STREAM HABITAT INVESTIGATIONS AND ASSISTANCE
PROJECT SUMMARY

Eric E. Richer
Aquatic Research Scientist/Hydrologist

and

Matthew C. Kondratieff
Aquatic Research Scientist

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STATE OF COLORADO

Jared Polis, Governor

COLORADO DEPARTMENT OF NATURAL RESOURCES

Dan Gibbs, Executive Director

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AQUATIC RESEARCH STAFF

George J. Schisler, Aquatic Research Leader
Kelly Carlson, Aquatic Research Program Assistant
Brian W. Avila, Aquatic Research Scientist, Population Genetics
Peter J. Cadmus, Aquatic Research Scientist/Toxicologist, Water Pollution Studies
Eric R. Fetherman, Aquatic Research Scientist, Salmonid Disease Studies
Tawni B. Firestone, Aquatic Research Scientist, Aquatic Toxicology and Disease
Ryan M. Fitzpatrick, Aquatic Research Scientist, Eastern Plains Native Fishes
Adam G. Hansen, Aquatic Research Scientist, Coldwater Lakes and Reservoirs
Zachary Hooley-Underwood, Aquatic Research Scientist, West Slope Three-Species Studies
Matthew C. Kondratieff, Aquatic Research Scientist, Stream Habitat Restoration
Dan A. Kowalski, Aquatic Research Scientist, Stream and River Ecology
Jesse M. Lepak, Aquatic Research Scientist, Warm and Coolwater Lakes and Reservoirs
Eric E. Richer, Aquatic Research Scientist/Hydrologist, Stream Habitat Restoration
Kevin B. Rogers, Aquatic Research Scientist, Cutthroat Trout Studies
Andrew J. Treble, Aquatic Database Manager, Aquatic Data Management and Analysis
Brad Neuschwanger, Hatchery Manager, Fish Research Hatchery
Tracy Davis, Hatchery Technician, Fish Research Hatchery
Troy Meyer, Hatchery Technician, Fish Research Hatchery
Karen Hertel, Librarian

Prepared by: ________________________________
Eric E. Richer, Aquatic Research Scientist/Hydrologist

Prepared by: ________________________________
Matthew C. Kondratieff, Aquatic Research Scientist

Approved by: ________________________________
George J. Schisler, Aquatic Wildlife Research Chief

Date: September 29, 2025

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PROJECT SUMMARY

Period Covered: July 1, 2024 through June 30, 2025

PROJECT OBJECTIVE:

To advance the science of stream restoration for the benefit of sportfish management and native species conservation in Colorado; to collect data and conduct experiments for the evaluation of stream restoration and fish passage projects; to provide technical assistance in support of project assessment, design, and evaluation.

RESEARCH PRIORITY:

Kemp-Breeze State Wildlife Area Habitat Project, Colorado River

OBJECTIVES

1) Increase sediment transport capacity and competence by manipulating channel dimensions
2) Decrease the prevalence of fine sediment and reduce embeddedness within riffle habitats
3) Increase the frequency of flushing flow events in riffle habitats under the future flow regime by manipulating channel dimensions
4) Activate floodplains with a frequency of 1-3 years under the future flow regime
5) Increase the density of native riparian vegetation along streambanks and floodplains to increase flood resilience and improve wildlife habitat
6) Increase the density of Colorado Sculpin and Salmonflies within the project reach
7) Increase trout population biomass (lbs/acre) and quality (# of fish > 14"/acre)
8) Increase Rainbow Trout reproduction (fry density) and recruitment (adult density)
9) Increase habitat suitability and diversity for Rainbow Trout, Brown Trout, and Colorado Sculpin by improving instream hydraulics
10) Increase the abundance, distribution, and diversity of benthic macroinvertebrates

INTRODUCTION

The Upper Colorado River Habitat Project (Habitat Project) was developed in coordination with the Municipal Subdistrict, Northern Colorado Water Conservancy District (Subdistrict) and Denver Water to address concerns raised by Colorado Parks and Wildlife (CPW) and other stakeholders regarding conditions of the aquatic ecosystem in the Colorado River downstream of Windy Gap Reservoir (Subdistrict 2011). Altered hydrologic and sediment regimes have adversely affected the ecological integrity of the Upper Colorado River (UCR). The accumulation of fine sediments has increased substrate embeddedness and degraded habitat for Colorado Sculpin *Cottus punctulatus* and Salmonflies *Pteronarcys californica*, both of which are important prey resources for trout (Nehring et al. 2011; Kowalski and Heinold 2019; Young et al. 2022). Sediment supplies have also been impacted by the construction of reservoirs, contributing to armoring of the streambed. Altered hydrology has reduced the frequency of flows with sufficient magnitude and duration to flush fine sediments from the riffle habitats that Sculpin and Salmonflies occupy. Trout populations between Windy Gap and Kremmling have also declined since the construction of Windy Gap Reservoir. In particular, Rainbow Trout *Oncorhynchus mykiss* populations have decreased significantly due to the prevalence of whirling disease, which has been exacerbated by the favorable conditions for whirling disease within Windy Gap Reservoir and the river downstream.

Aquatic habitat restoration for a 16.7-mile reach of the UCR was identified as mitigation for the firming of water rights on the Colorado and Fraser rivers (Denver Water 2011; Subdistrict 2011). The goal of the Habitat Project is to design and implement a stream restoration program to improve the existing aquatic environment in the Colorado River from the Windy Gap Diversion to the lower terminus of the Kemp-Breeze State Wildlife Area (SWA) by returning the river to a more functional system considering current and future hydrology. Project objectives include improving sediment transport processes, floodplain connectivity, quality and diversity of trout habitat, habitat for Sculpin and Salmonflies, as well as restoring benthic macroinvertebrate populations and riparian corridors. Creating and maintaining interstitial habitat in riffles is critically important for the restoration of Sculpin, Salmonfly, and other benthic aquatic organisms in the Colorado River. Improving riffle habitats may also increase prey resources and spawning habitat, which should have beneficial effects on the trout fishery. Aquatic habitat restoration at the Kemp-Breeze SWA was selected for the first phase of the larger Habitat Project on the Colorado River. The restoration design for Kemp-Breeze was completed in spring 2021 and the first phase of construction began in August 2022. The second phase of construction at Kemp-Breeze was initiated in August 2023 and completed in December 2023, with final seeding and planting taking place in the summer and fall of 2024.

Understanding sediment transport is critically important for the assessment, design, and evaluation of the habitat restoration project. Target flow ranges for summer, winter, and flushing flows were identified for the Colorado River in the Grand County Stream Management Plan (Tetra Tech 2010). The Kemp-Breeze SWA is contained within the Grand County study reach that starts at the Williams Fork confluence and ends at the Kemp-Breeze Ditch. Flushing flows were identified as the flow threshold at which gravel mobilization was initiated, and were intended to periodically remove fine sediments (such as silts and sands) from the streambed surface and inter-gravel environment (Tetra Tech 2010) and ultimately create and maintain interstitial habitats in riffles. Flushing flows were estimated to occur at or above 800 cfs and recommended for a minimum of three days once every two years in late May to late June. Estimates for flushing flows were obtained from hydraulic and sediment transport models, but were not yet supported by empirical evidence. Target winter flows range from 150-250 cfs and target summer flows range from 250-500 cfs for Kemp-Breeze reach.

Salmonflies and Sculpin may serve as ecological indicators for improvements in sediment transport processes. The Salmonfly, or Giant Stonefly, is a large aquatic invertebrate that can reach high densities in some Colorado rivers. These invertebrates play an important ecological role as grazers in stream systems and can be extremely important for stream dwelling trout as a food source. Salmonflies have relatively specific environmental requirements and are considered intolerant of disturbance (Erickson 1983; Fore et al. 1996). In Colorado, high Salmonfly density was associated with low amounts of fine sediment, low cobble embeddedness, and large cobble size (Kowalski and Richer 2020). Although they were once common in the UCR (USFWS 1951; Dames and Moore 1977; Erickson 1983), the abundance of Salmonflies has declined, especially downstream of Windy Gap Reservoir where flow alterations associated with trans-mountain water diversions are greatest (Nehring et al. 2011). Restoring sediment transport processes to improve habitat for Salmonflies is a critical design objective for the Habitat Project on the Colorado River.

Sculpin are an ecologically important part of freshwater ecosystems because they can occur in high densities in depauperate coldwater mountain streams (Adams and Schmetterling 2007). Sculpin prefer cool, high gradient mountain streams with cobble habitat and are rarely found in stream reaches where substrate is embedded with silt (Sigler and Miller 1973; Woodling 1985). As such, their habitat preferences for cobble substrate and high quality riffle-run habitat make Sculpin a good ecological indicator of stream health (Adams and Schmetterling 2007; Nehring et al. 2011). Sculpin were common in the main stem Colorado River prior to the construction of Windy Gap Reservoir, but are rare or absent after construction (Erickson 1983; Nehring et al. 2011; Kowalski and Heinold 2019). No Sculpin were detected within the Kemp-Breeze SWA during adult population or fry surveys in 2018-2021, and the last documented observation was reported in 1998. Restoring connectivity around Windy Gap Reservoir and addressing habitat limitations associated with flow and sediment regimes should improve conditions in the UCR for this important native fish.

The effectiveness of the restoration project is being evaluated with a combination of biological and physical monitoring. Salmonfly, benthic macroinvertebrate, and Sculpin monitoring will be conducted by CPW under the Colorado Coldwater Stream Ecology Investigations and Sport Fish Research Studies programs. Changes in adult trout populations will be evaluated by the local CPW Aquatic Biologist with support from CPW Aquatic Research. Changes in geomorphology and sediment transport will be monitored by the Stream Habitat Investigations research program. This report provides an update on activities that occurred during this reporting period, including the completion of revegetation efforts, photogrammetry surveys, sediment surveys, relocation of tracer rocks, deployment of additional tracer rocks, and log-jam surveys.

METHODS

Project Construction:
The conceptual design for the Kemp-Breeze project was developed by CPW (Richer et al. 2019). Stillwater Sciences and AlpineEco were then hired to develop preliminary (Stillwater Sciences 2020) and final (Stillwater Sciences 2021) designs for the restoration project, and L4 Environmental was hired to construct the project. Detailed information on design criteria and methods is available in the aforementioned reports. Construction of the project was divided into two phases, with the first phase being constructed in the fall/winter of 2022 and the second phase in the fall/winter of 2023 (Figure 1). Project construction utilized a variety of heavy equipment, including excavators, haul trucks, loaders, and a bulldozer. CPW, Stillwater Sciences, and AlpineEco provided project oversight. Restoration activities included realignment of an irrigation ditch, construction of islands, side channels, overflow channels, new floodplain benches, log-jam structures, brush trenches, riffle development, and pool development. Vegetation treatments included willow, alder, cottonwood, and sod-mat transplants, as well as plantings, seeding, and mulching. Riffle dearmoring and gravel augmentation were utilized as experimental treatments to

improve sediment transport processes. Photogrammetry was used to document changes in channel and floodplain morphology by capturing high-resolution aerial imagery with unmanned aircraft systems (UAS).

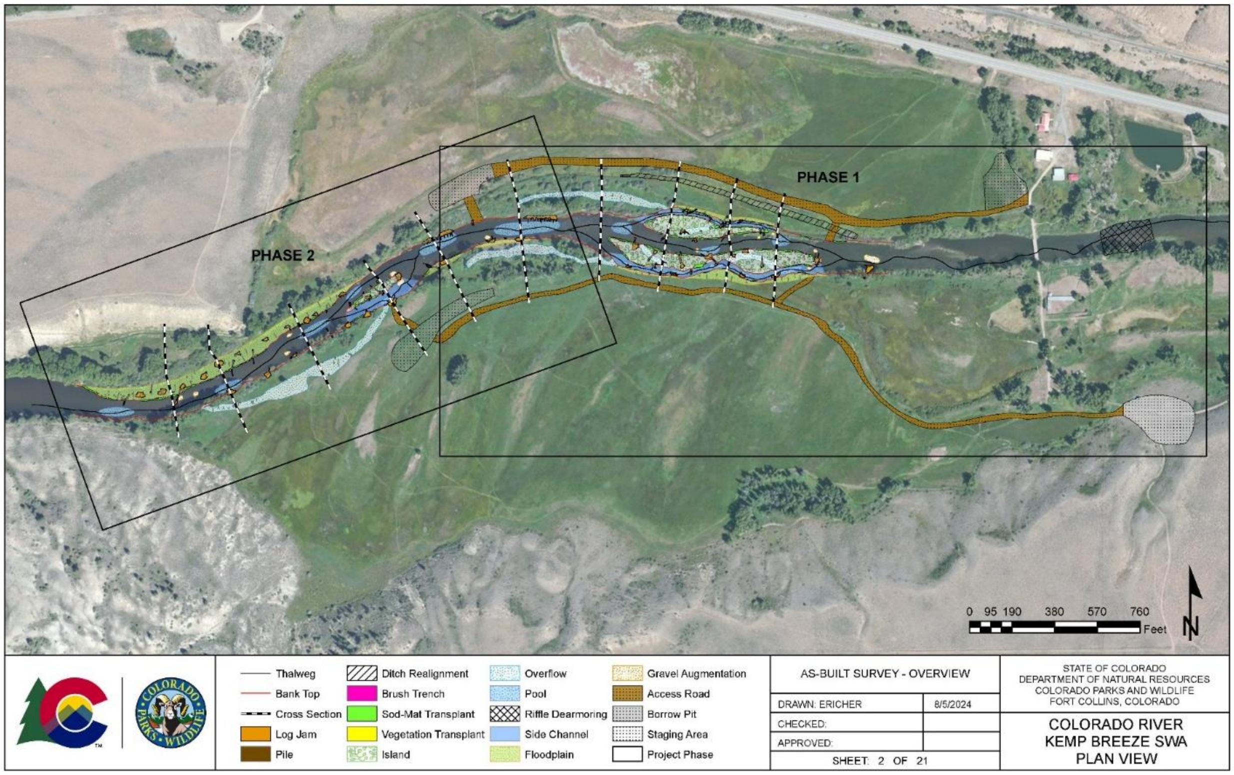

Figure 1. Overview of restoration treatments for the Kemp-Breeze SWA Habitat Project on the Colorado River, including the location of Phase 1 and Phase 2 project reaches.

Sediment Surveys:

Grid-frame pebble counts (Bunte and Abt 2001) were conducted at previously surveyed locations and newly established sites in October 2024. Site PC1A was the location of an experimental riffle dearmoring treatment, sites PC2A and PC2B were located within the main channel in the Phase 1 reach, and site PC3A was located at a new riffle in the Phase 2 project reach. We also established a new pebble count transect (site PC0A) at a control riffle within an unrestored section of the Kemp-Breeze SWA upstream of the project reach. The proportion of particles within dominant size classes (i.e., fines, gravel, cobble, and boulder) were quantified from pebble counts and used to evaluate changes following restoration. Changes in grain size distribution were also investigated by deriving the particle size corresponding to the cumulative frequency of 16% (D_{16}) as an index of fine sediment, 50% (D_{50}) as the median particle diameter, and 84% (D_{84}) to represent the coarser sediment fraction. Results were compared to pre-construction and as-built pebble counts to evaluate how gradations changed during the second post-construction runoff cycle in the Phase 1 reach and first post-construction runoff cycle in the Phase 2 reach.

Tracer Rocks:

Methods for the pre-construction tracer rock study were previously described in Kondratieff and Richer (2023), and included three years of tracer-rock relocation in 2019-2021. All tracer rocks deployed during the preconstruction monitoring period were removed prior to construction. Following completion of instream construction for the Phase 1 project reach, tracer rocks were redeployed within three riffle locations (riffle 1, riffle 2A, and riffle 2B). Riffle 1 was located in the same location for both pre and post-construction evaluations. As the channel morphology was greatly altered at riffle 2 during Phase 1 construction, rocks were deployed in two separate riffles (riffles 2A and 2B) for the post-construction evaluation. Two riffles were needed to represent riffle 2 in the post-construction study because the channel was narrowed substantially and the area of the riffles was significantly smaller, which required that the tracer rocks be deployed in two riffles to meet the pre-construction sample size while avoiding issues with tag collision when PIT-tagged rocks are placed too close together. Tracer rocks were also deployed in transects over the top of all gravel augmentation locations and within two overflow channels as part of the post-construction evaluation. Tracer rocks in the Phase 1 reach were deployed in April 2023, and then relocated during September 2023 and September 2024 to evaluate movement during the first and second post-construction runoff cycles, respectively.

Although we intended to deploy tracer rocks in the Phase 2 reach during the spring of 2024, higher-than-expected flows prevented the deployment of tracer rocks prior to runoff. We were able to deploy tracer rocks at gravel augmentation sites in the Phase 2 reach during the April 2024, but deployment of tracer rocks at riffle locations in the Phase 2 reach was delayed until the fall of 2024. In October 2024, we deployed 100 tracer rocks at the new riffle 3 site in the Phase 2 reach. This constructed riffle had already experienced one runoff cycle prior to tracer rock deployment. We also deployed 100 tracer rocks at a new riffle site (riffle 0) located in an unrestored area upstream of the project reach to provide a control site for comparison with the treated riffles locations. Additional tracer rocks were deployed in riffles 2A and 2B during the fall of 2024, as many rocks had washed out of the riffles during the previous two runoff cycles. As many of the previously deployed rocks were now located in pools, additional tracers rocks were needed in these locations to maintain the focus on sediment transport in riffle habitats.

The size distribution of tracer rocks changed between the pre and post-construction studies. For the preconstruction study, the size distribution for tracer rocks was designed to match the gradation of the existing streambed, which lacked gravels, to determine the overall proportion of the streambed that moved. As the fill material utilized for construction had a larger size distribution that included more medium and coarse gravels than the preconstruction streambed, tracer rocks from those size classes were tagged with 12 mm PIT tags and incorporated into the post-construction study. The initial sample size (n = 100) for all riffles was held constant for both periods, which entailed reducing the number of large cobbles that were included in the post-construction study. Around 65% of the tracer rocks from the preconstruction study were used for the initial deployment during the post-construction period to support a before-after analysis with the same sample of tracer rocks. However, with the deployment of the additional tracer rocks in riffles 2A and 2B during the fall of 2024, all tracer rocks from the preconstruction study have now been deployed as part of the post-construction study.

The total number of post-construction tracer rocks deployed in each location was summarized in Table 1. Previously deployed tracer rocks were relocated in the fall of 2024 to assess distance moved by size class and study site, and for comparison to observations from the 3-year preconstruction study period. The first relocation event for tracer rocks in riffles 0 and 3 is scheduled for September 2025.

Table 1. Number of PIT-tagged rocks deployed at post-construction study sites (GA = gravel augmentation, OV = overflow) within the project reach, including the size range for the intermediate axis of individual particles.

Size Class	**GA**	**OV**	**Riffle 0**	**Riffle 1**	**Riffle 2A**	**Riffle 2B**	**Riffle 3**	**Total**
Medium gravel	8	5	6	15	9	12	15	70
Coarse gravel	12	5	25	15	10	7	15	89
Very-coarse gravel	14	0	23	24	16	13	24	114
Small cobble	15	0	34	33	52	50	33	217
Large cobble	4	0	8	10	5	7	11	45
Small boulder	0	0	4	3	3	2	2	14
Total	53	10	100	100	95	91	100	549
Size range (mm)	15-175	16-39	15-224	12-290	12-280	15-290	13-277	12-290

Log-Jam Assessment:

Log-jam structures were utilized to provide a variety of geomorphic functions, including localized scour to maintain pool habitat, creating depositional areas to help narrow the channel over time, and creating localized areas with increased shear to improve sediment transport capacity (Stillwater Sciences 2021). Structures were also expected to provide a variety of habitat benefits, such as overhead cover, slower velocity zones for different aquatic species and life stages, erosion/deposition on riparian benches for cottonwood regeneration, and a general increase in aquatic and riparian habitat diversity. Log-jam structures were initially assessed during the as-built survey in April 2024 using a rapid-assessment procedure that was adapted from previously published methods (Bain and Stevenson 1999; Miller and Kochel 2013; Rosgen 2008; Weber et al. 2020). Attributes evaluated during the assessment included structure type, wood count, condition, integrity, dominant flow type, lateral response, elevation response, erosion ranking, deposition ranking, beaver maintenance, fish passage risk, geomorphic classification, channel location, fish habitat, vegetation, and maintenance needs. Structure types evaluated during the assessment included bar-apex jams, in-channel jams, bank jams, large-pool jams, downed cottonwood trees, and floodplain jams. All structures were numbered and photographed from the ground and air (i.e., UAS) to support repeat surveys and document changes over time. The field procedure entails visiting each log-jam structure at least one time per year following runoff. Log-jam structures in the Phase 1 reach were initially assessed in April 2023 (as built), and then resurveyed in October 2023 (year 1) and April 2025 (year 2). Phase 2 log jams were initially surveyed in April 2024 (as built) and resurveyed in April 2025 (year 1). Detailed descriptions for attributes and assessment methods were provided in Richer and Kondratieff (2023).

RESULTS AND DISCUSSION

Project Construction:

Phase 2 of the project was constructed during August-December 2023, focusing on the downstream half of project reach (Figure 1). Major activities included mass grading to narrow the channel and create a new floodplain bench, installation of log-jam structures, vegetation transplants, and gravel augmentation. Although fill material had been stockpiled prior to construction, the amount of fill proved insufficient to meet design elevations for the large floodplain area on river right. As such, this new floodplain bench was left 1 ft lower than design elevations in many locations. Floodplain jams, vegetation transplants, brush trenches, and topographic complexity were utilized to provide stability and induce sediment deposition on the new floodplain bench. Similar to Phase 1, the use of piles to anchor the log jams proved challenging, as the depth to bedrock was shallower than anticipated. All of the in-channel jams had to be relocated to the streambank or floodplain, and alluvial sediment was used to provide additional ballast for floodplain and bank jams. Willow staking and restoration of access roads were completed in the spring of 2024 prior to snowmelt runoff. Planting, seeding, and mulching were then conducted after runoff in the summer and fall of 2024. Photogrammetry surveys were completed in April 2025 and comparisons of preconstruction and post-construction aerial images were included in Appendix A (Figures A1-A4).

Sediment Surveys:

The fill material used to create the new channel, islands, and floodplain bench was sourced from an alluvial fan on a nearby hillslope (Figure 1). Material from the borrow pit at the alluvial fan was generally smaller than the specified gradations in the design plans (Richer and Kondratieff 2023), which were based on the existing streambed. Therefore, observed gradations are expected to coarsen over time as finer sediment is winnowed away during high flow events. Pebble counts for as-built and post-runoff conditions at riffles were used to investigate changes in sediment gradation following each post-construction runoff cycle. Riffle 1 was treated with experimental dearmoring, while riffles 2A, 2B, and 3 were treated with channel narrowing, which included a top dressing with fill material from the borrow site to meet the design elevations and channel dimensions. Riffle 0 is an untreated control above the project reach, and was established as a new control site in October 2024 to support comparisons with the treated riffles.

After two post-construction runoff cycles, riffle dearmoring appears to have decreased the D_{16} and D_{50} at riffle 1, but the D84 remained similar to preconstruction observations (Table 2). We also see evidence of increased fines and gravels, with a corresponding decrease in the amount of cobble substrate (Figure 2). The D_{16} was classified at very-coarse gravel prior to construction, and decreased to coarse gravel after the first post-construction runoff cycle and to medium gravel after the second runoff cycle. The D_{50} and D_{84} remained classified as small and large cobble, respectively. The increase in gravels may indicate that riffle dearmoring has improved the heterogeneity of sediment sizes at this location, but additional monitoring will be needed to see if the effects are sustained over time.

More substantial changes in sediment size were observed at riffles 2A and 2B when compared to riffle 1. Comparison to preconstruction pebble counts indicates that construction decreased the D_{16}, D_{50}, and D_{84} at both riffles 2A and 2B due the larger fraction of gravel-sized material in the fill material from the borrow pit (Table 2). As expected, sediment size coarsened following the first post-construction runoff at these locations. The D_{16}, D_{50}, and D_{84} all increased following runoff at riffles 2A and 2B, with many values doubling in size between the as-built and post-runoff pebble counts. The coarsening trend continued in 2024 following the second post-construction runoff cycle. The proportion of sediment classified as gravel decreased, while the fraction of cobble increased (Figure 3). However, fewer fines and cobbles, and more gravel, were observed in the 2024 sample when compared to preconstruction conditions, indicating the sediment diversity remains improved at these sites. We also observed more gravel and less cobble at riffle 3 when the preconstruction and post-runoff pebble counts are compared (Figure 4). Overall, the streambed continued to coarsen during runoff in 2024, but the magnitude of change was less pronounced in 2024 when compared to the changes observed in 2023. If the streambed continues to armor over time, additional gravel augmentation may be needed to maintain a heterogeneous sediment gradation that includes a mixture of spawning-sized gravels and coarser cobbles that provide habitat for Sculpin and Salmonflies.

Table 2. Sediment gradations for preconstruction (before), as-built, and post-runoff conditions at four treated riffles (riffles 1, 2A, 2B, and 3) and one control riffle (riffle 0) within the Kemp-Breeze SWA Habitat Project reach on the Colorado River.

Site	Date	Survey	D16 (mm)	D50 (mm)	D84 (mm)	n
Riffle 0	10/4/2024	Control	35	96	200	275
Riffle 1	4/27/2022	Before	39	85	144	321
	9/28/2023	Post-runoff	25	80	165	327
	10/3/2024	Post-runoff	10	66	148	324
Riffle 2A	4/29/2022	Before	15	76	165	372
	11/16/2022	As-built	11	32	110	257
	9/28/2023	Post-runoff	18	64	125	176
	10/3/2024	Post-runoff	15	51	116	176
Riffle 2B	11/17/2022	As-built	14	34	100	235
	9/28/2023	Post-runoff	22	70	200	184
	10/3/2024	Post-runoff	28	102	210	176
Riffle 3	4/29/2022	Before	37	102	205	334
	10/4/2024	Post-runoff	16	64	150	243

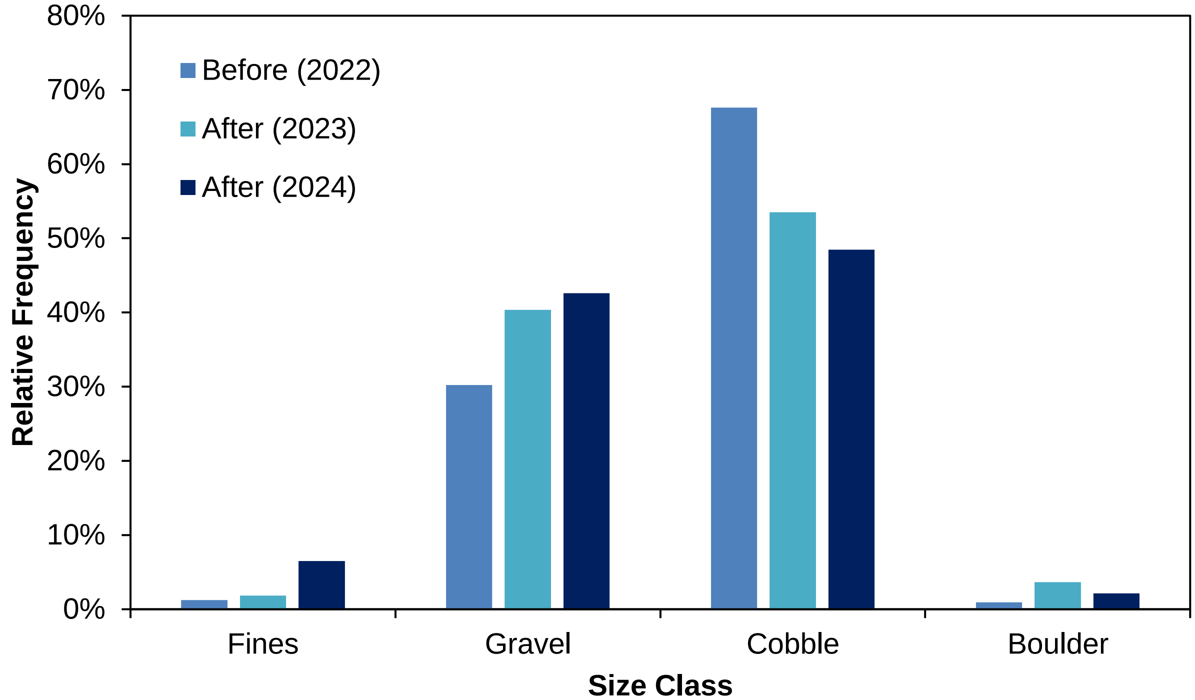

Figure 2. Percentage of sediment particles by size class from pebble counts at the riffle 1 showing the change in sediment gradation following riffle dearmoring.

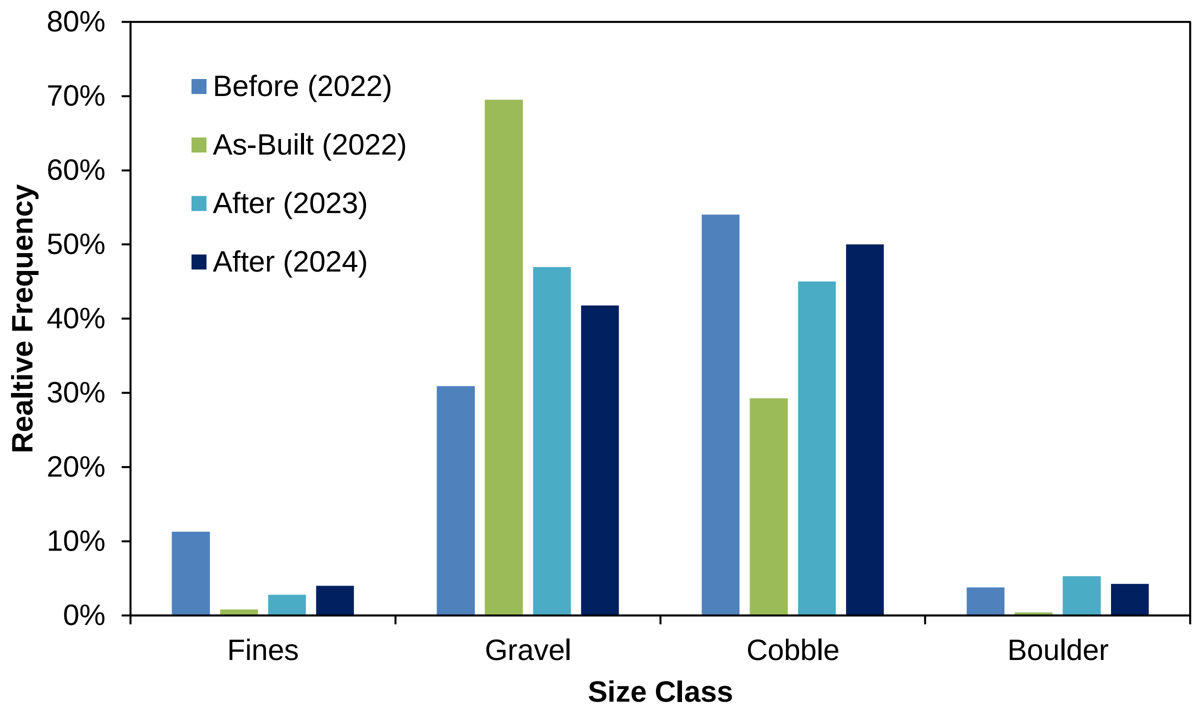

Figure 3. Percentage of sediment particles by size class from pebble counts at the riffle 2 (before) and riffles 2A/2B combined (as-built and after) showing the change in sediment gradation following channel narrowing.

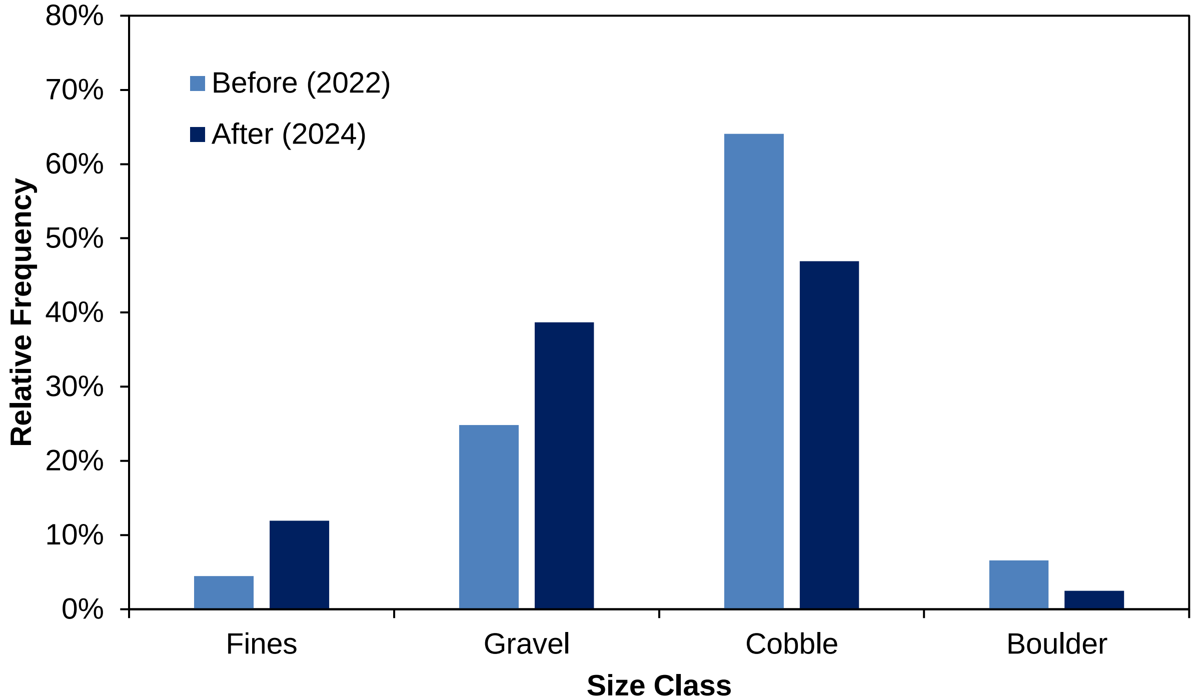

Figure 4. Percentage of sediment particles by size class from pebble counts at the riffle 3 showing the change in sediment gradation following channel narrowing.

Tracer Rocks:
For the post-construction study, we deployed 240 PIT-tagged tracer rocks within the Phase 1 project reach prior to snowmelt runoff in April 2023. We then deployed 23 tracer rocks at gravel augmentation sites in the Phase 2 reach in April 2024 and 286 tracer rocks in October 2024. The October 2024 deployment included 100 tracer rocks at riffle 0 (upstream control), 100 tracer rocks at riffle 3 (Phase 2 reach), 45 additional tracer rocks at riffle 2A (Phase 1 reach), and 41 additional tracer rocks at riffle 2B (Phase 1 reach). The total number of deployed tracer rocks for the post-construction study is now 549, the majority of which were placed in riffle locations (n = 486), followed by gravel augmentation sites (n = 53) and overflow channels (n = 10). Tracer rocks ranged in size from 12 to 290 mm (Table 3), with size classes ranging from medium gravel to small boulder.

We relocated 185 tracer rocks (70%) during the fall of 2024. Preliminary results indicate the distance moved was much greater in 2023-2024 when compared to the pre-construction surveys (Figure 5), with the average distance moved increasing from 0.5 ft to 95.7 ft between before and after periods (Table 3). The difference in distance moved is partially explained by the inclusion of smaller-sized particles in the after period (Table 3), but was primarily driven by the combination of high flows (Figure 6) and the placement of unconsolidated fill material at study riffles during construction. Within the post-construction period, the average distance moved increased slightly from 87.6 ft in 2023 to 104.1 ft in 2024. Gravel particles moved the farthest, followed by cobbles and boulders (Figure 7), and distance moved appeared to decrease with increasing sediment size (Figure 8). The average distance moved by tracer rocks in 2024 was greatest for overflow sites (1,563 ft, n = 1), followed by riffle 2 (165 ft, n = 69), gravel augmentation sites (147 ft, n = 29), and riffle 1 (30 ft, n = 85). The maximum distances moved was 1,563 ft for overflow sites, 1,306 ft for riffle 2, 1,010 ft for gravel augmentation sites, and 719 ft for riffle 1 (Figure 9). Excluding the lone relocated rock from overflow sites, the minimum distance moved by site ranged from 0.03-0.08 ft. Tracer rocks in riffle 1 moved shorter distances relative to other sites, but were transported much farther in after period when compared to the before period. Biological monitoring of benthic macroinvertebrates and Sculpin will help determine if riffle dearmoring is an effective restoration treatment that should be utilized in future phases of the Habitat Project.

Table 3. Summary statistics for distance moved and tracer-rock size during the before (2019-2021) and after (2023-2024) study periods. SD = standard deviation.

Period	**n**	**Distance Moved (ft)**			
		Max	**Mean**	**Min**	**SD**
Before	898	11	0.5	0.01	1.1
After	333	1563	95.7	0.03	224
Period	**n**	**Particle Size (mm)**			
		Max	**Mean**	**Min**	**SD**
Before	300	290	101	41	45
After	263	290	77	12	60

The relocation rate for tracer rocks during the before period was very high (99%), but we were only able to relocate 70% of the tracer rocks in 2023-2024 due the greater distances moved. We developed two new pack-raft antennas in 2024 to help survey the entire river channel (Figure 10) using similar components to those described in Richer et al. (2017). After detecting a tracer rock with the pack-raft antennas, we then investigated each detection with backpack antennas until we relocated the actual tracer rock in the streambed. If we could not relocate the actual rock, we used the backpack antenna to identify the location of the detected tracer rock in the streambed and then surveyed the center of the detection field (~1 ft^2). The location of 21 tracer rocks (11% of relocations) had to be approximated in this manner in 2024, typically because the rock was buried too deeply to be physically relocated or located in a deep pool. The more intensive relocation methods have increased the number of tags we detected, as well as the amount of effort required to complete each survey. Results from pebble counts and tracer rocks indicate that bedload transport occurred at all study sites during 2024, which redistributed tracer rocks through the project reach (Figures A5-A6). At least three years of post-construction tracer rock surveys are planned to investigate sediment transport over a range of flows, including the fall of 2025. Final analyses will be performed following completion of the post-restoration monitoring period in 2026.

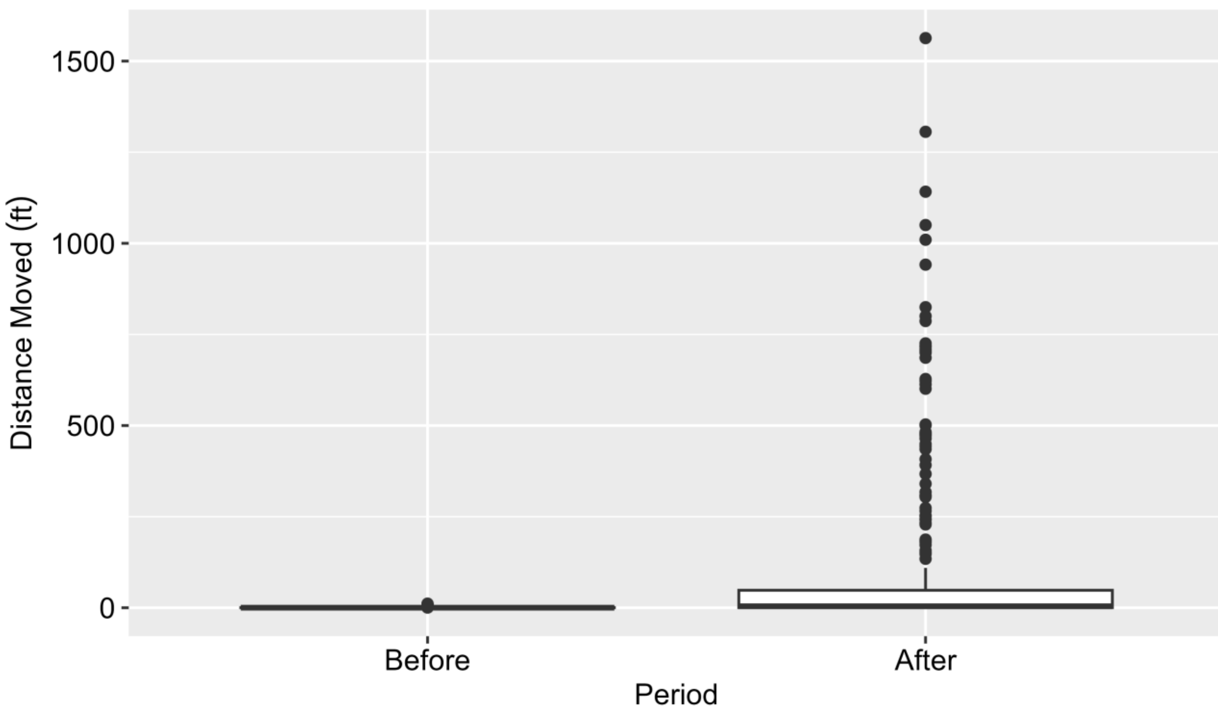

Figure 5. Boxplots for distance moved by tracer rocks during the before (2019-2021) and after periods (2023-2024).

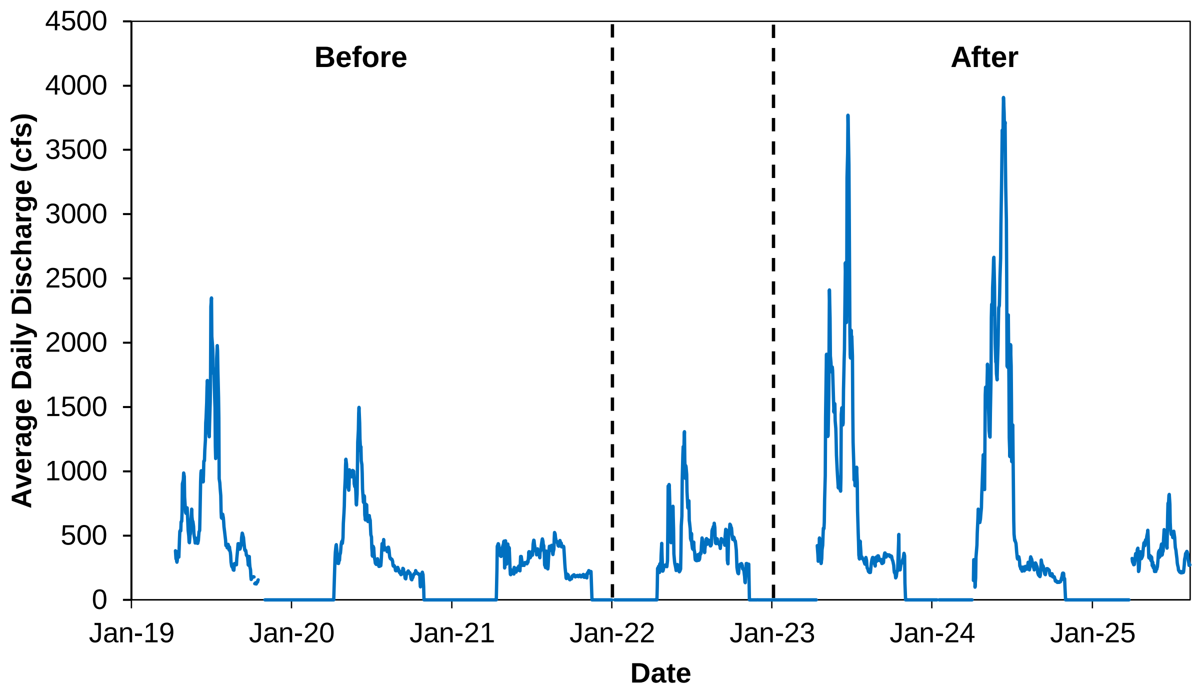

Figure 6. Average daily discharge (cfs) at the Kemp-Breeze SWA project site on the Colorado River, 2019-2025. Periods: before = 2019-2021, construction = 2022-2023, after = 2023-2025.

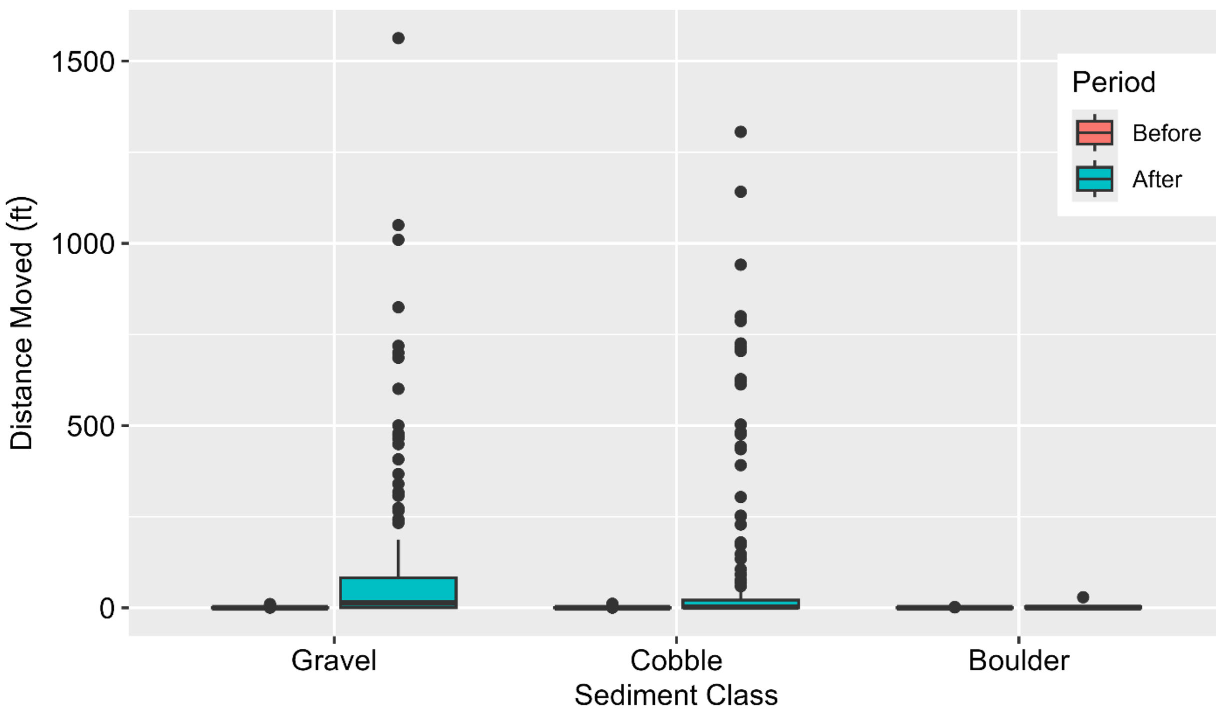

Figure 7. Boxplots for distance moved by tracer rocks within sediment size classes during the before (2019-2021) and after periods (2023-2024).

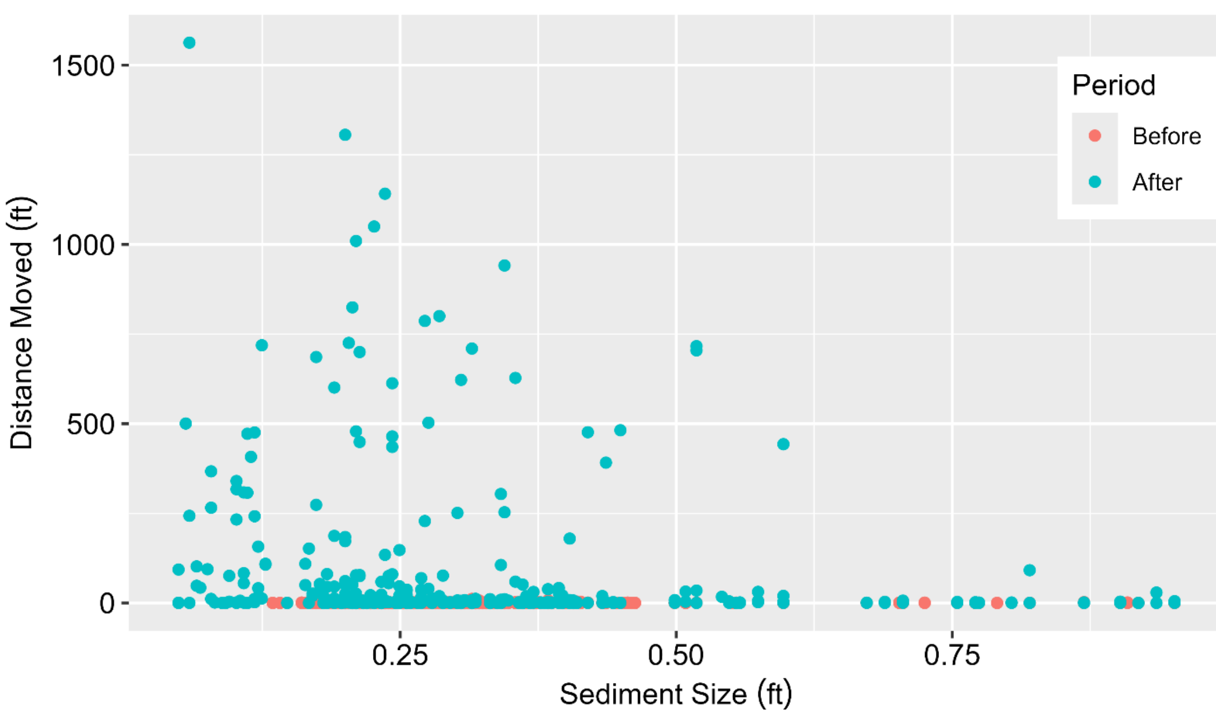

Figure 8. Comparison of sediment size and distance moved for tracer rocks that were relocated during the before (2019-2021) and after (2023-2024) periods.

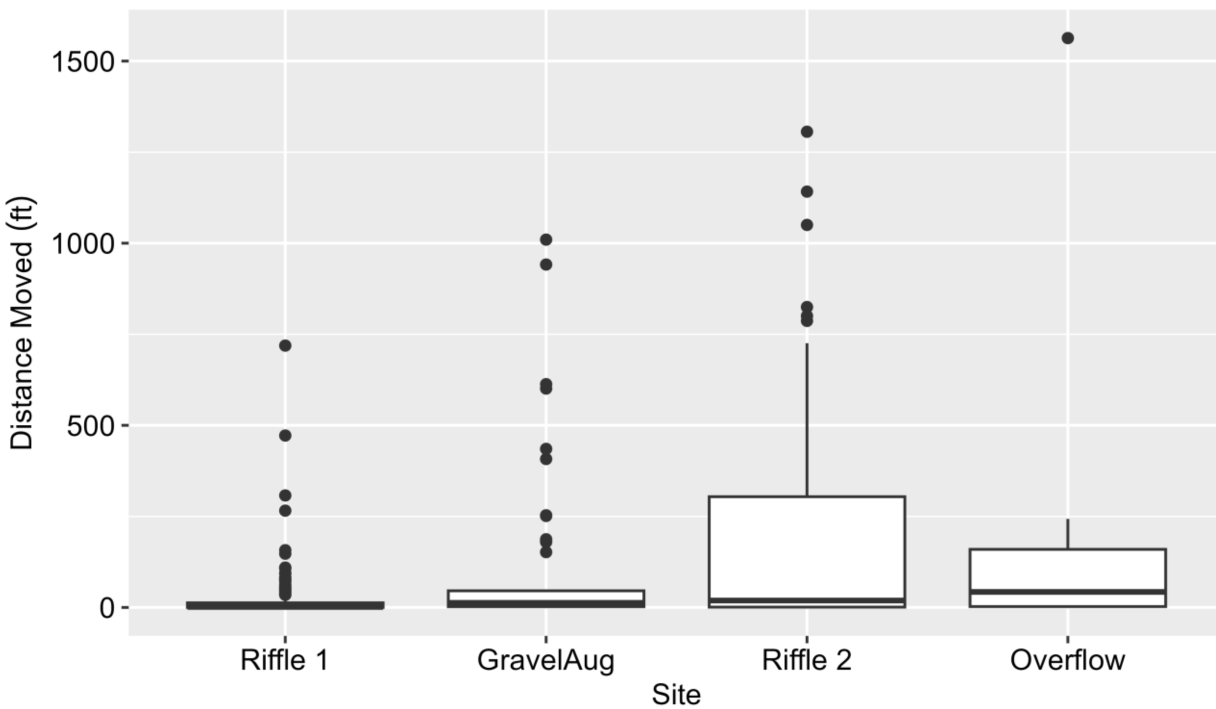

Figure 9. Distance moved per year for tracer rocks at each study site during the after period (2023-2024). Note that riffle 2 includes data from both riffles 2A and 2B.

Figure 10. New pack-raft antenna system used to relocate PIT-tagged tracer rocks in 2024.

Log-Jam Assessment:

We used the log-jam assessment procedure (Richer and Kondratieff 2023) to evaluate 70 structures during April 2025, including post-runoff conditions for 27 engineered log-jams installed within the Phase 1 project reach and 43 log-jams within the Phase 2 reach. Bank jams were the most common structure type (41%), followed by downed cottonwood trees (24%) and floodplain jams (21%). Large-pool jams and bar-apex jams were used less frequently (7% and 4%, respectively), and a lone in-channel jam was installed in a Phase 1 side-channel. In total, 279 piles, 233 horizontal logs without rootwads, 173 logs with rootwads, and 21 cottonwood trees were used in construction of the log jams. All but one of the structures was considered stable and intact during the as-built assessments.

Flows were higher than average in 2024 and peaked around 3,908 cfs (Figure 6), inundating the constructed islands and floodplains (Figure 11). Some bank erosion was evident after the 7-year flood event, and 16% of the structures were ranked as damaged, impaired, or failed during the 2024 assessment. Five structures were flagged for additional monitoring due to compromised integrity, but those structures were still providing beneficial functions and maintenance is not recommended at this time. Maintenance was recommended for another four structures due significant damage or failure and loss of beneficial functions. However, as access roads have already been restored, the amount of disturbance to the floodplain and channel from accessing the structure sites was considered prohibitive. As such, those structures were considered a loss and no maintenance activities are planned at this time.

Minor erosion and deposition was common at log jams following the high flows of 2024, occurring at 74% and 63% of the structures, respectively. Moderate to severe erosion was observed at 18 structures (26%), while moderate to severe deposition occurred at 37% of the log jams. No structures were considered a risk to fish passage. Habitat assessment indicated that 66% of the log jams provided overhead cover for fish, 57% created complex habitat, 46% provided depth cover, 53% provided juvenile refuge for trout, 59% provided foraging habitat, and 33% provided rearing habitat for trout fry. Habitat scores were lower for log-jam structures in 2024 when compared to 2023 due to the addition of 10 floodplain structures in the Phase 2 reach that were dry on the day of the assessment. The percentage of structures that received poor vegetation rankings decreased from 71% during the previous survey to 64% in the most recent survey. The number of structures that received vegetation rankings of fair to good increased from 28% to 35%, indicating that riparian vegetation cover was improving. The growth of riparian vegetation is also evident in Figure 11.

Repeat photography at each structure was used to document changes over time. Although log-jams were engineered to withstand a 10-year flood, some structures failed during the 7-year flood events that occurred in 2023 and 2024. An example of a failed bank jam is shown in Figure 12. This structure likely failed because the logs were not buried far enough into the bank to provide sufficient ballast. Evidence of wood racking on a downed cottonwood tree is shown in Figure 13, which increases the forces acting on the log jam. The failure of piles at a downed cottonwood tree is shown in Figure 14. These piles likely failed due to inadequate embedment depth between the top of the new floodplain bench and underlying bedrock. Sufficient embedment depth for structures anchored with piles and sufficient ballast for structures anchored without piles are critical design considerations for the longevity of engineered log jams.

Figure 11. Select photos showing flows (Q) in the Phase 2 project reach of the Kemp-Breeze SWA Habitat project during 2024, including a downed cottonwood tree in the foreground, as well as a gravel augmentation pile, constructed island, and bar-apex jam in the background.

Figure 12. Example of failed bank-jam structure from log-jam assessments at the Kemp-Breeze SWA Habitat Project on the Colorado River.

Figure 13. Example of wood racking on a downed cottonwood tree from log-jam assessments at the Kemp-Breeze SWA Habitat Project on the Colorado River.

Figure 14. Example of failed piles at a downed cottonwood tree observed during log-jam assessments at the Kemp-Breeze SWA Habitat Project on the Colorado River.

ACKNOWLEDGEMENTS

We would like to acknowledge Barry Nehring for his work documenting changes in benthic macroinvertebrates, Colorado Sculpin, and trout populations following construction of Windy Gap Reservoir that ultimately led to the development of the greater Habitat Project on the Colorado River. We also thank the various collaborators and technicians that have contributed to the data collection and analysis, including Jon Ewert, Eric Fetherman, and Dan Kowalski. Finally, we would like to thank George Schisler, Lori Martin, Karlyn Armstrong, Ken Kehmeier, and Sherman Hebein for their contributions to development and implementation of the fish and wildlife mitigation and enhancement plans for the Colorado River.

REFERENCES

Adams, S. B., and D. A. Schmetterling. 2007. Freshwater sculpins: phylogenetics to ecology. Transactions of the American Fisheries Society 136:1763-1741.

Bain, M. B., and N. J. Stevenson, editors. 1999. Aquatic habitat assessment: common methods. American Fisheries Society, Bethesda, Maryland.

Bunte, K., and S. R. Abt. 2001. Sampling surface and subsurface particle-size distributions in wadable gravel- and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring. Gen. Tech. Rep. RMRS-GTR-74. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 428 p.

Dames and Moore. 1977. Environmental assessment report Windy Gap project Grand County, Colorado for municipal subdistrict, Northern Water Conservancy District. Denver, CO.

Denver Water. 2011. Moffat Collection System Project: Fish and Wildlife Enhancement Plan. Prepared for the Parks and Wildlife Commission. 26 p.

Erickson, R. C. 1983. Benthic field studies for the Windy Gap study reach, Colorado River, Colorado, fall, 1980 to fall, 1981. Prepared for The Northern Colorado Water Conservancy District, Municipal Sub-District.

Fore, L. S., J. R. Karr, and R. W. Wisseman. 1996. Assessing invertebrate responses to human activities: Evaluating alternative approaches. Journal of the North American Benthological Society 15(2):212-231.

Kondratieff, M. C., and E. E. Richer. 2023. Stream Habitat Investigations and Assistance Project Summary. Colorado Parks and Wildlife, Fort Collins.

Kowalski, D. A., and B. D. Heinold. 2019. Colorado River ecology and water project mitigation investigations. Colorado Parks and Wildlife. 12 pp.

Kowalski, D. A., and E. E. Richer. 2020. Quantifying the habitat preferences of the stonefly *Pteronarcys californica* in Colorado. River Research and Applications 36:2043-2050.

Miller, J. R., and R. C. Kochel. 2013. Use and performance of instream structures for river restoration: a case study from North Carolina. Environmental Earth Science 68: 1563-1574.

Nehring, R. B., B. D. Heinold, and J. Pomeranz. 2011. Colorado River aquatic resources investigations. Colorado Division of Wildlife, Federal Aid in Sportfish Restoration, Project F-237R-18, Final Report, Fort Collins.

Richer, E. E., E. R. Fetherman, M. C. Kondratieff, and T. A. Barnes. 2017. Incorporating GPS and mobile radio frequency identification to detect PIT-tagged fish and evaluate habitat utilization in streams. North American Journal of Fisheries Management 37:1249-1264.

Richer, E. E., M. C. Kondratieff, J. Ewert, E. R. Fetherman, D. A. Kowalski, and T. Kittell. 2019. Kemp-Breeze State Wildlife Area Habitat Project, Colorado River: Site Assessment and Conceptual Design Report. Colorado Parks and Wildlife, Fort Collins.

Richer, E. E., and M. C. Kondratieff. 2023. Stream Habitat Investigations and Assistance Project Summary: 2023 Progress Report. Colorado Parks and Wildlife, Fort Collins.

Rosgen, D. 2008. River stability field guide. Wildland Hydrology, Fort Collins, Colorado.

Sigler, F. F., and R. R. Miller. 1963. Fishes of Utah. Utah Department of Fish and Game, Salt Lake City. 203 p.

Stillwater Sciences. 2020. Kemp Breeze State Wildlife Area Colorado River Aquatic Habitat Project Basis of Design Report: Draft 60% Design. Stillwater Sciences, Boulder, Colorado.

Stillwater Sciences. 2021. Kemp Breeze State Wildlife Area Colorado River Aquatic Habitat Project Basis of Design Report: Final “Construction Ready” Design. Stillwater Sciences, Boulder, Colorado.

Subdistrict (Municipal Subdistrict, Northern Colorado Water Conservancy District). 2011. Windy Gap Firming Project: Fish and Wildlife Enhancement Plan. Prepared for the Parks and Wildlife Commission. 16 p.

Tetra Tech. 2010. Stream Management Plan, Phase 3, Grand Country Colorado. Prepared for Grand Country, Colorado. 37 p.

USFWS (U.S. Fish and Wildlife Service). 1951. Recreational use and water requirements of the Colorado River fishery below Granby Dam in relation to the Colorado-Big Thompson diversion project. U.S. Fish and Wildlife Service, Region 2, Albuquerque, NM.

Weber, N., G. Wathen, and N. Bouwes. 2020. Low-tech process based restoration project implementation and monitoring protocol. Eco Logical Research and Oregon Watershed Enhancement Board.

Woodling, J. 1985. Colorado's little fish: a guide to the minnows and other lesser known fishes in the state of Colorado. Colorado Diversion of Wildlife, Denver. 82 p.

Young, M. K., R. Smith, K. L. Pilgrim, D. J. Isaak, K. S. McKelvey, S. Parkes, J. Egge, and M. K. Schwartz. 2022. A molecular taxonomy of *Cottus* in western North America. Western North American Naturalist 82(2).

RESEARCH PRIORITY:

Making waves: the effects of whitewater parks on fish passage in Colorado

OBJECTIVES

The objective of the study was to evaluate changes in fish passage over a range of flows for a variety of fish species and size classes using two-dimensional hydrodynamic modeling, spatial analysis, and logistic regression modeling. Study sites included the Gore Canyon Whitewater Park at the Pumphouse Recreation Area on the Colorado River and the Montrose Whitewater Park on the Uncompahgre River.

The study was described in detail in a manuscript that was submitted for publication in River Research and Applications. The paper is currently in review and the abstract is provided below.

ABSTRACT

Instream structures have fragmented riverine habitats throughout much of the world, including in the western US. Whitewater parks (WWP) are relatively new instream structures designed to create hydraulic waves for recreational boating and surfing by constricting flows into a steep chute or drop. The altered hydraulics at these structures can adversely affect fish passage, particularly in locations where fish species are not adapted to the new hydraulic regime. This study evaluates the effects of WWPs on fish passage at two sites in Colorado by comparing water velocity and depth to fish passage criteria for three size classes (juvenile, average adult, and large adult) and species of interest (Brown Trout, Colorado Sculpin, and Flannelmouth Sucker). The before-after study design utilized two-dimensional hydrodynamic modeling, spatial analysis, and logistic regression to evaluate fish passage over a range of flows. Whitewater park construction altered channel hydraulics, including elevated and more variable velocity, and decreased depth. Complete barriers to upstream passage were created for certain combinations of species, size class, and flow rate due to velocity and/or depth limitations. Passable pathways decreased for all species following WWP construction, with Brown Trout maintaining the highest proportion of passable paths (23%) when averaged across flowrate and structure, followed by Colorado Sculpin (15%) and Flannelmouth Sucker (2%). These results indicate that WWP construction decreased fish passage at these sites, and highlight the importance of using site-specific criteria and permitting requirements to ensure that adequate safeguards for fish passage are incorporated into the design of WWP structures.

ACKNOWLEDGEMENTS

We thank Eric Gardunio, Jon Ewert, Tom Fresques, and numerous technicians for supporting fieldwork.

REFERENCES

Richer, E. E., B. F. Friesen, A. E. Brubaker, D. A. Kowalski, M. C. Kondratieff, and T. A. Barnes. *In review*. Making waves: the effects of whitewater parks on fish passage in Colorado. River Research and Applications.

RESEARCH PRIORITY:

White River Toe-Wood Study

OBJECTIVES

1) Design and construct a toe-wood structure to stabilize a lateral scour bend experiencing accelerated erosion and protect a wetland mitigation area on the Rio Blanco Lake State Wildlife Area (SWA), White River
2) Evaluate the response of pool depths and native Three Species (Bluehead Sucker, Flannelmouth Sucker, and Roundtail Chub) to the addition of large wood habitat treatments (i.e., toe wood) within pools

INTRODUCTION

The White River Toe-Wood study is a new concept, bridging stream habitat projects that historically focused on non-native game species (i.e., Brown Trout *Salmo trutta* and Rainbow Trout *Oncorhynchus mykiss*) to native species of conservation concern. We will take knowledge and concepts learned from two decades of habitat restoration work on coldwater non-native salmonid streams and apply those techniques to benefit the native Three Species (Roundtail Chub *Gila robusta*, Bluehead Sucker *Catostomas discobolus*, and Flannelmouth Sucker *Catostomas latipinnus*; Figures 15) as well as other native fish species found in the White River (e.g., Mountain Whitefish *Prosopium williamsoni*; Figure 16). We have documented from our previous stream habitat work that toe wood can increase fish abundance by 1.5 times and biomass by up to 10 times versus non-treated impaired reaches (Kondratieff and Richer 2022). This has not been attempted for Colorado native Three Species, but the results from salmonid habitat projects and the response of native species present (i.e., White Sucker *Catostomus commersonii*) indicate that this project should be successful at increasing the quality of habitat for these native fishes. We hope that by showing a successful response in native fish abundance and biomass in this small-scale project on the White River, we can then begin to refine and apply these habitat projects in other parts of the Upper Colorado River Basin where stream habitat has been impaired. We are implementing a before-after, control-impact (BACI) study design to monitor the response in the fish community and habitat pre and post-construction. Additionally, we will attempt to use an Integrated Population Model (IPM) that incorporates estimates of survival and movement derived from monitoring PIT-tagged fish to determine the proportion of the population composed of local survivors (residents) and immigrants (migratory fish) making up the total fish population within the White River (Kanno et al. 2025).

Figure 15. Photos of a Roundtail Chub (top), Bluehead Sucker (middle), and Flannelmouth Sucker (bottom), commonly referred to as the Three Species.

Figure 16. Native fish of the White River (from top to bottom): Speckled Dace, Sculpin, Mountain Sucker, and Mountain Whitefish.

The 550-ft section of the White River on the Rio Blanco Lake SWA is experiencing accelerated erosion (averaging over 10 ft of bank loss per year) due to historical agricultural practices, loss of deep-rooted vegetation, and improperly installed instream grade-control structures (Figures 17-18). The river is becoming increasingly over-wide and shallow, as well as experiencing a decrease in substrate size due to the erosional issue on the SWA. We plan to address the erosional issue to restore the proper geomorphology of the river, while also increasing native aquatic species habitat in the form of increased riparian vegetation and instream wood. Over the past century, throughout most of the United States, humans have removed much of the instream wood that would normally migrate downstream and form log jams. This instream wood is vital for increasing habitat complexity and enhancing geomorphic functions. Along with the supporting evidence of fish preference for instream wood from our work in South Park, our local fisheries biologists note that they commonly find a high abundance of our focal species in log jams, so we anticipate that this project will provide beneficial habitat. The project will also reduce the width-to-depth ratio of the stream and increase substrate size, thus reducing water temperature and increasing interstitial habitat for benthic macroinvertebrates and foraging opportunities for our focal species. Another potential benefit of this project is to provide a showcase example of how toe wood can be used as an alternative to typical bank stabilizing techniques practiced on the White River, such as using car bodies, riprap, and concrete rubble (Figure 19).

Figure 17. Accelerated erosion on a 550 ft long bank of the Rio Blanco Lake SWA.

If we are not seeing a positive response in the native aquatic species community and river geomorphology we will attempt to determine the limiting factors (i.e., competition with non-native fishes, species-specific habitat suitability preferences, etc.). In South Park, monsoonal flooding has damaged some of the habitat work the year after construction before vegetation was fully established to secure the bank. In these events we have gone back to conduct maintenance work by retreating toe wood banks with heavy equipment and additional vegetation to ensure the security of the habitat work.

Figure 18. Accelerated erosion on a 550 ft long bank of the Rio Blanco Lake SWA. Over thirty feet of bank loss in three years (2022-2025) using a River Birch (red circle) as an indicator.

Figure 19. Bank stabilizing techniques typical of the White River downstream of Meeker, Colorado, including use of car bodies and concrete rubble.

There are very few non-native species present in the White River (3-10% of fish sampled in our study pools) and the project site occurs at the transition zone between cold and warm water habitats, so it is unlikely that salmonids will become so abundant that they exclude the native species. In the South Platte drainage, we have documented native suckers competing well with salmonids where they do overlap. We conduct extensive non-native fish control projects throughout western Colorado and will be ready to remove non-native fish in the event a new species is illegally introduced that may threaten the native fishes of the White River.

From our previous work in South Park, Colorado, we can anticipate a positive response in the fish community by increasing the abundance and biomass of the fish in the project reach versus untreated areas (Kondratieff and Richer 2022). We hope this will lead to an overall increase in the native fish community in the area surrounding the SWA. Instream wood is also known to be attractive habitat for macroinvertebrates that will provide forage for the focal species of the project. By stabilizing the bank, we expect to decrease the width-to-depth ratio, leading to an increase in substrate size in treated areas. The larger substrate is preferable for spawning habitat and creates interstitial spaces for macroinvertebrates. By decreasing the width to depth ratio and encouraging riparian vegetative cover, we have also documented a drop in stream temperatures in treatment reaches. This drop in stream temperature will benefit fish populations, especially during hot summer months and in the face of climate change. Along with the aforementioned benefits, we also have documented an increase in residual pool depth, which will increase refuge during low-flow periods and additional cover from avian and terrestrial predators.

METHODS

Baseline Surveys:

Hydraulic, geomorphic, and topographic surveys of the treatment site and upstream/downstream control sites began in October 2023 and was completed in October 2024 (Figure 20). Baseline fish population surveys (Figure 21) began in October 2023 and will continue until construction begins in the fall of 2026. We intend to collect up to three years of baseline data on fish populations prior to construction if flow conditions permit. Upon completion of construction, we plan to conduct the same sampling; 1 year, 3 years, 5 years, and 10 years after construction is complete to monitor the fish community and geomorphic response through time.

Fish surveys targeted habitat as two distinct spatial scales: (1) at the microhabitat scale of individual pools and (2) the reach scale, which is defined as having a minimum of three consecutive riffle-pool sequences and total reach lengths greater than 1,400 ft. The overall study site consists of three reaches with a single individual pool nested within each reach (Figure 22). There is an upstream, treatment, and downstream reach. The upstream and downstream reaches are located on either side of the treatment reach and serve as controls for comparison with the treatment reach. The treatment reach includes the 550 ft bend (treatment pool) that will be restored using toe wood. Nested within each reach are individual pools that will be used as either a control (upstream or downstream) or treatment within our BACI study design. The intention of including multiple spatial scales is to determine what level of restoration (i.e., number of pools treated or miles of habitat restored) is capable of producing a fish population response at the microhabitat, reach, or even segment scale within the river.

Figure 20. Collecting baseline geomorphic data in October 2023 and 2024.

Fish sampling methods have evolved from our first attempt to sample the population in October 2023 using two barge electrofishing units equipped with five electrodes each and deployment of downstream block nets (Figure 21). Population estimates within individual pools were estimated using depletion methods. In 2023, flow conditions in the White River were very high, running at nearly 400 cfs during the time of sampling. Under these flow conditions, we found that the river was nearly un-wadable (too deep and fast) and yet the length of our pools was too short to employ mark-recapture techniques for population estimation. As a compromise, we modified our fish sampling techniques and changed to using a raft equipped with a thrown electrode in 2024 (Figure 23). A large crew (>10 people) deployed a 100 foot seine downstream, stretched across the river to serve as a block net and meet our assumption of closure. We then fished from upstream to downstream toward the block net for each pass. All fish that were captured were identified, weighed, and measured (TL). In addition, any native fish or sportfish (Rainbow Trout and Brown Trout) over 150 mm TL were PIT tagged using Biomark 12 mm tags.

Figure 21. Collecting baseline fish population data using a barge electrofishing unit in October 2023 under high-flow conditions approaching 400 cfs.

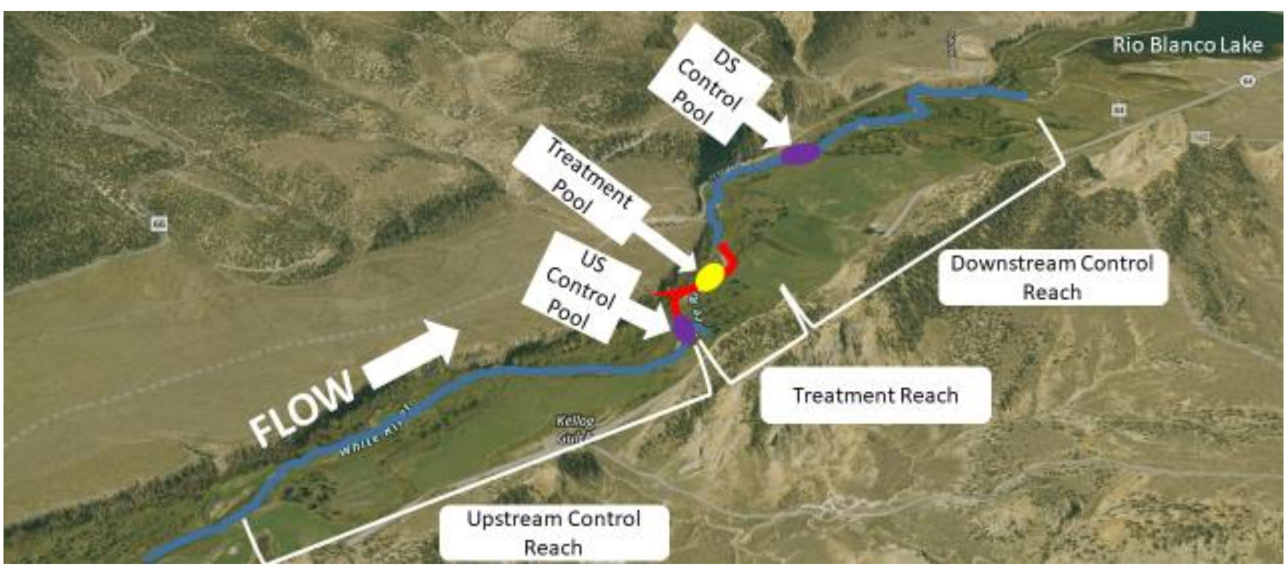

Figure 22. Study site on the White River upstream of Rio Blanco Lake including the location of control and treatment pool and reaches.

Figure 23. Collecting baseline fish population data using an electrofishing raft with thrown electrode at baseflow conditions of approximately 100 cfs.

PIT Tagging:

As part of our effort to estimate movement and survival for our species of interest, we PIT tagged over 1,200 fish in 2024 (Figure 24) and placed 3 ft Biomark submersible antennas at the upstream and downstream boundaries of each of our three study reaches (upstream, treatment, and downstream; Figure 25). We PIT tagged a total of 1,210 individual fish in 2024 that included Mountain Whitefish (75%), Bluehead Sucker (9%), Brown Trout (8%), Rainbow Trout including hybrids (6%), and Roundtail Chub, Cutthroat Trout *Oncorhynchus clarkii*, Flannelmouth Sucker, Mountain Sucker *Catostomus platyrhynchus*, and Sculpin *Cottus* spp. (all 1% or less). Fish were PIT tagged using 12 mm Biomark RFID tags. Fish movements were monitored from late August 2024 until ice formation in early November 2024. PIT tag antennas were again deployed in spring 2025 and will remain in place until ice forms this year.

Figure 24. PIT tagging a Bluehead Sucker using pre-loaded Biomark 12 mm RFID tags

Concept Design Development:

Topographic surveys were conducted with a Trimble Survey-Grade Global Navigation Satellite System (GNSS) to document the existing conditions of the channel and floodplain (Richer and Kondratieff 2024). Survey data were post-processed and then used to create a triangular irregular network (TIN) in ArcGIS Pro to represent the existing surface. Breaklines were digitized and used to edit the TIN in locations with distinct slope breaks. Longitudinal and cross-sectional profiles were extracted from the TIN to later be compared with the post-construction surface to document changes in morphology and develop concept designs. Using these profiles, bankfull width, cross sectional area, and average depth were calculated for each of the eight cross sections.

The existing conditions survey and assessment will be used for development of a concept design including optimization of river alignment, bankfull channel dimensions, cut and fill calculations, optimal locations to install toe wood treatments, and appropriate locations for grading river bedform features such as runs, pools, glides, and riffles. We will work with a professional engineer to help us develop a final design and work within the constraints of the project including property boundaries, project budget, and CPW land management practices on the SWA. Project funding includes money from CPW capital construction, the Desert Fishes Council, and SCTF money for assistance with design costs. Materials such as boulders and large wood are currently being staged near the project site. We plan to use our own CPW heavy construction operators and project managers to assist with the construction and implementation of this project.

RESULTS AND DISCUSSION

Baseline surveys for fisheries will be collected annually until project construction occurs in the fall of 2026. Preliminary results from fish population estimates are presented in Table 4. Population estimates were higher at all sites in 2025 when compared with 2024, possibly due to the lower flows in 2025 that provided more optimal conditions for surveying and the change to a thrown electrode approach with downstream block net. PIT-tag detections were dominated by Mountain Whitefish, but included detections of Brown Trout, Rainbow Trout, Rainbow Trout hybrids, Bluehead Suckers, Flannelmouth Suckers, as well as some unknown tags (Figure 25). Analysis of survey data indicated that the average bankfull width was 143 ft and the average bankfull cross-sectional area was 445 ft^3. The geomorphic data from existing conditions will help inform conceptual designs and lead to a final construction design.

Table 4. Population estimates using the thrown electrode electrofishing technique during higher (2024) and lower (2025) baseflow conditions. Population estimates are for all fish >150 mm TL.

Study Pool	2024			2025		
	Population Estimate (95% CI)	Passes (n)	Stream Discharge (cfs)	Population Estimate (95% CI)	Passes (n)	Stream Discharge (cfs)
Upstream	108 (98-119)	3	390	420 (368-473)	3	100
Treatment	142 (85-200)	2	390	227 (209-245)	3	100
Downstream	89 (78-101)	2	340	95 (81-110)	3	100

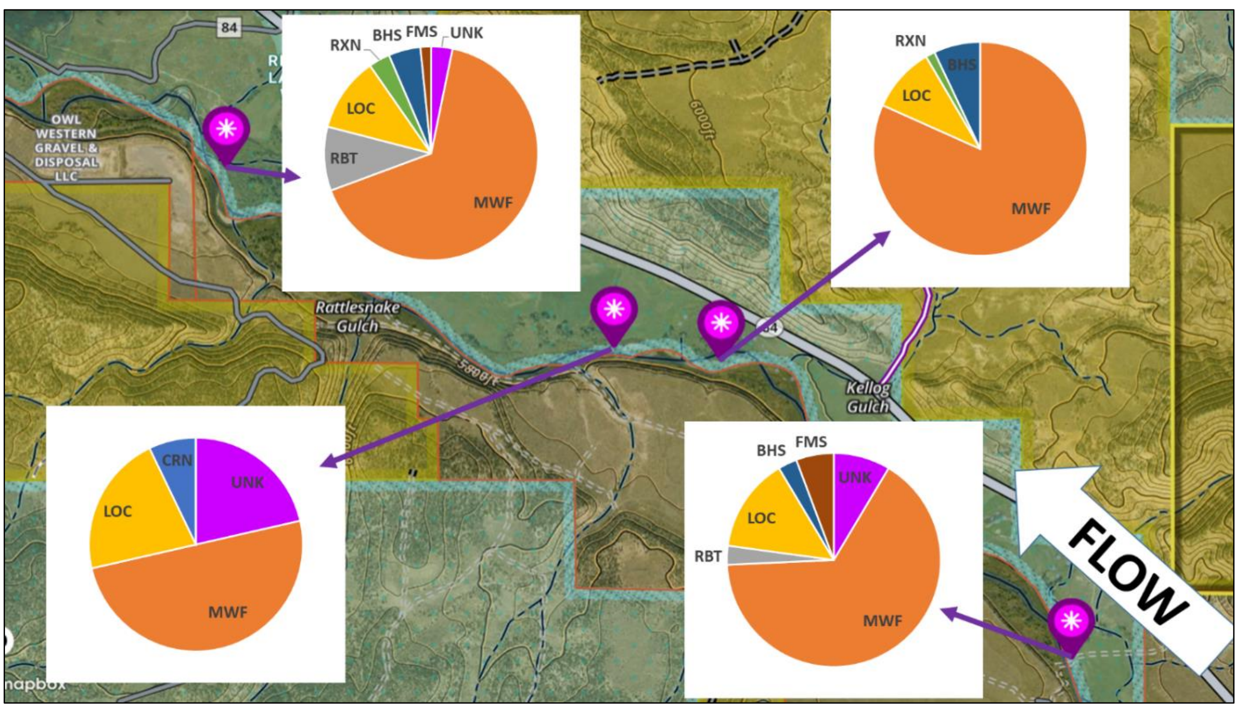

Figure 25. PIT tag detections at four locations (white asterisks) using 3 ft diameter Biomark submersible antenna arrays from August through November 2024.

ACKNOWLEDGEMENTS

We would like to thank the many CPW aquatic biologists, researchers, and technicians that have contributed to data collection and analysis. Area Aquatic Biologist Gage Dean and Native Aquatic Species Coordinator Tory Eyre are responsible for project support, monitoring, outreach, and coordination with Rio Blanco Ranch. Native Aquatic Species Biologist Tyler Swarr is responsible for project support, monitoring, PIT-tag antenna maintenance, and outreach. Senior Aquatic Biologist Benjamin Felt and Native Aquatic Species Coordinator Jenn Logan are also responsible for project support. CPW Engineer Kyle Hardie provided invaluable guidance related to contracting and project management. Heavy Equipment operator A.J. Stoffle and project manager Tyler Jacox are responsible for implementation and labor. Rio Blanco Ranch has offered to provide the trees and root wads needed for the project.

REFERENCES

Kanno, Y., N. M. Clark, K. C. Pregler, and S. Kim. 2025. Integrated analysis of marked and count data to characterize fine-scale stream fish movement. Oecologia 207:25

Kondratieff, M. C., and E. E. Richer. 2022. Stream Habitat Investigations and Assistance Project Summary. Colorado Parks and Wildlife, Aquatic Wildlife Research Section. Fort Collins, Colorado, pp. 37-87.

Richer, E.E., M. C. Kondratieff, and M. Molter. 2024. Stream Habitat Investigations and Assistance Project Summary. Colorado Parks and Wildlife, Aquatic Wildlife Research Section. Fort Collins, Colorado.

RESEARCH PRIORITY:

Avian Predation Study, Colorado River

OBJECTIVES

To determine if merganser movement patterns near Windy Gap dam are similar to anomalous upstream fish movements observed during the Upper Colorado River Fish Movement Study.

INTRODUCTION

Reconnecting rivers by removing or bypassing existing dams is becoming increasingly common to restore physical and ecological processes, restore longitudinal connectivity for aquatic organisms, development of alternative methods of water storage and energy production, and modernization of deteriorating dams (O'Connor et al. 2015; Bellmore et al. 2017). Removal or bypassing dams has significant environmental effects on the ecosystem including changing hydrology, water temperatures, sediment supply, and connectivity for organisms, among others (Bednarek 2001). Improved fish migration rates after dam removal has been documented (Burroughs et al. 2010; Tonra et al. 2015) and is cited as a reason to reconnect rivers (Grant 2001).

Windy Gap Reservoir was constructed by damming the Colorado River in 1985 to store and supply water for the Colorado Front Range. The Colorado River Connectivity Channel (CRCC) was constructed to bypass the dam and reservoir and provide renewed connection of the Colorado River longitudinally for the re-establishment of sediment transport and fish passage, as well as restoration of a well-vegetated floodplain (NRCS 2022). CPW Aquatic Researchers have been assessing fish movement patterns before and after construction of the CRCC. Fish movements are being monitored upstream and downstream of Windy Gap dam and within the CRCC using Passive Integrated Transponders (PIT) tags inserted into the intraperitoneal cavity of the fish. Six fixed antenna sites (two below the dam and one above) and three portable antennas (two above the dam and one below) were located within our 14.8 km study reach (Figure 26). These fixed, swim-over antennas are installed on the bottom of the river channel perpendicular to the flow. When a PIT tagged fish crosses over an antenna, the antenna reader is activated and records the individual tag number along with a timestamp. Paired antennas were installed at each site to determine the direction of individual fish movements. Prior to CRCC construction, we observed anomalous movements where a tag was detected moving upstream past the channel-spanning dam in a matter of hours. These tags also skipped antennas located between the sites where the tag was detected. It is possible for fish to move through the dam under certain river flow and reservoir conditions. However, this happens infrequently and for a fish to move upstream through the dam and then back downstream while skipping antennas between the detection locations seems highly unlikely. Furthermore, the fish making these anomalous movements were smaller individuals (<300 mm TL) relative to the overall population of tagged fish. These observations are consistent with the idea that an avian predator consumed the fish and the tag was detected from within the bird's digestive tract as it flew near the water surface or swam over the antennas both upstream and downstream of the dam (Figure 27). Detections may have been skipped if the bird flew too high above the detection range of the antenna, which extends up to 0.5 m above the streambed and is typically above the water surface during low flows.

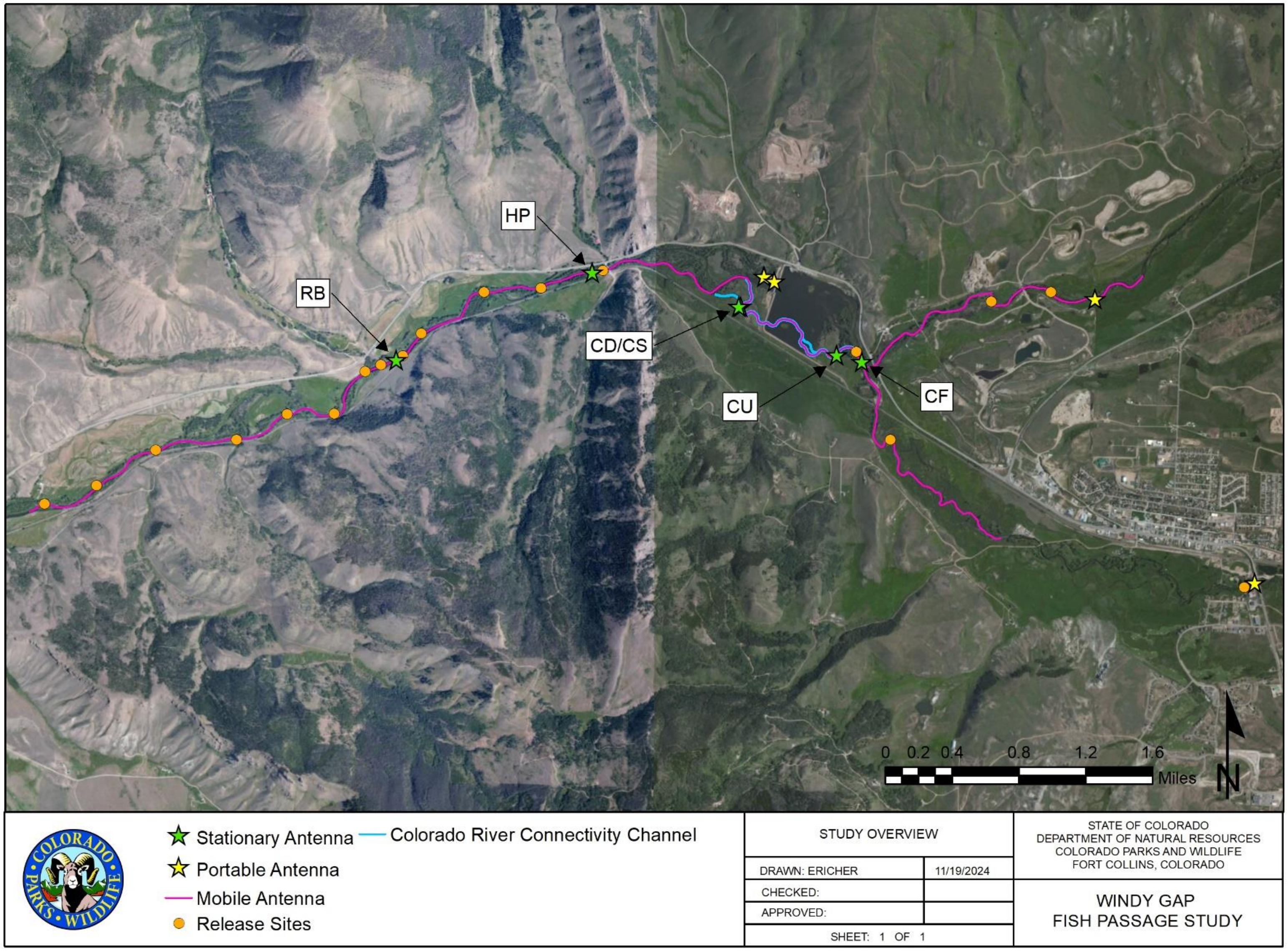

Figure 26. Overview map for the Windy Gap Fish Movement study showing the location of stationary and portable antenna sites.

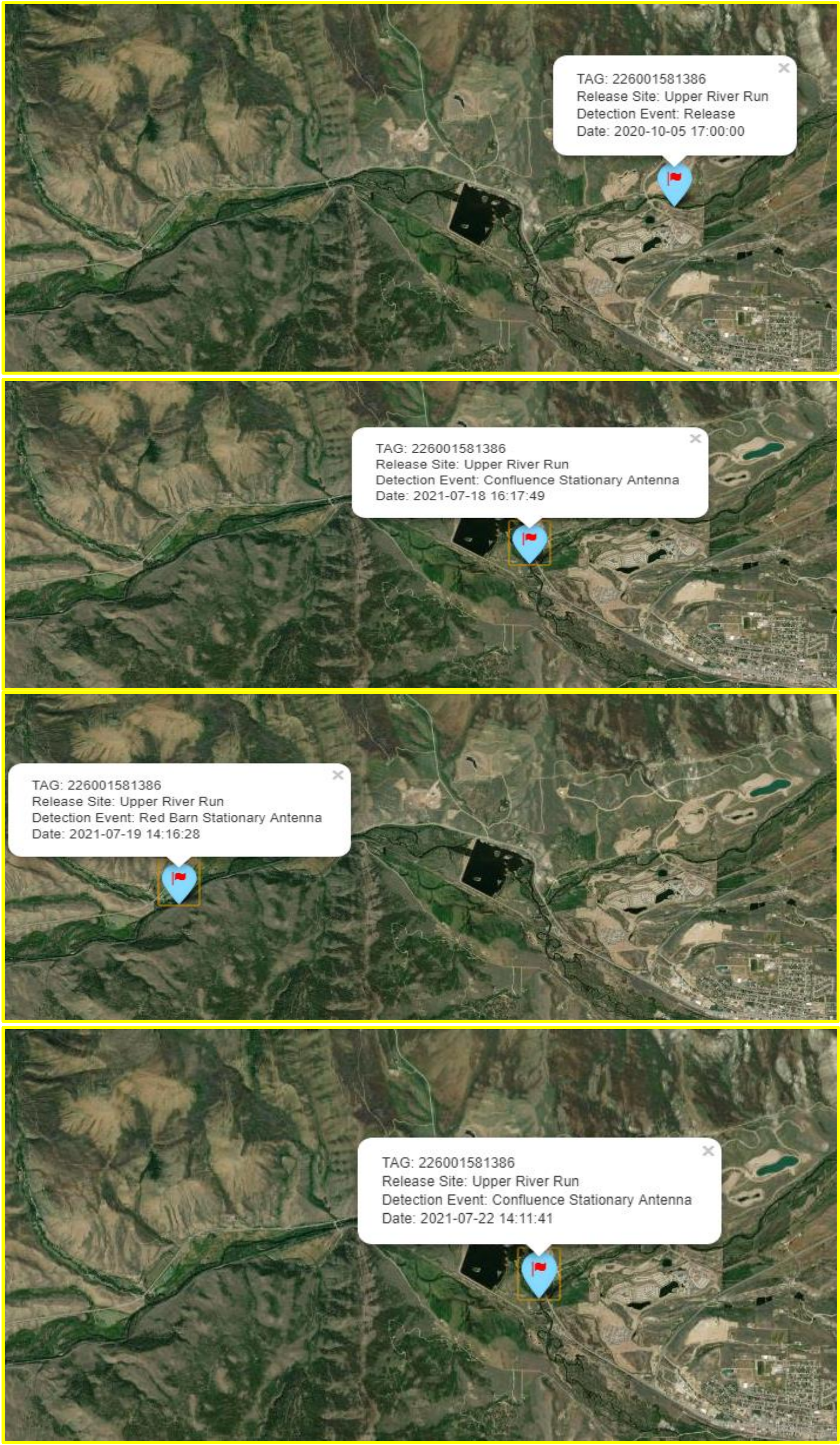

Figure 27. Example of an anomalous movement encounter history for a Colorado Sculpin that was part of the fish movement study. Top to bottom: initial release on Colorado River (10/5/2020), detection at Confluence antenna (7/18/2021), detection downstream of Windy Gap dam at the Red Barn antenna (7/19/2021), and final detection upstream of Windy Gap dam at the Confluence antenna (7/22/2021).

Experience from past PIT-tag studies has shown that tagged fish can be consumed by other predatory fish and trigger detections on antennas, resulting in a false movement record because the movement is no longer associated with the originally tagged animal. In a similar way, we suspected that the anomalous upstream movements might be the result of tagged fish being ingested by avian predators. Those birds can then trigger false detections while the tag is inside the digestive tract. To assess this possibility, we deployed trail cameras at fixed antenna locations with a goal of detecting possible avian predators that spend time near the antennas. To date, a variety of avian predators have been documented near our fixed antenna sites including Common Mergansers *Mergus merganser*, Great Blue Herons *Ardea herodias*, and American White Pelicans *Pelicanus erythrorhynchos* (Figure 28). On the Colorado River near Windy Gap Reservoir, Common Mergansers seem to be the most likely avian predator that would lead to these anomalous fish movements upstream and downstream of the dam. Common Mergansers generally fly low over the water surface and are known to consume fish of the same size as those fish that were associated with the anomalous detections (Pearce et al. 2020). Bald Eagles *Haliaeetus leucocephalus*, Osprey *Pandion haliaetus*, Great Blue Herons, American White Pelicans, Double-Crested Cormorants *Phalacrocorax auritus*, and other birds also consume fish in this area, but these avian predators usually fly higher above the water surface outside the detection zone of our antennas, or have not been observed near our antennas by the trail cameras.

In addition, a literature review of fish sizes consumed by Common Mergansers determined that fish consumed by Mergansers are typically 100–300 mm long (White 1936; Dement'ev et al. 1952; Latta and Sharkey 1966; Miller and Barclay 1973; Mccaw III et al. 1996) with Mergansers selecting disproportionately more large fish compared with available sizes (e.g., prefers 40-g salmon fry over 2-g fry; Wood 1987b). Fish up to 360 mm long are commonly consumed with reports of Mergansers eating eels up to 55 cm long (White 1957; Palmer 1976). Size of fish consumed is apparently restricted by fish girth not length, with an upper girth limit of 165–198 mm (Latta and Sharkey 1966; Mccaw III et al. 1996). A summary of the fish sizes associated with anomalous upstream movements show a range of fish sizes from 71 to 301 mm TL for Brown Trout, Rainbow Trout, and Colorado Sculpin.

To justify the over $30 million dollar CRCC project that includes a partial deconstruction of the dam, restoration of the historic Colorado River and adjacent floodplain, and has a primary objective of restoring fish passage, then the dam must be functioning as a fish migration barrier. The observed anomalous fish detections both upstream and downstream of the dam are contrary to the assumption that the dam is a barrier to upstream movement. If the anomalous movements are not the result of fish traversing the dam, these movements need to be documented, investigated, and explained. Our objective is to tag Common Mergansers and determine their movement patterns near the dam. We plan to compare movements of PIT-tagged Mergansers to the anomalous fish movements. If they are similar, we can reasonably determine that the detections are a result of avian predation of fish, rather than actual fish swimming upstream past the dam. To investigate movement patterns, we plan to look at time of day, season, antenna detection sequence, travel times, fish size, and longevity of detections compared to Merganser gut-evacuation rates.

Figure 28. Some examples of potential avian predators observed at antenna sites with trail cameras, including Great Blue Herons (top), American White Pelicans (middle), and Common Mergansers (bottom).

For the purposes of our study, we plan to conduct this research on the Colorado River upstream and downstream on Windy Gap Reservoir, and within the CRCC in Grand County, Colorado. Riparian habitat in the area is typical for the region, consisting of cottonwood groves, willows, alders, and other shrub/grassy riparian vegetation surrounding the river corridor.

METHODS

We plan to use a variety of methods (Richer and Kondratieff 2023) as needed to attempt to capture up to 20 Common Mergansers across four years (20 total birds; 2023 through 2026). All captures will take place during the breeding season (April-September). After capture, all birds will be banded on one leg with a standard size 7A aluminum numbered U.S. Geological Survey band, issued by the Bird Banding Laboratory. On the other leg, birds will be tagged using a 3D-printed plastic leg band with an affixed 32 mm PIT tag (Figure 29). The unnumbered plain plastic 3D printed band will contain a 32 mm PIT tag attached to the band with epoxy. Leg bands will be located in closer proximity to the antenna than subcutaneous tags, giving leg bands a higher detection probability. PIT tags have been used successfully in a wide variety of bird applications with few drawbacks reported (Bonter and Bridge 2011). Bird processing should take less than five minutes and birds will be released at the same location where they were captured. Equipment used in contact with birds will be disinfected between uses to reduce the chance of spreading disease.

Figure 29. Close up photo of the 3D printed plastic leg band fitted with a 32 mm PIT tag on the leg of a captured Common Merganser.

Mist Nets:

Our preferred alternative to capture Common Mergansers is the mist net (Figure 30). We will search for Mergansers within the fish-movement study reach. Once Mergansers have been sighted, we will confirm their identities using binoculars and multiple observers. Mist nets will be deployed approximately 100-500 m away from the bird(s). Mist nets over water have been used successfully to capture Common Mergansers as well as other ducks (Bengtson 1972; Briggs 1977; Brodeur et al. 2008; Smith et al. 2015). We will attempt to set up the net across the river as close to the bird as possible without altering the bird's behavior or causing the bird to leave the area. Smith et al. (2015) reported that capture of Harlequin Ducks *Histrionicus histrionicus* using this technique was slightly more effective when setting up downstream of target birds but the upstream side also worked. We will select a site to set up the net where it is shallow enough to wade across the river and the current does not pose a threat to personnel safety. We will use an 18 m by 2.6 m mist net with 127 mm nylon mesh. If that is not long enough to span the entire river, we will add an additional 6 m mist net to increase total length. The bottom of the net will be located as close to the water surface as possible without contacting flowing water. Once driving rods are securely pounded into the riverbed, we will slide aluminum poles over the top of rod to provide supports for mist net suspension. Once the net is deployed, upstream and downstream spotters equipped with radios will be stationed approximately 200 yards upstream or downstream of the net to alert the mist-net crew of any birds approaching the mist net so that the crew can operate the net accordingly. Once Mergansers have been observed in the vicinity, personnel will walk to the far side of the birds and attempt to flush the them into the net. After the bird has become captured, we will immediately wade out into the river to remove the bird from the net, carry it to shore, and tag it. After the bird is removed from the net, we will immediately remove or collapse the net by pushing the top and bottom together on the poles to prevent additional birds from being captured while we process the captured bird. Processing consists of recording the date and capture location as well as the bird's age, sex, mass, tarsus and wing cord lengths, and tag numbers for the aluminum band and PIT tag (Figure 31). After recording data for the captured bird, the bird will be released in close proximity to where it was captured (±100 m).

Figure 30. Mist net deployed on the Colorado River to capture Common Mergansers for tagging.

Figure 31. Weighing and processing a Common Merganser using a spring scale.

It is possible that non-target birds will become entangled in the net before the Merganser. To avoid this possibility, we will not deploy the mist net if large non-target birds are observed in the immediate vicinity. If a large non-target bird is flying toward the net, personnel stationed at the sides of the net will attempt to haze the birds away from the mist net. In the unlikely event that a large non-target bird, such as a Great Blue Heron, becomes entangled in the net, we will immediately stop the operation and attempt to free it from the net. Personnel will wear heavy leather gloves and eye protection, and will not hesitate to cut the net in order to free Herons or other non-target large birds if necessary. For small songbirds and shorebirds, the mesh size is large enough that they should be able to free themselves from the net. If a songbird remains caught in the net for longer than 20 minutes (Fair et al. 2010), we will suspend attempts to drive target Mergansers into the net so that the songbird can be released. During normal songbird banding activities, birds are commonly left tangled in mist nets for 0.2-1 hours before they are removed (Fair et al. 2010).

Statistical Analysis:
We do not plan to use any statistical techniques to draw inference. Our research question is simple: are the observed anomalous tagged fish detections consistent with Common Merganser movements? We believe we can answer this question by visually examining patterns of detections of tagged mergansers. This is an exploratory pilot study and if we decide that this research question warrants more in-depth research, we will explore more statistically rigorous ways to draw inference.

Sample Size:
This is an exploratory pilot study. We do not know how many Mergansers will stay in the area and how many will leave. Furthermore, we do not know how difficult it will be to catch them. We had hoped to tag 10 birds each year of the monitoring study (2023 through 2026). If even one bird displays the movements consistent with the anomalous fish detections, it would be enough to say that the fish detections *could* be a result of avian predation by Common Mergansers. If more than one Merganser makes a similar movement, it would add to the strength of evidence.

Based on a consultation with Jon Runge (CPW Biometrician), the scenario is similar to an occupancy analysis, where the number of sites sampled for occupancy is approximated by the number of tagged Mergansers. In occupancy analyses, if no detections occur at any site, there is still a probability that the site is occupied but the right sites were not sampled. Similarly, if we do not get any Merganser movements consistent with the anomalous fish detections, there is still a probability that it is occurring but we did not tag the right Merganser to detect it. The key is to keep that probability at an acceptable level. To do this, we need to know the number of Mergansers in the area. Common Merganser density along rivers has been reported to be 0.4–1.4 pairs/km (Pearce et al. 2020). If we use the mean (0.9 pairs/km) over the ~8 km area that will be targeted for Merganser capture, we can expect about 14 individual Mergansers. Based on the equation for computing the probability of occupancy given no positive detections (Mackenzie et al. 2017), if we tag 10 Mergansers each year, the probability of Mergansers actually doing the movements observed in the fish data, but us not observing it in a tagged bird is <0.001 (Table 5), which we find to be acceptable.

Table 5. Probability that an anomalous fish movement will not be observed using PIT-tagged Common Mergansers given the number of Mergansers tagged relative to the Merganser abundance in the area of Windy Gap Reservoir, Colorado. Based on the literature, we can expect about 14 mergansers in our study area and we plan to tag 10 Mergansers per year.

Number of Common Mergansers Tagged	Number of Common Mergansers in the Area		
	20	50	100
5	0.237	0.590	0.774
6	0.118	0.464	0.690
7	0.049	0.348	0.602
8	0.017	0.248	0.513
9	0.005	0.168	0.428
10	0.001	0.107	0.349
11	0.000	0.065	0.278
12	0.000	0.037	0.216
13	0.000	0.020	0.164
14	0.000	0.010	0.121
15	0.000	0.005	0.087
16	0.000	0.002	0.061
17	0.000	0.001	0.042
18	0.000	0.000	0.028
19	0.000	0.000	0.018
20	0.000	0.000	0.012

RESULTS AND DISCUSSION

Data collection is ongoing. During 2023, a preliminary test deployment of the mist net was conducted, but unusually high runoff and a wetter than normal weather patterns limited our ability to safely wade in the river to deploy mist nets. Due to high flow conditions and safety concerns, no mergansers were captured and tagged in 2023.

Two merganser-trapping excursions occurred on the Colorado River the following year (2024), during July and August. In August, we successfully captured, tagged, and released one fledgling male Common Merganser downstream of the diversion structure located near the Red Barn antenna (Figure 32). No other trapping excursions occurred during 2024. After release, this single Common Merganser was detected on three separate antenna locations on the mainstem Colorado River including Red Barn, Hitching Post, and River Run. The River Run detection occurred on a 3 ft submersible Biomark antenna, located approximately 10 km upstream of Red Barn where the bird was originally captured and released, in late September 2024. The merganser was never detected at the Confluence antenna site. Following its release on August 8, 2024, this merganser was detected multiple times from August 20 through September 28, 2024, after which it was never detected again. A total of 28 unique detections occurred during this period, with 15 detections at Red Barn, 12 at Hitching Post, and one at River Run. There are a few possible explanations for the disappearance of the Merganser tag after September 28: (1) the PIT tag may have come out of the plastic leg band; (2) the bird migrated to a new location during the winter and then died or migrated to a different location in the following spring; or (3) the bird was harvested during waterfowl season in the fall/winter of 2024. We plan use the observed movement patterns from this bird for comparison with the anomalous detections that have been flagged for possible avian predation. Approximately 60 anomalous fish movements have been flagged for further investigation through the end of 2024.

Figure 32. Photo of a fledgling Common Merganser captured on August 8, 2024, and fitted with PIT-tagged plastic leg band and aluminum leg band before being released.

We conducted two additional trapping excursions in 2025 on July 15 and August 6. In July, we deployed the mist net near the fixed antenna site located near the downstream end of the CRCC (site CD). A hen Common Merganser and seven fledglings were located near this site. We determined that the Mergansers were using this location from our camera trap at the CD antenna site. We planned our netting concurrently with mobile antenna surveys so that personnel on the rafts could communicate with the Merganser crew via radio if any Common Mergansers were observed as they floated downstream. The plan worked well as Mergansers were observed ahead of the rafts when floating down the CRCC and Colorado River above the Red Barn antenna site, allowing the Merganser crew to prepare for the birds moving downstream in response the rafts. Unfortunately, we were unsuccessful at netting and capturing birds along the CRCC (Figure 33).

Figure 33. Mist net set up on the Colorado River Connectivity Channel downstream of fixed antenna site CD.

However, later that same day we deployed the mist net downstream of the diversion structure near the Red Barn antenna site, and successfully captured five Common Mergansers, including an adult female, two male fledglings, and two female fledglings (Figures 34 and 35). All five birds were successfully processed and released for inclusion in the study. No data has been downloaded from antenna sites since the release of these birds, so we do not know if they are still in the area or how they are moving throughout the study reach. Those questions will be investigated as new detection data is downloaded from antenna sites and incorporated into the database.

Figure 34. Photo showing the crew processing Common Mergansers with a close-up view of a Common Merganser fledgling (including Matt's fledgling son Zane Kondratieff).

Figure 35. Photo showing an adult female Common Merganser held by CPW Avian Research Scientist, Casey Setash.

ACKNOWLEDGEMENTS

Joint collaboration between Aquatic and Avian Research has been ongoing specifically between Avian Researcher Adam Behney and Aquatic Researcher Matt Kondratieff. We would like to acknowledge George Schisler and Jim Gammonley for their support in this research effort that crosses research section boundaries. We would also like to acknowledge Barry Nehring for his work documenting changes in benthic macroinvertebrates, Mottled Sculpin, trout populations, and whirling disease following construction of Windy Gap Reservoir, which were instrumental to the development of the Connectivity Channel Project on the Colorado River. We also thank the various collaborators and technicians that have contributed to the data collection and analysis, including Eric Fetherman, Becca Hiller, Sean Ingram, Michael Miller, Casey Setash and numerous avian research technicians and volunteers Anne Hoffman and Zane Kondratieff. Finally, we would like to thank George Schisler, Lori Martin, Karlyn Armstrong, Ken Kehmeier, and Sherman Hebein for their contributions to development and implementation of the fish and wildlife mitigation and enhancement plans for the Colorado River.

REFERENCES

Bednarek, A. T. 2001. Undamming rivers: a review of the ecological impacts of dam removal. Environmental Management 27:803-814.

Bellmore, J. R., J. J. Duda, L. S. Craig, S. L. Greene, C. E. Torgersen, M. J. Collins, and K. Vittum. 2017. Status and trends of dam removal research in the United States. WIREs Water 4:e1164.

Bengtson, S. 1972. Breeding ecology of the harlequin duck *Histrionicus histrionicus* (L.) in Iceland. Ornis Scandinavica 3:1-19.

Bonter, D. N., and E. S. Bridge. 2011. Applications of radio frequency identification (RFID) in ornithological research: a review. Journal of Field Ornithology 82:1-10.

Briggs, R.L. 1977. Mist netting waterfowl. North American Bird Bander 2:61-63.

Brodeur, S., G. H. Mittelhauser, J. L. Savard, P. W. Thomas, R. D. Titman, and D. Comeau. 2008. Capture methods for migrating, wintering and molting sea ducks. Waterbirds 31:133-137.

Burroughs, B. A., D. B. Hayes, K. D. Klomp, J. F. Hansen, and J. Mistak. 2010. The effects of the Stronach dam removal on fish in the Pine River, Manistee County, Michigan. Transactions of the American Fisheries Society 139:1595-1613.

Dement'ev, G. P., N. A. Gladkov, Y. A. Isakov, N. N. Kartshev, and S. V. Kirikov. 1952. Birds of the Soviet Union. Volume 4.

Fair, J., E. Paul, and J. Jones, Eds. 2010. Guidelines to the use of wild birds in research. Washington, D.C.: Ornithological Council.

Grant, G. 2001. Dam removal: Panacea or Pandora for rivers? Hydrological Processes 15:1531-1532.

Latta, W. C. and R. F. Sharkey. 1966. Feeding behavior of the American Merganser in captivity. The Journal of Wildlife Management 30:17-23.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, and J. E. Hines. 2017. Occupancy Estimation and Modeling. Elsevier Inc., Burlington, Massachusetts.

McCaw III, J. H., P. J. Zwank, R. L. Steine. 1996. Abundance, distribution, and behavior of common mergansers wintering on a reservoir in southern New Mexico. Journal of Field Ornithology 67:669-679.

Miller, S. W. and J. S. Barclay. 1973. Predation in warm water reservoirs in wintering common mergansers. Proceedings of the 27th Annual Conference Southeast Association Game and Fish Commission 27:243-252.

O'Connor, J. E., J. J. Duda, and G. E. Grant. 2015. 1000 dams down and counting. Science 348:496-497.

Palmer, R. S. 1976. Handbook of North American birds. Vol. 3. New Haven: Yale University Press.

Pearce, J., M. L. Mallory, and K. Metz. 2020. Common merganser (*Mergus merganser*), version 1.0 In Birds of the World (S.M. Billerman, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA.

Richer, E.E., and M. C. Kondratieff. 2024. Stream Habitat Investigations and Assistance Project Summary. Colorado Parks and Wildlife, Aquatic Wildlife Research Section. Fort Collins, Colorado.

Smith, C. M., P. G. Trimper, L. J. Bate, S. Brodeur, W. K. Hansen, and M. Robert. 2015. A mist-net method for capturing harlequin ducks on rivers. Wildlife Society Bulletin 39:373-377.

Tonra, C. M., K. Sager-Fradkin, S. A. Morley, J. J. Duda, and P. P. Marra. 2015. The rapid return of marine-derived nutrients to a freshwater food web following dam removal. Biological Conservation 192:130-134.

Natural Resources Conservation Service (NRCS). 2022. Draft watershed plan and the environmental assessment for the Colorado River headwaters connectivity project Windy Gap Watershed Grand County, Colorado.

White, H. C. 1936. The food of kingfishers and mergansers on the Margaree River, Nova Scotia. Journal of the Biological Board of Canada 2:299-309.

Wood, C. C. 1987. Predation of juvenile Pacific salmon by the common merganser (*Mergus merganser*) on Eastern Vancouver Island. I: Predation during seaward migration. Canadian Journal of Fisheries and Aquatic Sciences 44(5): 941-949.

RESEARCH PRIORITY:

Technical Assistance

OBJECTIVES

Provide at least 10 technical assistance reviews to CPW personnel, NGOs, and Federal agency personnel as requested.

INTRODUCTION

CPW and other state and federal personnel are frequently in need of technical assistance related to stream habitat restoration, conservation barriers, fish passage, whitewater park, and post-flood recovery projects. Technical assistance for projects will be provided as needed, including project identification, selection, design, evaluation, and permitting. Technical assistance includes design review for CPW biologists and district wildlife managers, site visits to proposed stream restoration locations, consultations with various agencies on stream restoration opportunities associated with highway and bridge improvement projects, project management, consultations and technical support related to stream mitigation work for 404 permits, technical assistance related to fish passage design, conservation barrier design and construction, and teaching at various technical training sessions for CPW and other state and federal personnel.

METHODS

Technical assistance includes the review of proposed stream habitat restoration, fish passage, and conservation barrier projects, including design, contractor selection, and permitting for CPW and other state and federal personnel as requested. Proposed designs for post-flood road reconstruction and stream restoration will be reviewed for the Colorado Department of Transportation as requested. We will also provide training to CPW and other state and federal personnel on stream restoration techniques and fish passage design criteria, including guidance for permitting.

RESULTS AND DISCUSSION

We provided technical assistance for the following projects:

1) Colorado River Connectivity Channel at Windy Gap
2) Windy Gap Fish Passage Study, Colorado River
3) Poudre Valley Canal Fish Passage and Screening Project, Cache la Poudre River
4) Shoshone Water Rights Preservation Project, Colorado River
5) Continental-Hoosier System Project
6) Cherry Creek Stabilization Project
7) George Creek Cutthroat Trout Restoration
8) Colorado River Aquatic Connectivity Team
9) Gateway Diversion Fish Passage Project, Cache la Poudre River
10) 2025 Nationwide Permits Reissuance, Army Corps of Engineers
11) Colorado Regional Permit 87 for Non-WOTUS Waters

12) Evaluation of Floodplain Restoration Projects in Colorado
13) Brown Trout Population Study, Middle Fork South Platte River
14) State Wildlife Action Plan 2025, Habitat Subcommittee
15) White River and Rio Blanco Reservoir Habitat Project, White River
16) Northern Integrated Supply Project (NISP) Fish and Wildlife Mitigation and Enhancement Plan (FWMEP) Projects, Cache la Poudre River
17) Trinchera Ranch Cutthroat Trout Reclamation Project
18) Chuck Lewis SWA Toe Wood Repair, Yampa River
19) Poudre River Headwaters Project Fish Barrier Design, Big South Fork of Cache la Poudre River
20) Trinchera Ranch Fish Barrier Design, West Indian Creek and Trinchera Creek
21) Bobtail and Steelman Fish Barrier Designs, Williams Fork River tributaries
22) Charlie Meyer SWA Willow Planting, South Platte River
23) CPW Beaver Conservation and Management Strategy

ACKNOWLEDGEMENTS

We acknowledge and appreciate Dr. George Schisler for his support and leadership.

APPENDIX A

Kemp-Breeze SWA Habitat Project Aerial Imagery and Tracer Rock Maps

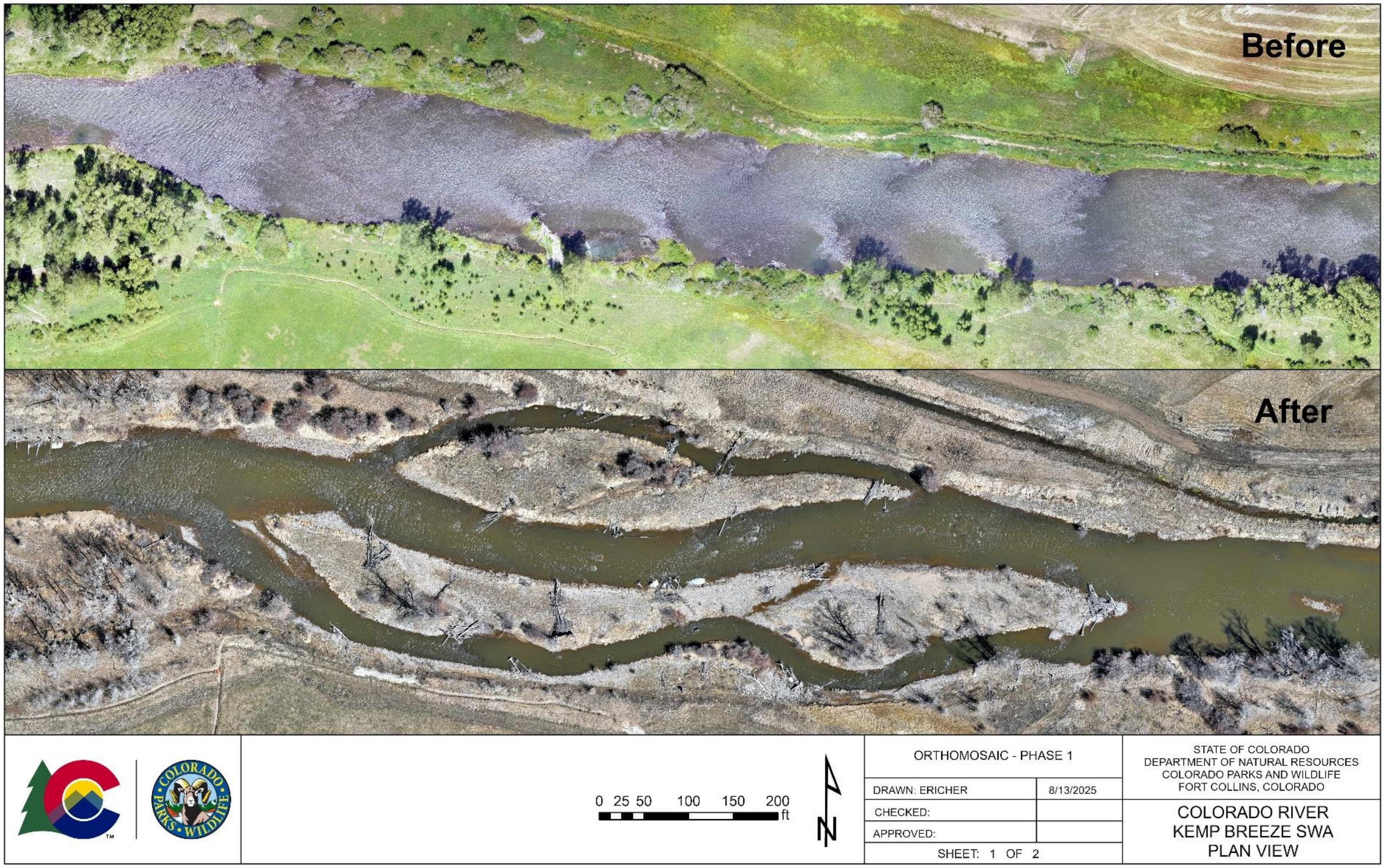

Figure A1. Comparison of unmanned aerial system (UAS) imagery from before and after construction of the Kemp-Breeze SWA Habitat Project for the Phase 1 reach.

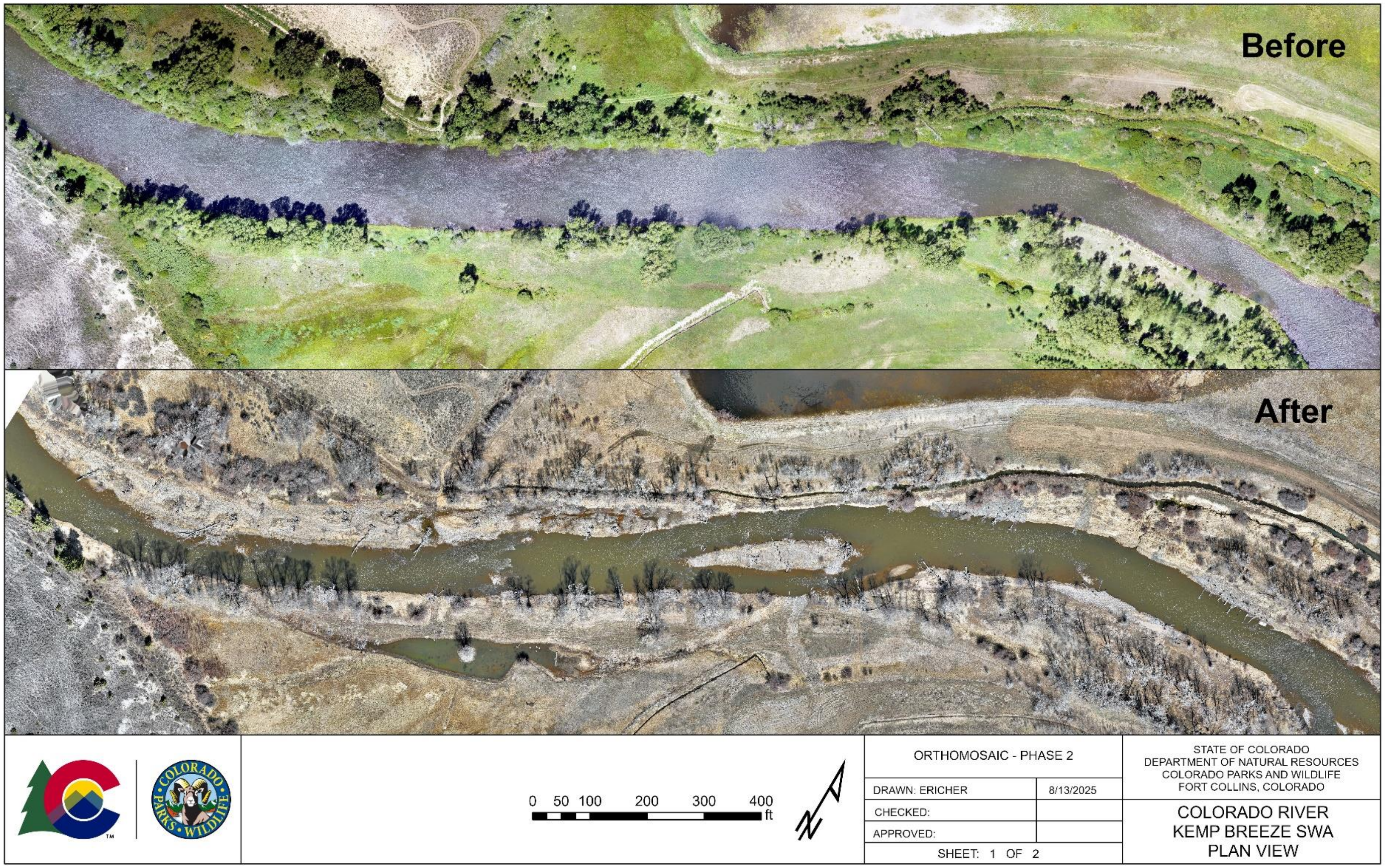

Figure A2. Comparison of unmanned aerial system (UAS) imagery from before and after construction of the Kemp-Breeze SWA Habitat Project for the Phase 2 reach.

Figure A3. Comparison of standard world imagery basemap (resolution = 0.5 m) and unmanned aerial system (Anzu Raptor) imagery (resolution = 0.02 m) for the Kemp-Breeze SWA Habitat Project, Phase 1 reach.

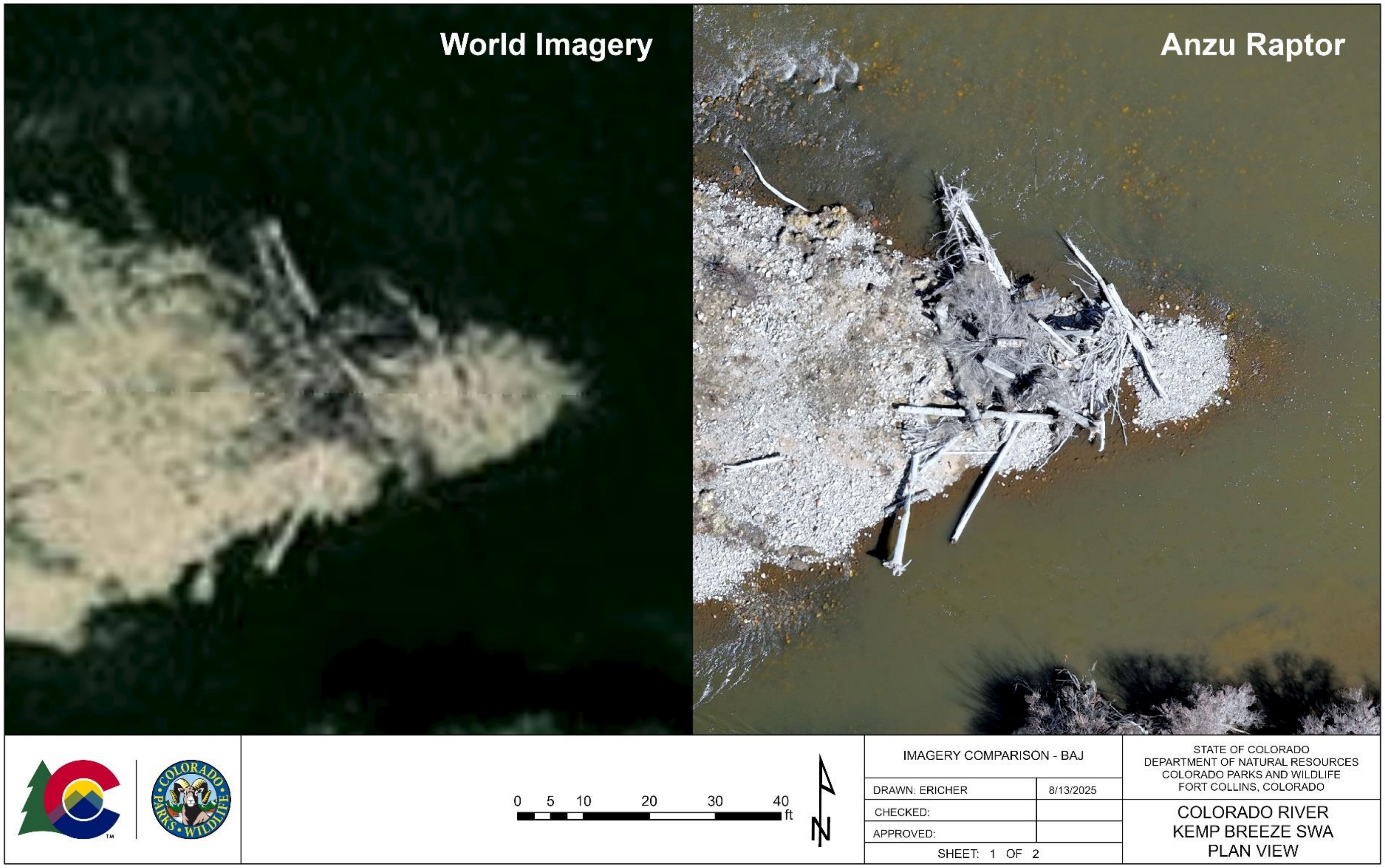

Figure A4. Comparison of standard world imagery basemap (resolution = 0.5 m) and unmanned aerial system (Anzu Raptor) imagery (resolution = 0.02 m) showing a bar-apex jam (BAJ) within the Kemp-Breeze SWA Habitat Project.

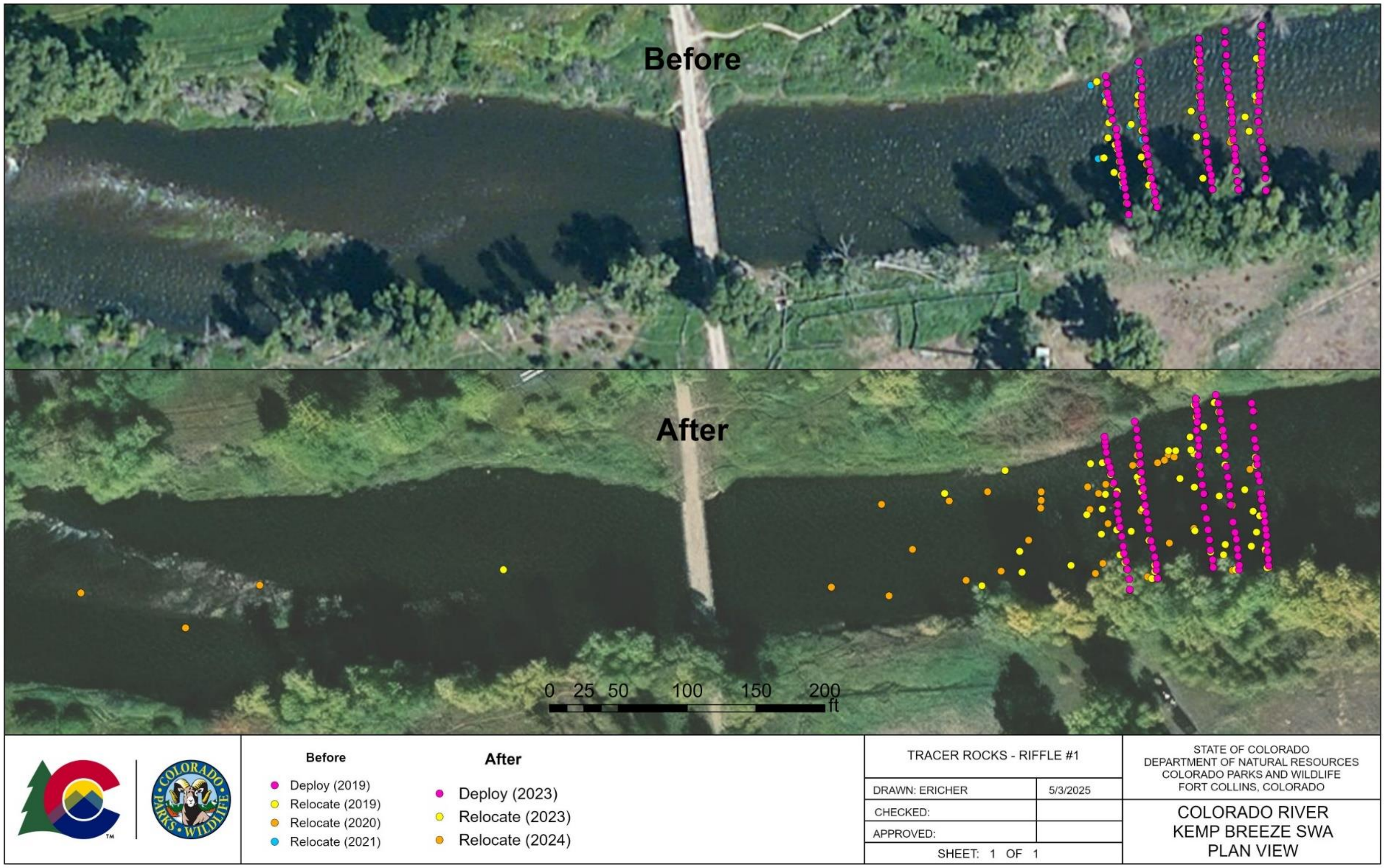

Figure A5. Tracer rock locations showing movement by year during the before and after period at riffle 1, an experimental location that was treated with riffle dearmoring.

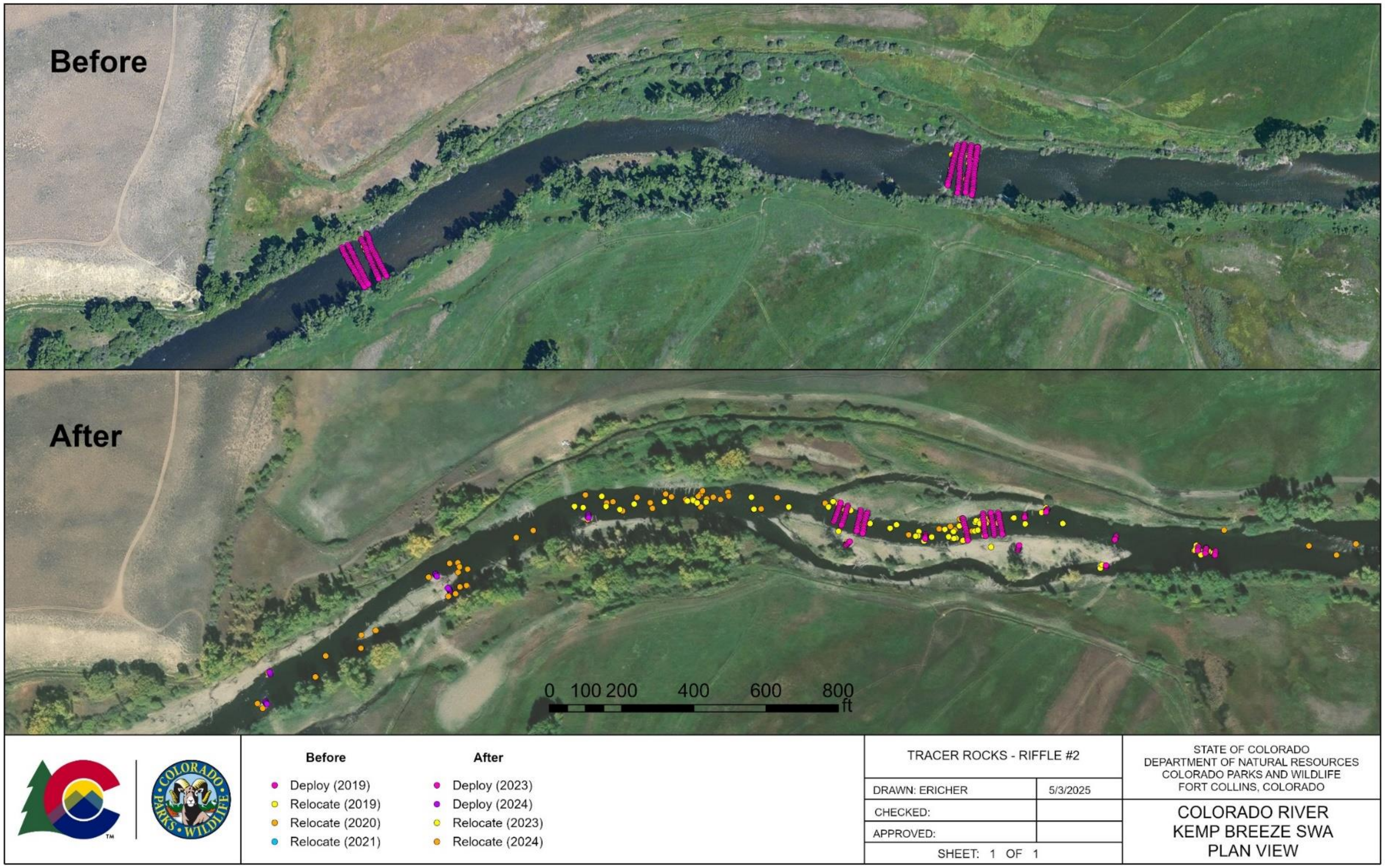

Figure A6. Tracer rock locations showing movement by year during the before and after period at riffle 2 (before), riffles 2A/2B (after), and experimental gravel augmentation and overflow sites (after).