1999 and 2000 and established two permanent monitoring reaches (1.0 and 2.25 miles in length) in 2000 to be re-visited in subsequent years. These two reaches have been adjusted as needed to ensure they encompass redds noted in basin-wide counts. Redd counts are completed in late September. Trained field crews walked the channel, visually searching for redds identified by a depression and associated tail area of sorted, clean gravel (Deleray et al. 1999; Spalding 1997). Redds are only counted if they are >3 feet in length to minimize inclusion of redds constructed by stream-resident bull trout and brook trout.

Bull trout redd counts increased significantly beginning in 2001 when fish passage measures were initiated at the dam. Higher redd abundance continued through 2008 but decreased abruptly and has remained relatively stable after that time (Figure 14).

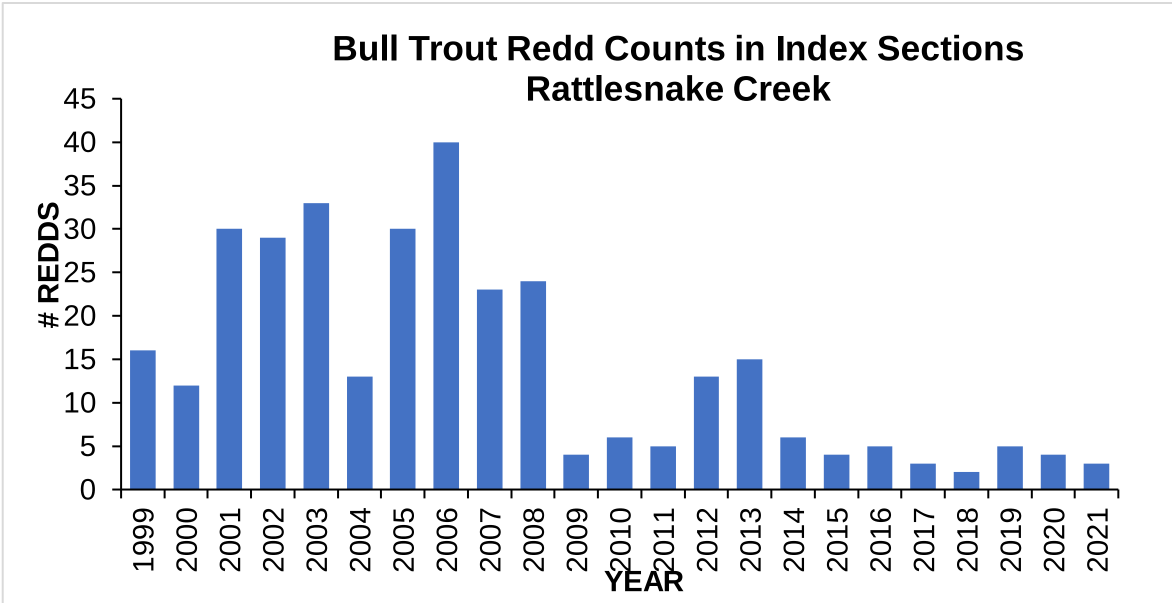


Figure 14 Bull trout redd counts in Rattlesnake Creek index sections 1999-2021. Data collection and figure by MFWP

Discussion and Future Monitoring

Redd counts in Rattlesnake Creek overall indicate a troubling future for bull trout in this drainage. While counts between 1999 (pre-dam passage) and 2008 suggest a positive response to fish passage efforts and other conservation measures, abundance overall has declined and remained stable since that time. The mechanism for decreased bull trout redd counts, abundance, and distribution in Rattlesnake Creek over the past decade is not clear but is likely related to a number of interacting factors, including the removal of Milltown Dam nearby in the Clark Fork River, increasing stream temperatures and rapid expansion of brown trout.

The notable and precipitous change in redd counts since 2009 has been the subject of many discussions among fisheries biologists and managers, as it coincided with the removal of the Milltown Dam. Recent genetic analyses of bull trout collected from 1999-2021 suggests that straying rates for adults that originated in Blackfoot River tributaries were high in Rattlesnake Creek relative to other tributaries in the basin prior to Milltown Dam removal (MFWP and UM data, 2022). This and the direct fish mortality associated with toxin released during Milltown Dam removal may have contributed to the observed reduction in redd counts since 2008, but these factors alone do not explain the magnitude or persistence of declines that have been observed.

Floy Tag Study (MFWP, TU)

Introduction

Details of fish migration such as timing, distance traveled between spawning and mainstem habitats, and the relative importance of individual tributary spawning populations, supports fisheries management decisions and helps fisheries managers communicate the value of connected habitat to the public. Fish tagging is one method used to track the movement of individual fish and, when relying on recapture data from anglers, to engage the public.

Methods and Results

In 2020, MFWP, with the support of TU and 30+ citizen science volunteers, initiated a tagging study of adult migratory cutthroat, rainbow, and rainbow x cutthroat hybrid trout in seven Missoula-area tributaries, including Rattlesnake Creek. A total of 795 fish, (180 fish from Rattlesnake Creek), were caught and implanted with floy tags as they ascended into their spawning habitat in tributary headwaters. Over the next two years, the study relied on voluntary reporting from anglers who caught tagged fish as they moved between spawning tributaries and mainstem habitats. Trout Unlimited developed outreach materials and an interactive website (https://montanatu.org/trouttag/) for anglers to easily report fish when they were caught and to see where the fish was originally tagged. As of winter 2022, 15 Rattlesnake fish have been recaptured (8.8% of those tagged). Rattlesnake fish had the highest recapture rate and the widest distribution of movements as compared with the other six tributaries (Frey et al. 2020). While many fish were recaptured at the mouth of Rattlesnake Creek, several traveled much longer distances. One Rainbow hybrid was caught in June 2020, 20 miles downstream near Frenchtown, MT. One female Rainbow trout was caught twice (November 2020 and March 2021) nearly 40 miles upstream of the Rattlesnake in the lower Clearwater River within the Blackfoot River Watershed (Montana Trout Unlimited)

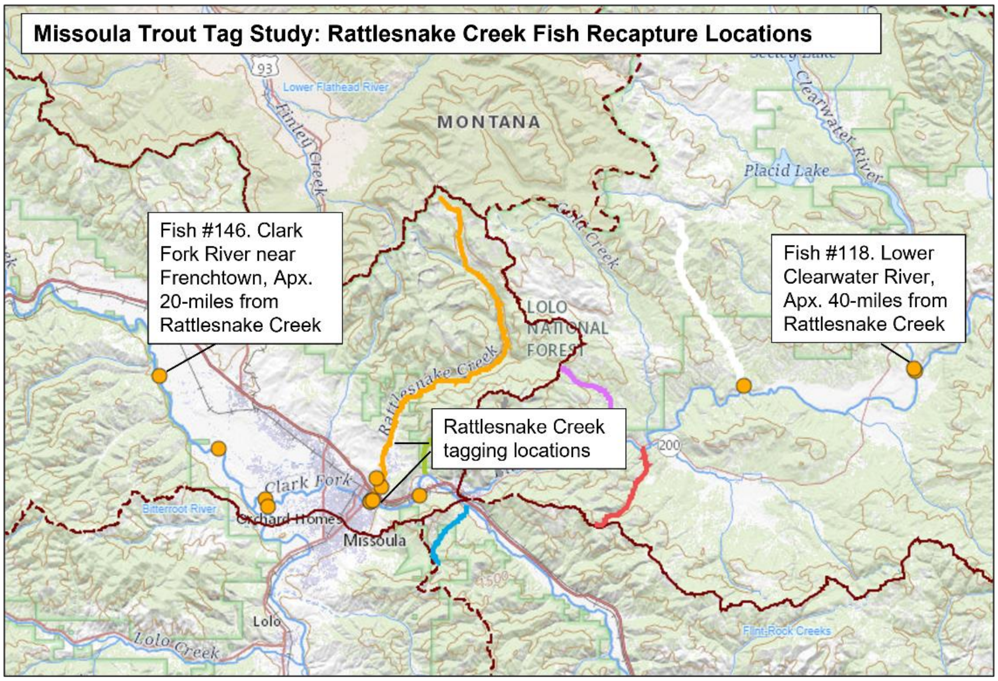


Figure 15 Locations of recaptured fish (orange dots) originally tagged at one of two Rattlesnake Creek locations. Map taken from Montana Trout Unlimited's "Missoula Trout Tag Study" website.

Discussion & Future Monitoring

The continued use of Rattlesnake Creek by Clark Fork River migratory fish, as seen in the Missoula Trout Tagging study, underscores the importance of connectivity between these systems, the extensive geographic scale influenced by large tributaries, and the contribution of Rattlesnake Creek to the broader collection of adjacent river fisheries.

Aquatic Habitat

Instream Temperature (Montana FWP)

Summary: Aquatic Habitat

- Average instream temperatures in 2020 reached 15 degrees C, a thermal threshold for bull trout, at nearly all sites and for much of the summer, with the exception of Site 13 near Beeskove Creek

- Instream temperatures did not exceed 17 degrees C at any location, within Westslope cutthroat trout's thermal tolerance.

- Instream wood surveys clearly indicate the importance of wood jams on pool formation. Wood densities in upper and lower Rattlesnake were highly variable and likely linked to channel morphology.

- Groundwater inflows vary greatly in the upper Rattlesnake with concentrations highest near Fraser Creek, a known spawning area for trout.

Introduction

Temperature is a leading variable dictating the distribution of aquatic species. Within its range, bull trout, which cannot tolerate extended temperatures of >15 degrees Celsius (59 degrees Fahrenheit) are one of the most thermally sensitive species (Poole et al. 2001, U.S. Fish and Wildlife Service, 2010). Westslope cutthroat trout, though less sensitive than bull trout, have been shown to be at a distinctive disadvantage to rainbow trout, a non-native species often overlapping in habitat, above 20 degrees C (Baer et al. 2007). For this reason, temperature is a crucial variable to understand in bull trout and westslope cutthroat trout systems. When viewed longitudinally, temperature provides insights into crucial thermal refugia, and the extent (or limit) of suitable habitat during high and low temperature periods.

Methods and Results

Montana Fish, Wildlife and Parks maintains a longitudinal array of Hobo temperature sensors deployed in Rattlesnake Creek and its tributaries. Temperature is recorded hourly from September-September, providing a year-round record of hourly data that can be used to understand longitudinal trends commonly summarized into daily mean, maximum and minimum temperatures. Based on thermal thresholds for bull trout (15 C) and westslope cutthroat trout (20 C), these data can also be summarized simply as a count of the days within a season that these temperature thresholds were exceeded. Figure 16 presents a heat ramp of mean daily temperatures at all mainstem sites form May-September 2020. For a map of monitoring locations and a summary of days exceeding 15 degrees C by location, see Appendix 4.

Instream temperatures reached at least 15 degrees Celsius at all but one mainstem Rattlesnake Creek monitoring site in 2020 with 22–58 days and average daily summer temperatures (July and August) ranging from 11.8 – 13.1 degrees C (average max daily summer temperature = 14.0-14.6 degrees C). Site 13, near Beeskove was the exception with zero days exceeding 15C and an average daily temperature in

July and August of 9.3 (average max daily temperature in July and August= 9.8 degrees C). Site 14, the next site downstream, was the second coolest, with 22 days exceeding 15C and an average daily summer temperature of 11.8 C. While conditions were clearly warmest at the downstream-most site, (Site 17) stream temperatures at the majority of the other sites regularly reached 15 degrees C. No mainstem or tributary habitat reached 20 degrees C, the thermal threshold for Westslope cutthroat trout. Tributaries were generally cooler than the adjacent mainstem water, with Wrangle Creek and the East Fork Rattlesnake Creek being the coldest (average max daily summer temperature of 9.1 and 11 degrees C respectively. Lake Creek (Site 7) was the exception, with 37 days exceeding 15C and average daily summer temperature of 13.3 degrees C.

Longitudinal Temperature Trends in Rattlesnake Creek, 2020

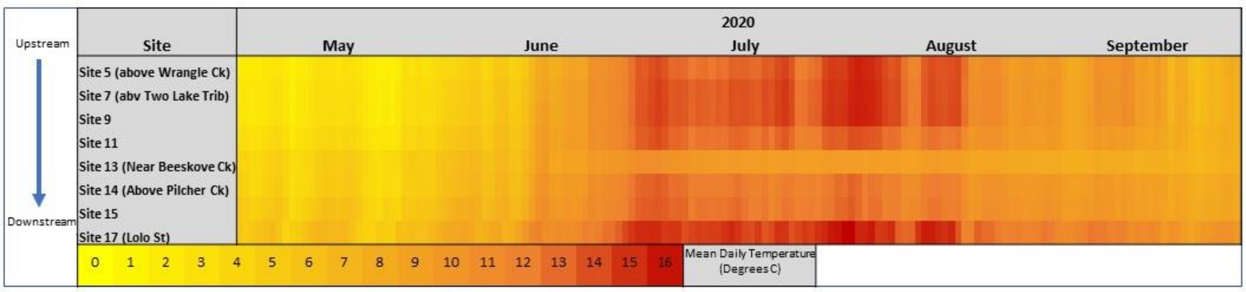


Figure.16 Longitudinal temperature trends in Rattlesnake Creek, May-September 2020. Red hues represent temperatures at or above 15 degrees C, a known upper thermal threshold for bull trout.

Discussion and Future Monitoring

In the summer of 2020, the majority of mainstem Rattlesnake Creek regularly reached the 15-degree thermal threshold for bull trout. The area near Beeskove Creek (Site 13) was the clear exception, offering consistently cold refuge when water temperatures upstream and downstream began to climb. The cool temperatures at this are likely due to a combination of increased groundwater and the cooling influence of Beeskove Creek and the East Fork of Rattlesnake Creek which enters the mainstem approximately 2 miles upstream of site 13. Unsurprisingly, fisheries sampling in this area confirms bull trout occupancy (Figure 13). MFWP will continue to monitor instream temperatures at these sites, providing a long-term dataset to track trends over time.

Instream Wood (WEN, TU)

Introduction

Large woody debris (LWD) is an essential component of stream ecosystems that drives pool formation, increases sinuosity, and provides complex habitat (Schuett-Hames, 1999). The goal of the survey was to characterize LWD distribution and the role it plays in habitat formation throughout Rattlesnake Creek. In upper Rattlesnake Creek, wood distribution may be impacted by factors such as historic fire, as well as valley form and beaver activity. In the lower Rattlesnake, factors such as channel straightening, confinement and riparian forest clearing may impact wood recruitment and whether it remains or is exported from the system at high flows. Additionally, when the Rattlesnake Dam was in place, the logs that were caught behind it were removed, decreasing the amount of wood imported into downstream reaches. For these reasons, collecting data on wood densities and the habitat associated with that wood (i.e. pools) was identified as a valuable monitoring activity.

Methods and Results

Wood Distribution

In the summer of 2021, Watershed Education Network and Trout Unlimited collaborated to design and implement a survey of large woody debris throughout Rattlesnake Creek. WEN collected data along 14 reaches (approximately 6 kilometers) from the lowest extent of the restoration area down to the mouth of Rattlesnake where it meets the Clark Fork River ("downstream reaches"). "Upstream reaches" were all above the dam removal site in the Rattlesnake National Recreation Area. WEN surveyed 6 km along five reaches between Poe Meadows up to where Beeskove Creek enters Rattlesnake Creek. Trout Unlimited surveyed the following 6 km of stream along reaches 6-14, extending from Beeskove Creek to the East Fork of Rattlesnake Creek. The same methods and tools were used for sampling regardless of the organization or personnel. Appendix 5 presents maps of the Upper and Lower reaches, as well as large wood and beaver dams.

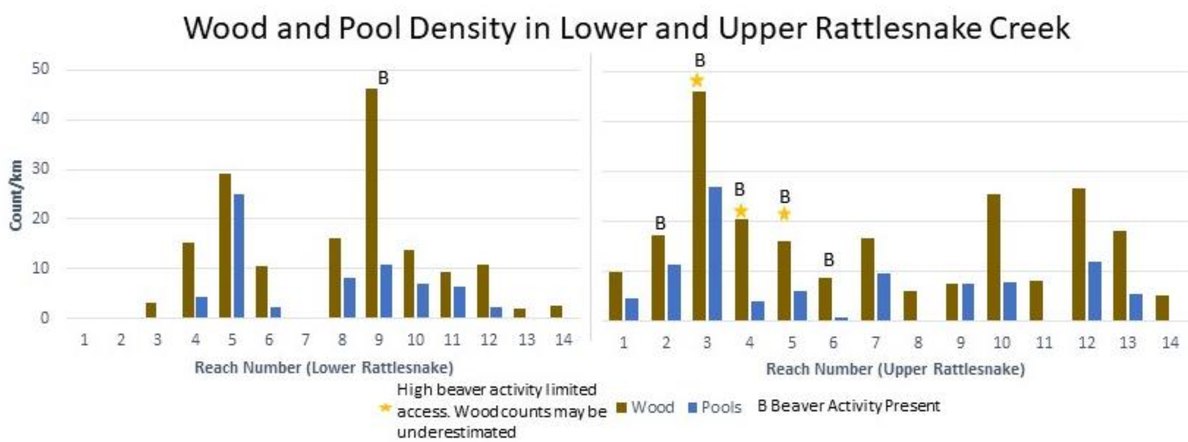


Figure 17. Wood and Pool density in upper and lower Rattlesnake Creek. Stars indicate reaches with high beaver activity where wood counts may be underestimated. B indicates a beaver-influenced reach.

Overall, density of large woody debris (LWD/km) was highly variable along Rattlesnake Creek, as seen in Figure 17. Reach 9 had the most wood out of the lower reaches while Reach 3 had the most wood in the upper reaches. Both reaches also had high beaver presence, as indicated with the "B" above their wood counts. Reaches 3-5 upstream, indicated with stars, had so many side channels and pools caused by beavers that it was nearly impossible to determine where the main channel was. These reaches likely had much higher wood counts, as sections of them were skipped due to time and safety constraints. While the density of small logs stayed similar along the reaches, there were many more medium logs in the upper reaches compared with the lower reaches (Table 4). This was likely also due to more beaver presence and stream complexity in the upper reaches. In Table 4 we can see that the count of LWD features (including all individual large logs, rootwads, and jams as individual features) follows the same pattern, with slightly higher wood counts upstream versus downstream. The total LWD (which counts all pieces, including multiple pieces in one jam) follows this pattern as well and also illustrates that much of the wood counted is being held within wood jams. These jams contained an average of 19.3 pieces per jam in the upstream reaches, and 15.8 pieces per jam in the downstream reaches.

Table 4. Summary statistics of reaches, wood and pools inventoried

		Lower Reaches	Upper Reaches
Reaches	Total Length of Stream Surveyed (km)	6.99	12.65
	Number of Reaches	14	14
	Mean Reach Length (km)	0.5	0.9
Logs	Small Log Density (Small Logs/km)	32.6	37.6
	Medium Log Density (Medium Logs/km)	31.7	51.5
	Large Log Density (Large Logs/km)	7.4	10.3
	Density of LWD Features (LWD Features/km)	12.7	19.2
	Average Number of Pieces in Jams	15.8	19.3
	Density of all Wood Pieces (Total pieces/km)	114.4	201.5
Pools	Mean Density of Pools (Pools/km)	5.3	6.5
	Average Max Pool Depth (ft)	1.8	3.2

When it comes to their ability to drive pool formation, not all pieces of large woody debris are created equal. Long jams account for the majority of pools, with 70% of log jams creating a pool, often with multiple pools being created by one jam (Figure 18). In contrast, large pieces with rootwads formed pools 42% of the time and large logs without rootwads only formed pools 16% of the time. Over half (55%) of LWD associated pools were adjacent to jams, with the remaining pools split evenly between the other wood classifications. The maximum depth of pools was on average 3.2 feet in the upper reaches, compared with 1.8 feet in the downstream pools.

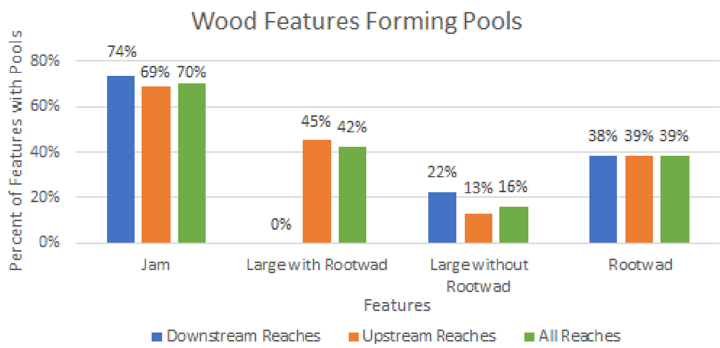


Figure 18. The likelihood that a specific wood feature will form a pool

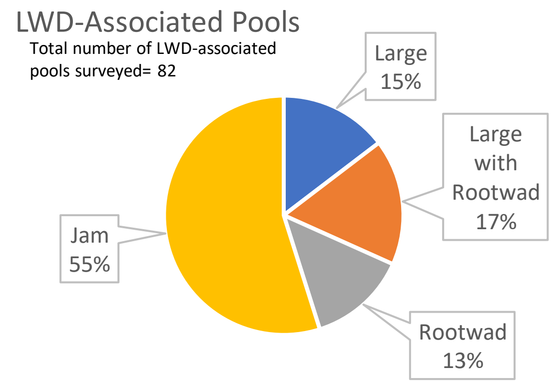


Figure 19. The proportion of pools associated with different LWD features

Discussion and Future Monitoring

The wide variations in LWD density generally mirror observed differences in stream morphology and the presence/absence of beavers. There are indications that the dam may have limited the amount of wood in the creek, with lower wood counts directly below the dam site and counts increasing with distance downstream. Survey notes and satellite imagery, however, indicate that sections of the creek with the highest LWD densities also feature multiple channels with high sinuosity. While the reaches with the lowest LWD densities consist primarily of single-thread channels dominated by long, straight, boulder-strewn riffles and runs. For this reason, it is difficult to separate the impact of the dam from channel form.

While there did not appear to be any difference in the presence of pools between the upstream and downstream reaches, there was a clear difference in the presence of pools between the types of wood features. Larger and more complex the wood feature, such as jams or large logs are clearly important to pool formation.

The general lack of sinuosity in the below dam reaches results in higher stream velocities that often export wood. This may explain the generally lower wood counts in those reaches than can be seen upstream. Wood recruitment relies on trees dying or being blown into the creek in a weather event. Due to the nature of these weather events this metric will require a longer timescale to evaluate. Long-term monitoring will also help reveal if the stream characteristics or the lack of imported wood from outside or within the reach are dictating the lower wood counts.

Groundwater (WEN, UM (Sawyer Meegan))

Introduction

Groundwater serves a crucial role in aquatic ecosystems affecting key variables like streamflow, temperature, and nutrient availability. Groundwater's relatively constant temperature buffers aquatic organisms from in-stream temperature extremes. Notably, groundwater upwelling zones have been correlated with bull trout spawning site selection (Baxter et al. 1999, Bean at al. 2014). While groundwater benefits to aquatic ecosystems are generally accepted, the distribution of groundwater upwelling zones in a given watershed is often unknown. In an effort to identify groundwater upwelling zones in Rattlesnake Creek, Watershed Education Network partnered with a student from the University of Montana, Sawyer Meegan (under the direction of UM Geosciences professor Payton Gardner) to sample, analyze and interpret water samples from Rattlesnake Creek to evaluate longitudinal trends in groundwater concentrations.

Methods and Results

Groundwater concentrations were evaluated based on concentrations of radon-222, a groundwater tracer, in Rattlesnake creek water samples. Radon-222 is a naturally occurring, radioactive element in soils and rocks that is also water soluble. As groundwater travels through the subsurface, it accumulates radon-222. However, because of the extremely low concentrations of radon in the atmosphere, radon-222 dissipates rapidly when exposed to air. Based on these characteristics, high concentrations of radon-222 can effectively be used to identify locations of groundwater upwelling (Gardner et al. 2011; Cook et al. 2003; Genereux et al. 1990).

Samples were collected in the winter of 2018 by a group of Watershed Education Network volunteers, led by Sawyer Meegan, who traveled to each site on skis. Volunteers collected nine water samples on an approximately 1-km (0.62 mile) interval from the Rattlesnake National Recreation Area trailhead to Pilcher Creek (8 km or 4.9 miles upstream). Water samples were then transported to the University of Montana and analyzed for Radon-222 concentrations using a Durridge RAD 7. Measured concentrations were adjusted for radioactive decay based on the hours between sampling and run time.

Figure 20 presents the sampling locations and their respective radon-222 concentrations. Sites 6, 7 and 8 had the highest radon-222 concentrations (18.77, 28.83, 14.66 pCi/L respectively), with notable increases near Frasier Creek (between sites 8-7 and 7-6), indicating high inflows of groundwater. Radon-222 concentrations at all other sites ranged from 0.53-2.07 pCi/L.

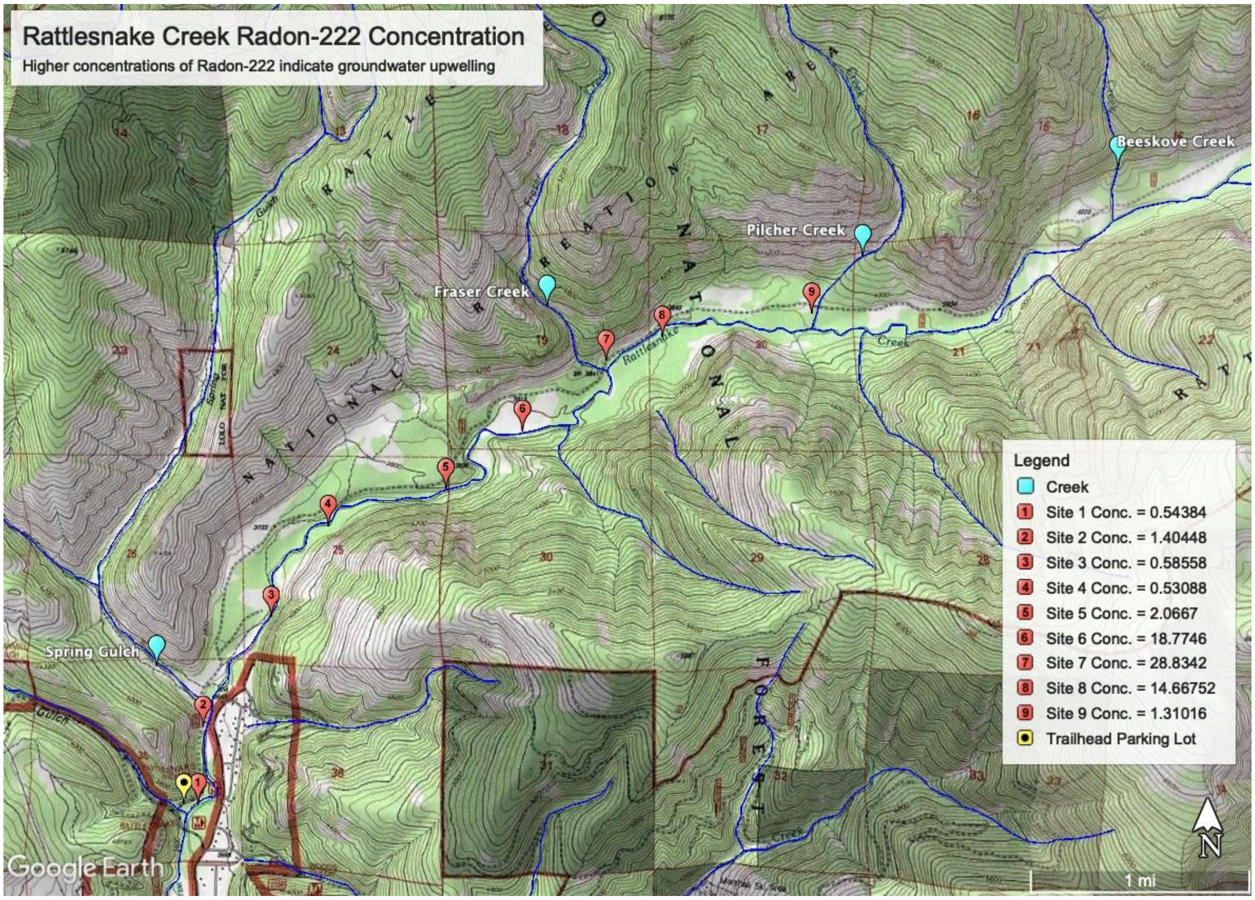


Figure.20 Map of Rattlesnake Creek Radon-222 sampling locations and results. Sites 6-8 near Pilcher Creek showed the highest Rn-222 concentrations, indicating that this is an area of groundwater upwelling.

Discussion and Future Monitoring

The longitudinal groundwater trends on Rattlesnake highlight the area near Fraser Creek as one with especially high groundwater influxes. These results align well align well with our current understanding of trout spawning preference, as Fraser Creek is also known to attract trout spawning and rearing. Future sampling could evaluate groundwater upwelling further up the Rattlesnake drainage or during summer months.

References

Archer, Eric K., Henderson, Richard, Ojala, Jeffrey V., Gavin, Amanda and Burke, Karen K. (2016), PacFish InFish Biological Opinion (PIBO) Monitoring Program: Effectiveness Monitoring Sampling Methods for Stream Channel Attributes. Unpublished paper on file with PIBO Monitoring Program. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd494543.pdf

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. (Chapter 7 (part A): Benthic Macroinvertebrate Protocols).Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Barnett, T.P., J.C. Adam and D.P. Lettenmaier (2005), Potential impacts of a warming climate on water availability in snow-dominated regions, Nature, 438, 303-309, doi:10.1038/nature04141

Baxter, J. S., & McPhail, J. D. (1999). The influence of redd site selection, groundwater upwelling, and over-winter incubation temperature on survival of bull trout (Salvelinus confluentus) from egg to alevin. *Canadian Journal of Zoology*, *77*(8), 1233-1239.

Bean, J. R., Wilcox, A. C., Woessner, W. W., & Muhlfeld, C. C. (2015). Multiscale hydrogeomorphic influences on bull trout (Salvelinus confluentus) spawning habitat. *Canadian Journal of Fisheries and Aquatic Sciences*, *72*(4), 514-526.

Bear, Elizabeth A., Thomas E. McMahon & Alexander V. Zale (2007) Comparative Thermal Requirements of Westslope Cutthroat Trout and Rainbow Trout: Implications for Species Interactions and Development of Thermal Protection Standards, Transactions of the American Fisheries Society, 136:4, 1113-1121, DOI: 10.1577/T06-072.1*Trout redds.*

Cherry, J. A. (2011) Ecology of Wetland Ecosystems: Water, Substrate, and Life. *Nature Education Knowledge* 3(10):16

City of Missoula (2018) Lower Rattlesnake Dam Site Restoration, Summary of Public Input. Parks and Recreation Department.

Collins, M., K. Lucey, B. Lambert, J. Kachmar, J. Turek, E. Hutchins, T. Purinton, and D. Neils. 2007. Stream Barrier Removal Monitoring Guide. Gulf of Maine Council on the Marine Environment. www.gulfofmaine.org /streambarrierremoval.

Cook, P. G., Lamontagne, S., Berhane, D., and Clark, J. F. (2006), Quantifying groundwater discharge to Cockburn River, southeastern Australia, using dissolved gas tracers 222Rn and SF6, Water Resour. Res., 42, W10411, doi:10.1029/2006WR004921.

Dahl, T.E., and Johnson, C.E., 1991, Wetlands-Status and trends in the conterminous United States, mid-1970's to mid-1980's: Washington, D.C., U.S. Fish and Wild-life Service, Deleray, M., W.L. Knotek, S. Rumsey and T.M. Weaver (1999) Flathead Lake and River system fisheries status report. Montana Fish, Wildlife and Parks, Kalispell, Montana. 200 pp.

Dunham, Jason, Rieman, Bruce, and Chandler, Gwynne, 2003, Influence of temperature and environmental variables on the distribution of bull trout within streams at the southern margin of its range: North American Journal of Fisheries Management, v. 23, p. 894–904.

Frey, R. C. Podner, L. Knotek, L., P. Uthe, R. Roberts & W. Pfeifer (2020) Fluvial Trout Spawning Populations, Movement, and Habitat Use in the Lower Blackfoot and Middle Clark Fork River Systems.

Gardner, W. P., Harrington, G. A., Solomon, D. K., and Cook, P. G. (2011), Using terrigenic 4He to identify and quantify regional groundwater discharge to streams, Water Resour. Res., 47, W06523, doi:10.1029/2010WR010276.

Genereux, D. P., and Hemond, H. F. (1990), Naturally Occurring Radon 222 as a Tracer for Streamflow Generation: Steady State Methodology and Field Example, Water Resour. Res., 26(12), 3065– 3075, doi:10.1029/WR026i012p03065.

Green, T.R., M. Taniguchi, H. Kooi, J.J. Gurdak, D.M. Allen, K.M. Hiscock, H. Treidel, A. Aureli (2011) Beneath the surface of global change: Impacts of climate change on groundwater, Journal of Hydrology, 405, 532-560

Huntington, J. L., & Niswonger, R. G. (2012). Role of surface-water and groundwater interactions on projected summertime streamflow in snow dominated regions: An integrated modeling approach. Water Resources Research, 48(11).

IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland

Jones, L.A., Muhlfeld, C.C., Marshall, L.A., McGlynn, B.L., and Kershner, J.L., 2013, Estimating thermal regimes of bull trout and assessing the potential effects of climate warming on critical habitats (abs.): River Research and Applications, accessed June 20, 2013, at http://onlinelibrary. wiley.com/doi/10.1002/rra.2638/abstract.)

Knotek, L. (2020) Fisheries and Wildlands Management in the Rattlesnake: Balancing Watershed Restoration, Native Trout Recovery, and Wilderness Character. University of Montana Wilderness Lecture Series

Knotek, L., R. Rashap & D. Schmetterling (2004) Rattlesnake Creek Fisheries Assessment and Enhancement 1999-2003. Montana Fish, Wildlife and Parks.

Lisle, Thomas E. (1987) Using "Residual Depths" to Monitor Pool Depths Independently of Discharge. United States Department of Agriculture Forest Service Pacific Southwest Forest and Range Experiment Station https://www.fs.fed.us/psw/publications/documents/psw_rn394/psw_rn394.pdf

MDEQ (Montana Department of Environmental Quality). (2006). Sample collection, sorting, and taxonomic identification of benthic macroinvertebrates. Standard operation procedure WQPBWQM-009. Revision no. 2.

Miller, Chris D (2019) Development Along Rattlesnake Creek: An Assessment of Stream Health, Channel Form, and Land Cover. Graduate Student Thesis, University of Montana, Missoula. https://scholarworks.umt.edu/etd/11350

Montana Department of Resources and Conservation (DNRC) *StAGE – Stream and Gage Explorer*. Retrieved from https://gis.dnrc.mt.gov/apps/stage/gage-report/ on 2/4/2022

Montana Fish Wildlife and Parks [MFWP], *Stocking Records*. Retrieved from https://myfwp.mt.gov/fishMT/plants/plantreport on 12/15/2021

Montana Trout Unlimited. *Missoula Trout Tag Study*. Retrieved from https://montanatu.org/trouttag/ 1/28/2022

Muhlfeld, C., S.T. Kalinowski, T.E. McMahon, M.L. Taper, S. Painter, R. Leary & F.W. Allendorf (2009) Hybridization rapidly reduced fitness of a native trout in the wild. *Biol Let* 5:328-331 https://doi.org/10.1098/rsbl.2009.0033

Poole, Geoffrey, Dunham, Jason, Hicks, Mark, Keenan, Dru, Lockwood, Jeffrey, Materna, Elizabeth, McCullough, Dale, Mebane, Chris, Risley, John, Sauter, Sally, Spalding, Shelley, Sturdevant, Debra, 2001, Technical synthesis— Scientific issues relating to temperature criteria for salmon, trout, and char native to the Pacific Northwest: Seattle, Wash., U.S. Environmental Protection Agency, EPA 910-R-01-007, 24 p., accessed June 14, 2013, at http:// yosemite.epa.gov/R10/water.nsf/water+quality+standards/ WQS+temperature+guidance.

Schuett-Hames, D., A.E. Pleus, J.Ward, M. Fox, and J. Light. (1999), TFW Monitoring Program method manual for the large woody debris survey. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-004. DNR #106. March. http://docs.streamnetlibrary.org/Protocols/001.pdf

Spalding, S. (1997) Montana bull trout redd survey manual. Montana Fish, Wildlife and Parks, Helena, Montana. 8 pp.

United States Army Corps of Engineers, Environmental Laboratory. 1987. Corps of Engineers wetlands delineation manual. Waterways Experiment Station Technical Report Y-87-1.

U.S. Fish and Wildlife Service, 2010, Endangered and threatened wildlife and plants—Revised designation of critical habitat for bull trout in the coterminous United States: Federal Register v. 75, no. 200, p. 63898-64070, accessed May 1, 2013, at http://www.fws.gov/pacific/ bulltrout/pdf/BTCHFR101810.pdf.

Appendix 1: Photopoints

View from cliff above project site, looking downstream

Upstream end of the project site with the former reservoir, retaining wall and Rattlesnake Creek.

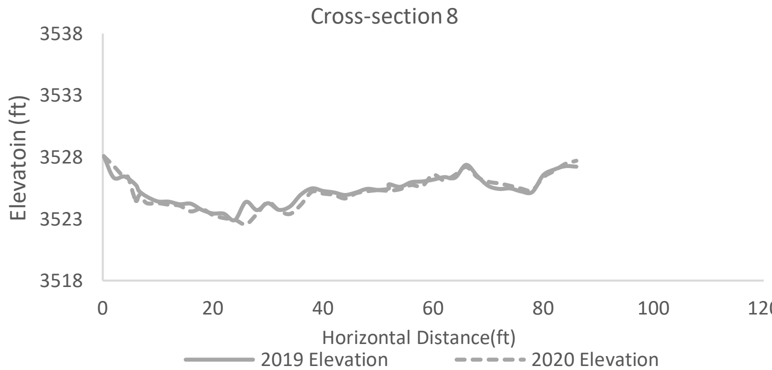
Aerial view of the project site in early summer (top) and fall (bottom) 2020

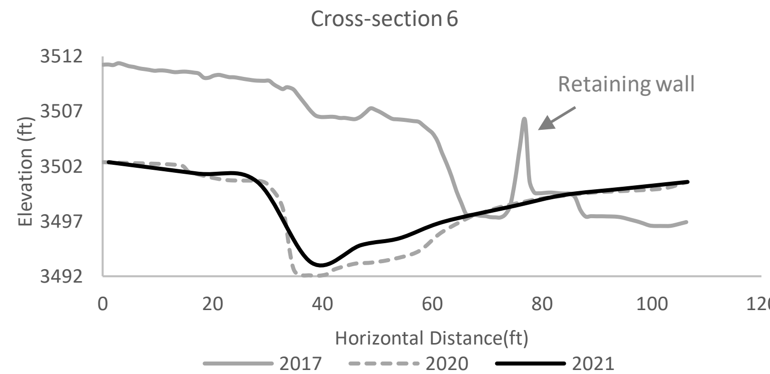
Looking downstream at the former reservoir (left), caretaker cabin (left background), Rattlesnake Creek (right) and dam

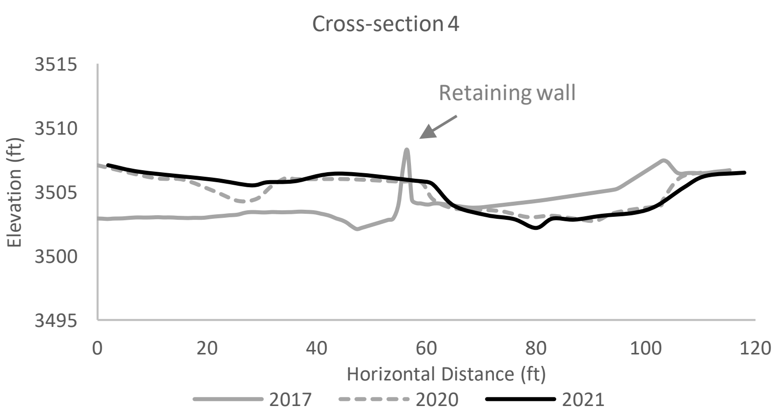
Dam site looking northeast (upstream) from right bank

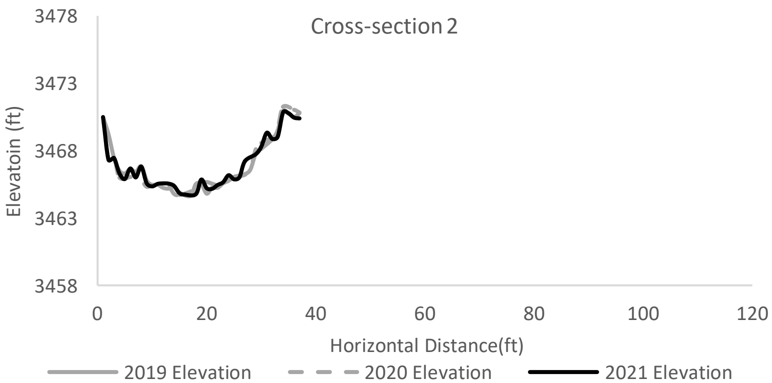
Former fish ladder and dam viewed from downstream

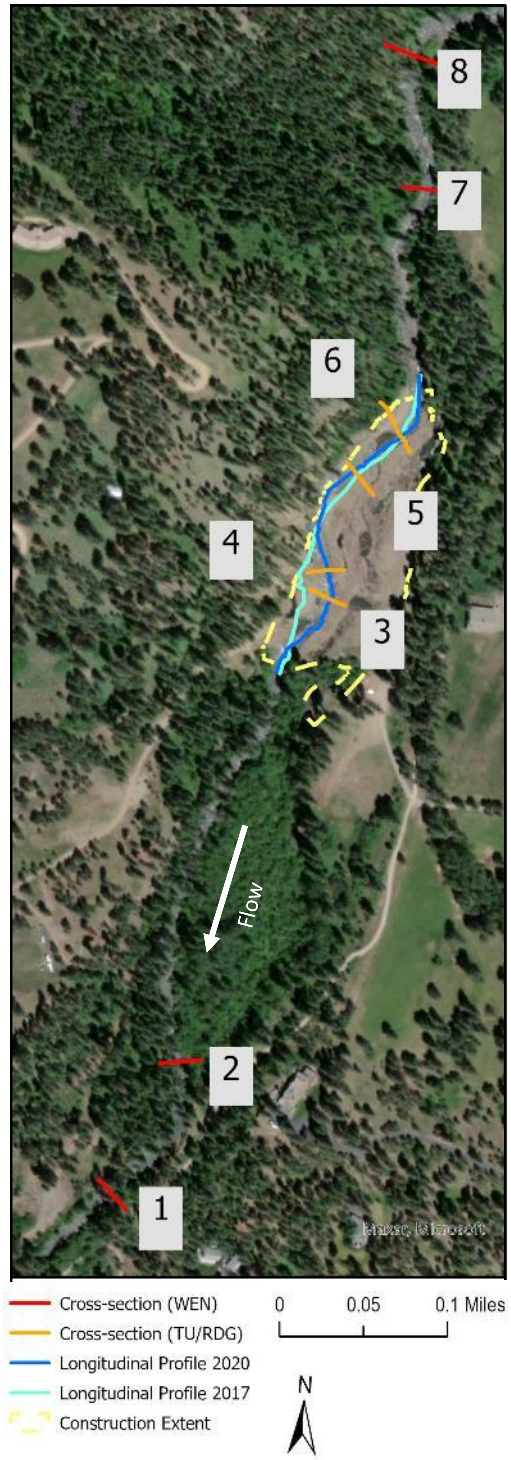
Appendix 2: Rattlesnake Dam Removal Topographic Survey

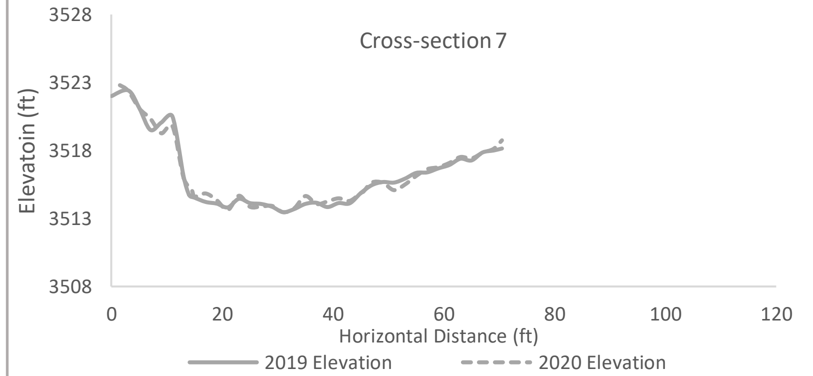


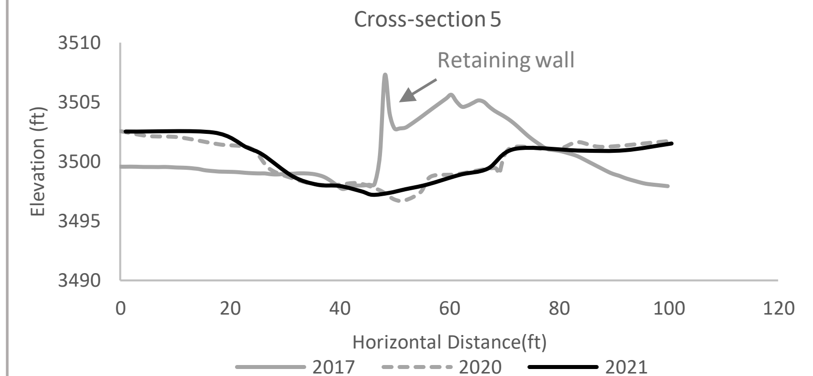


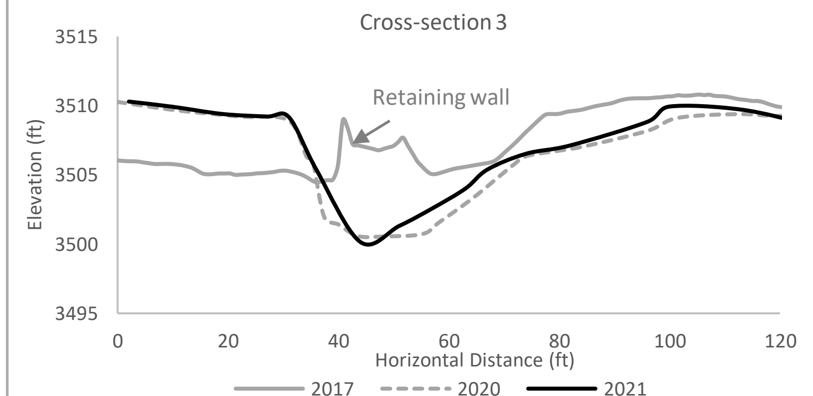


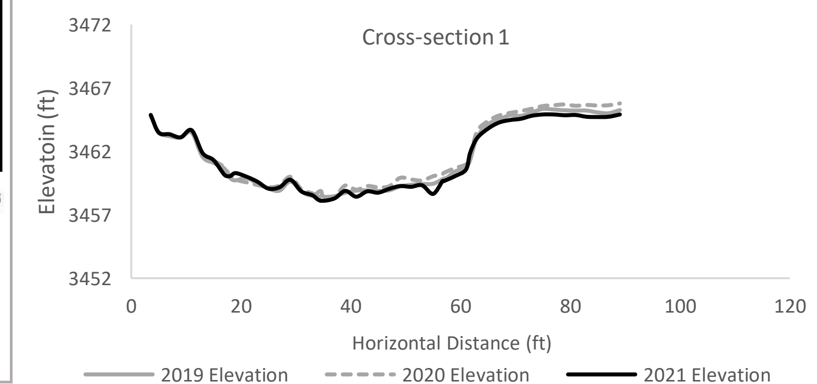












Appendix 3: Aquatic Macroinvertabrate Analysis

Figures by Sam Turner, University of Montana

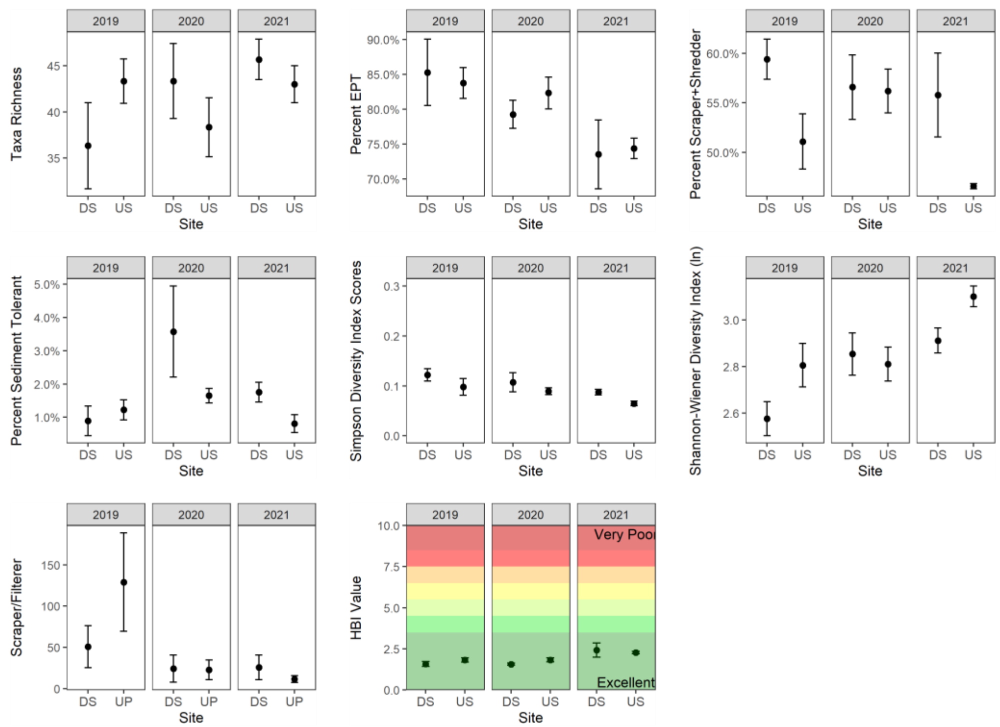


Figure 1: Plot of metrics chosen for site | year comparisons of BMI communities from 2019-2021 at Rattlesnake Creek, Missoula,MT.

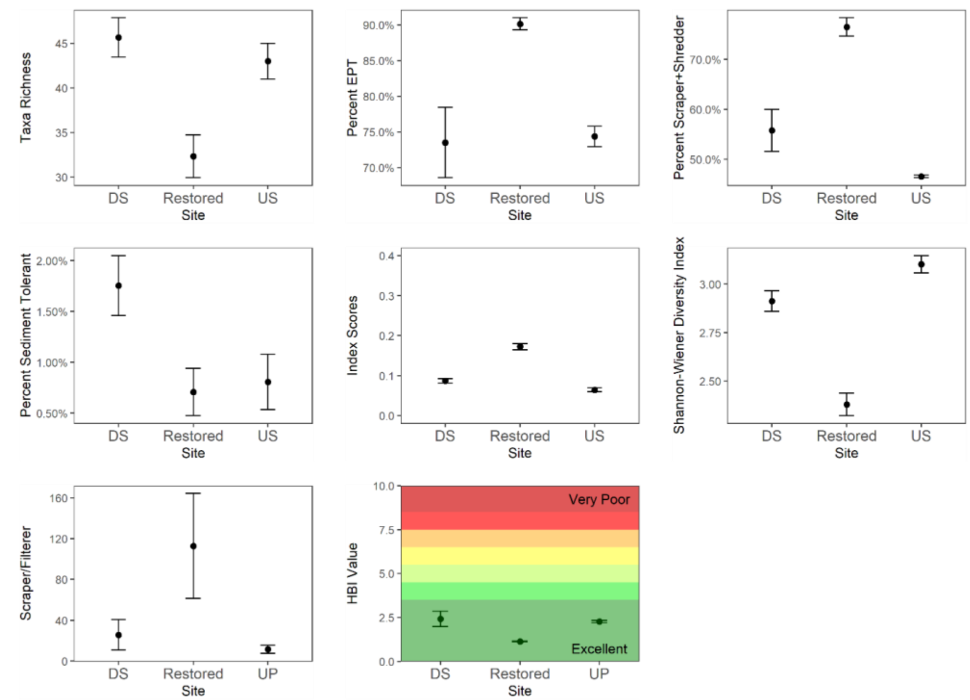
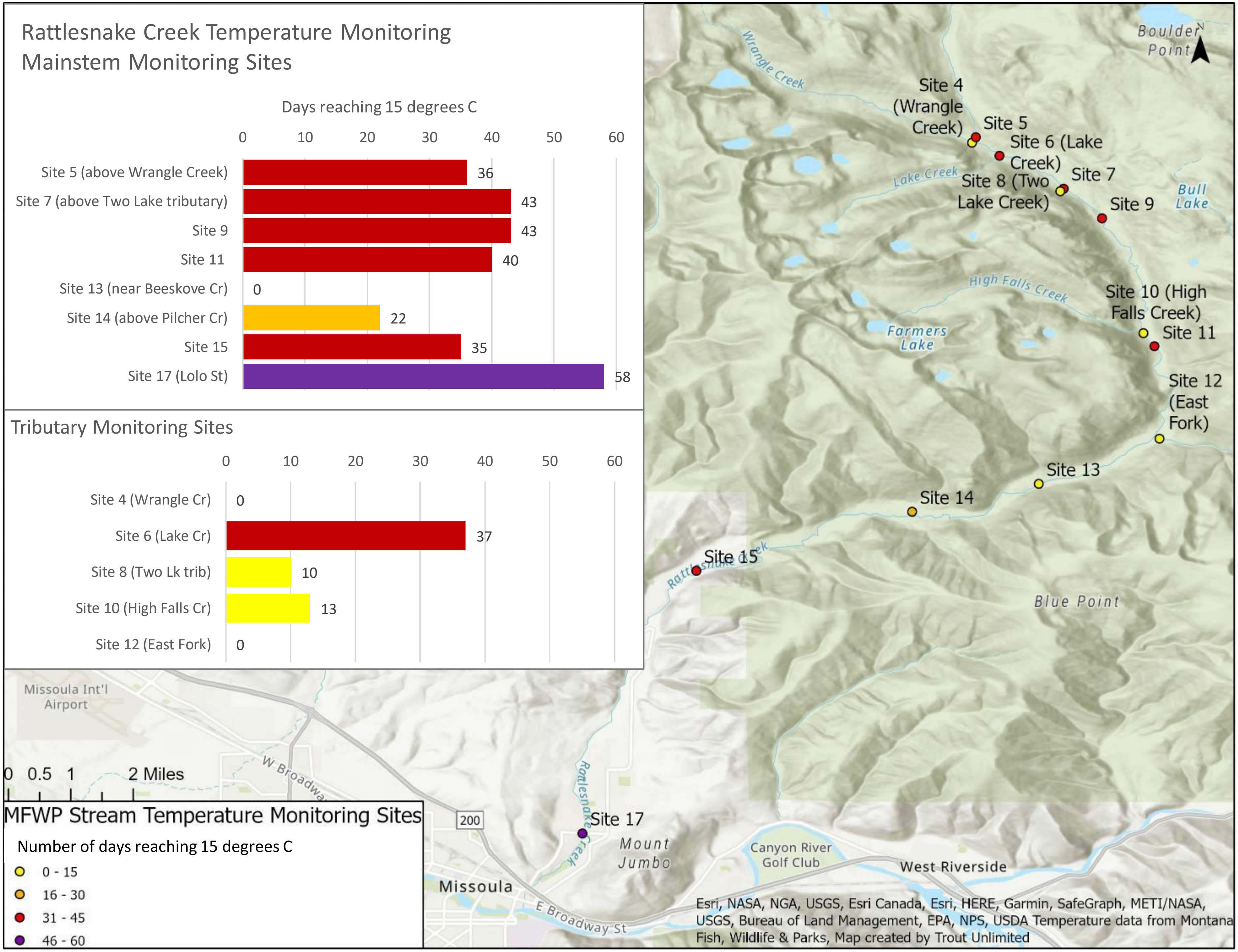


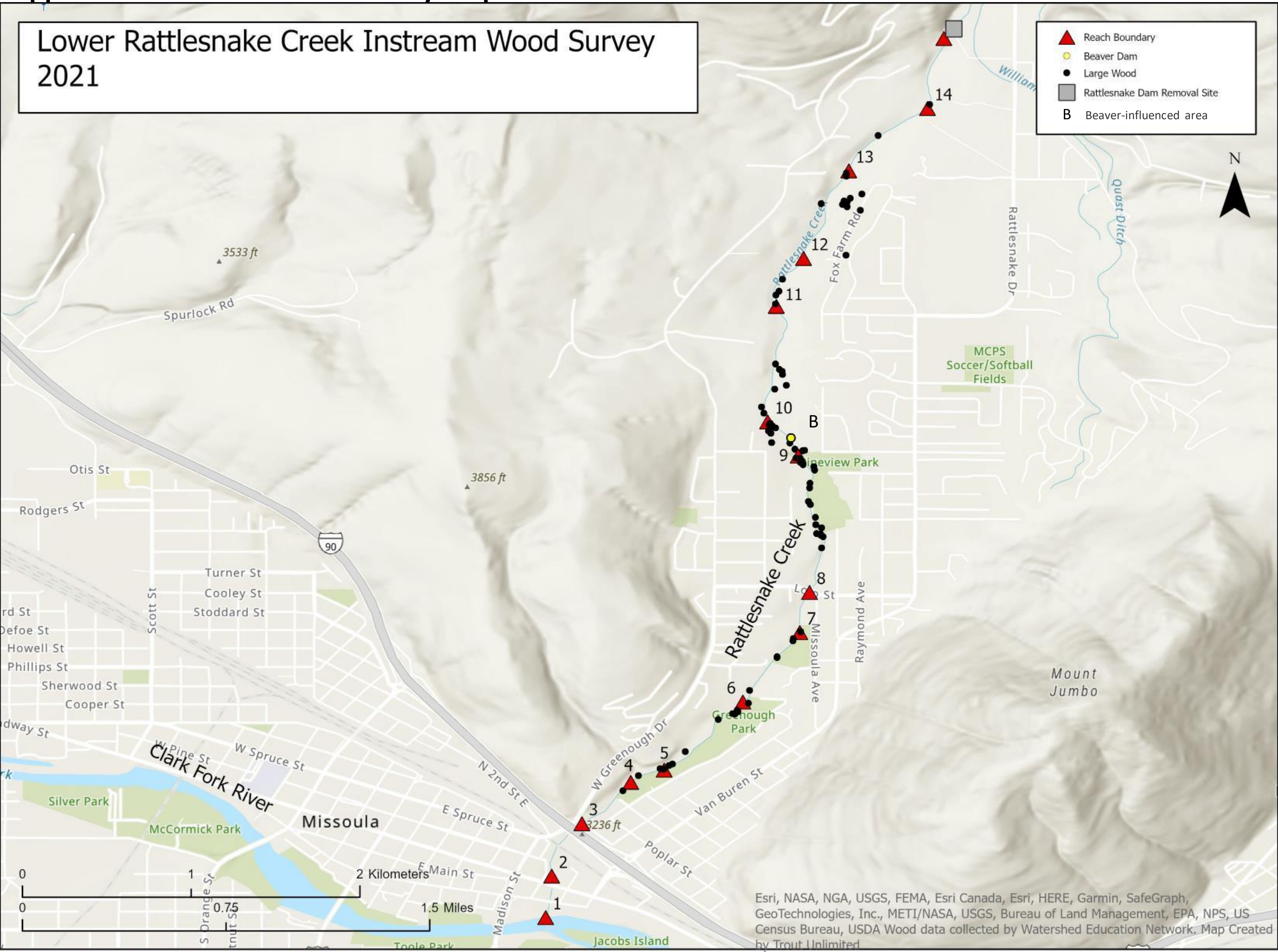
Figure 2Plot of metrics chosen for 2021 site comparisons of BMI communities at Rattlesnake Creek, Missoula,MT.

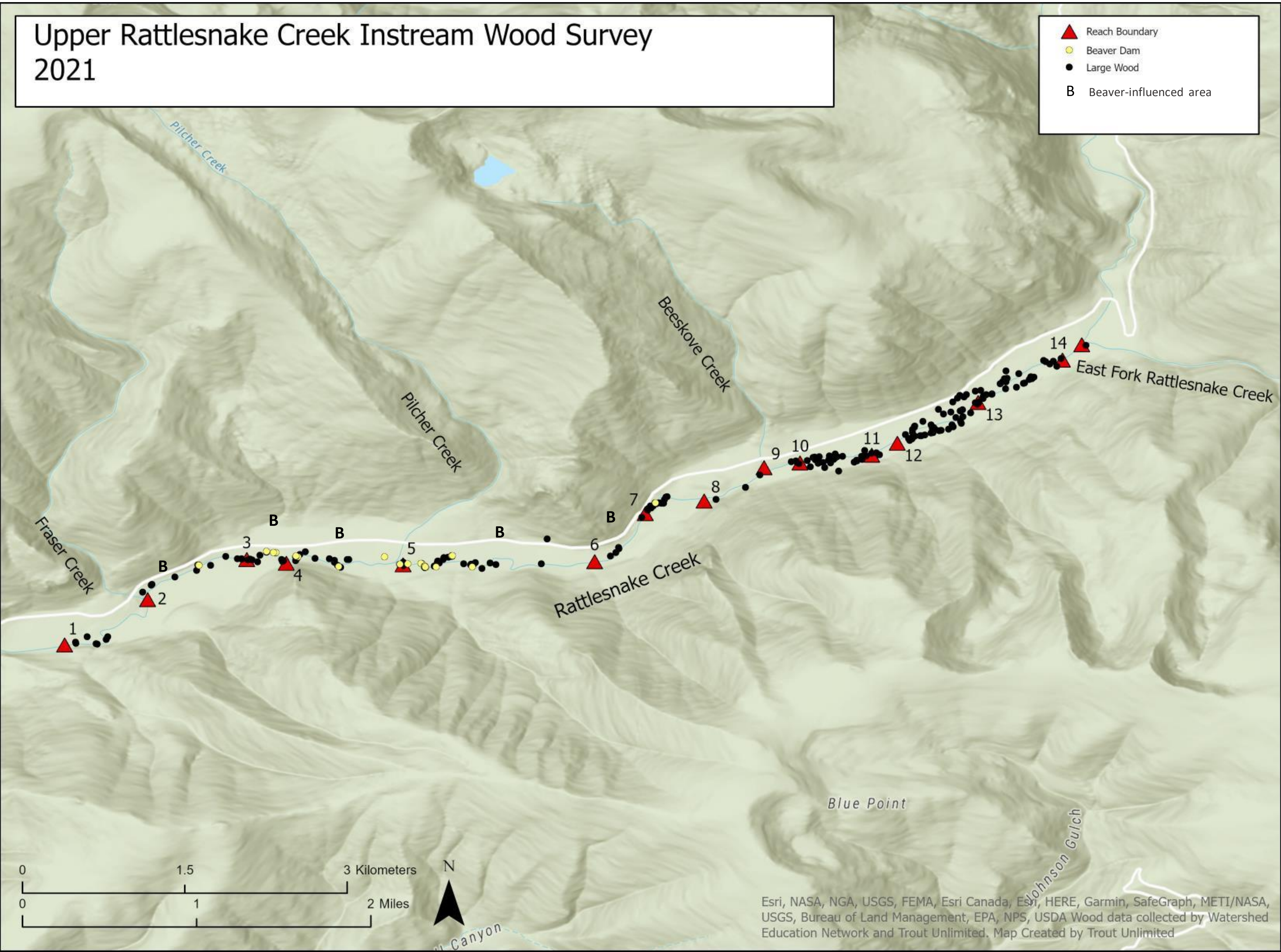
Category	Metric	Definition
Composition	Taxa Richness	Number of different taxa.
Composition	Percent EPT	Percent of the individuals in the sample that are mayflies, stoneflies, and caddisflies.
Function	Percent scraper+shredders	Percent of sample that are scrapers or shredders.
Sediment	Percent sediment tolerant	Percent of sample tolerant to sediment perturbation.
Function	Scraper/Filterer	Number of individual scrapers/shredders.
Diversity	Simpson Diversity Index	Measure of diversity that accounts for species and abundances.
Diversity	Shannon-Wener Diversity Index	Measure of diversity that accounts for species and evenness.
Biotic Index	Hilsenhoff Biotic Index	Measures relative sensitivity to nutrient perturbation.

Appendix 4: Rattlesnake Creek temperature monitoring



Appendix 5: Instream Wood Survey Maps





Upper Rattlesnake Creek Instream Wood Survey
2021
Reach Boundary
Beaver Dam
Large Wood
B Beaver-influenced area
Pilcher Creek
Beeskove Creek
Pilcher Creek
Fraser Creek
Rattlesnake Creek
East Fork Rattlesnake Creek
Blue Point
Johnson Gulch
1
2
3
4
5
6
7
8
9
10
11
12
13
14
B
0 1.5 3 Kilometers
0 1 2 Miles
N
Esri, NASA, NGA, USGS, FEMA, Esri Canada, Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA Wood data collected by Watershed Education Network and Trout Unlimited. Map Created by Trout Unlimited