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Associations Between Beaver Dam Complexes and Central Montana Prairie Fish Assemblages

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EXECUTIVE SUMMARY

In 2020 and 2021 we performed an assessment to evaluate prairie fish assemblages in areas with existing beaver complexes and those with no beaver complexes. We surveyed 9 sites in the Box Elder Creek drainage east of Lewistown. Four of the sites had active or remnant beaver structures present, while the remaining 5 sites did not have beaver structures. Sampling consisted of either seining or overnight sets of baited minnow traps, depending on site conditions. Analysis of the survey data indicates that beaver complexes appear to be beneficial to prairie fish assemblages in the area studied. There was a marginally significant difference in community composition based on beaver structure presence and metrics such as species of concern presence and prairie stream index of biotic integrity were higher in sites with beaver structures present. Metrics compared between the conditions suggest beaver complexes may be beneficial to prairie fish assemblages and at a minimum, not associated with declines in the metrics measured. These findings should be more thoroughly corroborated but provide some evidence that pursuing low-tech restoration practices in prairie streams is likely not detrimental, and possibly beneficial, to prairie stream fish assemblages with the broad caveat that the systems evaluated did not contain non-native piscivorous fishes.

INTRODUCTION

Prairie streams are often understudied and undervalued components of the broader landscape in central and eastern Montana. These systems can be oases of biodiversity and provide important cover habitat, water, forage, and movement corridors for terrestrial and aquatic organisms as well as livestock. Human modifications to prairie streams including channelization, impoundments, riparian grazing, pollution, and dewatering negatively impact prairie stream fish assemblages (Blann et al. 2022). In addition, prairie streams face challenges from the removal of beavers, competition from non-native fish species, and a changing climate (Blann et al. 2022, Stringer 2018). Habitat complexity in streams slows the flow of water and keeps it on the landscape for longer while building floodplain resilience to flood, drought, and fire (Blann et al. 2022, Wheaton et al. 2019). A loss of habitat complexity enhances flood events by reducing storage capacity and making prairie streams more susceptible to drying. Many prairie streams in central Montana are incised from degradation, unable to reach their floodplain in all but extreme flood events. Water that cannot escape the stream channel is transported quicky off the landscape and does little for fish or wildlife habitat.

Low-tech process-based restoration (LTPBR) is described as the process of using simple, low unit-cost, structural additions to riverscapes to mimic functions and initiate specific processes (Wheaton et al. 2019). LTPBR is becoming an increasingly popular way to repair degraded streams. LTPBR is lower cost than traditional stream restoration efforts because it lets the water do the work, uses materials that are often available on-site, and relies on manual labor rather than large equipment (Wheaton et al. 2019). Most of the interest in LTPBR in central Montana has been centered around Beaver Dam Analogues (BDA's). BDA's mimic the impact of beavers on a stream by slowing and spreading water across the floodplain. In eroded and incised streams, BDA's are intended to widen incised channels and/or accumulate sediment, enhancing or reestablishing channel-floodplain connectivity over time. As channel-floodplain connection improves and expands, there is a corresponding rise in the water table within the floodplain which gives riparian vegetation access to water, resulting in improved mesic and riparian habitats.

Research in the Pacific Northwest has indicated that BDA's can be beneficial to native salmonids (Weber et al. 2017, Davee et al. 2017, Bouwes et al. 2016, Pollock et al. 2003), but little work has been done to understand how BDA's impact prairie stream fish assemblages. Prairie streams in central Montana often go dry in stretches, and rapid recolonization during wet periods is essential to maintaining populations of prairie fishes in these waters. BDA's act as small, ephemeral dams in a stream, potentially impacting movement of fishes within the system. Another concern is that BDA's can create deeper water pool habitat that may be beneficial to undesirable non-native species such as northern pike, smallmouth bass, green sunfish, and common carp. These invasives, especially northern pike and smallmouth bass, can create havoc in small prairie streams, outcompeting and predating upon native fish and drastically reducing abundance and diversity within the system (Stringer 2018). There are also anticipated positive impacts of BDA's in prairie streams. BDA's keep stream reaches wetter for longer periods of time, reducing drought impacts and dry periods. BDA's also increase habitat complexity which is likely beneficial to fish diversity in prairie streams.

In central Montana, there is an ongoing and expanding effort to utilize LTPBR on degraded prairie systems. Numerous conservation entities are pursuing low-tech projects with limited understanding of potential impacts to prairie fish assemblages. Prior to further supporting and implementing low-tech restoration projects, it may be useful to evaluate existing fisheries conditions on the prairie landscape where beaver impacted streams are present. We attempted to address this issue by assessing prairie stream fish assemblages in areas within active or remnant beaver structures and in those without beaver structures. By gaining an understanding of how natural beaver activities correlate to prairie fisheries we hope to better understand the suitability and potential impacts beaver mimicry activities (e.g., BDA's) may have on prairie fish assemblages.

METHODS

Study Area: Box Elder Creek, an intermittent prairie tributary of Flatwillow Creek and the Lower Musselshell River, drains 3,033 km^2 of eastern Fergus and southwest Petroleum counties. The headwaters occur throughout the Judith Mountains and in foothills of the Big Snowy Mountains. Many of the headwater streams are perennial and generally provide cold/cool-water habitat above elevations of 1,370 m. Once beyond the mountain foothills, the landscape transitions to arid rolling hills and mixed shrub/grasslands. Most of the streams transition to warm-water systems between elevations of 1,370 and 1,220 m. Many of the drainages become intermittent below 1,220 m. Land use of the study area is primarily livestock rangelands, although some hay and grain crop production does occur. Many of the tributary streams contain onstream stock water impoundments and there is some irrigation infrastructure that impounds and diverts water from the active waterways. Our study sites occurred on reaches of eight tributary streams in the Box Elder Creek drainage. Study sites occurred at an elevation range of 1,189 m to 964 m.

Site Selection: Initial screening of potential central Montana prairie streams was performed by inspecting aerial imagery for existing beaver dam complexes within the eastern portion of the Lewistown Management Area. Additional sites in areas without beaver dam complexes were selected based on access and apparent lack of beaver dam influence. Site selection was not randomized. All sites selected were located on the eastern slope of the Judith Mountains and all streams were tributaries of Box Elder Creek in an effort to minimize drainage to drainage variations in species assemblages (Figure 1). The drainage area of each site was measured. Table 1 provides a summary of the sites sampled.

Fish Collection: In most cases fish were sampled via baited minnow traps. Minnow traps were utilized as aquatic vegetation density made the use alternative gear types (e.g., seine or backpack electrofishing) inefficient. Minnow traps measured 25.4 cm long by 22.9 cm diameter and were a two-piece design with a spring clip closure. Entrance holes at each end of the trap measured approximately 2.54 cm in diameter. Bait consisted of approximately 240 ml of dry dog food. Eight traps were set non-randomly throughout the sampling reach. All traps fished for a single night. Samples on Fords Creek were collected via a bag seine as environmental conditions accommodated the use of seining. The seine measured 9.1 m x 1.8 m with a 1.8 m x 1.8 m x 1.8 m bag. The mesh size measured 6.4 mm.

Fish were collected from the traps or seine and placed in holding containers. Sampled fish were identified to species and quantified. In instances where identification was uncertain, specimens were stored in ethanol and returned to the laboratory for identification. Length was measured on ten randomly selected individuals of each species. When fewer than ten individuals of a species were sampled, all fish were measured.

Data Analysis: Site characteristics, community composition and Prairie Stream Index of Biotic Integrity (IBI) were analyzed. The drainage area of each site was analyzed by a T-test.

Community composition was assessed by applying a Bray-Curtis measure of dissimilarity (Bray and Curtis 1957) to the square root transformed abundance of species present at each location. The square root transformation was applied to reduce bias towards the most frequent species. A permutational multivariate analysis of variance (PERMANOVA; 999 permutations) was applied to the Bray-Curtis measures to assess statistical significance. To assess the species contributing to the Bray-Curtis dissimilarity measures between treatments, a similarity percentage (SIMPER) test was used to measure the contribution of individual species to the overall dissimilarity measure. This test measures the influence of each species to the variation of the Bray-Curtis measure and can be strongly confounded by the contribution of between treatment differences and within treatment variation. The p-values associated with the SIMPER test are a measurement of the probability of getting a larger or equal species contribution to the Bray-Curtis measure in 999 random permutations of the treatment factor.

IBI scores were calculated as described in Bramblett et al. 2005. The metrics of the IBI consider native origin, relative abundance, general tolerance, trophic category, general feeding habits, and reproductive strategy. The IBI scores are also adjusted for watershed size. Differences in IBI scores between the treatments were assessed using a T-test.

All statistical tests were measured against a 95% level of significance and were performed in RStudio 2021.09.2 Build 382.

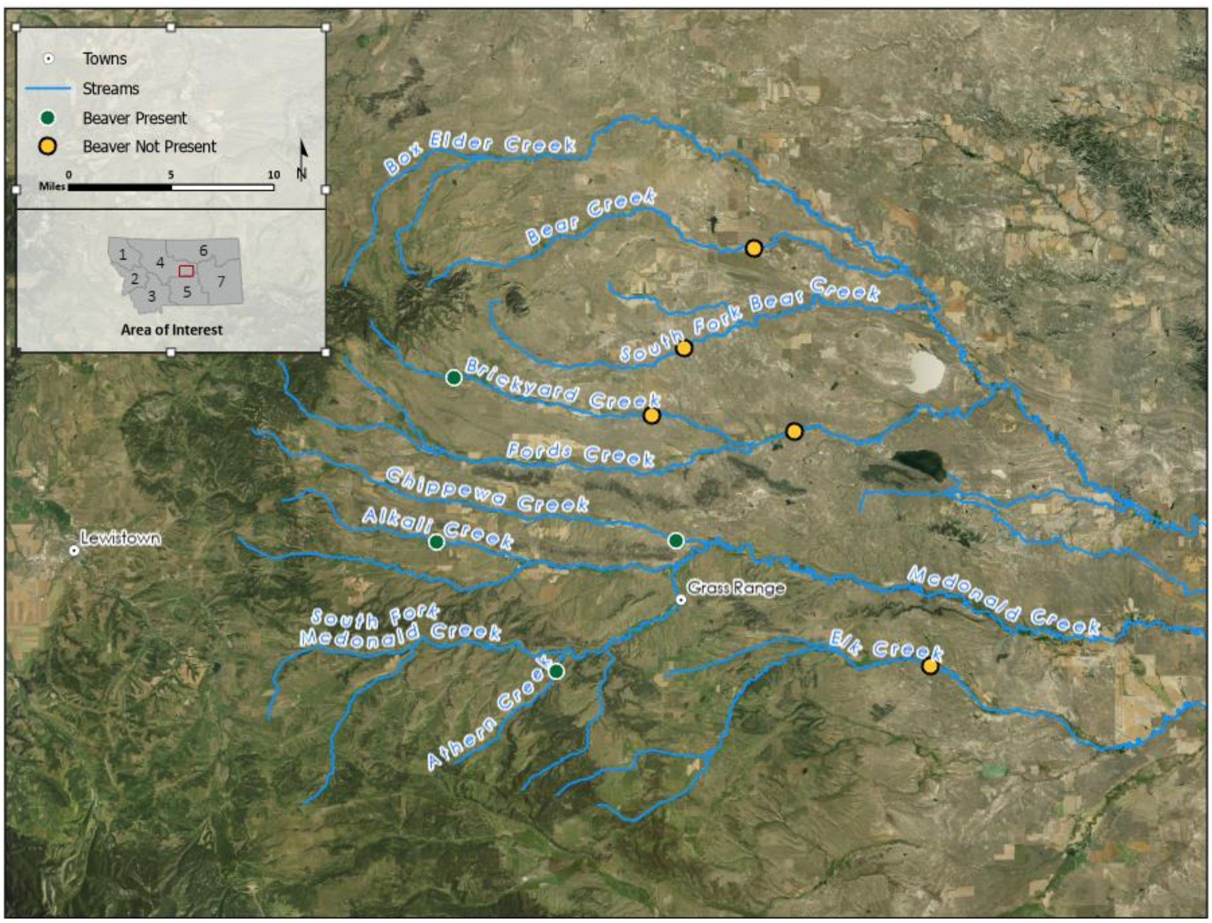

Figure 1. Map showing study area and sampling locations.

Table 1. Summary of sampling locations.

Waterbody	Section	Beaver Presence	Drainage Area (km^2)	Lat/Long
Alkali Creek	15 Mile State Section	Yes	40.1	47.06774, -109.05485
Athern Creek	Dixon Road State Section	Yes	31.6	46.97576, -108.93308
Bear Creek	State Section	No	186.5	47.27304, -108.72456
Brickyard Creek	Box Elder Lane	No	95.6	47.15528, -108.83144
Brickyard Creek	Black Butte Road	Yes	22.0	47.18302, -109.03571
Chippewa Creek	Chippewa Creek Road	Yes	127.9	47.06758, -108.80737
Elk Creek	Elk Ck Road State Section	No	220.7	46.97681, -108.54714
Fords Creek	Blakeslee Road State Section	No	397.3	47.14359, -108.68467
South Fork Bear Creek	Highway 19	No	104.9	47.20271, -108.79804

RESULTS

The mean drainage area of sites with beaver structures (55.4 km^2) was significantly lower than the sites without beaver structures (201 km^2; $p = 0.05$). This difference highlights the fact that site selection was not randomized and is likely an artifact of where beaver populations persist on the landscape (i.e., higher in the drainage networks). There are numerous potential reasons for this including stream power, level of incision, degree of degradation, degree of intermittence, and social tolerance, although such characteristics were not assessed in this study. Fish were captured at all sites tested. Ten species were sampled, eight of which are native to Montana. The number of fish collected by site differed substantially, ranging from 14 individuals at South Fork Bear Creek to 1,540 individuals collected at Fords Creek (Table 2). Northern Redbelly Dace, a Montana species of concern (SOC), and Brassy Minnow, a Montana potential species of concern, were collected. No non-native piscivorous species were captured.

Species assemblage and relative abundance at each site tested is summarized in Figure 2. Given the relatively small sample size and likely due to the diverse nature of the habitat available at the test sites, there was substantial variation in both species abundance and presence among the sites. The Bray-Curtis test of dissimilarity on the species composition between sites with beaver structures and those without beaver structures present was marginally statistically significant ($p = 0.09$). The results of the SIMPER analysis provide useful insights to the most influential species on the Bray-Curtis test (Table 3). The most influential species were Lake Chub (21.2%), Northern Redbelly Dace (17.8%), Fathead Minnow (13.8%), Longnose Dace (11.8%), and White Sucker (11.6%). The SIMPER analysis is heavily weighted by variation in species abundances and only partly by differences among the treatments. This attribute likely accounts for much of the degree of influence from Lake Chub, Longnose Dace,

Table 2. Attributes and count of fish collected by sampling site. Species abbreviations in table are BSMN – Brassy Minnow, BKSB – Brook Stickleback, CARP – Common Carp, FHMN – Fathead Minnow, GSUN – Green Sunfish, LKCH – Lake Chub, LNDC – Longnose Dace, NRBDC - Northern Redbelly Dace, SDSH – Sand Shiner, and WSU – White Sucker.

Waterbody	Section	Beaver Presence	BSMN	BKSB	CARP	FHMN	GSUN	LKCH	LNDC	NRBDC	SDSH	WSU	TOTAL
Alkali Creek	15 Mile State Section	Yes	365	-	-	31	9	88	14	281	-	35	823
Athern Creek	Dixon Road State Section	Yes	-	-	-	5	-	69	30	12	-	66	182
Bear Creek	State Section	No	2	63	-	129	-	3	-	-	-	4	201
Brickyard Creek	Box Elder Lane	No	-	-	-	57	-	74	6	-	-	36	173
Brickyard Creek	Black Butte Road	Yes	1	-	-	2	-	27	-	50	-	19	99
Chippewa Creek	Chippewa Creek Road	Yes	8	8	-	9	4	32	14	2	10	26	113
Elk Creek	Elk Ck Road State Section	No	-	-	-	45	-	6	161		3	109	324
Fords Creek	Blakeslee Road State Section	No				55		1285	55			145	1540
South Fork Bear Creek	Highway 19	No	2		5		5	1				1	14

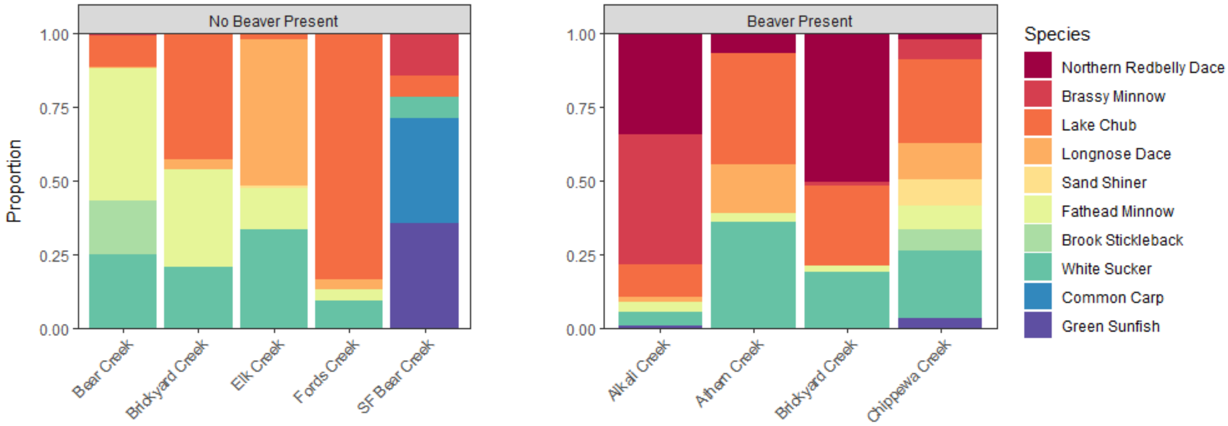

Figure 2. Stacked bar graphs showing proportional species composition at each sampling location. Left panel includes sites without beaver structures present. Right panel includes sites with beaver structures present.

and White Sucker. The influence of Northern Redbelly Dace and to a lesser extent Fathead Minnow, appear to be more strongly linked to differences among treatments when their influence is considered against the differences in mean relative abundance (Figure 3). A permutation test of the SIMPER analysis identified only Northern Redbelly Dace as statistically different between treatments ($p = 0.01$). Generally, Northern Redbelly Dace and Brassy Minnow were more common in sites with beaver structures present while Fathead Minnow, Common Carp, and Green Sunfish were more common in sites without beaver structures present.

The Prairie Stream IBI was used to assess the relative quality of sample sites based on the abundance and type of species observed. Based on the data collected in this study, central Montana prairie streams with beaver structures present had higher IBI scores than those without beaver structures (Figure 4; $p = 0.02$). While the IBI scores are relative only to the sites sampled, they do suggest that streams with beaver structures have more intact components of high-quality, functioning prairie systems than those without.

DISCUSSION & MANAGEMENT IMPLICATIONS

The findings from this study suggest that beaver presence on the landscape is associated with improved prairie fish community composition, increased biodiversity, and higher levels of IBI. At least among the sites we tested, prairie systems appeared to be healthier, more intact, and more often occupied with Montana SOC when beaver associated structures were present. Our study did not attempt to decipher the mechanisms for these differences in fish assemblage, but anecdotally streams in the beaver treatment appeared to have higher levels of habitat diversity and complexity. Additionally, beaver complexes likely act as sources to stream segment sinks in the prairie systems we studied, providing long-term connected water storage on the landscape that doesn't exist in degraded prairie systems, similar to the process described in Schlosser, 1995. A major concern regarding beaver ponds and associated habitats is that they are beneficial to piscivorous non-native fish, such as brook trout and northern pike, that are known to be detrimental to prairie assemblages in Montana (Stringer 2018). We did not capture piscivorous fish in our study, possibly due to gear bias or actual absence.

Table 3. Similarity percentage (SIMPER) analysis results of Bray-Curtis test on species contribution to observed differences in species assemblage between sites with beaver structures present and those without.

Species	Mean % Contribution	Permutation *p* - Value
Lake Chub	21.22	0.692
Northern Redbelly Dace	17.77	0.009*
Fathead Minnow	13.78	0.267
Longnose Dace	11.80	0.844
White Sucker	11.59	0.698
Brassy Minnow	11.01	0.231
Brook Stickleback	5.93	0.832
Green Sunfish	3.39	0.514
Common Carp	1.95	0.627
Sand Shiner	1.56	0.773

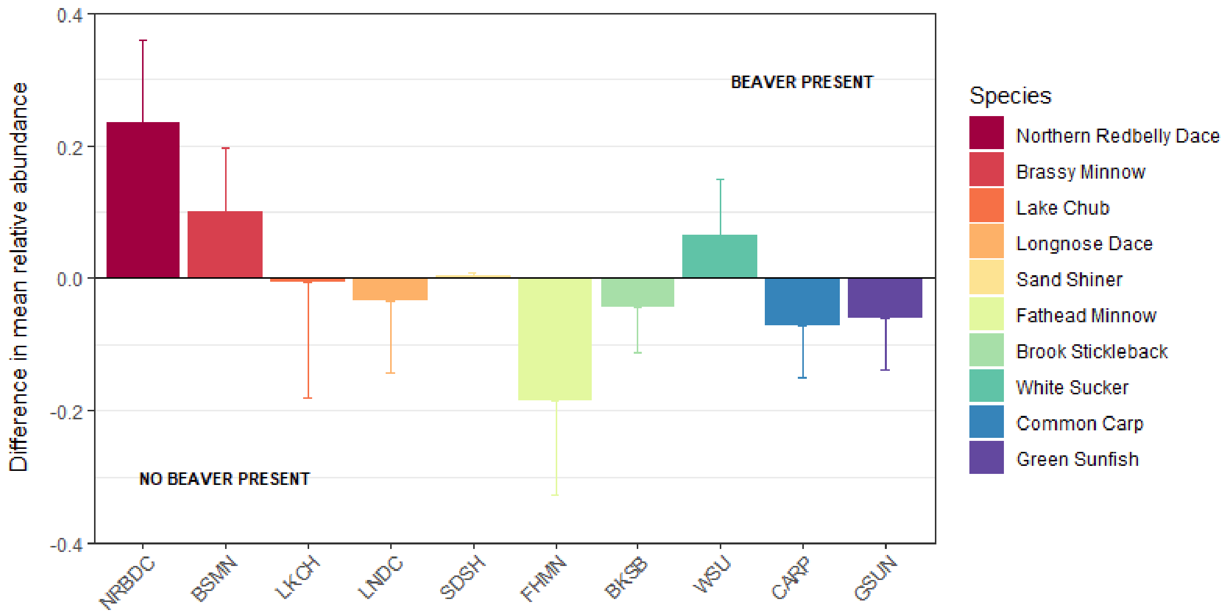

Figure 3. Bar chart showing difference in mean relative abundance by species among sites with and without beaver structures present. Bars above the zero line were more prevalent in sites with beaver structures present. Bars below the zero line were more prevalent in sites without beaver structures present. Error bars represent 1 standard deviation from the mean.

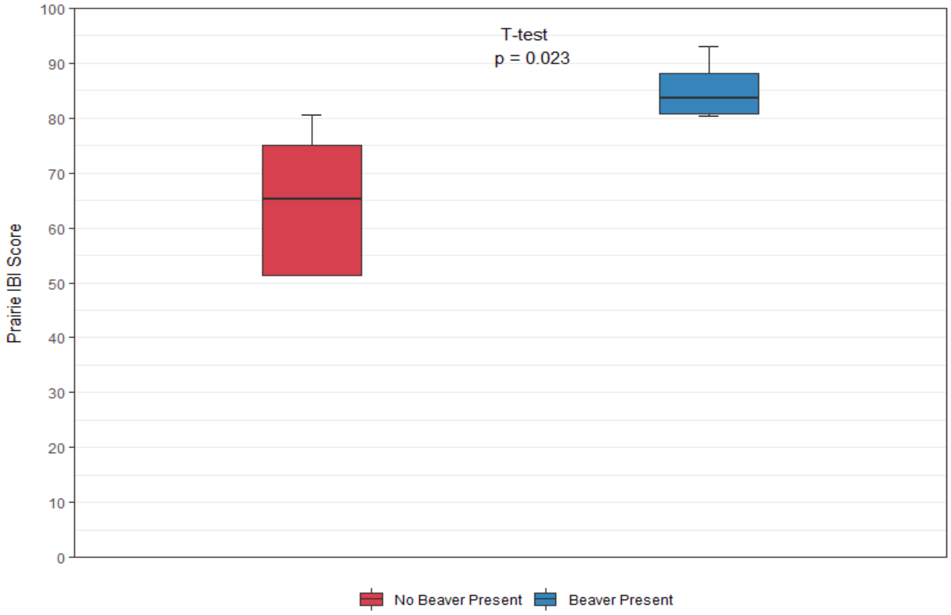

Figure 4. Boxplots showing calculated Prairie Stream Index of Biotic Integrity (IBI) scores among sites with and without beaver structures present.

Our findings suggest that low-tech restoration efforts that increase channel complexity and mimic beaver activity are likely beneficial to prairie fish assemblages. Degraded prairies systems are commonly entrenched, lack habitat diversity and have little floodplain connection. These streams currently function as intermittent systems and may entirely dry up during periods of prolonged drought. Hence, they are dominated by the more tolerant, habitat generalists that are able to persist in degraded habitats and recolonize when conditions are suitable. Certainly, some of the prairie systems in central Montana have existed as intermittent streams for centuries, however, some have likely been converted from perennial, more resilient streams as a consequence of anthropogenic alterations on the landscape. Based on the comparisons made in this study, it would appear that encouraging beaver occupancy and riverscape development would create more resilient prairie systems and aquatic biodiversity would benefit.

A major caveat of our study and point of discussion regarding the potential expansion of low-tech restoration projects is how non-native piscivorous fish may be impacted from such work. The results from this study suggest that in the absence of non-native predators, prairie fish assemblages appear to be more intact, support Montana SOC, and provide higher quality fisheries where beaver structures occur. It has been documented that trout, Northern Pike, and Smallmouth Bass can negatively impact prairie stream fish assemblages, primarily via predation (Stringer 2018, C. Smith, *unpublished data*). There is concern that promoting low-tech restoration may inadvertently benefit such predatory species thereby putting prairie fish assemblages at even greater peril.

Trout are likely not a concern in prairie stream systems due to typical thermal regimes of such systems. Northern Pike, Smallmouth Bass, and possibly other undesirable species may experience increased abundances and range expansion if low-tech restoration projects increase available suitable habitat. This could occur by both increasing the persistence of water on the landscape (i.e., streams become less intermittent) and by increasing available pond-like habitats through BDA's. Such risks are real and should not be dismissed. However, the results from this study suggest potential benefits of low-tech restoration to prairie systems. The creation of improved habitat conditions and pushing systems towards more natural function and process has the potential to create resiliency of prairie systems on the landscape. Based on our study, such efforts may be anticipated to increase the dispersion, abundance, and quality of intact prairie assemblages. There is strength in redundancy on the landscape. Restoring degraded systems and conserving prairie streams to function more naturally could benefit prairie fish overall and create more sources of prairie fish populations to disperse and recolonize areas negatively impacted by predation. On some localized scales, non-native predators may establish and negatively impact communities, but if there were many functioning areas throughout a watershed, these localized impacts could be overcome by the broadscale resiliency of healthy prairie populations.

An additional component to consider is how low-tech structures and the habitat complexes they are meant to induce may function as passage barriers. Much of the risk of non-native predatory fish in central Montana comes from established populations in the lower portions of the drainages, where some perennial prairie rivers support them. Upstream invasion of non-native predatory fish may be inhibited by instream barriers such as beaver dams and complexes, but this hypothesis requires testing. Additionally, the temporary nature of low-tech structures and associated habitats and stochastic events such as drought could create environmental conditions that may not be suitable for non-native predatory fish to persist. This is an area of low-tech restoration in prairie systems where non-native predatory fish may be a concern that warrants further investigation. It is our opinion that having plentiful functioning prairie streams with occasional predatory impacts would be more beneficial than having lots of degraded systems, minimally supporting prairie fisheries, that also occasionally suffer from the same predatory impacts. If non-native predatory fish are deemed a substantial risk to prairie stream fisheries, it may be appropriate to attempt removal efforts prior to implementing restoration activities.

It should also be acknowledged that low-tech restoration is not a silver bullet and shouldn't be considered as the perfect antidote for more than a century of degradation and manipulation of the landscape. There are certainly situations where the approach isn't appropriate, either due to the persistence of sensitive populations, risk of non-native expansion, ineffectiveness of the approach to the local conditions, or uncertainty of potential outcomes.

Anecdotally, central Montana prairie systems that contained beaver structures were oases of biodiversity, especially when compared to the other sites we visited. Waterfowl, songbirds, predatory birds, wading birds, mammals, amphibians, and reptiles clearly benefitted from the habitat diversity and complexity associated with beaver complexes. While challenges and caveats exist, this study suggests efforts that attempt to recreate beaver influence on prairie streams and restore associated natural processes may be beneficial to central Montana prairie fish assemblages.

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