Evaluating Conserved Consumptive Use in the Upper Colorado: 2022 Annual Report

Avian Response to Irrigation Changes at High-elevation Perennial Grass Pastures

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Abstract

Irrigated agricultural lands throughout Colorado provide important wildlife habitat for a number of avian species, and given the potential need for agricultural water conservation, there is a critical need to understand how and to what degree reduced irrigation may influence bird use of these habitats. To address this, five agricultural properties with varying levels of irrigation curtailment were monitored in 2020 (during curtailment) and 2 subsequent years (2021 and 2022, when irrigation levels throughout all properties were returned to normal) using the Integrated Monitoring in Bird Conservation Region's Field Protocols for Spatially Balanced Sampling of Landbird Populations. The results of these surveys were not entirely conclusive but may suggest that the occurrence (measured as detections and species richness) of water-associated species were influenced by both restored irrigation levels (i.e., water availability) and seasonal survey temperatures. In all likelihood, avian abundance and species diversity are highly influenced by a wide variety of factors including water conservation practices, habitat structure and availability, particular species life history traits, and numerous environmental influences. This study provides limited but important insight to the potential shifts in avian communities that may occur when water conservation practices are employed within high-elevation perennial grass pastures and highlights the need for further studies to better understand how to best manage such practices.

1. Introduction

The Colorado River is approximately 2,334 meters (1,450 miles) long and flows through portions of Wyoming, Colorado, Utah, New Mexico, Nevada, Arizona, California, and northwestern Mexico where it empties into the Gulf of California (Loeffler and Wescoat, 2019). As the Colorado River flows through these areas, it provides a multitude of natural services to the ecosystems it intersects, including numerous human settings immediately adjacent to the river channel or throughout the broader region. Some of these anthropogenic benefits include recreation, irrigation (covering approximately 5.5 million acres), municipal water (serving 40 million people), and hydroelectric energy (U.S. Department of the Interior Bureau of Reclamation, 2012). Of these, irrigation is the largest consumer of the Colorado River surface water, withdrawing approximately 85% from 1985 to 2010 (Maupin et al., 2018).

Recently, the Colorado River Basin has also experienced a multi-year drought, with water levels in Lake Powell reaching the lowest level since the 1960s (U.S. Department of the Interior Geological Survey, 2021). During that time, all of the Upper Colorado Region experienced abnormally dry conditions, with 94% of the Basin facing moderate drought, 68% undergoing severe drought, and 19% enduring extreme drought (National Integrated Drought Information System, 2022). The combination of recent sustained drought, climatic forecasts predicting more frequent and severe periods of drought in the future, and the current need and expected continuation of irrigation as a primary consumer of Colorado River water use has put agricultural producers throughout the region in a complicated situation by challenging them to develop a process to conserve water yet maintain viable and productive agricultural systems. In light of this, several water conservation strategies have been discussed to address the challenge, such as deficit irrigation, crop shifting, advanced irrigation technology, and rotational fallowing (Cohen et al., 2013; Udall and Peterson, 2017). Some of these efforts are being tested and implemented with agricultural producers that use surface or flood irrigation within their high-elevation grass pastures near Kremmling, Colorado. The objective is to experiment with reduced irrigation as a means to decrease the amount of water taken from the Colorado River but still allow the producers enough water resources to maintain their livelihood.

However, irrigated agricultural lands also provide important habitat for many wildlife species. These habitats not only supply water resource needs, but also provide places for shelter, foraging, nesting, and movement corridor and migratory staging sites for numerous taxa and species of wildlife. In Colorado alone, approximately 50% of the wetlands have been lost since the late 1800s (Colorado State University, 2022) and irrigated lands may help provide a degree of suitable habitat for some wetland-associated species. Given the incredible diversity and high mobility of avian species, coupled with the enhanced habitat suitability of agricultural water use areas (i.e., greater complexity due to water resources and increased vegetation production/diversity), understanding how and to what degree changes in irrigation practices may influence bird use in these habitats is an integral in determining the overall influence to wildlife resources. Agriculture, in general, has a complicated relationship with avian community use, as the conversion of natural habitats into agricultural lands can often result in large shifts or declines in avian communities. Conversely, irrigated agriculture or regenerative agricultural practices, such as rotational grazing, may attract a diverse array or even large suites of avian species utilizing the abundant water resources and heterogenous habitats resulting from these land use applications. For example, Cabodevilla et al. (2022) found that farmland, shrubland, forest, and non-specialist avian species were negatively impacted when irrigation was introduced into a previously rain-fed Mediterranean agricultural landscape in northern Spain. In contrast, several avian species specializing in diets consisting largely of flying insects were positively impacted. Findings reported by Giralt et al. (2021) at another study in northeastern Spain indicated that avian species richness increased up to 500 meters (1,640 feet) from established, irrigated tree orchards when additional irrigation occurred beyond the orchard; although, the presence of avian species associated with the dry cereal habitat at those locations prior to the expanded irrigation was negatively impacted as result. Individual avian species of management concern may also be reliant upon irrigated habitats, as Shuford et al. (2013) found long-billed curlews (*Numenius americanus*) were primarily found in irrigated alfalfa fields and irrigated pastures during the fall in California's Central Valley. Despite the complicated relationship with wildlife use, irrigated agricultural lands clearly provide unique aquatic and mesic habitats for avian species and are often surrounded by robust and complex native habitats (e.g., riparian corridors and wetlands) typical of low-lying agricultural settings. These landscapes often host and benefit a broad suite of avian species and other wildlife resources, but the connectivity between irrigated agricultural lands and surrounding native aquatic or mesic habitats is not clearly understood. A better understanding of these ecological relationships is important in the overall management of both habitats and the species that utilize them.

In this project, we examined the effect of reduced irrigation on avian communities in high-elevation grass pastures near Kremmling, Colorado. We expected the number (detections and species richness) of water-associated birds (i.e., avian species most likely to utilize irrigated pastures) to increase in response to a return of normal irrigation levels (in 2021 and 2022) after levels were curtailed in 2020. Since this report encompasses only 3 years of survey data, there are limitations in assessing the casual factors associated with the documented changes noted below (especially as it relates to other environmental factors beyond the scope or control of this project). Furthermore, due to small sample sizes associated with the limited monitoring efforts and spatial applications of the project, the power of inference for the remaining discussion is also limited and results should be interpreted with caution.

2. Materials and Methods

The project was conducted at five agricultural properties (GPR, RCR, RSR, SBR, and SPR) located in western Grand County, Colorado (Figure 1). The project area intersects a single Level III Ecoregion (Southern Rockies Ecoregion) (U.S. Environmental Protection Agency, 2011) and three Level IV Ecoregions (Crystalline Mid-Elevation Forests, Crystalline Subalpine Forests, and Sagebrush Parks ecoregions), with four of the five properties occurring within the Sagebrush Parks Level IV Ecoregion. The area is characterized by a continental subarctic climate with the 108-year mean minimum and maximum temperatures in January and July of -18 and 27.5 degrees Celsius (-0.5- and 81.5-degrees Fahrenheit), respectively (Western Regional Climate Center, 2022). The area averages approximately 30 centimeters (12 inches) of precipitation annually with the highest monthly precipitation occurring between May and September. Land use in the area largely consists of small municipalities, heavy to light paved and unpaved transportation routes, rural residences, heavy seasonal tourism and many active and passive recreational activities, and irrigated agriculture (i.e., surface or flood) and livestock grazing.

2.1 Agricultural Properties

As stated, the five agricultural properties included in this project were located near Kremmling, Colorado. The GPR site is situated north of Kremmling, west of State Highway 134; the Wolford Mountain Reservoir is east and adjacent to the property. The GPR site is adjacent to a minor tributary of the Colorado River but outside the main river floodplain, primarily hosting grassland habitats with a limited number of shrubs and/or trees in the area. The western half of the GPR site included a combination of normal irrigation (reference area) fields and full-season irrigation curtailment treatment in 2020, whereas the eastern half included full-season irrigation curtailment treatment. The RCR site is situated east and slightly south of Kremmling, beyond the Colorado River floodplain. The site hosts grassland habitat and is surrounded by dry shrubland in the immediate vicinity and rocky hills and limited scattered woodlands in the broader area. In 2020, the RCR site was fully in the split-season irrigation curtailment (no irrigation after June 15), though irrigation was still occurring during the avian surveys (June 24 and 25) that year. The RSR site is located immediately south of Kremmling along the southern bank of the Colorado River. Habitats at this site consist of grassland, wet meadow and other wetlands, and riparian shrubland and woodland. The RSR property was in the split-season irrigation curtailment treatment in 2020 (no irrigation after June 15), though large remnant pools in low-lying areas from recent water irrigation were still present during the avian surveys (June 24 and 25) that year. The SBR site is situated east of Kremmling along the north bank of the Colorado River and extended to the steeper uplands north of U.S. Route 40. This site consists of wet meadows and riparian shrubland and woodland in the southern half and dry shrubland and rocky hills in the north. In 2020, the SBR site was in the full-season irrigation curtailment treatment; however, due to a broken irrigation pipe, a portion the southern half was inundated with ample surface water during the avian surveys (June 24 and 25) that year. The SPR site is located southeast of Kremmling, at a moderate elevation near the Arapaho National Forest. Habitats at the SPR site consisted of grassland, wet meadows, and riparian shrubland, with montane shrubland and diverse woodlands in the surrounding vicinity. The SPR site was in the full-season irrigation curtailment treatment in 2020 (no irrigation after June 15).

Normal irrigation practices were restored at all five sites of the project in 2021 and 2022, though irrigation levels were still quite variable at individual survey sites, depending on a number of factors each year (e.g., annual precipitation, site-specific seasonal water availability, operational management practices and timing, elevation, aspect, and topography).

2.2 Avian Monitoring

Avian surveys were conducted using a modified design of the Bird Conservancy of the Rockies' Integrated Monitoring in Bird Conservation Regions (IMBCR) Field Protocols for Spatially Balanced Sampling Landbird Populations (McLaren et al., 2022). Per IMBCR protocols, randomized point count locations structured as a 4 x 4 grid with all points separated by 250 meters (820 feet) were established within each of the five agricultural properties. This design provides a scientifically rigorous and consistent sampling technique for the analyses of occurrence trends over time for most breeding, diurnal landbird species. However, as stated, the limited spatial extent of the project applications within each agricultural property restricted the overlap of both the overall and individual site (GPR, RCR, RSR, SBR, and SPR) data collection where actual irrigation changes occurred between years. Other project logistics, such as continued irrigation flow or substantial remnant water resources after curtailment (see *Section 2.1 Agricultural Properties*) in 2020, further complicated some of the spatial comparisons within and between years. Due to these limitations, a robust statistical analysis was highly constrained and not completed for the project.

In total, seven grids arranged in a 4 x 4 pattern of point count survey locations (all spaced 250 meters [820 feet] apart) were established across all five of the properties. Two grids were located on each of the GPR and SPR properties and one grid overlapped each of the RCR, RSR, and SBR properties. In all cases, many of the point count sites extended beyond the designated project area and respective property boundary. Therefore, with the exception of the larger GPR site that hosted 16 point count locations, only 8 point count sites at or near the center of the project area were designated within each of the four remaining properties (RCR, RSR, SBR, and SPR) (n = 48). Three point count sites associated with the SBR property were situated on U.S. Bureau of Land Management (BLM) lands and two other point locations near that same property were located on State lands; all other points in the study were on private lands.

IMBCR protocols (McLaren et al., 2022) recommend a seasonal timing for avian monitoring across all five properties near Kremmling, Colorado occur between June 1 and July 10 each year. This recommendation is based on the state where the monitoring occurs (as a surrogate for latitude) and the elevational range of the point count locations to determine the optimal breeding time for landbird populations in the region. This recommended timing coincides with the best opportunity for avian detection, as breeding birds are establishing nesting territories, singing, and highly active during this period. Avian surveys for the project occurred on two consecutive mornings at each grid in the summers of 2020 through 2022. In the first (2020) and second (2021) years, surveys were completed on June 24 and 25 and June 30 and July 1, respectively. In 2022, surveys were conducted on either June 21 and 22 or June 23 and 24 for each grid. All surveys began no sooner than 30 minutes before sunrise and were completed within 5 hours after sunrise. Surveys were conducted only under favorable weather conditions (dry, little or light wind). During the survey, an observer stood at each survey point for 6 minutes and recorded all birds heard and/or seen within an unlimited distance. Binoculars and pre-survey review of bird songs were used to aid with identification by sight and sound, respectively. Each individual detection was recorded under the minute it was first detected, and if no birds were detected in a given minute, the absence of birds during that minute was also recorded. IMBCR protocols include the documentation of all birds heard and/or seen at each point count site, regardless of whether the bird was recorded at a previous point count location within the grid. Therefore, all detections across an entire grid do not necessarily represent unique individuals. Avian species detected when walking between points were recorded in a separate way, indicating they were seen during the survey but not during the 6-minute count at a point. Other data collected included the observer, date, survey point

ID, start and end time, sky cover, wind, temperature, primary habitat, number of individuals, radial distance to each bird, how the bird was first detected, sex of the bird, if the bird was visually identified, if the bird was a migrant, and size of the flock. In 2021 and 2022, the maximum water depth and height of the tallest vegetation (e.g., grass, shrub) at each point location were also recorded. Additional bird species detected prior to the start or after the completion of the survey were not recorded within the IMBCR dataset but were noted annually on an incidental species observation datasheet for each agricultural property.

2.3 Water Conservation Practice

In 2020, reference and treatment fields were established within the project area on or near each agricultural property. Reference fields received normal irrigation and treatment fields received either the full- or split-season irrigation curtailment in 2020. The full-season curtailment treatment fields received no irrigation, whereas the split-season curtailment treatment fields received no irrigation after June 15, 2020. However, see *Section 2.1 Agricultural Properties* for some additional curtailment considerations, as it related to the water management on certain properties overlapping the areas where avian monitoring was completed in 2020. Among the 48 point count sites surveyed in 2020:

- 21 (44%) were located within the full-season curtailment treatment fields,
- 14 (29%) were beyond all project area designations (typically upland habitats),
- 9 (19%) were situated within the split-season curtailment treatment fields, and
- 4 (8%) were located in the reference area (normal irrigation) fields.

In 2021 and 2022, all reference area and treatment fields received normal irrigation and of the 48 point count locations sampled, 34 (71%) received normal irrigation and 14 (29%) were beyond all project area designations (typically upland habitats).

3. Results

3.1 General Species Occurrence and Richness

During the 3 years (2020 through 2022) of avian surveys for the project, biologists documented a grand total of 4,580 avian detections across 64 different species. The three avian species with the most recorded detections throughout all monitoring years combined and within each individual year were the cliff swallow (*Petrochelidon pyrrhonota*), savannah sparrow (*Passerculus sandwichensis*), and red-winged blackbird (*Agelaius phoeniceus*). The order of these three species' detections was slightly different each year, with the survey results from 2 years (2020 and 2022) representing a more equal proportion between species (i.e., none of the three species had more than 46% of the total detections). However, in 2021, the cliff swallow was clearly the most detected, exceeding 60% of the total detections across all three species. Regardless of the year, the combination of these three species represented 48% to 57% of the total detections among all identified avian species.

Forty-eight (48) total species were recorded across all point count locations in 2020, 57 in 2021, and 42 in 2022. The change in species richness between years does not translate into a one-for-one difference, as some species not previously recorded for the project were documented in subsequent years while others recorded in the earlier survey efforts were not always documented in the later years (i.e., each year had a different combination of species, with each annual suite of birds ranging from 66% [2022] to 89% [2021] of the total species identified across all 3 years). Thirteen (13) of the 64 species were recorded in only a single year during the 3 years of surveys. In total, 43 passerine (songbird), 15 waterfowl or shorebird, five raptor, and one upland gamebird species were documented.

3.2 Water-associated Species Occurrence and Richness

Utilizing ecological niche descriptions based on the natural history of each species, 30 of the 64 total species recorded from 2020 through 2022 were labeled as 'water-associated' species; the remaining 34 species were labeled as 'upland' species. Water-associated species had a combined total of 3,301 detections across all 3 years: 828 in 2020, 1,661 in 2021, and 812 in 2022. Despite consisting of only 47% of the total species richness recorded, water-associated species represented 72% of all detections documented over the 3 combined years of surveys and 64% (2020) to 76% (2021) of the detections in a given year. All three of the avian species with the most recorded detections throughout all monitoring years combined and within each individual year (the cliff swallow, savannah sparrow, and red-winged blackbird) were designated as water-associated species. Only 3 (10%) of the 30 water-associated species were recorded in a single year, suggesting that most of these species occur fairly regularly (but not necessarily in the same distributions or concentrations) among the habitats surveyed at the five agricultural properties included in the project.

3.3 Species Occurrence and Richness Comparisons Between Treatment Years

A fundamental premise of the IMBCR protocols is the randomization of point-count locations, which consequently resulted in several point count sites being located beyond the project treatment fields (full- or split-season curtailment) and reference areas. Again, 30 of the 48 total point count sites across all five agricultural properties were within treatment fields (21 in full-season curtailment and 9 in split-season curtailment) and only 4 sites were within reference areas. Due to the disparity between treatment field and reference area point count locations, no comparisons of avian detections or species richness were made between the two data subsets across the 3 survey years for the project. Furthermore, to best ascertain whether our expectation that the number of avian detections and species richness increased when irrigation levels returned to normal in 2021 and 2022 (after being curtailed in 2020), only water-associated species detected at point count sites within treatment fields were assessed. Beyond other analytical constraints, this approach was taken because if a response did occur, it would seem most detectable under these circumstances. We presumed that these species would most directly relate (spatially and ecologically) to the potential influence of hydrological changes in avian occurrence and species richness.

Avian detections of water-associated species among the treatment field sites were considerably greater in 2021 (1,242), the first year after irrigation levels returned to normal, compared to the curtailment treatment year (2020; 493 detections) and the second year after irrigation levels returned to normal (2022; 522 detections). That change represented an increase of approximately 252% more detections between 2020 and 2021 and a decrease of approximately 238% fewer detections between 2021 and 2022. Again, all three of the avian species with the most recorded detections throughout all monitoring years combined and within each individual year (the cliff swallow, savannah sparrow, and red-winged blackbird), were designated as water-associated species. The cliff swallow, in particular, accounted for the majority of those differences between years (ranging from 487 to 492 more/fewer detections annually or approximately 61% of both the increase between 2020 and 2021 and the decrease between 2021 and 2022). Of the other two water-associated species with the most detections, the red-winged blackbird and savannah sparrow, there was also an increase of 93 or approximately 279% more detections between 2020 and 2021. Otherwise, no more than a difference of 24 detections were recorded between any 2 years of surveys for either of these two species.

In total, 27 water-associated species were detected at point count sites located within the project treatment fields across all 3 years of surveys (2020 through 2022). Approximately 25% more species were recorded in 2021 (when irrigation was first returned to normal levels) than in 2020, with 19 of the 26 species documented in those years exhibiting an increase from 2020 to 2021. Between 2021 and 2022, a decrease of 36% in recorded water-associated species occurred, although irrigation levels remained unchanged between those years. Twenty-one (21) of the 26 water-associated species recorded in 2021 and 2022 exhibited a decrease between the first and second year of restored irrigation levels after curtailment treatments in 2020.

4. Discussion

Avian monitoring during irrigation curtailment (2020) and in the two subsequent years when irrigation was returned to normal levels (2021 and 2022) provided inconclusive results as to the short-term effects of irrigation water conservation practices on the occurrence of avian detections and species richness. Our expectation was that the number of avian detections and species richness would increase in response to a return of normal irrigation levels after curtailment. Surveys results in the first year after curtailment (2021) clearly demonstrated an increase in water-associated avian detections and species richness among treatment field point count locations, with a 252% increase in detections (493 in 2020 compared to 1,242 in 2021) and 25% more species recorded in 2021 (20 compared to 25 species, respectively). However, similar findings were expected in 2022 (the second year of normal irrigation levels after curtailment) and this was not demonstrated in the survey results that year. In some regard, the results from 2022 were actually diminished from those in 2020 (curtailment treatment year), which further opposed our expectations. Although water-associated species detections were slightly higher in 2022 than in 2020 (approximately 6% more), species richness was 20% lower in 2022.

Birds are highly diverse, mobile creatures that use a wide array of habitats for many different seasonal purposes, often making it challenging to interpret the outcomes of avian monitoring efforts. Avian abundance and diversity can be influenced by a combination of many factors including, habitat availability, composition, and configuration; latitude, elevation, and other seasonal range overlap and large-scale movement (migration) distribution patterns; and several environmental factors such as weather, climate, land use changes, predation, and disease. Sorting through the plausible combinations of influential factors can be difficult or infeasible, especially when baseline data were not collected prior to the implementation of this project. No statistical tests were applied due to study design limitations and other cautionary reasons already stated, but we did explore one particular environmental aspect (temperature at the time of each point count survey) that may have been integral to the results of this monitoring effort.

Temperatures at the beginning of each point count survey across all 3 years of surveys at all point count sites ranged from -2 to 21 degrees Celsius (28 to 70 degrees Fahrenheit) and averaged 11.3 degrees Celsius (52.3 degrees Fahrenheit) in 2020, 13.8 degrees Celsius (56.9 degrees Fahrenheit) in 2021, and 8.2 degrees Celsius (46.8 degrees Fahrenheit) in 2022. The total number of avian detections for all point count sites per year within four different temperature regimes were also tallied to further investigate whether temperature at the time of the survey may have influenced bird detectability (i.e., bird activity). The four temperature categories utilized were roughly 10-degree Fahrenheit intervals of 28-39 (-2 to 3 degrees Celsius), 40-49 (4 to 9 degrees Celsius), 50-59 (10 to 15 degrees Celsius), and 60-70 (16 to 21 degrees Celsius). For this effort, all point count locations and all species of birds were included in the analysis because we expected that, if there was an effect from temperature, it should be systematic across all locations and avian species independent of the project treatments.

Figure 2 includes the total number of avian detections per year within each Fahrenheit temperature regime (the number of point counts completed for each temperature range is included in parentheses), which illustrates a trend of more detections with higher temperatures. To standardize for the number of completed point counts under each temperature range, the average number of detections per point count within each temperature regime was calculated. The third year of surveys (2022) was the coldest with nearly 60% of the point counts being completed in temperatures under 10 degrees Celsius or 50 degrees Fahrenheit. In that year, three of the four temperature ranges had less than 11 detections per point count. The fourth temperature interval (40-49 degrees Fahrenheit or 4 to 9 degrees Celsius) was relatively similar with slightly more than 13 detections recorded per point. Conversely, 2021 was the warmest year for surveys with only 17% of the point counts completed below 10 degrees Celsius or 50 degrees Fahrenheit. In that year, one temperature interval (40-49 degrees Fahrenheit or 4 to 9 degrees Celsius) had approximately 13 detections per point count but all other intervals ranged from 19 to more than 25 detections per point count. In 2020, all four temperature intervals ranged from approximately 13 to 17 detections per point count, demonstrating a more uniform distribution of avian detections across all survey temperature conditions.

Although temperatures at the time of surveys appear to be consistent with the trends in avian detections of all species across the years of surveys, the combination of water availability and warmer temperatures may still be important. For example, when irrigation practices were restored to normal levels in 2021, the number of cliff swallow detections substantially increased, thereby contributing to one of the largest single species differences between treatment years. This may have been influenced by ample water providing suitable aquatic insect habitat coupled with temperatures to instigate greater levels of insect activity. Swallow species forage on flying insects and the combination of these two factors (surface water and warm temperatures) likely contributed to prevalent foraging habitat where concentrated swallow detections were observed. In 2021, flocks of swallows ranging from 17 to 42 individuals were common (i.e., more than 10 separate detections were recorded across all properties), whereas flocks of swallows with more than 17 individuals occurred only twice in each year of 2020 and 2022 across all point count survey sites. In addition, many swallow species nest within colonies in close proximity to water, further suggesting the importance of water availability for some of these species.

Variations in detection occurrence and species richness may also be affected by the habitats available at and in the general vicinity of the different agricultural properties, as increased structural taxonomic diversity in vegetation (e.g., shrubs, trees, and water features) tends to support more birds (Dickson et al., 1993; Hurlbert, 2004). Native, undisturbed water bodies (e.g., rivers and creeks) in the vicinity of the project, as well as restored irrigation levels to treatment fields in 2021 and 2022, provide increased habitat heterogeneity that can support complex niche habitats for many avian species. Each of the five properties surveyed throughout this project has unique diverse habitats within (i.e., grasslands, riparian, shrublands, and wetlands) and near (i.e., large reservoirs, dry upland hills, pine woodlands) them. These factors undoubtedly contribute to the overall and individual species detections and richness recorded during the project surveys.

Other environmental factors throughout the region and/or within close proximity to the project area may have been influential in the annual and overall survey results. The Kremmling area and majority of Colorado experienced a multi-year drought extending through the first 2 years (2020 and 2021) of the surveys for the project. In October 2020, the East Troublesome wildfire burned nearly 200,000 acres approximately 15 miles northeast of Kremmling, while a much smaller wildfire (Black Mountain wildfire) burned approximately 481 acres approximately 8 miles northeast of Kremmling from late August through mid-September 2021. Both of these events likely influenced avian distribution and diversity in those years, as well as habitat suitability throughout the region for several future years.

Finally, the results of the surveys for this project are likely impacted by the relatively small number of agricultural properties and the small extent within each individual property where the project was implemented. The treatment fields within each agricultural property ranged in size from 0.2 square kilometer (km^2) (38.7 acres; BSR) to 2.3 km^2 (561.5 acres; GPR areas). The majority of the agricultural areas were not large enough to contain one entire 4 x 4 grid of point count survey sites (separated by 250 meters [820 feet]), as required by IMBCR protocols. Therefore, not all established point count locations could be utilized for this study. Due to this limitation, as well as others stated above, inference of these results should be done with caution.

5. Conclusions

This project offered a unique opportunity to look at the effects of water conservation practices on avian communities. The results suggest that water-associated species detections and species richness may be influenced by both water availability (primarily represented as supplied irrigation) and temperature conditions at the time surveys were completed. Restored irrigation levels after curtailment practices may be important in providing greater resource supplies and heterogeneity to provide suitable habitat for a wide array of avian species. However, due to the design of the project, no avian data were collected prior to the implementation of the water conservation practices in 2020 (i.e., baseline data) to be able to compare the effects of the water conservation treatments both before and after the treatments were implemented. Further research is needed to assess more specific impacts to avian species (both in overall diversity as well as particular water-associated species) from irrigation curtailments. For example, split-season curtailment timing could possibly disturb nesting birds in the irrigated fields or may provide additional nesting resources for adjacent or upland species. Several project and avian monitoring designs could be altered to best pursue many of these opportunities. Additional studies across multiple seasons may also provide meaningful information regarding the impacts of water conservation practices on avian communities, as some avian species may also use high-elevation perennial grass pastures outside the nesting season at other critical life-stage periods (e.g., as migration stopover habitat).

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FIGURES

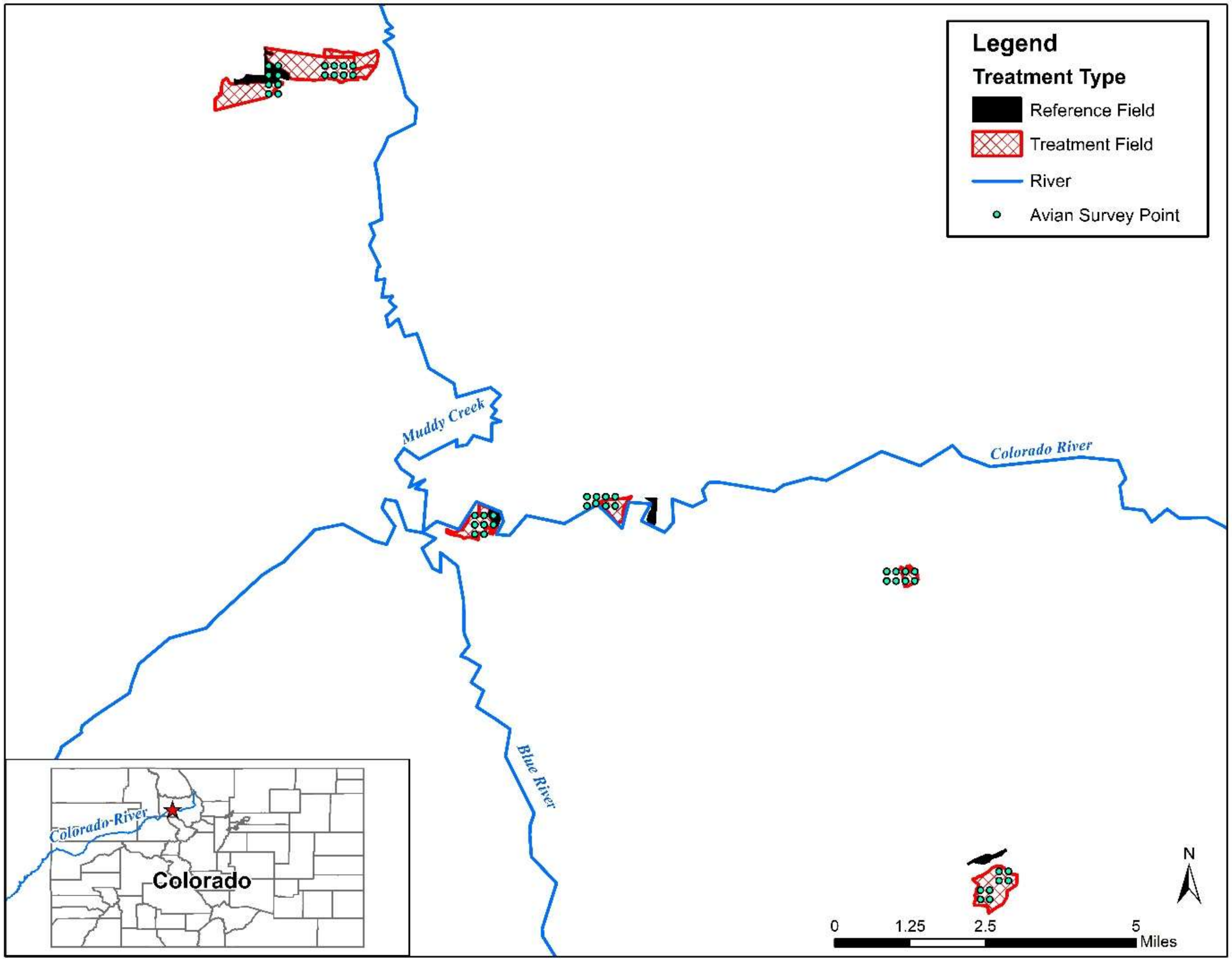

Figure 1. Location of the project area (in the inset) depicting the avian survey points located within the reference area fields, treatment fields, and beyond all property project areas.

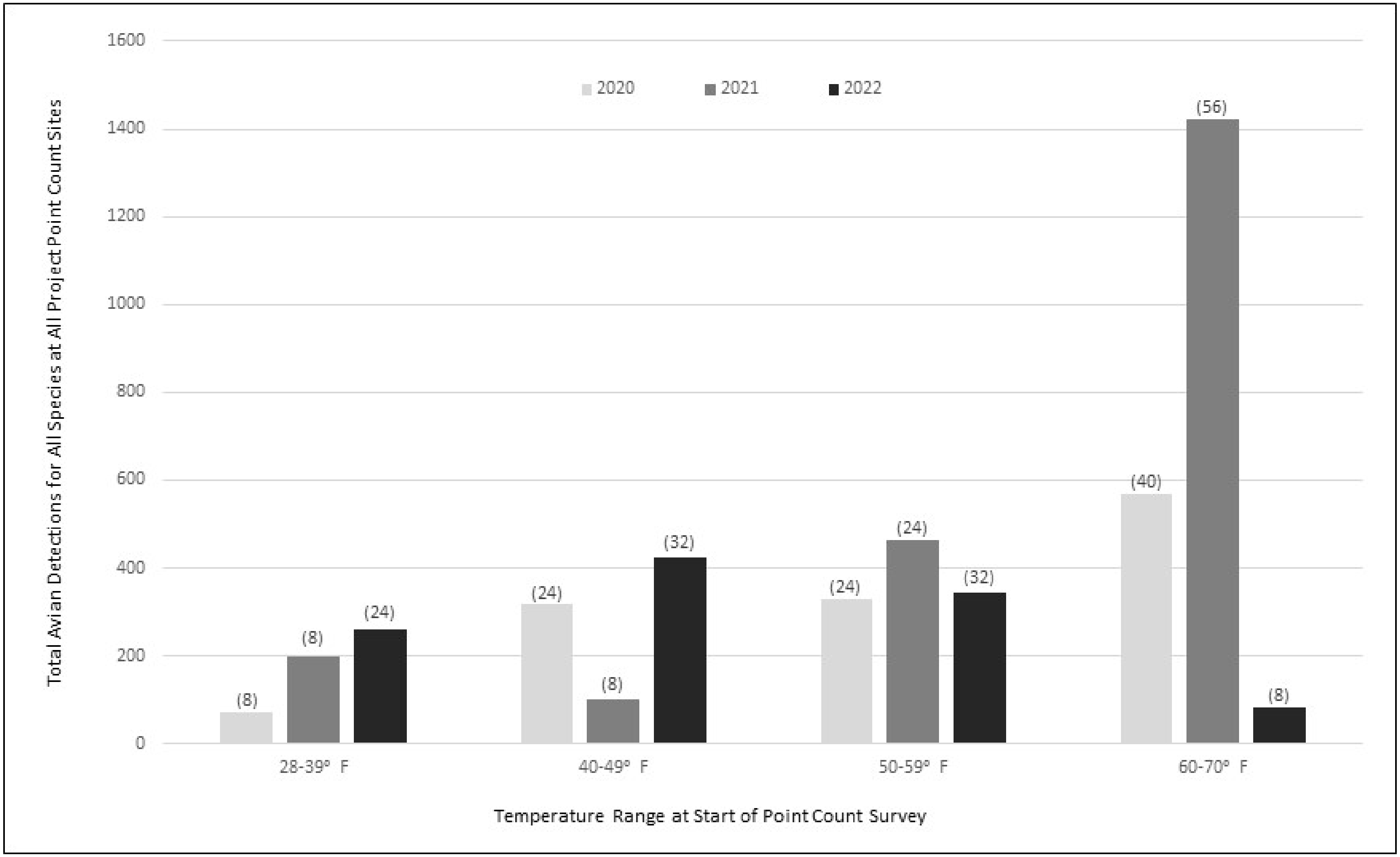

Figure 2. Total number (i.e., all species) of avian detections per year within four temperature regimes at the time of survey among all point count locations for the project. The number in parentheses represents the amount of point count sites per year that were conducted within each temperature range.