Monitoring Wetland Expansion Behind Campbell Valley's In-Stream Structures

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Honors Thesis

Introduction

As demand for water intensifies across the Front Range, so has focus on existing water quality. The North Poudre Irrigation Canal's construction is a testament to Livermore, Colorado's agricultural history. Over an eight-year period, canal builders in the early 1900s diverted the irrigation water through a channelized Campbell Creek, gouging out 12- meter deep gullies. Today, Campbell Creek, which runs through the 6,852-hectare Robert's Ranch, carries a high sediment load compared to surrounding streams. Erosion from stream channelization has resulted in nearly 3.7 million cubic meters of soil loss from Robert's Ranch into the agricultural systems downstream and has destroyed 4.8 kilometers of riparian habitat. (Boschmann 2020). Leaky Creek, the main channel of the gully that begins just south of the North Poudre Irrigation Canal, follows a steepness grade approaching 3.4% and flow rates of .085-.142 cubic meters per second, while the previous reach of Campbell Creek, branching westward from a point further downstream, has only a 1% grade and a .028 cubic meter per second flow rate. (Boschmann, 2024). Long-term restoration efforts by Wildlands Restoration Volunteers (WRV) since 2009 have slightly lessened the stream's grade in key areas with wicker weirs, induced meandering structures, rock riffles, and low-tech process-based restoration (LTPBR). With its novel path, grade, and flow regime, Campbell Creek has been the subject of various monitoring reports focusing on a range of attributes of the riparian zone related to vegetation species diversity.

This report's purpose is to help the managers at Robert's Ranch and Wildlands Restoration Volunteers decide whether to include grazing exclosures for wetland plant establishment at BDA sites. Results from this report can help guide strategic decisions of where to put future in-stream structures. This report attempts to assess the extent to which artificial in-stream structures installed by WRV in 2017-2019 have succeeded in spreading out the wetland spatially from previous years. Specific objectives are to (1) infer the effects of temporary grazing exclosures on wetland plant occurrence; (2) develop a method for measuring wetland occurrence using existing data collection protocol; (3) record vegetation on a species level when possible to classify species appropriately into functional groups; and (4) compare wetland coverage for grazed and ungrazed areas behind in-stream structures. These objectives will help meet the broader management goals of maintaining cattle on Robert's Ranch in perpetuity while allowing for the conservation of important wildlife species. To meet these objectives, the following three research questions were asked:

(1) Which species most frequently occur behind BDAs at Robert's Ranch?

(2) Does the cover of wetland vegetation behind BDAs inside exclosures differ from wetland vegetation cover behind BDAs outside exclosures?

(3) Do bare ground and litter cover between fenced and unfenced areas?

We hypothesized that fencing off BDAs will allow for a greater frequency of wetland species by reducing grazing pressure. Since the summer of 2024 was dry and cattle were allowed to stay in the riparian zone for longer, trampling left swaths of bare ground, especially at key entry points to the riparian zone. Additionally, multiple fences meant to exclude cattle were broken, allowing cattle to enter the exclosures and consume vegetation within fenced-off areas. We expected to find resilience to these disturbances in formerly fenced areas in the form of higher species richness of wetland vegetation. Heavily grazed areas will have fewer wetland plants. We also expected litter cover to be greater inside of fenced areas, providing the cool, moist conditions necessary for wetland plant recruitment, and we expected to see greater percent bare ground in unfenced areas due to increased grazing pressure.

Site Description

The sites surveyed for Robert's ranch are located along Campbell Creek, in Livermore, Colorado (40°47'34"N 105°09'16"W), at an elevation of 1694m. Using aerial imagery from 1975, Colorado Natural Heritage program classified the area as a seasonally flooded riverbed. While the Campbell Valley plots are only 22 km north of Fort Collins, driving to the site takes over an hour in a high clearance vehicle. Robert's Ranch is an operating cattle ranch that practices rotational grazing. It is also a conservation easement founded by The Nature Conservancy, owners of the ranch, Fort Collins Natural Areas, Great Outdoors Colorado, and Larimer County.

Landforms on the ranch include drainageways, foothills, and hogbacks. The areas we surveyed have soils under the Connerton-Sylvandale complex. Erosion hazards in the square-kilometer area enveloping the site are classified as low away from roads (USDA NRCS web soils survey). Annual precipitation ranges from 254-889 mm, with high variation between years. The growing season receives 60-75 percent of yearly precipitation. When intense precipitation occurs, erosion mitigation structures further upstream in Campbell Valley have been washed out (Boschmann, personal communication). Abundant species include *Hesperostipa comata* (needle and thread), *Bouteloua gracilis* (blue grama), *Pascopyrum smithii* (western wheatgrass), *Cercocarpus montanus* (mountain mahogany), *Eriogonum effusum* (spreading buckwheat), and *Rhus trilobata* (three-leaf sumac) in the upland areas, with *Carex aquatilis* (water sedge), willows (*Salix spp.)*, horsetails (*Equisetum spp.*), rushes (*Juncus spp.*), *Populus angustifolia* (narrowleaf cottonwood) and *Populus deltoides* (plains cottonwood) species around gullies and riparian zones. Arroyos and smaller gullies on the site are highly exposed and heavily trodden by cattle to access Campbell creek. According to the Loamy foothills reference community, rills and pedestaled plants are rare and only occur in heavily eroded sites, but here they are common at gully edges.

BDAs are meant to slow water on its way downslope spreading out the groundwater to support more wetland plant species that become self-sustaining erosion control systems over time. In Robert's Ranch, we focused on seven key areas, all upstream from semi-permanent in-stream log structures known colloquially as beaver dam analogs (BDAs). Three of the structures were outside of fenced areas, while four were inside of exclosures (Figure 2).

Field Methods

To best assess cover of vegetation, litter, and bare ground, field methods closely followed the protocol outlined by Grinstead et al (2018) and amended by Rose et al (2019). Ten-meter base transects were extended along both sides of the stream following its curves, with the lowest value of the transect tape at the in-stream structure and the highest value furthest upstream. From this baseline transect, three ten-meter transect tapes were pulled outward perpendicular from either stream bank at the zero, five, and ten-meter marks of the baseline, for a total of six measured transects (Figure 1). Photopoints were taken (A) from the BDA facing upstream; (B) from 10 m upstream of the BDA facing downstream; (C) from the middle transect on the north side of the stream facing the opposite transects; and (D) from the middle transect on the south side of the stream facing the opposite side transects (See Appendix A for a diagram of plot photos). Measurements taken along each transect included: (1) absolute cover estimates within 20x50cm frame subsamples; and (2) vegetation and substrate (litter and bare ground) cover using line-point intercept (LPI). Measurements were taken at 1-meter intervals. Line-point intercept measurements always started at zero, or point with the nearest vegetation to the stream, while Daubenmire frames started at a random point between 0 and 100 cm.

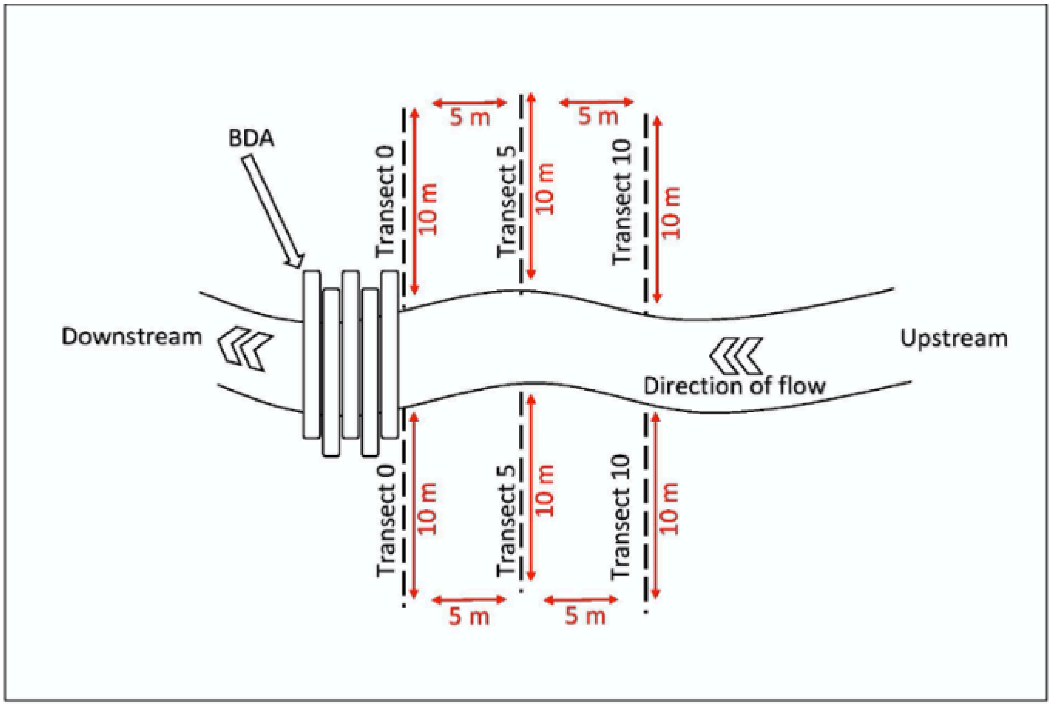

Figure 1. A diagram of plot setup showing positions of each transect. The transects should extend perpendicular from the stream bank and may not be parallel to each other.

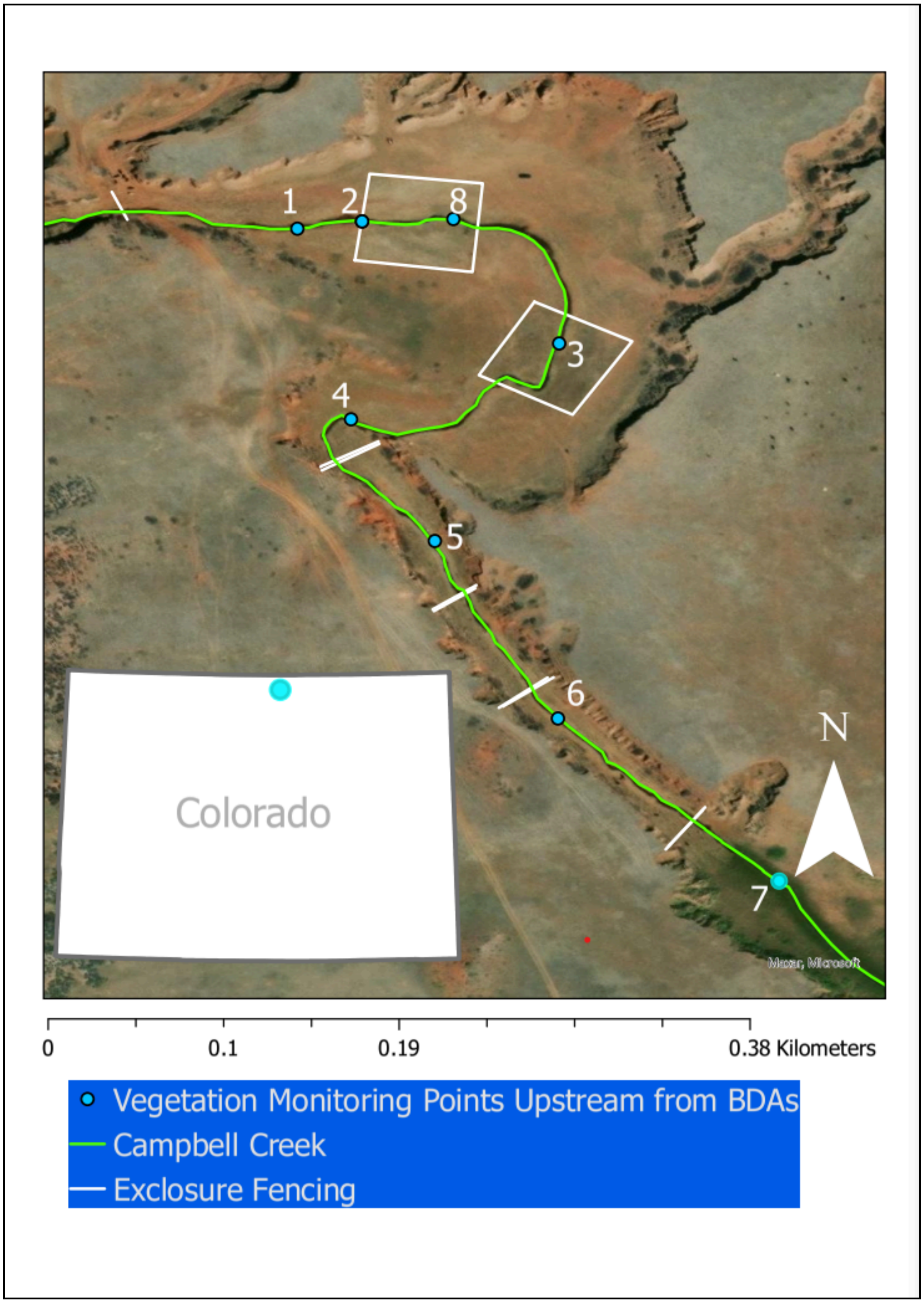

Figure 2. Locations of the seven permanent sampling units, plus the addition of an eighth in the square exclosure furthest to the right. BDA 8 was sampled in place of BDA 1 in 2024. Adapted from Rose et al (2019). Campbell creek flows from northwest (left) to southeast (right).

Calculations

Percent of wetland cover for each plot was calculated by dividing the number of frames deemed "wetland" in each plot by the total number of frames in the plot. Frames that met both of the following criteria were counted as wetland: 1) they had a Wetland Index greater than or equal to 0.50 and 2) They had bare ground less than a Daubenmire class 4 (less than 37.5 percent bare ground). To calculate the Wetland Index of each frame (Table 1), each species was assigned a probability of being found in a wetland when it occurs, known as a wetland indicator value (WIV). The WIVs used in this 2024 study come from a combination of species lists for the "Great Plains" and "Western Mountains, Valleys, and Coast" regions, which can be found on the Army Corps of Engineers website. Each species' WIV was multiplied by its estimated percent cover (based on the midpoint of its cover class range). Then, the resulting wetland indices were totaled for each species by frame.

In using a wetland index, this study aimed to emulate Coles-Ritchie et al's (2007) strategy to compare fenced and unfenced areas. Coles-Ritchie et al used a different wetland index to compare fenced and unfenced rangeland plots near wetlands that was also based on wetland indicator values. When a species was not known or where wetland indicator values were not defined by the Corps of Engineers regional species lists, we made an educated guess based on available information. In cases where plants appeared on both of the lists examined, we used the higher WIV. Wetland indicator values of taxa found in both fenced and unfenced areas can be found in Appendix C. Student's t-tests were used to evaluate differences in wetland cover between fenced and unfenced BDAs, and differences were considered significant when $P < 0.05$.

Table 1. Army Corps of Engineers Wetland Indicator Values (WIV) that were assigned to species found in Campbell Valley, Livermore, Colorado (40°47'34"N 105°09'16"W). Adapted from Coles-Ritchie et al. (2007).

Symbol	Meaning	probability of plant's habitat being wetland
OBL	Obligate	99.5
FACW	Facultative wetland	83
FAC	Facultative	50
FACU	Facultative upland	17
UPL	upland	0.5

Results

A total of 95 unique taxa were identified across the plots. We found a total of 66 species in unfenced and 70 species in fenced plots, with 41 species shared between the two treatment types.

Table 2. Most frequently occurring species found in Daubenmire frames. Data collected in Robert's Ranch, Livermore, Colorado, August-October, 2024.

Rank	USDA Code	Scientific Name	No. of frames observed
1	PASM	*Pascopyrum smithii*	233
2	MURA	*Muhlenbergia racemosa*	188
3	COAR	*Convolvulus arvensis*	183
4	POPR	*Poa pratensis*	112
5	BRIN2	*Bromus inermis*	70
6	CIAR4	*Cirsium arvense*	68
7	TAOF	*Taraxacum officinale*	67
8	EQAR	*Equisetum arvense*	59
9	MEAL	*Melilotus albus*	50
10	SYMPH	*Symphiotrichum* sp.	50
11	CAAQ	*Carex aquatilis*	45
12	CAREX4	(unknown sedge)	37
13	MELU	*Medicago lupulina*	35

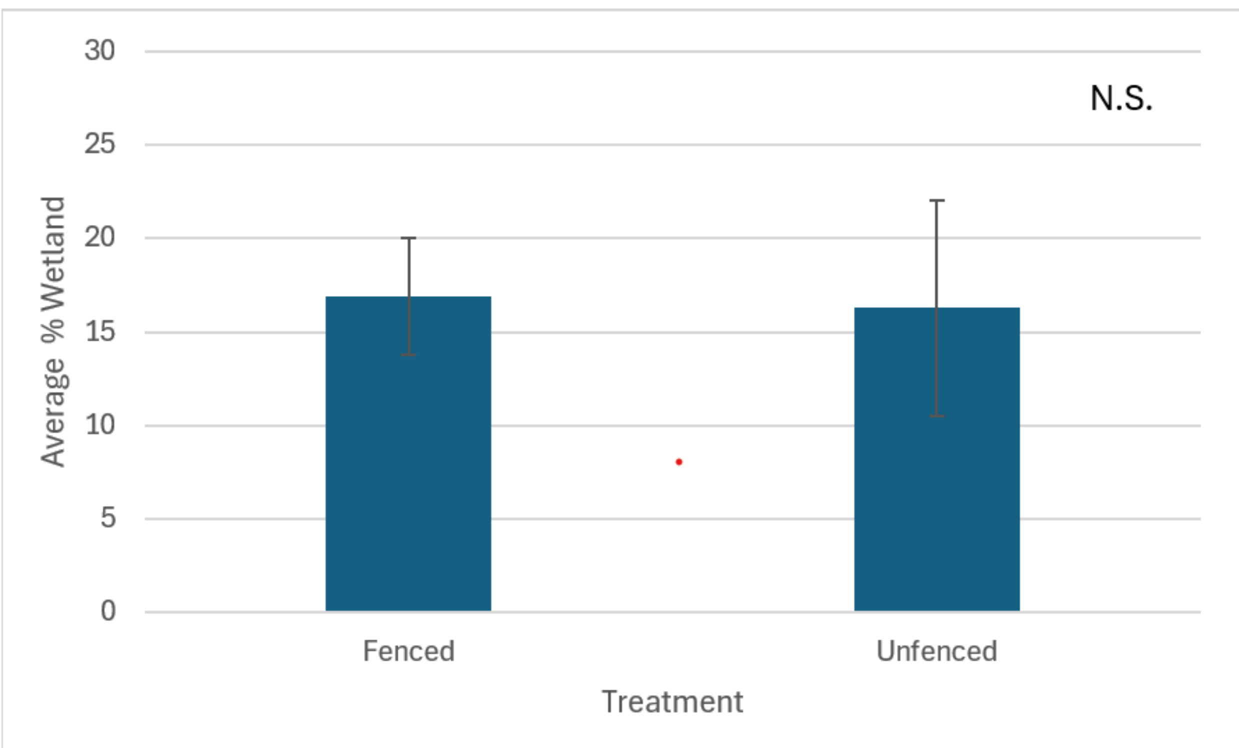

Figure 4. Average percent of frames considered wetland based on the wetland index (WI) outlined in Methods. Difference was non-significant based on the results of a t-test (P = 0.46, t = -0.103. SE (fenced) = 3.11. SE (unfenced) = 5.79). Data were collected August through October, 2024 in Robert's Ranch, Livermore, Colorado.

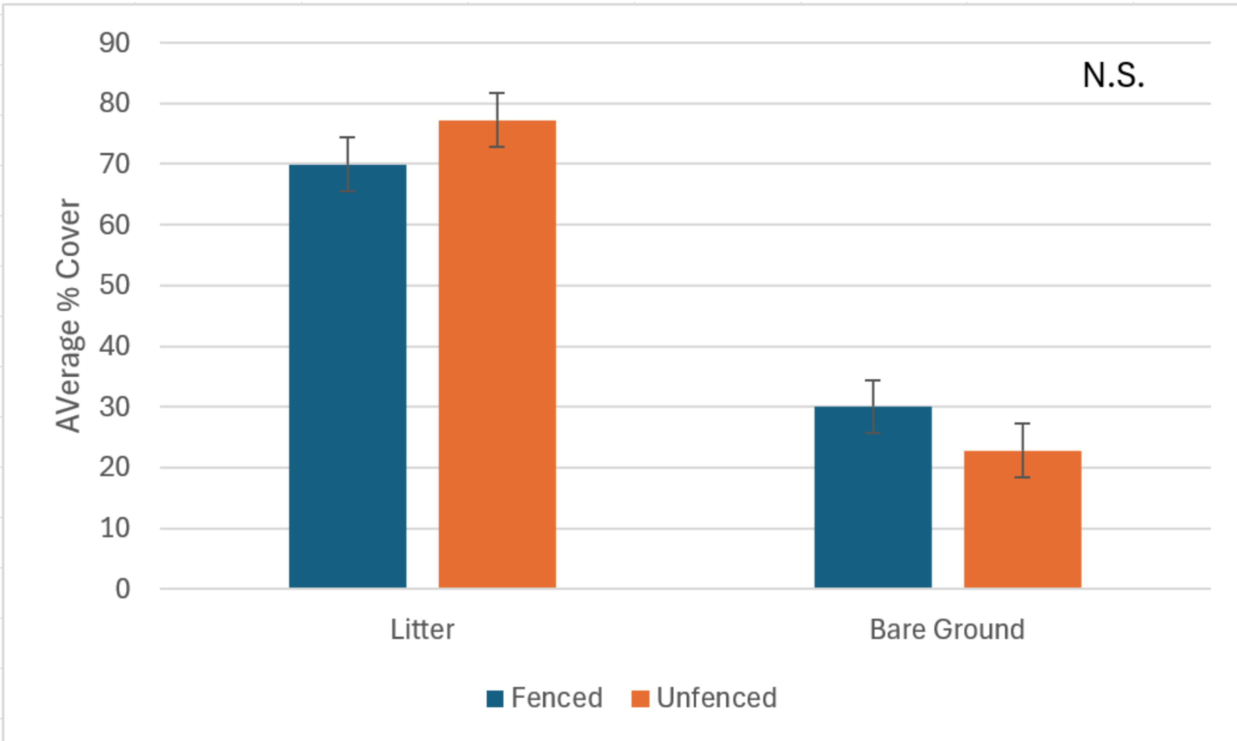

Figure 5. Relative percent of litter and bare ground recorded across grazed and ungrazed plots using Line-Point Intercept. Data were collected at Robert's Ranch, Livermore, Colorado, 17 Aug. to 2 Oct, 2024. Differences were non-significant for both litter and bare ground comparisons- ($t=1.135$, $P = 0.15$). For both litter and bare ground, SE (fenced) = 4.39, and SE (unfenced) = 4.44.

Some of the most frequent species included western wheatgrass, green muhly, field bindweed, and Kentucky bluegrass. The most common wetland species was *Carex aquatilis* (water sedge), which was only the eleventh most frequent species overall (Table 2). Of the 13 most frequently observed species in Daubenmire frames, seven were nonnative.

Summing our synthetic wetland indices by frame, Averages for fenced and unfenced plots were 16.9 and 16.3 percent wetland cover, respectively. There was no significant difference between fenced and unfenced plots for percent coverage of wetlands ($P = 0.46$; Figure 4) From this data, we cannot conclude that exclosures affected wetland vegetation establishment behind BDAs.

In both grazed and ungrazed plots, average percent coverage of litter for line-point intercept (LPI) was higher than average percent bare ground coverage (Figure 5). There was no significant difference between grazed and ungrazed plots for the amount of bare ground or litter ($P = 0.15$ for both).

Based on photo points in Appendix B, upstream and downstream perspectives show that upland vegetation extends to within a few meters of the stream. Photos clearly show narrow bands of greener vegetation within the first two meters of the creek, which are indicative of vegetation that receives more water.

Discussion

This study cannot determine whether similarities in exclosures and unfenced areas were due to broken fences. Since there is no statistically significant difference in wetland occurrence between grazed and ungrazed plots, we are tempted to suggest that grazing has little effect on the occurrence of wetland plants. On other species, however, heavy grazing may have changed species composition. In 2024, the two most frequent grass species observed in frames were both rhizomatous, sod-forming grasses. In contrast, Grinstead et al (2018) recorded bunchgrasses as their most common functional group. The 2018 monitoring group found that while there was no significant difference in species richness inside or outside of exclosures, variability in wetland indicator cover was much lower for fenced BDAs. The 2024 data suggest the same difference in variability between treatment types, where standard error for wetland occurrence in unfenced areas was 5.79 compared to 3.12 in fenced areas (Figure 4.) If the management goal is a variety of habitat, this variability in unfenced plots may be desirable, or it could mean that unfenced areas have lower resilience.

Willows, a hallmark of riparian zones, were rarely encountered on the transects. Taller, more sizable willows were seldom observed in large numbers in the seven plots we surveyed, with the exception of an area close to Plot 6 (Appendix D, Figure D3). There, observations are consistent with Holland et al (2005) observations in Larimer County. They found that willow height and canopy increased in exclosures, where willows were observed in this study. The plants were also self-thinning after five years before stabilizing, but overall willow diversity was highest in long-term grazing.Yochum et al (2017) have shown that in periods of intense flooding on St. Vrain creek, woody riparian vegetation reduced bank erosion, so maintaining willow presence on Campbell Valley is crucial.

It is important to consider the limited spatial extent of the wetland to the first few meters, which limits opportunities for wetland species to change over time. Furthermore, the exclosures surrounding most of the BDAs were broken and easily accessible to cattle in the summer of 2024. Although the exclosures previously prevented cattle from grazing the area, the reality of the 2024 growing season was that cattle could freely move into and graze those same areas. The 2024 study found no discernable difference between fenced and unfenced plots for percent of bare ground or litter occurrence for line-point intercept. This differs from the conclusions of Schulz and Lenniger (1990), which found that in exclosures, there was four times less bare ground and a greater coverage of litter. Schulz and Lenniger's study was done in Arapahoe and Roosevelt National Forest, where possibly a different soil type allowed for more water retention that favors wetland plant establishment.

The limited extent of wetland vegetation surrounding Campbell Creek (Appendix B) is probably related to limited groundwater reach as compared to higher elevation streams due to beaver dam height, and clayey soils at the site (Scamardo and Wohl 2017). The soil is friable, where large clods of soil can be broken up easily while smaller clods are difficult to break up (NRCS, 2013), which could alter infiltration behavior. Restoration activities at Campbell Valley could focus on promoting infiltration. Jones (2023) noted that differences in flow downstream of BDAs could not be attributed to the structures in central Wyoming, which is a similar system to Campbell Creek. For future monitoring, measuring flow and vegetation downstream before and after BDA installation can help restoration practitioners model long-term succession of the ecosystem. Some of the areas immediately surrounding Plot 3 showed signs of erosion. Davis et al (2021), note that installation of BDAs can initiate short-term erosion, but models predict that sediment capture and vegetation communities rebound after initial channel widening.

Studies from elsewhere point to the importance of site specificity. In Coles-Ritchie's 2007 study in Idaho, there was a clear difference between fenced and unfenced plots. In an Eastern Oregon study, four of ten vegetation communities exhibited major differences after 3 years, while others were unaffected (Kauffman, 1983).

Possible future areas of study at Campbell Creek would be assessing other metrics of wetland establishment, such as productivity inside versus outside of riparian exclosures using dry mass data. Examining rooting structures in grazed and ungrazed areas could reveal differences and could account for soil stabilization or moisture retention. Additionally, More data should be collected on the palatability of species between fenced and unfenced areas to determine the extent to which forage selection influences the ecosystem for other wildlife species of concern.

Monitoring recommendations

Key limitations:

- Data should be collected in August at the end of the growing season when the range reaches maximum biomass accumulation, but logistical difficulties of recruiting volunteers to the site and lack of forensic botany expertise stretched data collection over three months in 2024.
- With 2024 being an unusually dry year (Boschmann, personal communication), cattle remained in the preferred riparian zone for longer, leading to grass below a height of 10 cm in many areas. As a result, it was very difficult to identify vegetation.

To refine study purpose and usefulness:

- As mentioned in the 2020 monitoring report (Astvatsaturova et al 2020), a clear set of objectives for each monitoring year is crucial. Continue to evaluate diversity on a species level to allow for more versatility with data to conduct functional group analysis or to calculate future wetland indices.
- Analyzing percent cover by functional groups has shown significant results with the current number of plots (Baker et al 2022). To find out how many plots should be surveyed for comparing fenced and unfenced BDAs, ideal sample size should be recalculated.
- Implement consistent control plots to be able to compare results year-to-year, which was limited for this study. For more consistent data on effects of exclosures on wetland extent, adapt and repeat this analysis for future years.

For a more accurate, efficient study:

- Distinguish key physical traits between taxa. During pilot plots, research groups should practice identifying grass vegetative characteristics based on Chadde's 2017 field guide and learn to distinguish between types of *Poa*, as there was some confusion around the diversity of this genus.
- Bag unknown plant samples with roots, shoots, and flowers for the CSU Herbarium. Contact botanists with Wildlands Restoration Volunteers far in advance. Snaplands is a range monitoring firm highly active at Robert's Ranch and has skilled professionals in forensic botany who are also willing to do site visits (personal communication). Additionally, update the iNaturalist project so future monitoring crews and citizen science can reference the species we found there this year.

- Collect data with surveying software (e.g., Survey123) rather than on paper data sheets to save hours of data entry.

Management Implications

Checking fences multiple times a season to ensure that cattle do not enter will help to more accurately understand the effects of grazing exclusion because of having an ungrazed reference area. Due to the cyclical nature of stream incision in the western US (Davis et al 2021), continuous maintenance and monitoring will be necessary to induce stream aggradation in Campbell Valley. Tracking preferred cattle movements over time with remote sensing or visual observations could allow cattle to become part of the wetland restoration process. One restoration strategy that has not yet been tried at Robert's Ranch would be installing barriers to direct cattle in a meandering pattern across wider sections of the gully. This induced meandering could encourage the currently linear Campbell Creek to follow the cattle path over time, as demonstrated in the mini-documentary *A Glimpse into Thinking Like Water* (Roberts, 2021). Meandering would help spread out the water table, which is difficult to do with BDAs alone.

Conclusion

We proposed a wetland index as a new framework for comparing exclosures and unfenced areas. We found no significant difference between the two treatment types behind BDAs in litter cover, bare ground cover, or the amount of wetland vegetation coverage. We found that the extent of the wetland was limited to within a few meters of Campbell Creek based on combined evidence from photo points and our wetland analysis, revealing around 16 percent wetland cover for both fenced and unfenced areas. To be able to compare exclosures with unfenced areas, exclosures need to be repaired and maintained. The most frequently occurring species were western wheatgrass, green muhly, and common bindweed. Having botanical expertise is critical for being able to attribute species to the correct functional groups because there were many unidentifiable taxa that did not overlap between fenced and unfenced areas. Having better plant identification also provides more opportunities for future study. Plot locations and strategies were also clarified to make future studies more accessible, including resources for future monitoring crews to familiarize themselves more efficiently with the vegetation and landscape.

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Thank you, ranch manager Zach Thode, for generously allowing us on the property to collect data on short notice.

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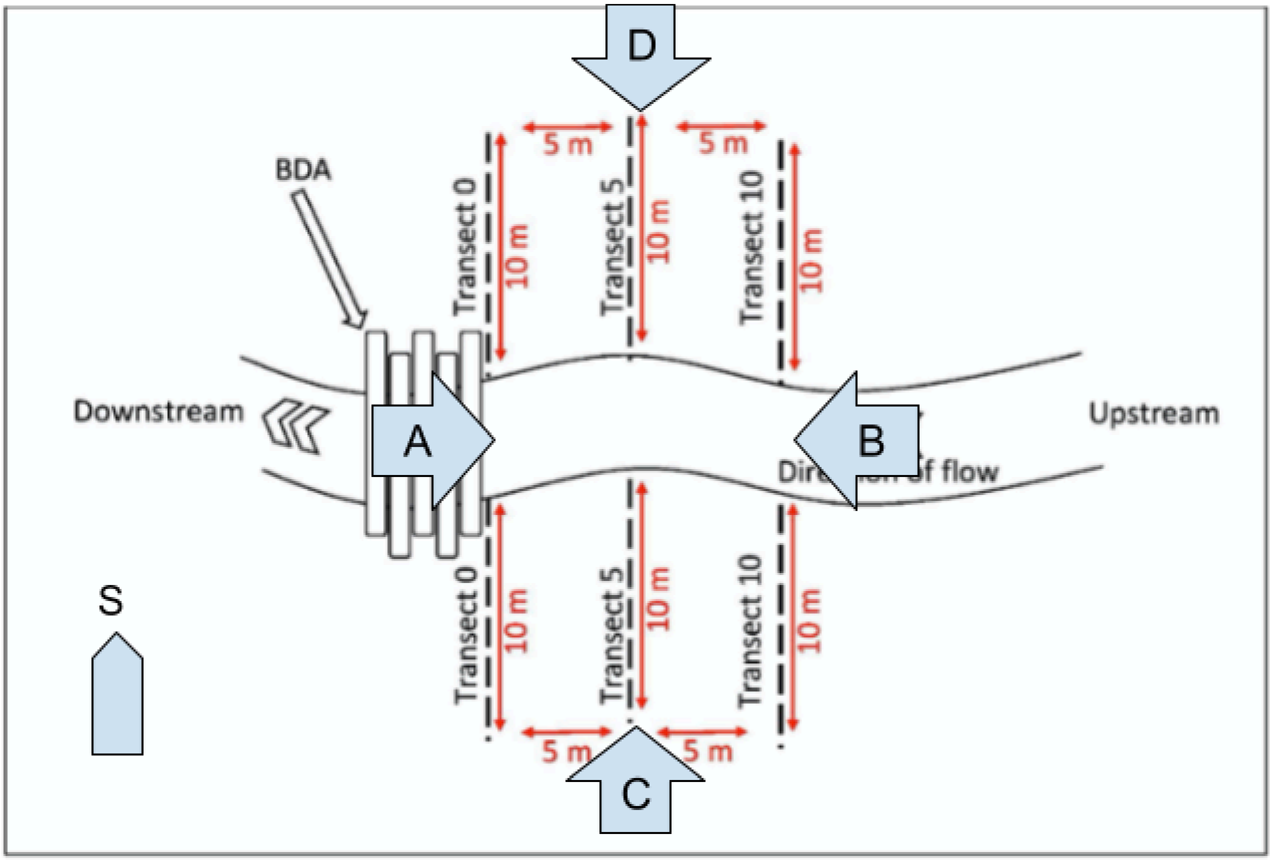

Appendix A. Locations and directions of photo points captured at each plot. Photo points were captured on an iPhone 13 with 0.5x zoom for maximum capture of the landscape.

Appendix B contains photo points for BDAs 2-8. Point A is facing upstream from the in-stream structure, point B is facing downstream from the furthest upstream end of the base transect, point C is facing southwest of Campbell Creek, and point D is facing northeast of Campbell Creek.

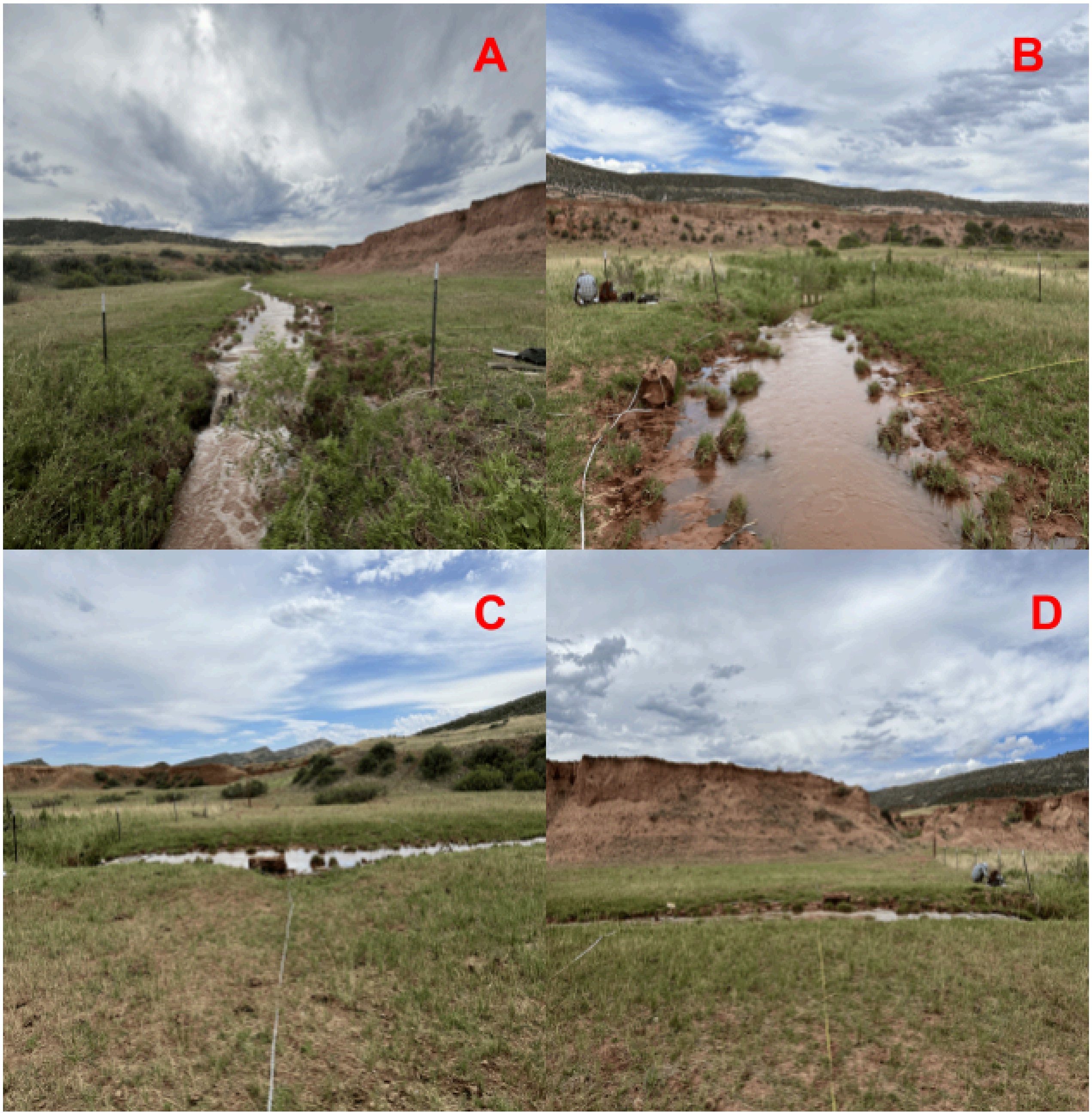

Figure B1. Photo points of BDA 2 (grazed), Campbell Valley, Livermore, CO (decimal degree coordinates are 40.792890, -105.155166). Data collected 17 Aug., 2024.

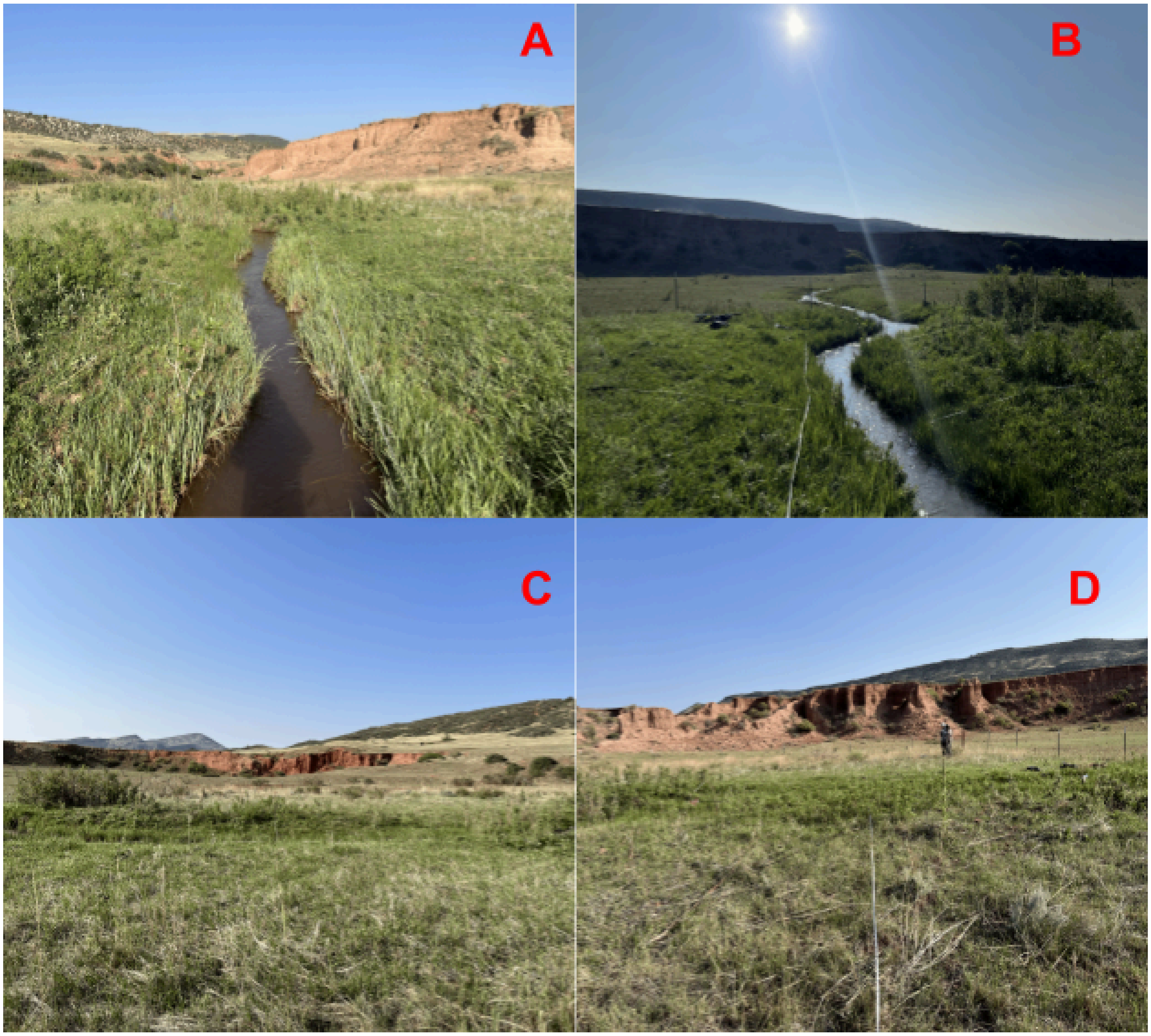

Figure B2. Photo points of BDA 8 (ungrazed), Campbell Valley, Livermore, CO (decimal degree coordinates are 40.792865, -105.154692). Data collected 31 Aug., 2024.

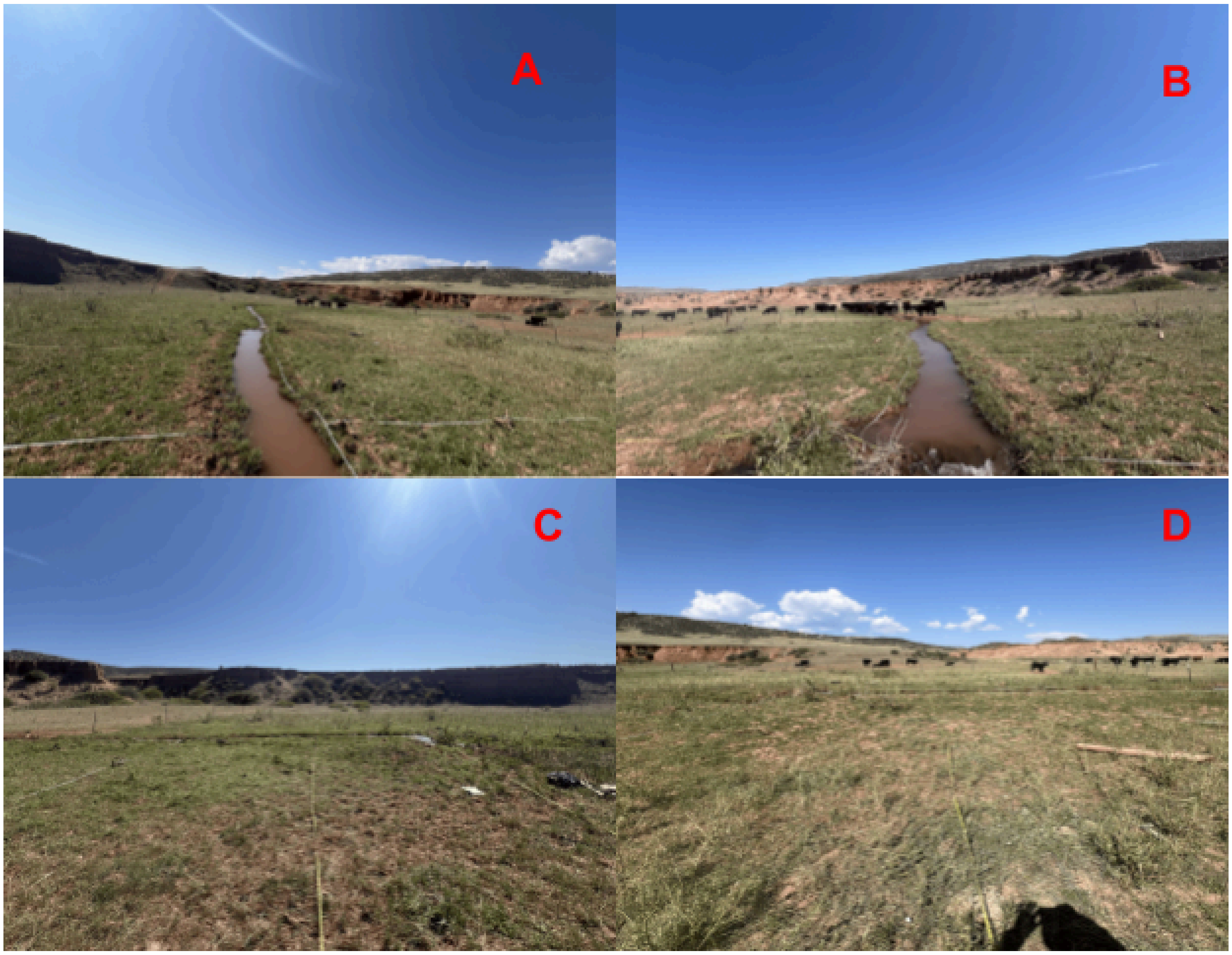

Figure B3. Photo points of BDA 3 (ungrazed), Campbell Valley, Livermore, CO (decimal degree coordinates are 40.792287, -105.154204). Data collected 31 Aug, 2024.

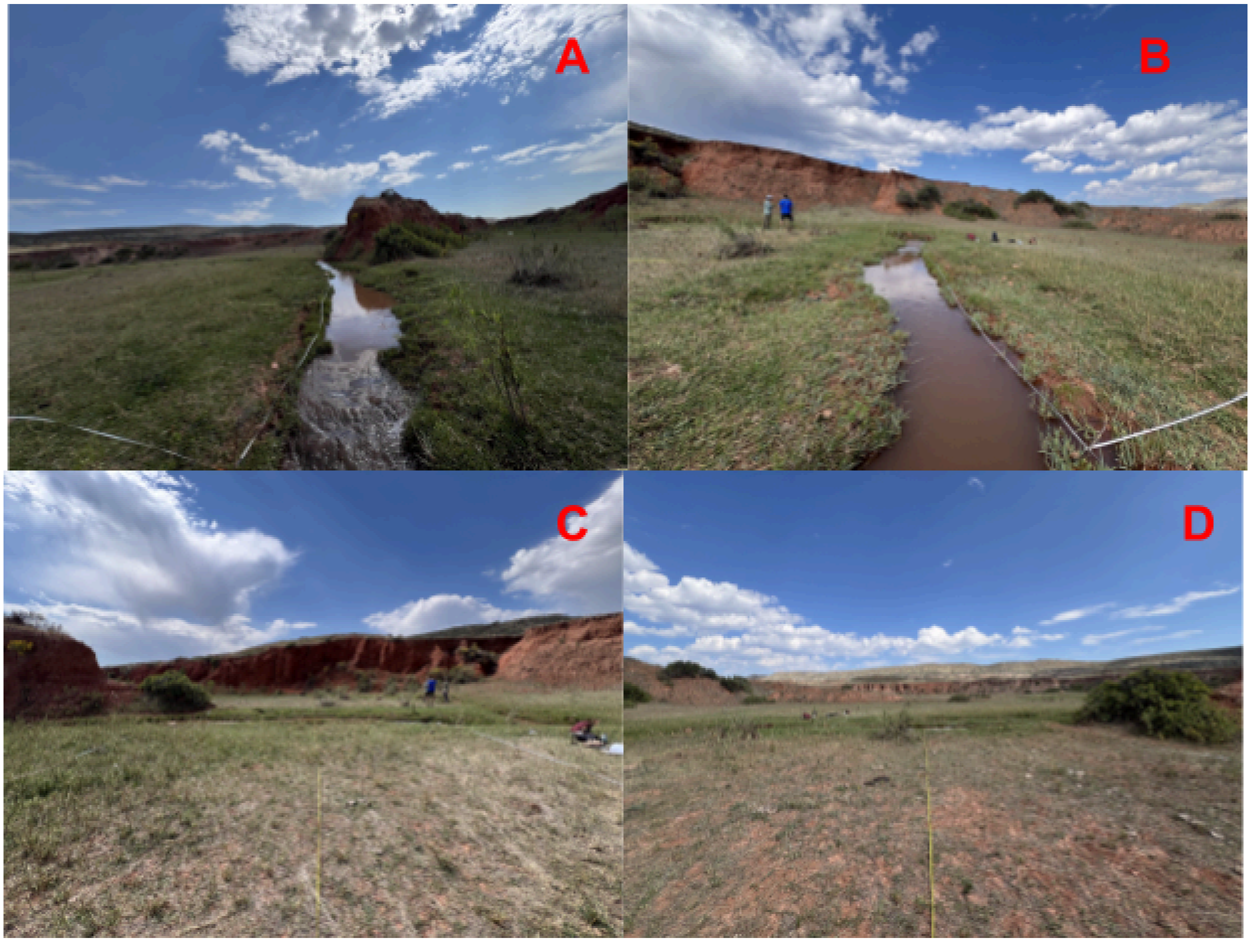

Figure B4. Photo points of BDA 4 (grazed), Campbell Valley, Livermore, CO (decimal degree coordinates are 40.791904, -105.155216). Data collected 8 Sept, 2024.

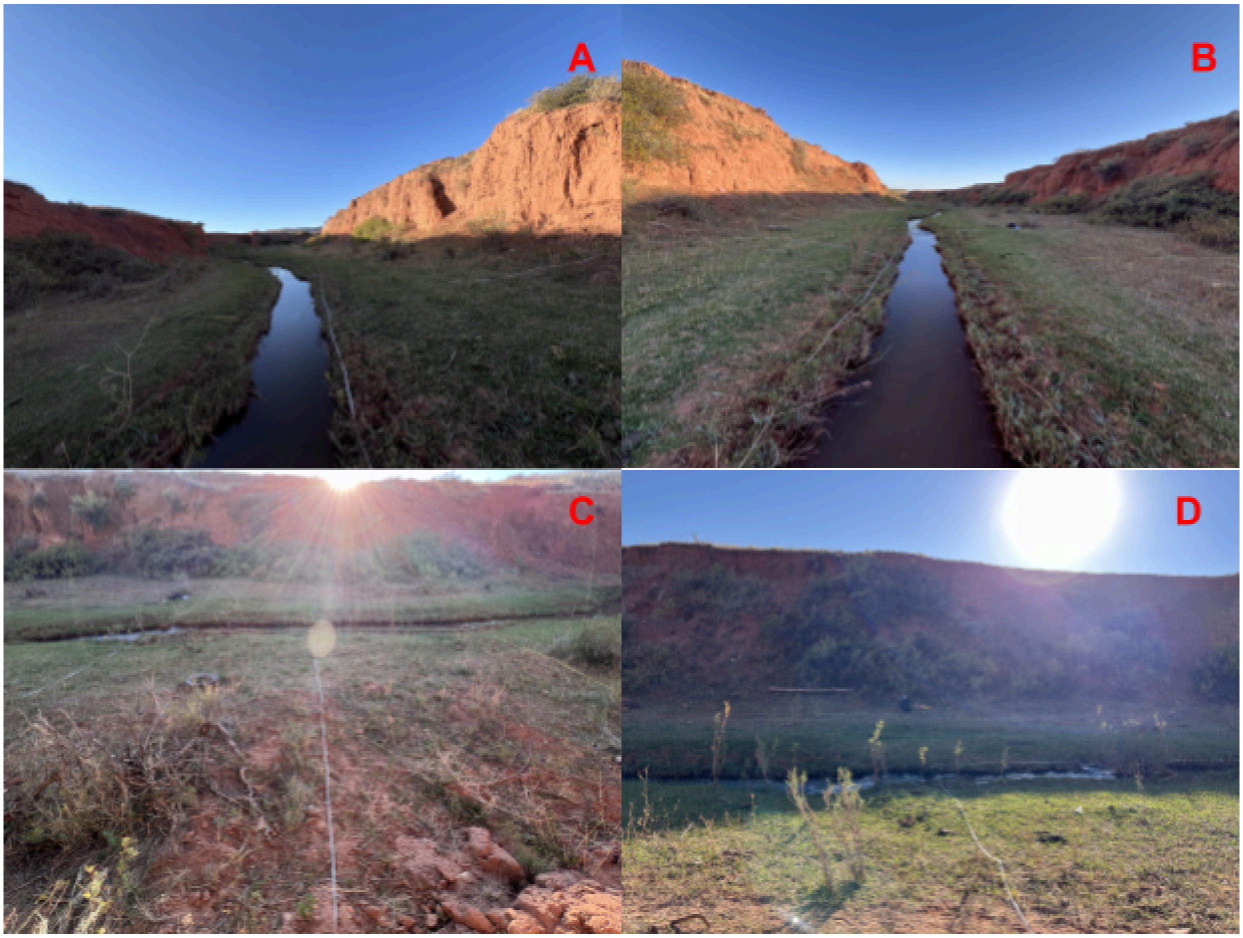

Figure B5. Photo points of BDA 5 (ungrazed), Campbell Valley, Livermore, CO (decimal degree coordinates are 40.791913, -105.154809). Data collected 2 Oct, 2024.

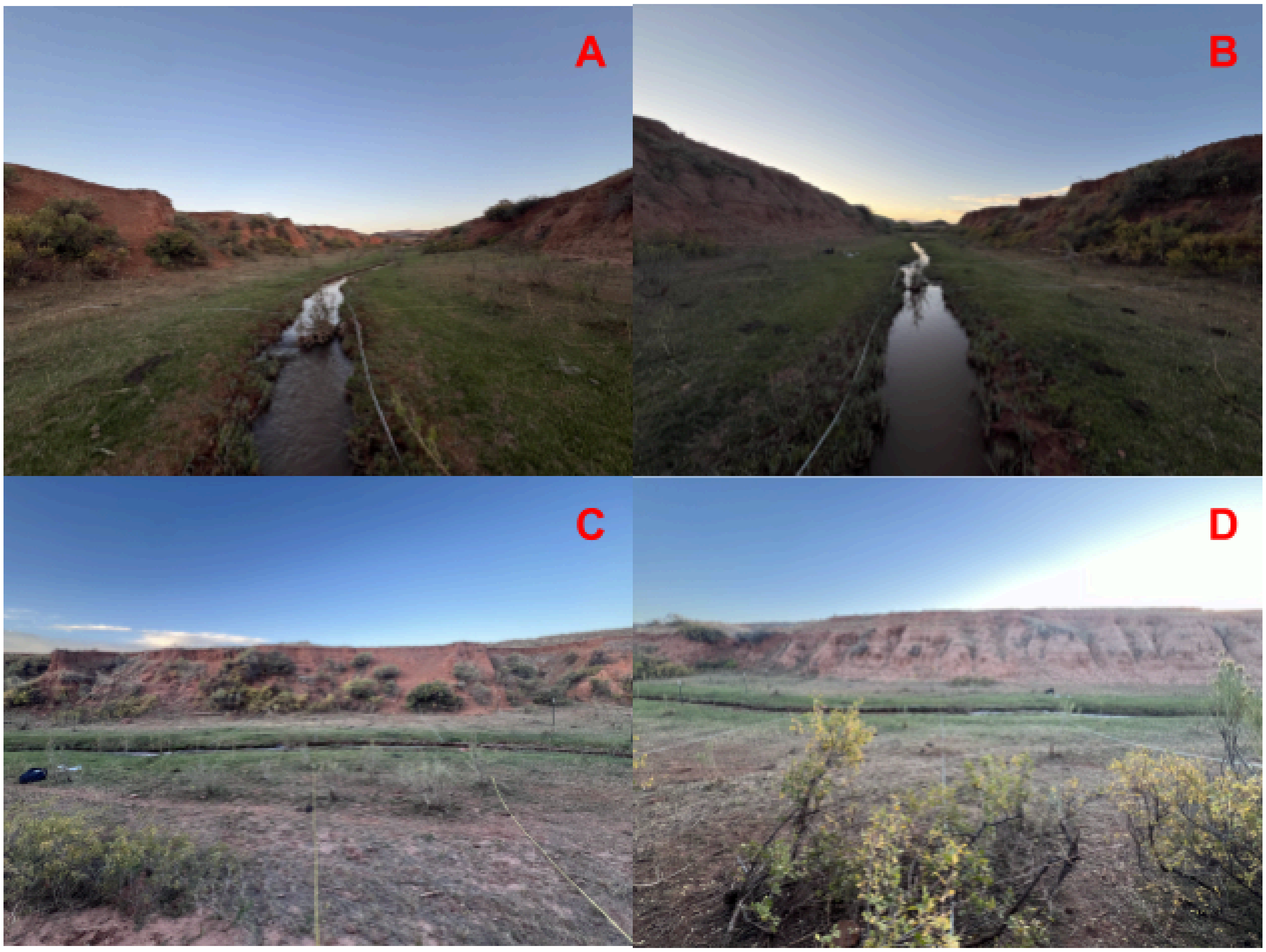

Figure B6. Photo points of BDA 6 (ungrazed), Campbell Valley, Livermore, CO (decimal degree coordinates are 40.790446, -105.154211). Data collected 31 Sept, 2024.

Figure B7. Photo points of BDA 7 (grazed), Campbell Valley, Livermore, CO (decimal degree coordinates are 40.789646, -105.153313). Data collected 22 Sept, 2024.

Appendix C. Table with taxa found in both fenced and unfenced plots. While there were more taxa, they were not identifiable to family level and are not regarded here. Additionally, multiple species in some genera could not be identified.

USDA Code	**Scientific Name**	**Wetland Indicator Status**
ACHNATHERUM spp.	*Achnatherum spp.*	FACU
ARLU	*Artemesia ludoviciana*	UPL
BRIN2	*Bromus inermis*	UPL
BROMUS	*Bromus* spp.	FAC
CAAQ	*Carex aquatilis*	OBL
CAREX	*Carex* spp.	FACW
CIAR4	*Cirsium arvense*	FAC
CICHORIEAE	Family *Cichorieae*	FACU
COAR	*Convolvolus arvensis*	FACU
CYOF	*Cynoglossum officinale*	FACU
ELEOCHARIS/JUNCUS	*Eleocharis* spp. / *Juncus* spp.	FACW
EQAR	*Equisetum arvense*	FAC
EQUISETUM	*Equisetum* spp.	OBL
ERNA10	*Ericameria nauseosa*	UPL
GLLE3	*Glycyrrizia lepidota*	FACU
GUSA2	*Gutierrezia sarothrae*	UPL
HECO	*Hesperostipa comata*	UPL
JUARA5	*Juncus arcticus*	OBL
JUEF	*Juncus effusus*	OBL
JUNCUS	*Juncus* spp.	OBL
MEAL	*Melilotus albus*	FACU

MELU	*Medicago lupulina*	FACU
MEOF	*Melilotus officinale*	FAC
MURA	*Muhlenbergia racemosa*	FACW
PASM	*Pascopyrum smithii*	FACU
PIOP	*Picradeniopsis oppositifolia*	FACU
POPR	*Poa pratensis*	FAC
RHTR	*Rhus trilobata*	UPL
ROWO	*Rosa woodsii*	FACU
SPCR	*Sporobolus cryptandrus*	FACU
SYMPH	*Symphiotrichum* spp.	FACU
TAOF	*Taraxacum officinale*	FACU
THERMOPSIS	*Thermopsis rhombifolia/montana*	FACU
TRDU	*Tragopogon dubius*	FAC

Appendix D. Supplemental photos for understanding range conditions in Campbell Valley at Robert's Ranch, Livermore, Colorado

Figure D1. The high steppe of Robert's Ranch, with views of pinyon-covered hillsides and the gully that Campbell Creek flows through.

Figure D2. Dark manure (left) demonstrating high forage quality. Daubenmire frame (right) with typical stubble found in both fenced and unfenced plots

Figure D3. Plot 6 was in one of the exclosure areas. Here, some of the only willows in this section of the creek show signs of heavy browse.