RECREATION AND CONSERVATION PLANNING FOR FISHERS PEAK STATE PARK, COLORADO

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The Nature Conservancy Colorado

Ucross High Plains Stewardship Initiative at the
Yale School of the Environment

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Introduction

Trinidad is the most populous city in Las Animas County in southern Colorado, with a population of about 9,000 people. Despite its increasing population, the areas surrounding Trinidad only contain about 16 kilometers (10 miles) of recreational trails in Colorado. Recreational areas, such as local parks, are crucial for creating equitable access to natural areas for those who would not otherwise have the means to access remote natural places. In addition, natural areas function as spaces for people to improve physical and mental well-being, especially during times of major worldwide health crises. Protected natural areas that surround cities also act as buffer zones for wildlife and preserve vital habitat that may otherwise be compromised by urban sprawl. Local parks also provide a place for people to interact with nature and gain an appreciation for wildlife that may otherwise be seen as nuisance species in an urban setting.

The newly acquired Fishers Peak State Park (FPSP) outside of Trinidad, Colorado will not only provide these benefits for both people and wildlife but will also offer an outdoor recreational space that can help alleviate more congested parks and trails along the Front Range. Fishers Peak offers mesas surrounded by a variety of ecosystems boasting natural and cultural histories that create a mosaic of ecological and recreational attractions unique to the area. This park will give people access to natural scenery and recreational activities while also providing habitat for flora and fauna with regulated human impact and conservation management.

Purpose of Study and Project Scope

In partnership with The Nature Conservancy Colorado and the Ucross High Plains Stewardship Initiative (UHPSI) at the Yale School of the Environment, a team of three graduate research assistants was assembled to support research related to the planning of FPSP. This research paper summarizes findings from scientific literature on select species, ecosystems, and recreational activities. Relevant literature was analyzed to provide a scientific basis that will be used to monitor long-term park management practices. This study will ultimately provide the management team of FPSP with tools to guide land-use decisions using a scientific approach, as well as set an example for collaborative recreation and conservation planning. This project occurred during September 2020 - May 2021.

The target species, ecosystems, and recreational activities were identified based on a modified Open Standards for the Practice of Conservation (cmp-openstandards.org) model. The Open Standards model is used by practitioners to improve the practice of conservation implementation through project design, management, and monitoring. At Fishers Peak, the Open Standards process was modified to include recreational indicators in addition to the standard ecological indicators. This new approach allows recreational interests to be evaluated and included earlier in park planning discussions, with the goal of promoting greater collaboration and reducing late-stage planning conflicts. This research paper occurred adjacent to the Open Standards process, with a specific focus on understanding the depth and applicability of research at intersections between select species, ecosystem, and recreational targets.

In alignment with Colorado Parks and Wildlife's (CPW) multipronged mission statement, the planning process at FPSP aims to balance preserving wildlife resources and creating outdoor recreation opportunities.

Study Site: Fishers Peak State Park

Fishers Peak State Park (FPSP) is a 7,770 hectares site recently acquired by Colorado Parks and Wildlife in southern Colorado for the purposes of becoming a new state park. FPSP is bounded on the southern edge by New Mexico's Sugarite Canyon State Park, on the west by Interstate-25, the city of Trinidad to the north, and other protected lands to the east. FPSP elevation ranges from approximately 1,829 to 2,936 meters at the top of the Fishers Peak mesa, which is the highest natural point east of I-25 in the continental United States. FPSP was previously a privately-owned ranch and contains many existing ranch roads as a result, but few recreation trails.

Fishers Peak State Park is ecologically diverse. The park includes pinyon-juniper, ponderosa, mixed conifer, riparian, gambel oak, and grassland ecosystems which are home to numerous wildlife species. Large mammals on the property include black bears, mountain lions, elk, mule deer, and coyotes. Several birds of prey hunt and nest at FPSP, including the peregrine falcon and golden eagle. Additionally, the endangered New Mexico meadow jumping mouse is found at FSPS in riparian zones, representing some of the northernmost bounds of its range.

Fishers Peak State Park also offers significant recreation potential. As the preeminent peak outside of Trinidad, FPSP's alluring presence attracts interest from many potential recreationalists. A report by University of Colorado Boulder graduate students assessed recreational potential and interest for FPSP and found significant opportunities including site-based recreation (picnic tables, gazebos, etc.), hiking, mountain biking, and educational services.

Key Intersections

This report reviews relevant literature at the following intersections and their applicability to FPSP:

- Elk x Trails
- Elk x Hunting
- New Mexico meadow jumping mouse x Trails
- Large block ecosystems x Trails
- Riparian ecosystems x Trails

Understanding the existing body of research at play at these intersections, and assessing its relevance and similarity to FPSP systems, allows planning teams to work more collaboratively to pursue the dual purpose of perpetuating wildlife and creating outdoor recreation opportunities.

Methodology

Scientific literature was chosen for analysis based on its applicability to FPSP and target species, ecosystems, and recreational activities. Literature was searched using online databases such as ScienceDirect, Yale University Library, and Web of Science using the following keywords and combinations of these keywords: *elk, North American elk, recreation, hunting, hiking, New Mexico meadow jumping mouse, fragmentation, large block ecosystems, and riparian.* Other sources such as University of Colorado Boulder, Colorado Parks and Wildlife, ECOs, and the New Mexico Department of Fish and Game were also consulted. Finally, literature that the project partners referenced in their work regarding Fishers Peak was analyzed. Citations in these project literature sources were also reviewed for this study.

Literature sources were analyzed based on a list of criteria and were numerically ranked on a 1-4 scale with 4 being Most Preferred and 1 being Least Prefered. Literature sources were given a numerical value based on how closely they related to the list of criteria which included the following:

- Quality
    - Literature Type
    - Duration
    - Replicated Findings
- Relevance
    - Relevance of Question
    - Species Behavior/Human Interaction
    - Ecosystem/Habitat/Species
    - Spatial Scale

In terms of quality, Most Preferred literature types were long-term studies published in peer-reviewed sources with findings that had clear replication across other similar studies. In terms of relevance, Most Preferred literature sources were studies where the focus of the study was on recreational activities and associated impacts on species and ecosystems that are found in FPSP. In addition, Most Preferred studies were conducted in areas with a similar scale and surrounding land uses to FPSP.

Meta-analyses were included in the literature review, however due to the range of studies included within them they were not included in the ranking system. More information about the evaluation criteria is in Appendix A.

<u>Reading Guide</u>

Each of the key intersections researched for this paper has its own section below. Each intersection can be read as follows:

- <u>Introduction</u>: an introduction to the intersection and its importance at FPSP.
- <u>Literature Overview (brief)</u>: a condensed literature review that brings to light major findings from the most applicable research.
- <u>Applicability & Recommendations to FPSP</u>: a list of recommendations based on best practices derived from relevant literature. Each recommendation is accompanied by a

subjective quality assessment, which serves to indicate the general strength of the recommendation based on how well supported it is by scientific evidence.

- Limitations: A brief description of limitations in literature at the relevant intersection. This is followed by a table showing the most relevant studies for the intersection. Each study is given a Quality and Relevance score (1-4) based on the criteria above in the Methodology section. These scores are meant to serve as indicators, with Most Supported having the greatest amount of scientific literature supporting it, More Supported having some support, and Moderately Supported having less supporting research. No recommendations were made if scientific underpinnings were lacking.

Elk x Trail Effects at FPSP

Understanding the intersection of elk and trail targets is critical to the success of managing FPSP. Early observations on the property have shown elk at all elevations. In the winter, elk are primarily found in the southern region of the park. Elk have also been observed at mid- and high- elevation areas year-round. Given the proximity of other protected lands to the south and east, elk have also been observed migrating across boundaries. Trails on the property are currently minimal, with a "first look" trail on the northern part of the property, but a trail network will be developed at FPSP and its impact on the elk population is a key consideration in effective planning and management.

Literature Overview (brief)

Several studies of elk response to trail-based recreation, specifically, and ungulate responses, broadly, have been published and provide baseline information that may be useful in planning and management at FPSP. Wisdom et al. (2018), in a multi-year study of elk fenced in at the Starkey Experimental Forest in Oregon, found that elk distanced themselves from human recreationalists on trails. This result has been replicated across several studies and ungulate species. Scholten (2018) found that the density of red deer decreased immediately around biking trails, peaked 40 meters from trails, then decreased and leveled off 100 meters from trails. Taylor and Knight (2003) found that several species of ungulates in Utah fled when recreationalists used trails within 100 meters of them. Elk have been shown to create a buffer of at least 200 meters between themselves and recreation trails (Wisdom et al. 2018).

Notably, ungulate species have shown some awareness and adaptability to recreation. Per Stankowich (2008), humans acting predictably, such as on trails, were perceived as less threatening and resulted in reduced weariness for elk. Longshore et al. (2013) found dynamic habitat use among bighorn sheep in Joshua Tree, with the sheep creating greater buffer zones on weekends (during high recreational use) than weekdays. Taylor and Knight (2003) also found that 70% of mule deer fled during on-trail recreation within 100 meters, while 96% fled during off-trail recreation in that range. Particularly sensitive habitat, such as elk calving areas, may warrant additional safeguards from trail-based recreation, as research shows reduced reproductive success is correlated with human disturbance (Shively et al. 2010).

The type of trail-based recreation may also impact elk response. Wisdom et al. found that elk kept a greater distance from trails when they were used for ATVs than when they were used for hiking and horseback riding, while mountain biking caused an intermediate response. Stankowich (2008) found that humans on foot were more disturbing to various ungulates than humans on horseback or biking, possibly because bikes and horses are seen as more predictable or less threatening. Longshore et al. (2013) also found that bighorn sheep had a greater response to hikers than mountain bikers. Taylor and Knight (2003) found no significant difference in response of ungulates between hiking and biking.

Taylor and Knight (2003) also found that recreationalists perceived little effect of their actions on wildlife, believed they could approach wildlife more closely than what data indicates wildlife would allow, and generally did not take responsibility for increasing wildlife stress.

Applicability & Recommendations for FPSP Planning & Management

- Reduce thinning around and minimize clearing for trails: Much of FPSP is covered by pinyon-juniper, mixed conifer, oak, and ponderosa ecosystems, these last three dominating higher elevations where elk are seen year-round. In developing trails, clearing and thinning should be minimized in order to more rapidly decrease elk vigilance (Ciuti et al. 2012) and create noise and disturbance barriers (Kie et al. 2005).
    - Quality of Recommendation: **More Supported**. Multiple studies show positive impacts of increased cover, although these studies do not specifically look at recreational effects on elk.

- In planning trails, ensure core elk habitat includes critical habitat features: These features include water, minerals, forage, south-facing slopes, and wintering habitat. At FPSP the primary caution is to verify water access, since much of the property includes south-facing slopes, and part of FPSP is used for wintering habitat (as of initial findings).
    - Quality of Recommendation: **Most Supported**. Multiple studies show habitat requirements for elk, and if core habitat does not include these necessary features, elk will seek them out at greater distance, which has been shown to reduce fecundity (Shively et al. 2005).

- Promote on-trail predictability: FPSP has many existing ranch roads, some of which are not (and likely will not be) part of the trail system. The park's topography and prominent features may encourage recreationalists to venture off trails, and these antiquated ranch roads may facilitate such behavior. This can increase disturbance and reduce predictability. Efforts should be made to encourage and enforce on-trail use, such as clear signage and trails, maps, and ranger or volunteer enforcement. Increased predictability of recreationalists during most of the year may also benefit hunters, whose short burst of activity could have a reduced negative impact on flight response if elk are otherwise accustomed to on-trail human disturbance (Stankowich 2008).
    - Quality of Recommendation: **Most Supported**. Multiple studies document reduced ungulate responses when humans act predictably.

Limitations

Several studies have researched elk response to human behavior of one sort or another, but relatively few studies have researched the interactions most applicable here - elk response to on-trail hikers. Fewer still have made this question the focus of their research. Beyond this limitation, few of the studies we found shared similar elk habitat to the elk population at Fishers Peak; most studies conducted on elk in Colorado reference populations in the Rocky Mountains, where higher elevations and greater snowfall result in different site characteristics and species abundance.

Studies are wildly inconclusive regarding the relative effects of mountain biking vs hiking on ungulate species, with various researchers finding biking more disturbing, hiking more disturbing, or both equally disturbing to ungulates. More research is needed to understand the relative effects of types of recreation on this elk population.

Additional research on the recreational habits of bikers and hikers while recreating would also add value. Only one study questioned recreationalists as part of its data collection process, and in doing so found that recreationalists underestimate their effects on wildlife and lack understanding of wildlife recreation tolerance levels.

Below are the quality and relevance scores for studies referenced in the above review of elk x trails. Additional information on these rankings, and additional studies that were not directly cited, can be found in Appendix A.

Study	**Quality**	**Relevance**
Ciuti et al. 2012. Effects of Humans on Behaviour of Wildlife Exceed Those of Natural Predators in a Landscape of Fear. PLOS ONE.	**3.33**	**3.50**
Kie et al. 2005. Landscape-level movements of North American elk (Cervus elaphus): effects of habitat patch structure and topography. Landscape Ecology.	**4.00**	**1.75**
Longshore et al. 2013. Detecting short-term responses to weekend recreation activity: Desert bighorn sheep avoidance of hiking trails: Short-Term Response of Bighorn Sheep. Wildlife Society Bulletin.	**3.67**	**3.00**
Shively et al. 2010. Elk Reproductive Response to Removal of Calving Season Disturbance by Humans. The Journal of Wildlife Management.	**3.33**	**3.50**
Stankowich. 2008. Ungulate flight responses to human disturbance: A review and meta-analysis. Biological Conservation.	***meta-analysis***	
Taylor, Audrey R., and Richard L. Knight, 2003. Wildlife Responses to Recreation and Associated Visitor Perceptions. Ecological Applications.	**3.00**	**3.25**
Wisdom et al. 2018. Elk responses to trail-based recreation on public forests. Forest Ecology and Management.	**3.00**	**3.25**

Elk x Hunting Effects at FPSP

Colorado Parks and Wildlife is committed to sustainable hunting practices at Fishers Peak, including seasonal elk hunting, as well as hunting of other animals, which may include mountain lion, bear, and deer. The existing elk population at Fishers Peak is part of a large population that uses Raton Mesa. Elk habitat extends from near Branson, Colorado on the east; to Bartlett Mesa on the south; the northern slope of Raton/Fishers Mesa to the north; and down to the city of Trinidad and the prairie on the northwest. At the time of writing, elk populations are still being studied at Fishers Peak, and key decisions, such as the appropriate size of the herd, will depend on understanding historical data.

Literature Overview

Significant research has been conducted on the effects of hunting on elk populations both in Colorado and elsewhere. Vieira et al. (2003) in coordination with the Colorado Division of Wildlife, found that elk moved from public hunting lands to private land upon commencement of the hunting season; this behavior persisted even as the start of hunting season changed over the years. CDW also found that reducing the number of hunters had no effect on this behavior; a 50% reduction in hunter numbers still resulted in elk migration to private lands (Vieira et al. 2003). Many other studies replicate CDW's finding that elk prefer private lands during hunting season (Proffitt et al. 2009, Ranglack et al. 2017, Conner et al. 2001). These effects persist for both bow and rifle-based hunting.

More nuanced conclusions on elk behavior can also be drawn from existing studies at this intersection. Brough et al. (2017) found that while hunting pressure causes elk movement, the center of a herd's home range does not change; this implies that elk retain home-range fidelity even during hunting season. A study on elk movement during rifle hunting season found that elk selected for areas that restricted access to hunters, were further from motorized routes, had higher canopy cover, and required higher effort on the part of hunters; these factors were listed in order of statistical significance (Ranglack et al. 2017). DeVoe et al. (2019) replicated the finding that elk in higher risk hunting areas selected for habitat further from motorized routes. Notably, during hunting season elk do not change their behavior at night; that is, their selection of refuge areas remains consistent day and night during hunting season, even though no threat was present at night (Proffitt 2010).

Some studies have shown minimal effects of hunting on ungulate flight response and wariness. Colman (2001) found that a caribou population may become habituated to humans due to high year-round recreation traffic; thus, a short burst of hunting may not significantly impact the population's survival (Stankowich 2008). Similarly deer in the northeast U.S. exhibited reduced vigilance in areas with greater human recreation, and neither hunters nor coyotes seemed to affect deer vigilance during fall (Schuttler et al. 2017). Bender et al. (1999) did note a 25% increase in elk flight distance during hunting season over an 8-year observational study in Michigan, but acknowledged that some indicators of elk wariness, including elk sightings and hunter effort were mixed; in fact, viewer satisfaction did not decrease during hunting seasons.

Applicability & Recommendations for FPSP Planning & Management

- Coordinate Hunting with Sugarite Canyon State Park and State Wildlife Areas (Lake Dorothey and James M. John): Elk show proclivity to spend time outside of active hunting territory. Since the elk population's range includes both FPSP, Colorado State Wildlife Areas, and Sugarite Canyon State Park, coordination could better facilitate elk population management and hunting experience.
    - Quality of Recommendation: **Most Supported**. Several studies demonstrate elk respond to hunting by moving out of dangerous areas. Coordinating activity with Sugarite and other hunting areas nearby will allow for better management and could improve the hunting experience.

- Communicate with Trinidad Residents: Since elk tend to move out of public lands during hunting season, and FPSP borders the city of Trinidad, CPW should coordinate with nearby residents to inform them about what to do if you see an elk and to minimize harm to locals. Stakeholders could also consider fencing, similar to that near I-25, in areas (especially in New Mexico), which could reduce permeability of the range at the far northern end where FPSP is closest to residential areas.
    - Quality of Recommendation: **Moderately Supported**. Studies show elk tend to move out of active hunting areas during hunting season, but little research exists on how to moderate the effects of this migration on nearby human communities. To preempt human/wildlife conflict in neighborhoods, where the elk may go, communication will be critical.

- Allow Both Bow and Rifle Hunting: Studies do not show significant differences in elk response based on the type of hunting pursued. Allowing for multiple forms of hunting could broaden the attraction of this recreation type.
    - Quality of Recommendation: **More Supported**. While no studies look specifically at the effects of rifle vs. bow hunting on elk, several studies that pursue either rifle or bow hunting show similar effects on elk population response.

- Carefully Manage Motorized Access: Elk inhabit areas further from motorized routes during hunting season. Reducing motorized vehicle use on back roads (even by CPW staff) in the months leading to hunting season could allow for greater hunting range. Similarly, vehicle parking areas near I-25 and the city of Trinidad are likely to have the smallest effects on elk populations, since these areas already experience regular vehicular traffic.
    - Quality of Recommendation: **Moderately Supported**. Studies show clear avoidance of roads used by motor vehicles; thus, reducing the area of motorized vehicle access may increase total range within FPSP. While not specifically studied, we believe elk do not exempt CPW vehicles and thus park use of vehicles should also be limited leading up to and during hunting season.

- Consider Hunting Near Trail Systems (Northern End of FPSP): As noted by some studies, elk are likely to have the least response to hunting when they are accustomed to regular human recreational activity in the area. Closing recreation trails to allow for hunting during certain times of the year may reduce elk wariness and flight response compared to other hunting management strategies. However, pursuing this strategy would necessarily limit trail-based recreation; a cost-benefit analysis and safety assessment should be conducted to determine whether this management strategy would benefit FPSP.
    - Quality of Recommendation: **Moderately Supported**. Several studies show some level of habituation by ungulates (not elk) to human activity. One study suggested that a short burst of hunting near areas of habituation may result in fewer effects on the herd's survival (Stankowich 2008).

Limitations

Several studies have researched elk response to human hunting in some form, but many research findings lack replicability at this point in time. The result is that many findings lack significant support. This is compounded by data from other ungulate species that paints an incomplete, and possibly false, picture of elk behavior patterns related to human hunting.

Below are the summary quality and relevance scores for studies referenced in the above review of elk x hunting. Additional information on these rankings can be found in the appendix.

Study	**Quality**	**Relevance**
Bender et al. 1999. Effects of Short-Duration, High-Intensity Hunting on Elk Wariness in Michigan. Wildlife Society Bulletin.	**4.00**	**3.25**
Brough et al. 2017. Summer-fall home-range fidelity of female elk in northwestern Colorado: Implications for aspen management. Forest Ecology and Management.	**3.00**	**3.50**
Conner et al. 2001. Elk Movement in Response to Early-Season Hunting in Northwest Colorado. The Journal of Wildlife Management.	**3.67**	**3.50**
DeVoe et al. 2019. Elk forage and risk tradeoffs during the fall archery season. The Journal of Wildlife Management.	**3.33**	**3.25**
Proffitt et al. 2009. Contrasting Effects of Wolves and Human Hunters on Elk Behavioral Responses to Predation Risk. The Journal of Wildlife Management.	**3.67**	**3.50**
Proffitt et al. 2010. Changes in Elk Resource Selection and Distributions Associated With a Late-Season Elk Hunt. The Journal of Wildlife Management.	**3.67**	**3.50**
Ranglack et al. 2017. Security areas for elk during archery and rifle hunting seasons. The Journal of Wildlife Management.	**4.00**	**3.50**
Schuttler et al. 2017. Deer on the lookout: how hunting, hiking and coyotes affect white-tailed deer vigilance. Journal of Zoology.	**3.33**	**2.25**

Stankowich. 2008. Ungulate flight responses to human disturbance: A review and meta-analysis. Biological Conservation.	***meta-analysis***	
Vieira et al. 2003. Effects of Archery Hunter Numbers and Opening Dates on Elk Movement.	**3.67**	**3.50**

New Mexico Meadow Jumping (NMMJ) Mouse x Trails

Literature Overview

Species Background: Viability and Habitat Requirements

The New Mexico meadow jumping mouse *(Zapus hudsonius luteus)* (hereafter referred to as the *jumping mouse*) was listed as federally endangered in 2014, and therefore wherever it is found, the habitat is considered critical. The species' current range spans across select areas in Colorado, New Mexico, Arizona, and in the Rio Grande Valley (US Fish and Wildlife Service 2020). Jumping mouse populations are restricted by small patches of suitable habitat within this range and current populations do not meet US Fish and Wildlife Service criteria for high viability of the subspecies. In order to ensure high viability, jumping mice need resilient populations distributed throughout different drainages that are located along functionally connected streams, within dispersal distance from one another, and absent of barriers between detection sites. These criteria are importantly not only for defining viable populations, but also creating suitable habitat and connecting different sites and populations.

The jumping mouse is a habitat specialist which means that it is more likely to be impacted from habitat loss and disruption in wetland and riparian zones. The jumping mouse requires dense riparian/wetland vegetation along flowing perennial streams for food and shelter (Frey 2006). It uses two types of riparian community types which are persistent, emergent, herbaceous wetlands (i.e., beaked sedge and reed canary grass alliances); and scrub-shrub wetlands (i.e., riparian areas along perennial streams that are composed of willows and alders) (Frey 2005). Adjacent uplands are needed to support breeding and hibernation (US Fish and Wildlife Service 2020). The jumping mouse hibernates in September or October and emerges in May or June which is cued by soil temperature. Elevation and latitude affects the soil temperatures which results in later emergence for jumping mice found in higher elevation sites (US Fish and Wildlife Service 2020). With the little research that has been conducted, jumping mice have been found to hibernate from about 1 to 10 meters from stream, however, it is assumed that jumping mice might hibernate elsewhere throughout their range underground or under shrubs outside of the stream channel flood prone area (US Fish and Wildlife Service 2020). Upon emergence from hibernation, jumping mice must breed, rear their young, and then accumulate sufficient fat reserves to sustain them through the next nine month hibernation period (US Fish and Wildlife Service 2020). Jumping mice are considered granivores and do not appear to cache food for winter and therefore survive solely on what they can forage during the spring and summer months (US Fish and Wildlife Service 2020).

Recreation and its Effects on the Jumping Mouse

Recreational activities such as camping, fishing, and using off-road vehicles, as well as the use or development of trails, can impact jumping mouse habitat by reducing, trampling, or removing dense riparian herbaceous vegetation required by the species. In a comprehensive study in Arizona, the jumping mouse was not found in two locations where heavy human recreational use (e.g., angling) had historically occurred (Frey 2011). In areas that allowed for fishing, dense riparian herbaceous vegetation was trampled by anglers. Field surveys from this site indicated that the habitat conditions could not support the jumping mouse (Frey 2011). The development of streamside trails and large, bare, compacted areas used for camping and fishing has been, and continues to be, reported throughout jumping mouse habitat in areas of the Jemez Mountains, New Mexico, and White Mountains, Arizona (Frey 2005).

The New Mexico Department of Game and Fish recommends vehicle use and camping be prohibited or severely restricted using pole fences in riparian zones within the range of the jumping mouse (Frey 2005). For other recreational activities such as hiking and fishing, pole fencing can direct trail paths and reduce off-trail trampling of herbaceous vegetation, soil compaction, and erosion of waterbanks. Herbaceous wetland habitat restoration can also reduce overall human disturbance in the riparian zone (Frey 2005).

Other Human Impacts to Consider: Incompatible Grazing of Livestock
Grazing can cause changes in the hydrology, soils, and vegetation of riparian areas. Impacts to jumping mouse habitat from poorly managed grazing include streambank erosion, burrow collapse, loss of riparian cover, decrease in herbaceous plant diversity, soil compaction, lower water tables, and the resulting microclimatic changes from moist to mesic or xeric. These impacts could lead to a decrease in food availability on which the subspecies depends (US Fish and Wildlife Service 2020). To prevent degradation of jumping mouse habitat, livestock grazing must be entirely excluded or severely restricted through fencing or natural protection from extensive beaver complexes (US Fish and Wildlife Service 2020). In less than 60 days (in some cases within 7 days) livestock grazing can cause a rapid loss of riparian herbaceous vegetation within suitable jumping mouse habitat (Frey 2005). A field study in Arizona showed that jumping mice were only found in areas where livestock grazing has been excluded (Frey 2011).

In addition to livestock grazing, elk grazing can adversely impact jumping mouse habitat. However, the impact of wildlife grazing is not as detrimental as livestock because livestock tend to concentrate in montane and valley riparian habitats during the summer and graze in higher concentrations (US Fish and Wildlife Service 2020). Cattle also tend to use lower gradient riparian meadows as resting areas and travel corridors rather than step hillsides (US Fish and Wildlife Service 2020). The presence of functioning livestock exclosures has been reported as the best predictor of jumping mouse occupancy in montane riparian areas (Frey 2005). However, these exclosures require constant maintenance to maintain their effectiveness. When livestock enter unauthorized exclosures for short periods of time (such as a few hours or days), the population abundance of the jumping mouse may be reduced but not extirpated (US Fish and Wildlife Service 2020). Although the impacts of short-term grazing on the persistence of jumping mouse populations has not been specifically studied, several populations continue to persist in areas where unauthorized livestock grazing has been noted (Frey 2005).

Future Risks of the Mouse: Climate Change, Fire Severity, and *Mismanagement of Water Resources*
Jumping mice have been extirpated from areas with incompatible water development and usage (US Fish and Wildlife Service 2020). Canals, ditches, and dams alter hydrological processes in riparian zones and have affected the growth of herbaceous vegetation which has resulted in the loss of critical jumping mouse microhabitat. Riparian development, water usage, or divergence

of water should be restricted or limited and carefully analyzed for potential effects on the jumping mouse habitat.

Water management should also include the conservation of beavers (*Castor canadensis*) which can affect the frequency and intensity of severe wildfire through the creation of extensive wetland habitat and alteration of hydrology, vegetation, and composition of riparian areas (US Fish and Wildlife Service 2020). Because beaver populations have been reduced in many areas through the range of the jumping mouse, the corresponding loss of wetland habitats and perennial flow has perhaps contributed to the flooding and loss of moisture of riparian vegetation, which would increase the flammability of riparian vegetation (US Fish and Wildlife Service 2020).

Climate change and drought will likely exacerbate existing stressors to riparian habitats and therefore increase the vulnerability of the jumping mouse as well as its susceptibility to other climatic events. For example, wildland fires will have more severe impacts on the jumping mouse populations when soils become more dry from drought (US Fish and Wildlife Service 2020). Direct effects to jumping mouse populations include individual die off from high-severity fire and post-fire flooding, while indirect effects include habitat alteration from high severity fire or post-fire flooding (US Fish and Wildlife Service 2020). It should be noted that low-intensity fire and non-scouring floods are natural components of the jumping mouse habitat and although they can result in the deaths of jumping mouse individuals, low-intensity fires can help maintain the riparian communities at an early seral stage (US Fish and Wildlife Service 2020). These low-intensity fires can increase in intensity, frequency, and overall threat to the jumping mouse with the dewatering of the jumping mouse habitat, which is why compatible water management is critical to the survival of this species and its habitat (US Fish and Wildlife Service 2020).

Applicability & Recommendations for FPSP Planning & Management

- Coordinate recreational activities with seasonality of NMMJ mouse hibernation: The NMMJ mouse hibernates underground or in logs for nine months out of the year. Recreational activities, such as hunting, that may require off-trail travel can occur while the NMMJ mouse is hibernating to alleviate disturbance. Recreational activities in riparian areas during spring months can be restricted to assure that herbaceous vegetation is intact for the 3-4 months that the NMMJ mouse is active.
    - Quality of Recommendation: **Most Supported.** Intact and untrampled vegetation is needed for the mouse to find enough food in order to reproduce and store enough energy to hibernate for the rest of the year (Chambers 2019). In addition, during the breeding months of July and August, female mice require dense herbaceous vegetation to give birth and provide shelter for rearing their young outside of the riparian zone. Tracking has shown that the species hibernates within 4 meters of streams (Chambers 2019). In a study on a close relative of the NMMJ mouse, the Preble’s Meadow Jumping Mouse, it was observed that limited

grazing between December and February did not have an effect on the Preble's Meadow Jumping Mouse (Meaney et al. 2002).

- Use recreational infrastructure to mitigate disturbance during months of mouse activity: For activities like fishing that require water access, elevated boardwalks or pole fences can be constructed and used to prevent herbaceous vegetation trampling, soil compaction, and off-trail travel.
    - Quality of Recommendation: **More Supported.** Pole fencing for anglers and other recreationists can be used to keep foot traffic on trails and mitigate off-trail impacts (Frey 2005, 2011).

- Where cattle grazing is necessary, implement compatible fencing strategies: Where cattle need access to water, "water lanes" have been constructed to minimize cattle impact in the riparian zones. These water lanes direct cattle movement to the water without allowing the livestock to move about the riparian area. These fences can be mobile or temporary to allow for seasonal usage or at site specific locations. Locations for cattle drinking access can be identified and predetermined to minimize impact on critical habitat areas for the jumping mouse.
    - Quality of Recommendation: **Most Supported.** Where cattle grazing and the jumping mouse habitat intersect, cattle fencing has been used to mitigate herbaceous vegetation trampling, overgrazing, and soil compaction (US Fish and Wildlife 2020, Frey 2005, 2011).

- Herbaceous vegetation restoration: Restoring herbaceous wetland vegetation can lessen the impact of human disturbance in riparian zones and increase resiliency against floods, fires, droughts, and climate change. More research is needed to look at the effects of riparian restoration on the presence of New Mexico meadow jumping mouse.
    - Quality of Recommendation: **Moderately Supported.** Studies have shown that the NMMJ mouse is threatened by floods, fires, droughts, and climate change (Frey 2005, 2011).

Limitations

The jumping mouse is a naturally rare species and therefore population numbers can significantly fluctuate on a yearly basis. More research, particularly in Colorado, is needed to assess the impacts of human disturbance in a more local context. Studies on species that are closely related and have similar life histories such as the Preble's Meadow Jumping Mouse have been used to find more localized research on the jumping mouse species.

Below are the references that were used to support the above recommendations and background information regarding the New Mexico Meadow Jumping Mouse. Studies were species specific but study locations varied, occurring largely in the southwestern states of Arizona and New Mexico where the jumping mouse is most commonly found. The relevance score reflects this species specifically but varied based on locality discrepancies. In addition, some references were New Mexico Meadow Jumping Mouse species status reports that were submitted to Fish and Wildlife Departments, while others were peer reviewed articles. The quality of literature was reflected in the Quality score.

Study	Quality	Relevance
Frey. 2005. Status Assessment of Montane Populations of the New Mexico Meadow Jumping Mouse (Zapus hudsonius luteus) in New Mexico. New Mexico Department of Game and Fish.	**2.33**	**3.25**
Frey, J.K., Wright. G.D. 2011. Draft management recommendations; New Mexico meadow jumping mouse (Zapus hudsonius luteus) at Bosque del Apache National Wildlife Refuge. Submitted to U.S. Fish and Wildlife Service, Albuquerque, New Mexico.	**3.33**	**3.25**
Harrow et al. 2018. Track Plates Detect the Endangered New Mexico Jumping Mouse. The Wildlife Society.	**3.33**	**2.25**
U.S. Fish and Wildlife Service. 2020. Species status assessment report for the New Mexico meadow jumping mouse (Zapus hudsonius luteus), 1st Revision. January 2020. Albuquerque, NM. 160 pp.	**3.33**	**3.25**

Large Block x Trails (Fragmentation)

There are currently a small number of trails on a limited portion of FPSP as well as a larger number of ranch roads throughout the property. As the network of trails is expanded, evaluating the impacts of fragmentation from roads and trails on large block habitats will be an important consideration.

This section reviews existing published and gray literature on fragmentation as it relates to the intersection of large landscape blocks and trails and then attempts to draw conclusions and recommendations for planning and management at this intersection based on site characteristics at FPSP. Park management practices should be continually evaluated throughout park planning and operation to improve operations at this intersection.

Literature Overview

Fragmentation refers to the result of large, continuous blocks of habitat that have been broken into smaller, more disconnected patches. In a meta analysis of hundreds of terrestrial animal species across six continents, Prugh et al. (2008) found that of the animals included in their analysis birds and mammals were most sensitive to the size of fragmented patches whereas amphibians were least sensitive. Their analysis also showed that carnivores were more sensitive to patch area than omnivores, and arboreal species were more sensitive than terrestrial species (Prugh et al. 2008). A study of ground dwelling birds in forested areas in eastern North America, found that while trails did not significantly reduce habitat area, the density of forest birds in areas with trails decreased compared to trail-free habitat (Thompson 2015). In a study on the effects of recreational trails on forest birds in Switzerland and France, Bötsch et al. (2018) found that in forests with high levels of recreation there was a decrease in density of birds and richness of bird species near trails compared to areas further away from the trails. The same effect was not observed in forests with low levels of recreation.

The effects of fragmentation are often closely linked with other processes and disturbances, including trail construction activities and various forms of recreational trail use. For example, Miller et al. (2020) investigated the impacts of trail building on various species and found that rates of detection of white-tailed deer near trails decreased 41% during trail construction. After trail building was completed deer returned to pre-building levels (Miller et al. 2020). In their study of elk and wolves in the Canadian Rockies, Rogala et al. (2011) found that elk increased their avoidance distance from trails when trail use increased above two people per hour. Benniger-Truax et al. (1992) found that plant species composition was also affected by level of trail use as well as distance from the trail edge. Landscape level damage can be caused by the formation of informal trails and trampling of vegetation due to off-trail travel. In their study in Aconcagua Park, in the Andes, Barros and Pickering (2017) found that 94% of the trails they found were informal and 90% of the vegetation in Horcones Valley has been damaged by visitor use, nearly all of it from unregulated use.

The type of trails and recreational uses also impact erosion rates. Ballantyne et al. (2014) found that informal mountain bike trails had greater rates of soil loss and tended to be steeper than formal bike trails. Whereas Wilson and Seney (1994) found that trails used for hiking resulted in greater soil loss than those used for mountain biking, especially when the trails were wet.

Applicability & Recommendations for FPSP Planning & Management

- Trail building seasons: Restricting trail building to short time periods during seasons when species of concern are least sensitive can help minimize the initial disturbance of constructing new trails.
    - Quality of Recommendation: **Moderately Supported.** The study that found white-tail deer decreased their activity on and near trails during the construction phase did not specifically address the effects of trail building on species found in FPSP (Miller et al. 2020).

- Maintain blocks of unfragmented habitat: Trails should be planned to direct people around critical wildlife habitat and sensitive areas. Consolidating trails can help establish and protect refuge habitat without trails and lessen the impacts of fragmentation by maintaining blocks of unfragmented habitat.
    - Quality of Recommendation: **More Supported.** Several studies have shown a decrease in the density of certain species in areas with trails. However, effects of fragmentation due to trails varied depending on the specific species.

- Prevent off-trail travel: Off-trail travel can lead to vegetation being trampled and the formation of informal trails, which have been found to have greater rates of soil loss due to steeper grades. Installing and maintaining clear trail signage and barriers in select locations can be used to limit the amount of off trail travel. In addition, monitoring for early signs of informal trails and taking measures to close or block them can help control erosion and other impacts of off trail travel. For activities that require off trail travel, consider temporal and spatial restrictions to limit disturbance to sensitive areas such as nesting sites.
    - Quality of Recommendation: **Most Supported.** Several studies have documented the harmful effects of informal trail networks, including vegetation being trampled and increased rates of erosion (Barros and Pickering 2017, Ballantyne et al. 2014).

- Develop trails along existing natural barriers: To prevent informal trails from forming, develop trails alongside naturally occurring barriers such as at the base of cliffs or following ridgelines.
    - Quality of Recommendation: **More Supported.** While studies have not specifically looked at the effect of incorporating existing natural barriers into trail networks, several studies have documented the negative effects of informal trails. Using natural barriers can help to reduce the potential for informal trails to form (Barros and Pickering 2017, Ballantyne et al. 2014).

- Seasonal trail closures: Implementing a system of seasonal trail closures can be used to maintain a buffer between humans and target species' breeding or nesting grounds.
    - Quality of Recommendation: **More Supported.** Multiple studies have shown a decrease in density and richness of various species in areas with high levels of trail-based recreational use compared to areas with low levels of recreation (Bötsch et al. 2018, Rogala et al. 2011).

- Use permits system to manage access: A permit system can be used to manage or limit recreational use in ecologically sensitive areas.
    - Quality of Recommendation: **More Supported.** Multiple studies have shown a decrease in density and richness of various species in areas with high levels of trail-based recreational use compared to areas with low levels of recreation (Bötsch et al. 2018, Rogala et al. 2011, Benniger-Truax et al. 1992).

- Incorporate existing roads into trail plans: Where possible, incorporate existing ranch roads into expanded trail networks to reduce additional fragmentation in areas where existing roads are not needed for vehicle access. In addition, evaluating the spatial distribution and stage of revegetation can inform the process of deciding which roads to close. Closing certain roads may have a disproportionately large benefit in preserving large block ecosystems. Due to the arid climate, reestablishing plant cover on former roads can occur slowly; closing roads where vegetation has already started to regrow may help to accelerate reconnecting previously fragmented areas.
    - Quality of Recommendation: **More Supported.** Several studies have shown various species' range in levels of sensitivity to patch size (Prugh et al. 2008). Selectively closing certain ranch roads and incorporating others into the trail network can help establish and maintain larger patches of unfragmented land within the park.

- Consider mountain bike specific trails: Research indicates that compared to mountain biking, hiking produces more sediment yields from trails. Establishing separate mountain biking trails may help reduce the amount of trail damage due to sediment loss. This recommendation should be weighed against the possible increase in the total number of trails.
    - Quality of Recommendation: **Moderately Supported.** The type and amount of recreation is one of many factors including complex interactions between topographic, soil, and geomorphic variables that impact rates of erosion along trails (Wilson and Seney 1994).

- Follow best management practices for trail building and maintenance: To minimize the overall impact of trails follow best management practice for trail planning, construction, and maintenance.
    - Quality of Recommendation: **More Supported.** There is a wide range of research on the effects of fragmentation, with a more narrow subset focused on the impacts of trails. Numerous studies have shown a variety of impacts and effects

of trails including changes in wildlife species density and richness, sensitivity to habitat patch size, increased avoidance distances, and altering of natural processes such as soil erosion rates (Miller et al. 2020).

Limitations

There is considerable variation in the forms and extent of fragmentation and the complex and interlinked effects of fragmentation make it difficult to generalize across differing spatial and temporal scales. Fragmentation has a variety of effects and ecological responses to fragmentation can vary over time, yet much of the current research focuses on the short-term impacts. More research is needed to better understand the long-term effects.

In addition, many studies on the impacts of trails and recreation on habitat fragmentation do not differentiate between the effects of the physical presence of trails versus the impacts due to human use of trails. This makes it difficult to determine which factor contributes most to changes in ecological conditions.

Below are the summary quality and relevance scores for studies referenced in the above review of large block x trails. Additional information on these rankings can be found in the appendix.

Study	**Quality**	**Relevance**
Ballantyne et al. 2014. How formal and informal mountain biking trails result in the reduction, degradation and fragmentation of endangered urban forest remnants.	**3.00**	**2.75**
Barros and Pickering. 2017. How Networks of Informal Trails Cause Landscape Level Damage to Vegetation. Journal of Environmental Management.	**3.00**	**2.75**
Benniger-Truax et al. 1992. Trail corridors as habitat and conduits for movement of plant species in Rocky Mountain National Park, Colorado, USA. Landscape Ecology.	**2.67**	**3.25**
Bötsch et al. 2018. Effect of recreational trails on forest birds: Human presence matters. Frontiers in Ecology and Evolution.	**3.67**	**2.50**
Miller et al. 2020. Wildlife response to recreational rail building: An experimental method and Appalacian case study. Journal for Nature Conservation.	**3.00**	**3.25**
Prugh et al. 2008. Effect of habitat area and isolation on fragmented animal populations. PNAS.	***meta-analysis***	
Rogala et al. 2011. Human Activity Differentially Redistributes Large Mammals in the Canadian Rockies National Parks. Ecology and Society.	**4.00**	**3.50**

Thompson. 2015. Recreational Trails Reduce the Density of Ground-Dwelling Birds in Protected Areas.	**3.00**	**2.75**
Wilson and Seney. 1994. Erosional Impact of Hikers, Horses, Motorcycles, and Off-Road Bicycles on Mountain Trails in Montana. Mountain Research and Development.	**3.00**	**3.25**

Riparian x Trails

Riparian zones are some of the rarest ecosystems at Fishers Peak State Park, while hosting significant plant and animal diversity found nowhere else on the property. They also provide unique recreational opportunities and attractions, from ideal hiking locations by waterbeds to potential water sources for backcountry users. Thus, it is important to consider the specific effects at the intersection of riparian ecosystems and trail-based recreation.

Due to extremely limited literature on the effects of hunting on riparian areas (and vice versa), we have not specifically addressed hunting in this assessment. Some findings and recommendations here may be applicable to that recreation type, and we encourage cross-referencing where possible and further research on the topic.

Literature Overview

Effects of Riparian Habitat on Recreation

A recent study analyzed the effects of riparian zones on hikers and found that time spent in biodiverse riparian areas and areas of perceived aesthetic value correlated with decreases in salivary cortisol and improved well-being for hikers (Opdahl 2021). Riparian zones offer environmental educational opportunities for recreationists to learn about endangered species, ecosystem ecology, native waterfowl and migratory birds. Riparian zones are also places where recreationists can learn stewardship practices. Taylor et al. (2003) surveyed 640 backcountry trail users on Antelope Island to investigate their perceptions of the effects of recreation on wildlife. Approximately 50% of recreationists felt that recreation was not having a negative effect on wildlife (Taylor et al. 2003). Through informational panels, blazers, signs, and interpretative signage and maps, recreationists can become more aware of the sensitive areas in which they recreate.

Effects of Land Use Practices on Riparian Habitat

Papers considering human effects on riparian habitats have percolated through academia since at least the 1970s at a trickling pace. Johnson and Carothers (1982) specifically addressed riparian habitats and recreation in southwestern ecosystems as a meta-analysis of several site-specific case studies across the southwest. They found that the significance of recreation’s impact on a riparian habitat depends on its ability to purge the effects of recreation. For example, if a system regularly floods, human usage may change over the course of the year and impacts at low-water levels may literally be purged as water saturates the system. The impact of human recreation is also dependent on the type of substrate; trails built on sand and gravel show low-impact even at relatively high levels of recreational use. However, soils compacted by repeated recreational use may deteriorate rapidly, resulting in reduced vegetation and hydrologic changes (Johnson and Carothers 1982). Similarly, use of seasonally dry streambeds by 4-wheelers has been shown to damage banks in riparian zones (Patten 1998). Rocchio (2006) found that altering the hydrology of a riparian zone can lead to excess nutrients and fragmentation, in addition to exotic species introduction.

Excess nutrients can enter riparian ecosystems through various land use practices. Excess nutrients can alter species composition by allowing for more aggressive, invasive species to compete with native species. A disruption in the nutrient cycle can alter organic material deposition in floodwaters and their associated flushing cycles (Rocchio 2006). This change in nutrients and cycling can create conditions that allow exotic plant species to be more easily introduced and outcompete native species. These changes in the nutrient conditions also allow non-native invertebrates to more easily dominate (Rocchio 2006). Non-natives that are difficult to eradicate, such as Tamarisk (*Tamarix spp.*), can decrease sedimentation in floodplains, displace native vegetation, alter nutrient cycles by adding salts, and contribute to disconnectivity between rivers and floodplains (Rocchio 2006). Invasives like the Tamarisk can alter riparian water flow and overall composition of the riparian ecosystem mosaic.

Other land use practices such as intensive grazing and unmanaged recreation can create barriers to ecological processes. Landscape fragmentation reduces connectivity between riparian patches and upland areas. This can negatively impact the movement of surface and groundwater and nutrients, and the dispersal of flora and fauna (Rocchio 2006). Vegetation around trails is particularly vulnerable to the effects of recreation. Treading through riparian zones can reduce ground cover, introduce invasive species, and cause tree root dieback (Johnson and Carothers 1982). Miller et al. (2003) also found declines in native bird species, a more open understory, reduced ground cover, and higher overall tree density in riparian areas closer to human development in Colorado. Miller also found that periodic flooding may benefit cottonwood trees, which can result in a more-open canopy structure.

These changes in vegetation and hydrology also affect wildlife, particularly birds. Miller et al. (2003) found that reduced understory vegetation and herbaceous ground cover strongly determined the local bird community structure in Colorado riparian zones. Ultimately, high recreation seems to benefit some species and disadvantage others. Birds tolerant of human activity, such as American Crows, Black-billed Magpies, and European Starlings, remained present even when human activity was high, possibly because the rewards of foraging near humans may outweigh the costs for these omnivorous species. More diet-restricted species that forage only for seeds or insects were not found in high-use recreational areas. Miller and Hobbs (2000) found that nest predation was higher further away from recreation trails, which may convey an advantage to some bird species nesting nearby. However, nest predation by birds specifically was found to increase near trails, possibly because some species like corvids adapt to human presence.

Effects of Historical Land Use Practices on Riparian Areas

Frey (2011) found that the New Mexico meadow jumping mouse was only found in locations that were excluded from livestock grazing. It was found that NMMJM remained absent from riparian areas previously used to graze livestock in areas of Arizona that historically supported jumping mice populations (Frey 2011). Research has not been done on whether these riparian areas could be restored to support the jumping mouse once again. Restoration of riparian areas that were previously grazed by livestock could be considered to increase habitat viability for native flora and fauna like the jumping mouse.

Applicability & Recommendations for FPSP Planning and Management

- Complete impact assessment and implement monitoring: Assess the impact of historical human development and practices (i.e., trails, livestock grazing) to determine areas of degradation. Monitor future land use practices and extreme flooding/fire events in riparian zones to assess the impacts on herbaceous vegetation, soil, fauna, and riparian processes such as erosion, sedimentation, and undercutting.
    - Quality of Recommendation: **Moderately Supported.** Inventory of riparian habitats may be combined with indicators to assess riparian health or ecological status (Gonzalez et al. 2017).

- Restore riparian ecosystems: Riparian areas that have been degraded by human development, livestock grazing, or extreme flooding/fire events can be restored through strategies such as herbaceous vegetation planting, bank stabilization, and livestock exclosures. Restoring riparian habitats can include softening streambanks and wetland edges.This includes the removal of obsolete historical infrastructure (such as retention walls, rocks walls, concrete structures, fencing) can help flora and fauna (i.e., turtles, salamanders, rodents) access the water edge.
    - Quality of Recommendation: **Moderately Supported.** Livestock enclosures and infrastructure (i.e. pole fencing) to prevent stream bank degradation by humans has been recommended to improve riparian habitat (Frey 2011; Gonzalez et al. 2017).

- Conduct habitat quality assessments: Assessing the habitat quality in terrestrial and aquatic ecosystems can help inform effective restoration strategies. Water quality assessments can help determine if excess nutrients are present that allow for invasive plant species to colonize more easily.
    - Quality of Recommendation: **Most Supported.** Stream bank assessments as well as groundcover surveys can help prioritize areas for restoration efforts (Gonzalez et al. 2017).

- Implement species monitoring: Due to the vulnerability of riparian species like the New Mexico meadow jumping mouse, continued monitoring can help determine the impacts of restoration efforts as well as identify populations that were not previously known in the species range (Frey 2005, 2011).
    - Monitoring beaver presence: Beaver presence in a riparian ecosystem has been positively associated with the New Mexico meadow jumping mouse. Beavers create wetland habitat and therefore are important riparian ecosystem engineers. Monitoring their presence and impact can help practitioners understand the condition of the riparian zone and can also be used in riparian ecosystem restoration.

  - Quality of Recommendation: **Most Supported.** The presence of beaver has been positively correlated with the presence of other native wildlife species, such as the NMMJ mouse, in riparian habitats (Frey 2011).

- Keep trails to one side of waterways: Studies found that recreation trails have mixed effects on animal species depending on each species' sensitivity to humans, and that these differences could cause trophic cascade. Should recreation trails be built in riparian systems, keeping them to one side of the waterway will allow for varied ecosystem response and minimize recreational impacts.
  - Quality of Recommendation: **Moderately Supported.** Miller et al. (2003) found that species exhibited mixed responses to recreational trails. Keeping recreation trails to one side of riparian zones can minimize the effects of such trails on local flora and fauna.

- Implement informational infrastructure: Infrastructure such as signs and other forms of communication like informational panels can educate recreationists about their impacts on riparian zones and sensitive flora and fauna found there. In addition to educational communication, directional communication with blazes and restricted area signs can show recreationists where to go and what areas may be sensitive.
  - Quality of Recommendation: **Moderately Supported**. Taylor and Knight (2003) found that nonconsumptive recreationalists are generally unaware of their impact on the landscape. Informing them of their effects and promoting/enforcing responsible recreational behavior can reduce negative effects to riparian zones.

- As needed, construct boardwalks/planks over riparian zones for trail-based recreation: Boardwalks and planks can keep recreationists on-trail, especially in dense, herbaceous vegetated areas. Boardwalks or planks can be designed to elevate walkways above riparian vegetation.
  - Quality of Recommendation: **Moderately Supported.** This type of trail infrastructure can also give recreationists access to the riparian area while avoiding erosion, compaction, and trampling of vegetation and riparian soils (Gonzalez et al. 2017).

Limitations

Relatively few academic articles have been published specifically considering the effects of human-based recreation on riparian areas in the southwest, and no more than a handful of publications occur each decade. Further research, particularly into the effects of hunting on riparian zones, would enable more robust management decision making.

Little writing exists on the importance of developing trail networks that include access to riparian areas. We did not find many publications mentioning riparian areas as either a goal or limitation specifically; rather, recreationalists consider riparian zones within a broader context - can they traverse a diversity of ecosystems, do they have access to water when needed, and which areas harbor sensitive and limited habitats?

Study	Quality	Relevance
Gonzalez et al. 2017. Integrative conservation of riparian zones. Biological Conservation.	***meta-analysis***	
Johnson and Carothers. 1982. Riparian Habitats and Recreation: Interrelationships and Impacts in the Southwest and Rocky Mountain Region. Eisenhower Consortium Bulletin.	***meta-analysis***	
Miller et al. 2003. Effects of Human Settlement on Bird Communities in Lowland Riparian Areas of Colorado (usa). Ecological Applications.	**4.00**	**2.50**
Miller and Hobbs. 2000. Recreational trails, human activity, and nest predation in lowland riparian areas. Landscape and Urban Planning.	**3.33**	**3.50**
Opdahl et al. 2021. Decreased cortisol among hikers who preferentially visit and value biodiverse riparian zones. Scientific Reports.	**3.00**	**3.00**
Patten. 1998. Riparian ecosytems [sic] of semi-arid North America: Diversity and human impacts. Wetlands.	***meta-analysis***	
Rocchio. 2006. Rocky Mountain Lower Montane Riparian Woodland and Shrubland Ecological System. Colorado Natural Heritage Program.	***meta-analysis***	
Shelby and Wittaker. 2020. Chapter 9. Recreation Habitat Versus Ecological Habitat in Riparian Areas: Can We Manage for Both?. USFS.	**2.67**	**3.00**

Conclusion

The objective of this study was to compile and analyze relevant scientific literature related to the intersections of elk x trail, elk x hunting, New Mexico meadow jumping mouse x trails, riparian ecosystems x trails, and large block ecosystems x trails, which will help inform recreation and conservation planning processes at Fishers Peak State Park. The recommendations included in this report aim to balance the goals of preserving the integrity of ecosystems, ensuring ecological functionality, and decreasing disturbance of flora and fauna while promoting recreational activities at Fishers Peak. Our main takeaways from this study will inform management decisions related to the select target species, recreational activities, and ecosystems at Fishers Peak and surrounding or similar natural areas. To mitigate disturbance for elk, we recommended that trails are planned and designed in a way that allows elk to access core habitat features such as water and south-facing slopes, wintering areas, foraging grounds, and rearing locations (Shively et al 2005). In addition to trail planning, hunting can also be managed through coordinating with surrounding natural area hunting seasons and communicating to Trinidad residents about increased elk movement. Finally, allowing for different types of hunting such as bow and rifle, carefully managing for motorized access, and considering a “hunting near trails system,” are also strategies to accommodate for more compatible hunting practices.

Main takeaways for the New Mexico meadow jumping mouse included coordinating recreational activities with the timing of mouse hibernation. The use of recreational infrastructure such as pole fencing or elevated boardwalks was recommended to minimize disturbance to both the jumping mouse and its riparian habitat. Compatible fencing techniques were also suggested for livestock grazing to decrease effects of overgrazing and disturbance to riparian and jumping mouse habitat. Restoration of these riparian zones, especially those that have been altered by former land use practices such as stream development, human travel, or livestock grazing, was recommended to maintain riparian ecosystem functionality and jumping mouse population viability. Such restoration and monitoring practices include impact and habitat quality assessments, livestock exclosures, bank stabilization, and softening stream edges where obsolete infrastructure may be impeding wildlife movement. Another recommendation was to keep trails to one side of waterways to minimize disturbance and also use informational signage to communicate areas of sensitivity and restricted zones.

Strategies to decrease effects of fragmentation on large blocks of habitat included coordinating trail construction seasons, maintaining large in-tact blocks of habitat, preventing off-trail travel, and developing trails along existing natural barriers. Using seasonal trail closures and a permit system, incorporating existing roads into trail plans, and having trails for specific recreational activities were also suggested to decrease infrastructure and human impact on the landscape. Continued trail maintenance following best practices will be key in monitoring impacts and ensuring sustainable use of the trail system.

These recommendations were rated on a scale (Moderately, More, and Most Supported) to indicate the level of certainty. Findings were limited by the scope of existing literature, specifically on the effects of human-based recreation on riparian areas in the southwest, recreation effects and the New Mexico meadow jumping mouse, and the response of elk to hiking and mountain biking. This study reviewed existing published and gray literature on these subjects and attempted to draw conclusions and recommendations for planning and management at these intersections based on site characteristics at FPSP. As monitoring and mapping at FPSP continue, management practices should be evaluated to improve operations at these intersections.

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Appendices

Appendix A

Literature evaluation criteria and scoring matrix