CATTLE GRAZING IN AMERICA'S NATIONAL WILDLIFE REFUGES: A SYNOPSIS

by

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ABSTRACT

America's National Wildlife Refuge system seeks to protect some of our most treasured landscapes and ecosystems and provides access to pristine, otherwise unaltered lands for naturalists and recreationalists alike. However, some of these ecosystems are under threat from human activities such as livestock grazing. Cattle grazing has historically had massive detrimental effects on public lands. Increased erosion and sediment transportation, removal of protective riparian habitat, and influxes of excess nutrients into natural systems are all common symptoms of cattle grazing. These effects not only directly alter the landscape but also the waterways that transect it. One of the most contentious aspects of grazing on public land and Wildlife Refuges is the effect on water quality, stream structure, and habitat suitability for aquatic vertebrates such as salmonids. As fish that require cold, clean water to survive and reproduce, salmonids are excellent indicator species of the detrimental effects of external forces. Based on a copious body of literature on the effects of livestock grazing on various ecosystems, I synthesized peer-reviewed sources and agency documents on natural resource management and grazing allotments for this project. My findings underscore the detrimental effects of livestock grazing on both terrestrial and aquatic ecosystems, and I provide solutions to mitigate these effects within the framework of our National Wildlife Refuge system. Ideally, complete removal of cattle grazing is one of my recommendations, but this may not be possible; yet a meaningful reduction in grazing operations is essential for the continued success and preservation of public lands. My hope is that this report, and others like it, will inspire advocates for public land conservation to speak up for the invaluable ecosystems protected under law that are currently threatened by policies prioritizing commercial gain.

CHAPTER ONE

Introduction

For thousands of years, humans have domesticated and utilized various livestock species to cultivate, produce, and expand civilization. One of the most ubiquitous livestock animals worldwide is cattle, a member of the bovine family of ungulates. Cattle were first domesticated approximately 10,500 years ago in the Near East, likely in modern-day Iran, from the wild ox, common throughout Europe and Asia at the time (UCL, 2012). These wild oxen were much larger than the cattle we know today and have been selectively bred for smaller sizes and traits such as docility (UCL, 2012). Cattle, by nature, are large mammals that require substantial sustenance to thrive. Thus, due to their size and food consumption rates, cattle grazing is often the most effective way for farmers and ranchers to maximize growth at the individual and herd levels (University of Minnesota Extension, 2023). One common and effective method of grazing is rotational grazing, the practice of moving cattle from one land plot (paddock) to another to allow the forage to rest and regrow during periods of inactivity (University of Minnesota Extension, 2023). Although rotational grazing is often seen as the most environmentally friendly option due to the regrowth of paddock forage, the dispersal of manure and nutrients, and reduced trampling and erosion in one area, it also has detrimental effects.

In 1991, the American Fisheries Society (AFS) reported that over 150 million acres of Bureau of Land Management (BLM) land and 138 million acres of Forest Service (FS) land allowed livestock grazing in 11 western states (Armour *et al*., 1991). According to the official AFS Position Statement, "52 million acres of big game habitat, 100 million acres of small game and nongame habitat, and 19,000 miles of sport fishing streams have declined in quality as a result of land management practices, including overgrazing" (Armour *et al*., 1991).

It has been well established that cattle grazing has substantial negative effects on native plants and animals, especially in riparian zones (Armour *et al*., 1991; Donovan & Monaghan, 2021; Environment Waikato Regional Council, 2004; Ohmart, 1996). Degradation through trampling of soils and increased erosion rates, defoliation and replacement of native species, and emission of large amounts of greenhouse gases are just a few of the common effects of cattle grazing (Kauffman *et al*., 2022a). Donovan and Monaghan (2021) found that across a grazing season (3-month period), soil erodibility in a paddock increased by 6% on average, and average soil loss increased by 87% when compared to non-grazed paddocks. Over an 18-month period, moderate grazing practices in a paddock resulted in a 3 cm streambank depression, with average spring foliage growth the following year being 20-43% lower than in non-grazed plots (Clary & Kinney, 2002). Over the same period of time, heavy grazing methods resulted in an 11.5 cm depression as well as a 51-87% decrease in foliage regrowth (Clary & Kinney, 2002).

A decrease in riparian foliage not only weakens bank stability and boosts erosion but also removes the natural filtration system provided by riparian vegetation for the stream. Riparian vegetation helps remove excess nutrients, pollutants, and other chemicals as they move downstream through various physical processes, including sedimentation, volatilization, and sorption (Armour *et al*., 1991; Peterjohn & Correll, 1984; Zaimes & Schultz, 2015). Biological processes include both assimilation by organisms and transformation by microbes (Peterjohn & Correll, 1984). Other impacts, such as changes in stream shape, increased sedimentation, and greater sediment transport, are commonly seen in cattle-grazed riparian and stream areas (American Fisheries Society, 2015; Goss & Roper, 2018; Taboada *et al*., 1999; Zaimes & Schultz, 2015). One study found that livestock disturbances, such as greater streambank alteration and lower vegetation stubble height, were associated with poorer salmonid stream

habitat across all tested scenarios (Goss & Roper, 2018). According to Goss & Roper (2018), salmonid densities are expected to increase as "undercut banks, bank stability, pool depth, percent pools, and wood frequency increase," and to decrease as "width-to-depth ratio, bank angle, and fine sediments in pool-tails increase"; all typical alterations made by livestock grazing in the riparian zone. Some of the most pristine riparian and aquatic habitats in the United States have been designated as Wildlife Refuges, with the mission of conserving fish and wildlife heritage, yet many allow livestock grazing within their borders despite calls for change (Miller, 2024; USFWS, 2011).

Red Rock Lakes National Wildlife Refuge (RRLNWR) is in southwestern Montana and hosts the largest wetland complex in the Greater Yellowstone Ecosystem (GYE) (USFWS, 2022) (Figures 1 and 2). Originally designated as a waterfowl-specific refuge in 1935 by President Franklin D. Roosevelt, RRLNWR has long served as an important breeding and resting area for migratory birds and mammals. These animals use the surrounding Centennial Valley as a corridor between Yellowstone National Park and the nearby lowlands (USFWS, 2022). Today, RRLNWR covers 53,418 acres, of which 32,350 acres are designated as wilderness under the Wilderness Act of 1964 (USFWS, 2022; Wilderness Act, 1964). Cattle grazing is currently allowed within certain wilderness areas, including those within RRLNWR, so long as wilderness character remains unchanged or possibly improved by the removal of excess thatch (USFWS, 2023). The population of the Arctic grayling (*Thymallus arcticus*) in the continental US has been declining for some time, with the GYE being no exception (Ratz, n.d.; USFWS, 2023). However, the Upper Red Rock Lake provides one of the last remaining strongholds for grayling, offering seasonal migration routes up tributaries like Red Rock Creek for spawning (USFWS, 2024). A letter from July 15, 1941, written by the USFWS states, "the streams on Red Rock Lakes Refuge

are some of the more important grayling streams in the United States, and it is the desire of the Division of Wildlife Refuges to preserve these streams for this purpose" (Guertin, 2009).

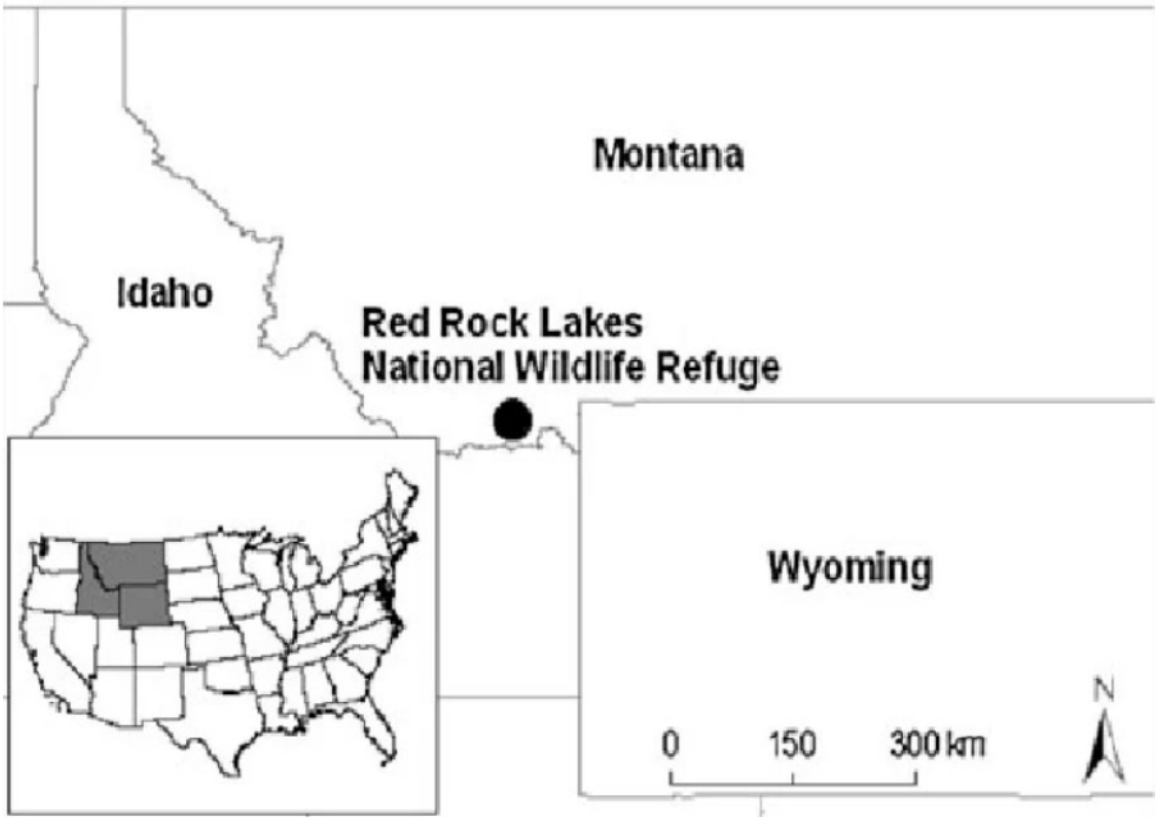


Figure 1. Map showing the location of Red Rock Lakes National Wildlife Refuge. (Warren & Cutting, 2010).

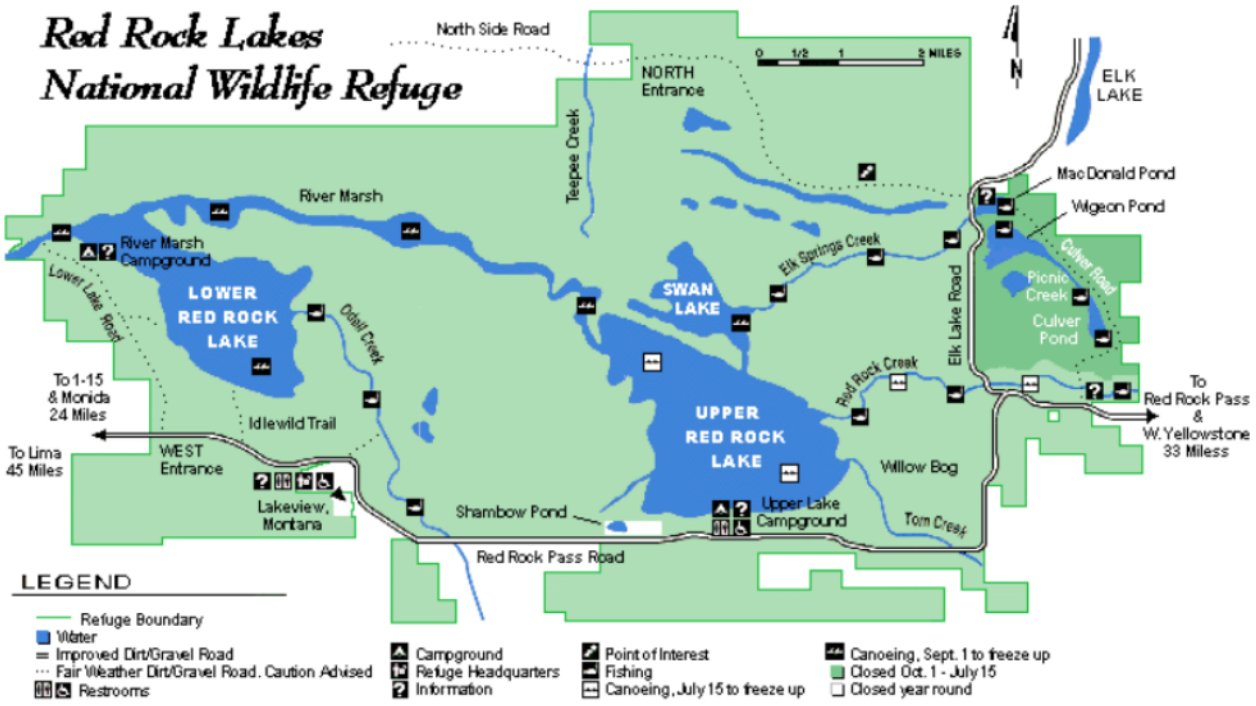


Figure 2. Recreational map of Red Rock Lakes National Wildlife Refuge. (Big Sky Fishing, n.d.).

Since its establishment, the lands within and around the refuge have been extensively used for cattle grazing, a practice that continues today despite opposition from environmental advocates (Miller, 2024). Twenty-six sub-units, covering about 52.5% of the refuge, are currently used for grazing, including 7,491 acres of wetlands (USFWS, 2023). Much of this grazed land includes streams, riparian zones, and wetlands, which are vital habitats for native species, including those of special concern, such as the Arctic grayling.

The continued presence of grazing livestock within these sensitive areas has clear detrimental effects on several aspects of the ecosystem. In their respective findings, Smith (1977) and Platts (1978) both concluded that livestock grazing is the single most important factor

limiting wildlife productivity in the modern American West. And in riparian ecosystems, especially on public land, overgrazing is the leading cause of deterioration (Carothers, 1977; Knoppf & Cannon, 1982). The plight of threatened aquatic species is further exacerbated by the well-documented tendency of livestock to congregate in riparian environments, owing to the biologically rich nature of these areas, especially in arid regions such as the American West (Fleischner, 1994). It is estimated that over 70% of wildlife species in the western United States require healthy riparian habitats for part or all of their life cycle (Kauffman *et al*., 2022b). This raises the question: why is livestock grazing a continuing practice when there is substantial evidence of its destruction of sensitive landscapes? The solution lies in evaluating current management policies and bringing allotment levels to an acceptable level for the intended primary beneficiaries of the public land and National Wildlife Refuge system. There have been many reviews of the historical and current livestock grazing practices used by public land managers and agencies in recent years, and the near-unanimous consensus is that these practices must be reevaluated and standardized to align with the goals of the National Wildlife Refuge system. Through public comment, providing valid evidence from peer-reviewed works, and applying consistent pressure to the management responsible for protecting our public lands, grazing may be reduced to acceptable levels for the refuge itself, recreational use, and the ranchers who use the land to their benefit.

Therefore, in this paper, I evaluate the acceptable level of grazing for RRLNWR by reviewing relevant information regarding the practice of livestock grazing within the refuge system and applying that to RRLNWR as a case study. Although all wildlife refuges are established to help conserve and restore some of our nation’s most pristine environments, the continued allowance of livestock grazing within their borders contradicts the refuges' purpose,

juxtaposing conservation and exploitation. My paper reviews the literature on grazing in protected wildlife areas and the reasons it is practiced, describes the effects of current grazing allotments, and offers improvements to counter the detrimental practice of allowing livestock in our treasured landscapes.

CHAPTER TWO

Methods and Findings

Methods

I used several notable peer-reviewed search engines to consolidate relevant material for review, including the Montana State University library, ScienceDirect, Springer Nature, JSTOR, Wiley Online Library, BioOne Digital Library, ESA Journals, Elsevier, and several state and federal databases. Applicable keywords such as "cattle grazing", "wildlife refuge", "salmonid spawning", "riparian", "Red Rock Lakes", and "cattle removal" were used to narrow the search results. Upon a quick review of the individual articles, I thoroughly read those that focused on the primary research target, adding notes and highlights to each. Upon further inspection, I also reviewed in a similar process references from the articles that contributed to the target research. I compiled citations and notes using a citation manager, ZoteroBib.

History of Livestock Grazing on Public Land

Livestock grazing has been the most common land use on federally managed public lands in the western United States since these lands were established as territories and later became states (Kauffman *et al*., 2022a). The Homestead Act of 1862, signed into law by President Abraham Lincoln, offered 160 acres of public land to any citizen who settled on it and farmed it for at least five years (National Archives, 2021). While this Act successfully encouraged thousands of settlers to move west, it also "set the stage for widespread land degradation" (Western Watersheds Project, n.d.-b). During the homesteading period, rangelands were often overgrazed due to lax regulations intended to motivate ranchers to expand and settle westward, as well as due to a misunderstanding of how to manage the land properly (BLM, n.d.). Many of

these settlers naturally claimed the land that included the most valuable resource for both livestock and themselves - water (Western Watersheds Project, n.d.-a).

After decades of harm to public lands, the Taylor Grazing Act of 1934 was enacted to prevent overgrazing and soil degradation and to provide oversight of grazing on public lands (BLM, n.d.; Western Watersheds Project, n.d.-b). The Division of Grazing, later renamed the Bureau of Land Management, was established to administer this initiative (Western Watersheds Project, n.d.-b). The Act required ranchers to purchase specific use permits for the land they intended to graze, and the funds collected by the BLM were designated for rangeland improvements and other management activities (BLM, n.d.; Western Watersheds Project, n.d.-a). Although the Act was enacted with good intentions, it led to little improvement in preventing rangeland degradation. Consequently, the law became nearly obsolete with the passage of several more comprehensive public land management laws in the 1960s and 1970s, including the National Environmental Policy Act of 1969, the Endangered Species Act of 1973, and the Federal Land Policy and Management Act of 1976 (BLM, n.d.). The role of the BLM also evolved with these new laws, shifting its focus toward managing and improving specific resources such as riparian areas, threatened or endangered native species, and cultural and historical sites (BLM, n.d.). Alongside this more proactive role, the BLM also amended existing grazing permit and lease terms or created entirely new ones (BLM, n.d.).

Contemporary Grazing Practices on Public Land

Today, the BLM manages approximately 18,000 special-use permits and leases for ranchers grazing livestock across more than 21,000 land allotments (BLM, n.d.). These permits and leases typically last for 10 years with the possibility of renewal if both parties meet the permit terms and conditions (BLM, n.d.). In 11 western states, including Montana, Wyoming,

Colorado, New Mexico, and those farther west, approximately 70% of the total land area is grazed by livestock (Fleischner, 1994). Over 165 million acres of BLM land (94%) and 103 million acres of Forest Service land are currently grazed in the western states, with the vast majority grazed by a total of 7 million head of cattle (Fleischner, 1994). Some of these millions of acres fall within the boundaries of National Wildlife Refuges (NWR), a practice known as "cooperative agriculture" (USFWS, 2008) (Figure 3). According to the USFWS, these cooperative agricultural activities must provide "aid or benefit to the wildlife management of the area" and may be authorized only on refuges where the FWS cannot meet management standards (USFWS, 2008). Many ranchers in the western states rely on BLM or Forest Service lands for their rich nutritional value, as well as the opportunity to grow hay on private lands to either supplement feed stores during the winter months or generate operational income (Charnley *et al*., 2018). Despite being advantageous for ranchers, the act of grazing within National Wildlife Refuges and other public lands has led to many detrimental effects on both plant and animal communities in the west (Tables 1 and 2) (Fleischner, 1994). In a nationwide 1989 survey, approximately 35% of federal Wilderness areas were actively used for livestock grazing, a percentage likely higher in western states (Fleischner, 1994).

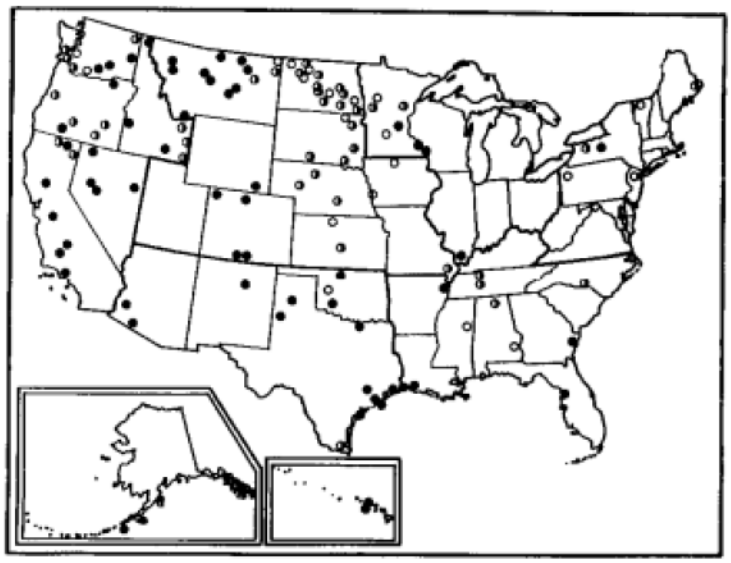


Figure 3. A map of the United States showing the locations of all National Wildlife Refuges which permit either cattle grazing (black circle), haying (white circle), or both (split circle) (n = 123). (Strassman, 1983).

Table 1. Detrimental effects of livestock grazing on plant communities in the western United States. (Fleischner, 1994).

Habitat	*Location*	*Effect*	*Authority*
Sonoran Desertscrub	Arizona	Perennial grasses and *Krameria* (palatable shrub) showed dramatic density decreases with grazing	Blydenstein et al. (1957)
Mojave Desertscrub	California	60% reduction in above-ground biomass of annuals, 16–29% decrease in cover of perennial shrubs with grazing	Webb & Stielstra (1979)
Sagebrush Desert	Idaho	Grazed site had ⅓ species richness of ungrazed site	Reynolds & Trost (1980)
Desert Grassland	New Mexico	Grass density increased by 110% after 30 years of protection from grazing	Gardner (1950)
Semidesert Grassland	Arizona	Species richness increased, as did canopy cover for midgrass, shortgrass, shrub, and forb groups, after removal of livestock	Brady et al. (1989)
Semidesert Grassland	Arizona	Woody plants significantly more abundant after removal of livestock	Bock et al. (1984)
Ponderosa Pine Forest	Washington	Decreased species richness on grazed sites	Rummell (1951)
Mountain Canyon	Utah	Absence or near absence of 10 grass species on grazed sites	Cottam & Evans (1945)
Riparian	Oregon	Species richness increased from 17 to 45 species nine years after removal of livestock	Winegar (1977)
Riparian	Arizona	Herbaceous cover of grazed plot less than half that of ungrazed plot	Szaro & Pase (1983)
Riparian	Colorado	Shrub canopy coverage increased 5.5 times, willow canopy coverage 8 times after removal of livestock	Schulz & Leininger (1990)

Table 2. Detrimental effects of livestock grazing on vertebrate communities in the western United States. (Fleischner, 1994).

Organism(s)	*Location*	*Effect*	*Authority*
Small Mammals	Idaho	Density and diversity reduced on grazed sites	Reynolds & Trost (1980)
Small Mammals	Nevada	Density over one-third lower, diversity almost half on grazed sites	Medin & Clary (1989)
Songbirds, Raptors, and Small Mammals	Utah	350% increase in use and diversity after 8 years rest from grazing	Duff (1979)
Ducks and all Terrestrial Nongame Birds	Colorado	All more abundant in ungrazed habitat	Crouch (1982)
Upland Sandpiper (*Bartramia longicauda*)	North Dakota	Nest density reduced on grazed sites	Bowen & Kruse (1993)
Riparian Birds	Montana	Species composition altered by grazing; densities of ⅓ of species differed significantly between heavily and lightly grazed sites—⅔ of these were higher on lightly grazed sites	Mosconi & Hutto (1982)
Riparian Passerines	Southeastern Oregon	Species richness decreased on grazed sites	Taylor (1986)
Willow Flycatcher (*Empidonax traillii*)	Southeastern Oregon	Abundance increased from 0 to 30 when grazing intensity reduced by 4 times	Taylor & Littlefield (1986)
Yellow Warbler (*Dendroica petechia*)	Southeastern Oregon	Abundance increased by 8 times when grazing intensity reduced by 4 times	Taylor & Littlefield (1986)
Dickcissel (*Spiza americana*) and Bell's Vireo (*Vireo bellii*)	Oklahoma	Populations 50% lower on grazed sites	Overmire (1963)
Lizards	California	Abundance 2 times and biomass 3.7 times higher on ungrazed site	Busack & Bury (1974)
Lizards	Arizona	Abundance and diversity higher on ungrazed site in 4 of 5 vegetation types	Jones (1981, 1988)
Wandering Garter Snake (*Thamnophis elegans vagrans*)	New Mexico	5 times more abundant in ungrazed sites	Szaro et al. (1985)
Desert Tortoise (*Gopherus agassizi*)	Western U.S.A.	Livestock trample young tortoises, damage burrows and shrubs used for shelter, and remove critical forage	Berry (1978); Campbell (1988)
Trout (Salmonidae)	Great Basin	Average increase in production of 184% when grazing reduced or eliminated	Bowers et al. (1979)
Trout (Salmonidae)	Idaho	More abundant, larger fish after removal of livestock	Keller & Burnham (1982)
Trout (Salmonidae)	Colorado	Standing crop doubled after removal of livestock	Stuber (1985)

Benefits of a Healthy Riparian Habitat

Salmonids require not only cold, clean water with an adequate gravel substrate for spawning and rearing juvenile fish, but also a complex habitat comprising pools, riffles, and structures such as woody debris, undercut banks, and coarse sediments (Bisson *et al.*, 2009; Charnley et al., 2018; Torgersen *et al.*, 1999). Healthy riparian habitats provide a multitude of services to an aquatic system, including an abundance of food for salmonids, valuable nutrients

otherwise unavailable, streambank stabilization, preventing erosion and sedimentation, as well as shade, which acts as a thermal regulator (Beschta, 1997; Charnley *et al*., 2018; Kauffman *et al.,* 2004; Roni *et al.*, 2002). In addition to supporting healthy salmonid habitats, riparian zones also provide refuge for a multitude of other species, especially in the semi-arid American West (Earnst *et al*., 2005). Despite making up only 1% of the landscape, western riparian habitats support a higher density of breeding songbirds than any other habitat type (Earnst *et al*., 2005; Knopf *et al.*, 1988). Higher riparian vegetation density also benefits small mammalian populations by providing greater protection from predators, reducing territorial conflicts, and increasing food availability (Whelham *et al*., 2013).

Grazing on the Red Rock Lakes National Wildlife Refuge

One of the many refuges that allow livestock grazing within its borders today is RRLNWR. Situated approximately 25 miles from West Yellowstone and the West Entrance to Yellowstone National Park, the Refuge encompasses a vast 18,210 hectares of the Centennial Valley, with elevations ranging from 6,670 to 9,400 feet above sea level, and including both designated wilderness and non-wilderness areas (Figure 4) (Davis & Cutting, 2014; Whelham *et al.*, 2013). With annual precipitation of 19.5 inches and an average temperature of 35° F, the semi-arid landscape supports many distinct ecotypes (Whelham *et al.*, 2013).

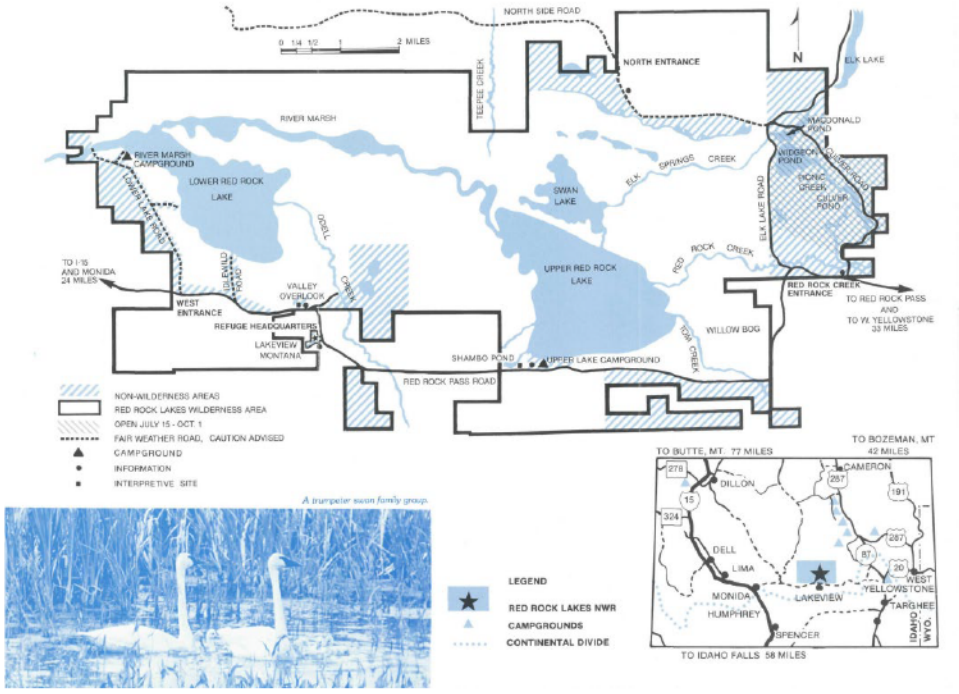


Figure 4. Map of Red Rock Lakes National Wildlife Refuge wilderness and non-wilderness areas. (USFWS, 1986).

Over half (52.5%) of RRLNWR is used annually for rotational grazing, which is labeled as "habitat management" (USFWS, 2023). Grazing occurs on 26 parcels within the Refuge itself, with an additional seven parcels currently leased by the Refuge from the state of Montana (Figure 5) (USFWS, 2023). Grazing unit sizes range from 25 to 2,789 acres, and are divided into three habitat types, totaling approximately 7,681 acres (21%) of wet meadow, 17,145 acres (47%) of grassland, and 11,479 acres (32%) of sagebrush-steppe (Davis & Cutting, 2014; USFWS, 2023). Grazing generally begins in early or mid-summer, although the Refuge staff sets the specific dates in line with the Refuge Comprehensive Conservation Plan (CCP), which may be updated; grazing ends no later than October 1st each year (USFWS, 2023). The units are managed with various grazing patterns, including high-intensity, short-duration; low-intensity, long-duration; rotational grazing; or rest periods, according to the desired goals in the CCP

(USFWS, 2023). The total grazing period typically lasts 90-110 days during the peak growing season (USFWS, 2023).

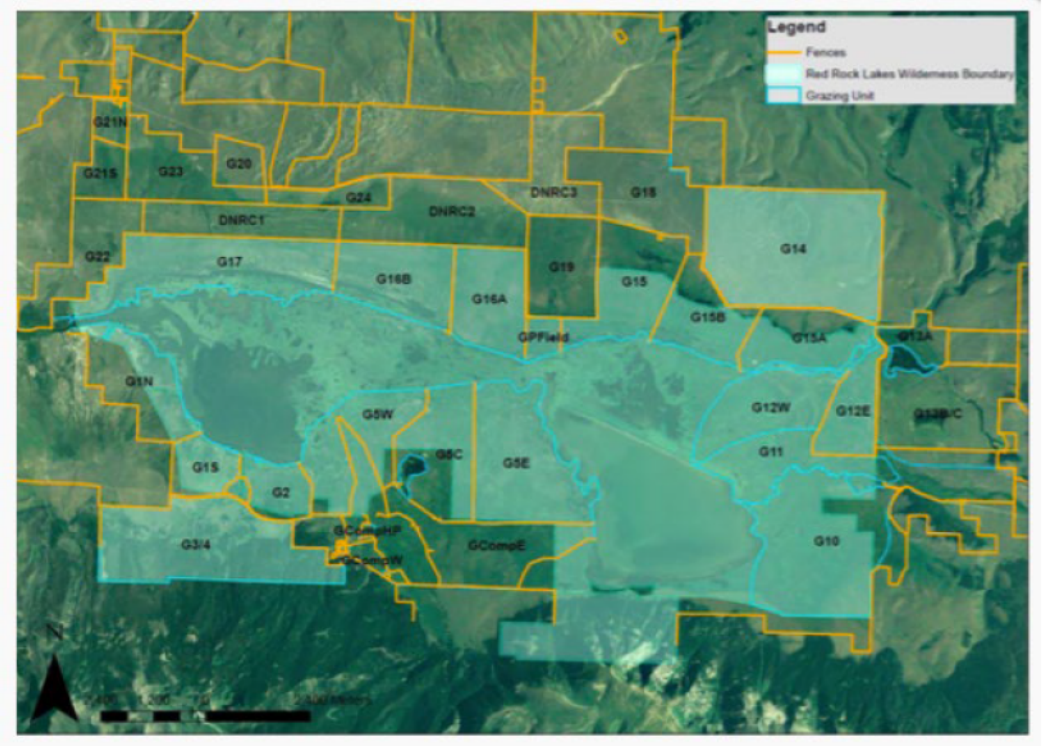


Figure 5. Grazing plots and fence map in and around Red Rock Lakes National Wildlife Refuge. (Miller, 2024).

The CCP details several focus plans, including improved management of wetland and riparian habitats within RRLNWR to achieve restoration and conservation objectives (Guertin, 2009). These objectives, regarding Arctic grayling, are to ensure that at least three refuge streams contain an adfluvial spawning grayling population, and to provide relatively shallow (<16 inches) gravel and pebble (0.1-2.4 inches) dominated spawning habitat (Guertin, 2009). One of the primary stipulations of both objectives is to work with adjacent landowners and grazing

permit holders to reduce the effects of cattle grazing on the designated streams (Guertin, 2009). As one of the last adfluvial populations of Arctic grayling remaining in the contiguous United States, these fish depend on the ability to spawn in tributaries with high-quality water and adequate gravel substrate to lay their eggs (Ratz, n.d.). The degradation of spawning tributaries over the past several decades has resulted in a lack of suitable spawning grounds, leading to a decline in the Arctic grayling population in RRLNWR from several thousand to just 73 recorded individuals in 2022 (Western Watersheds Project, 2025).

Today, RRLNWR stands as a stark reminder of the detrimental effects of livestock grazing on a pristine environment, as it once was. Several stretches of tributary streams are now impaired due to bank erosion, removal of riparian habitat, and excess nutrient input (*Wildearth Guardians and Western Watersheds Project v. USFWS*, 2024) (Figure 6). One of these severely impaired tributaries is Humphrey Creek, with much of the stream and grazed areas located within the designated Wilderness area (Figure 7). These effects of livestock grazing not only immediately alter the structure of the ecosystem but also all its inhabitants.



Figure 6. Image of Humphrey Creek, located within Red Rock Lakes National Wildlife Refuge, comparing stretches of the stream with and without cattle grazing. (Western Watersheds Project Instagram page, @westernwatersheds).

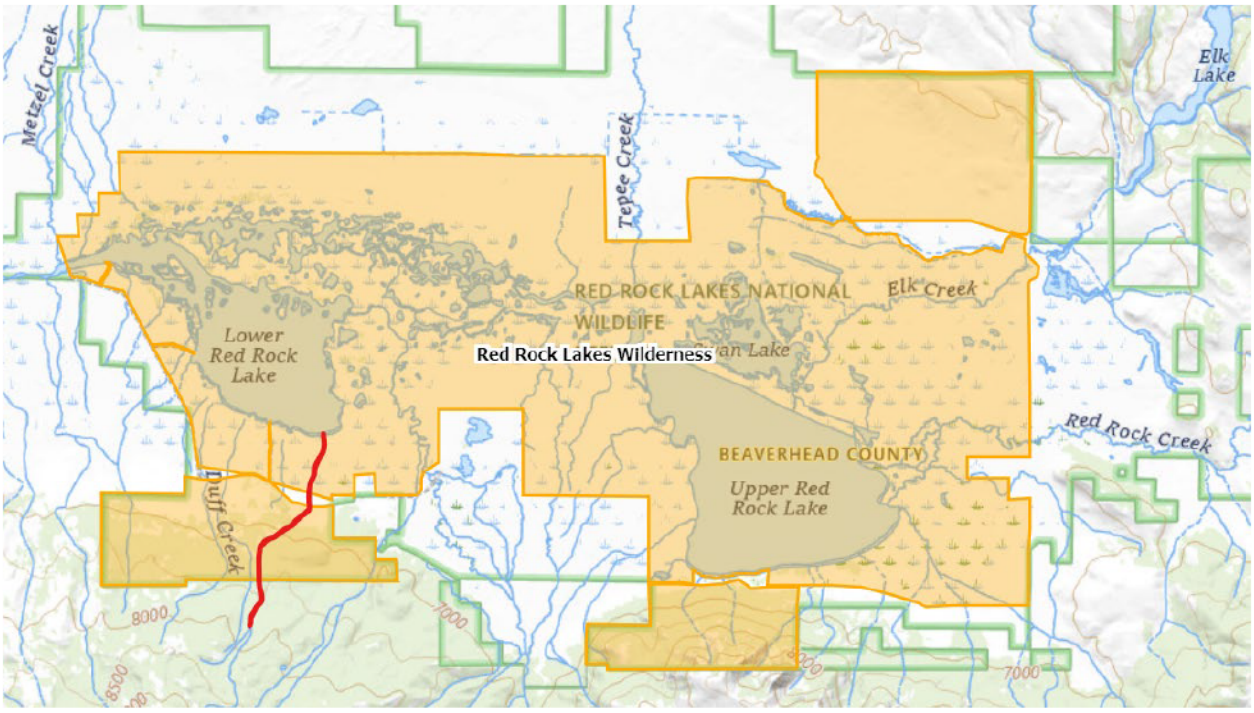


Figure 7. Map of Red Rock Lakes Wilderness area (yellow highlighted area), with Humphrey Creek shown in red. (Wilderness Connect, n.d.).

The decimation of the Arctic grayling population in RRLNWR is merely one example of the loss of the species' historical and native ranges, which once spanned much of the northern Rocky Mountains and Michigan (Figure 8) (Ratz, n.d.). Today, only a single native population strain exists in western Montana, located within the upper Big Hole River drainage (Ratz, n.d.). The loss of much of the native populations is attributed to many reasons, including “habitat fragmentation, dewatering, thermal stress, entrainment, riparian habitat loss, and effects from climate change” (Ratz, n.d.).

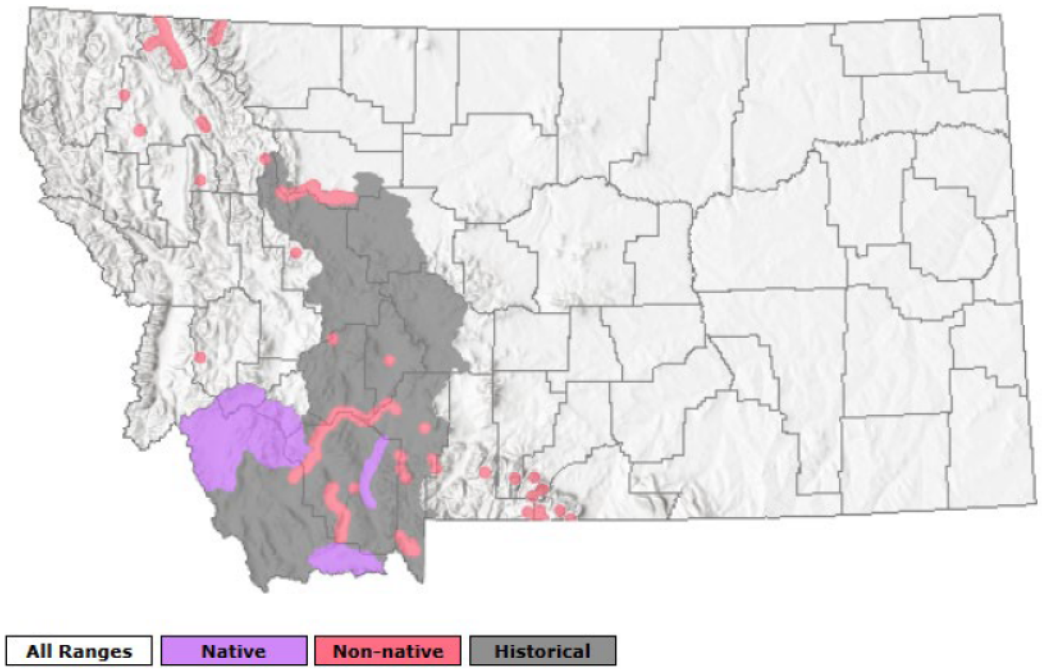


Figure 8. Historical and contemporary ranges of both native and non-native populations of Arctic grayling in the state of Montana. (Ratz, n.d.).

Alternative Grazing Management Strategies

Several strategies could be implemented in RRLNWR to more effectively achieve the desired habitat objectives. The first and perhaps most obvious solution is to adopt a strict no-grazing policy within the Refuge. This method has been shown not only to lead to rapid recovery of riparian and overall stream quality, but also to influence the rehabilitation of previously depleted natural resources and the abundance of wildlife (Earnst *et al*., 2005). The recovery of riparian habitat may also be accompanied by the reemergence of species that were displaced from the ecosystem during periods of annual grazing (Earnst *et al*., 2005). Several studies have found that the complete cessation of livestock grazing is the single most effective way to restore riparian and aquatic salmonid habitats, both ecologically and economically (Beschta *et al*., 1991;

Kauffman *et al.*, 2022b). This approach, although likely the most effective, is unlikely given the long-standing grazing program woven into the Refuge's history and current operations.

Removing cattle, either by fencing or complete exclusion, benefits both riparian vegetation growth and aquatic structure, with effects evident within just 2 years post-removal (Nusslé *et al*., 2017). Although recovery of vegetation growth rates is evident within just a few years, some aspects, such as the maximum height and density reached by recovering willows, remain stunted after 25 years (Nusslé *et al*., 2017). Moreover, for some highly impaired stretches of stream, total recovery of riparian habitat may take more than 65 years (Nusslé *et al*., 2017). Montane meadow habitats, such as those in RRLNWR, are also more likely to be degraded from increased erosion and xerification, which may result in longer recovery periods from the effects of cattle grazing (Nusslé *et al*., 2017).

Other strategies seek to mitigate the damage grazing causes while still allowing limited access and allotment periods during the grazing season. These recommendations are based upon relevant literature, local studies and expertise, as well as previous grazing practices and management constraints (Figure 9) (Davis & Cutting, 2014). Stocking rates, or the number of individual livestock heads grazed per unit, must be reduced based on a variety of factors. These factors include unit size, dominant vegetation type within the unit, and specific target species that utilize the unit (Davis & Cutting, 2014). Rest periods of each unit must follow a rigorous schedule, with a standard amount of time being allotted between grazing periods (Davis & Cutting, 2014). Special recovery timeframes must also be allocated for units with especially sensitive habitats, such as riparian and aquatic accesses (Davis & Cutting, 2014). The timing of the grazing periods must also be case-sensitive with regard to species that may be particularly

vulnerable to disturbance, such as spawning Arctic grayling or nesting birds (Davis & Cutting, 2014).

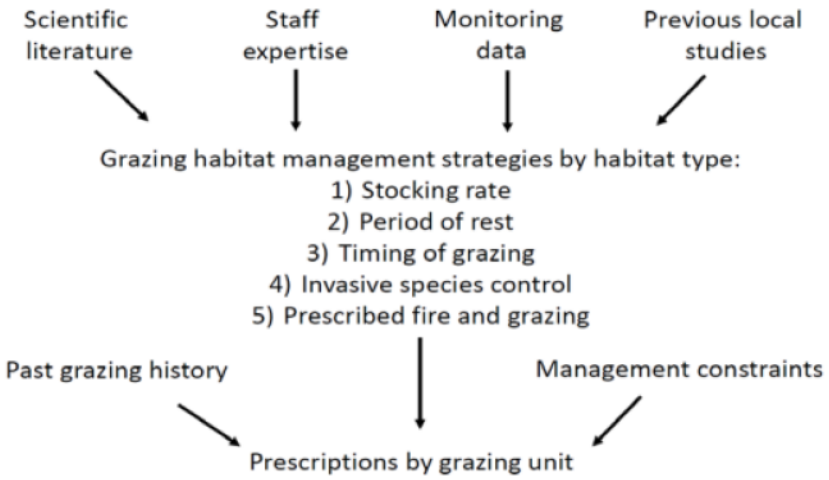


Figure 9. Conceptual diagram of the process of developing grazing habitat management strategies and prescriptions. (Davis & Cutting, 2014).

Grazing intensity is one of the most influential factors in management strategies because it determines the amount of forage consumed within an allotment (Holecheck & Galt, 2000). Intensity may be measured by stubble height or the use of forage by weight, both of which indicate an approximate amount of vegetation grazed by the livestock present (Holecheck & Galt, 2000). These measurements are particularly important with respect to distance from a water source or a riparian environment. Holecheck and Galt (2000) provide relevant qualitative characteristics for gauging grazing intensity, as well as a corresponding stubble height gauge specific to mountain grassland rangeland (Tables 3 and 4).

Table 3. Qualitative characteristics of grazing intensity categories used to characterize rangelands. (Holecheck & Galt, 2000).

Qualitative Grazing Intensity Category	Use of Forage by Weight	Qualitative Indicators of Grazing Intensity
	--- (%) ---	
Light to non-use	0–30	Only choice plants and areas show use; There is no use of poor forage plants.
Conservative	31–40	Choice forage plants have abundant seed stalks; Areas more than a mile from water show little use; About one third to one half primary forage plants show grazing on key areas.
Moderate	41–50	Most of accessible range shows use; Key areas show patchy appearance with one half to two thirds of primary forage plants showing use; Grazing is noticeable in zone 1–1.5 miles from water.
Heavy	51–60	Nearly all primary forage plants show grazing on key areas; Palatable shrubs show hedging; Key areas show a lack of seed stalks; Grazing is noticeable in areas over 1.5 miles from water.
Severe	61 +	Key areas show a clipped or mowed appearance (no stubble height); Shrubs are severely hedged; There is evidence of livestock trailing to forage; Areas over 1.5 miles from water lack stubble height.

Table 4. Grazing-intensity stubble-height guide for mountain grassland rangeland. (Holecheck & Galt, 2000).

Qualitative Grazing Intensity Category	Use of Forage by Weight	Stubble Height Guide				
		Arizona Fescue	Western Wheatgrass	Intermediate Wheatgrass	Mutton grass & Kentucky Bluegrass	Mountain Muhly
	--- (%) ---	(inches)				
Light to non-use	0–30	8+	7+	10+	5+	5+
Conservative	31–40	6–7	4–5	8–10	4–5	4–5
Moderate	41–50	5–6	3–4	6–8	3–4	3–4
Heavy	51–60	4–5	2–3	4–6	2–3	2–3
Severe	> 60	< 4	< 2	< 4	< 2	< 2

CHAPTER THREE

Discussion

Based on my review of existing literature regarding cattle grazing intensity, acceptable levels within National Wildlife Refuges should not exceed conservative (31 to 40%) use of forage by weight. This categorization is derived from grazing indicators such as an abundance of seed stalks in choice forage plants, areas more than one mile from a water source exhibit little to no use by grazers, and no more than one-third of primary forage plants exhibit signs of grazing in sensitive areas such as riparian zones (Holecheck & Galt, 2000). Primary forage plants in southwestern Montana consist largely of native sagebrush-steppe grassland species, including bluebunch wheatgrass (*Pseudoroegneria spicata*), Idaho fescue (*Festuca idahoensis*), and rough fescue (*Festuca altaica*) (The Nature Conservancy, n.d.). The stubble height of these primary forage plants should be reduced to no shorter than eight inches (Holecheck & Galt, 2000).

Although there have been many calls to eliminate grazing entirely within RRLNWR, there is little evidence that this is inevitable (Miller, 2024; Shoemaker, 2024; Western Watersheds Project, 2025). While most conservation groups argue that the presence of cattle within the refuge is unnatural, the USFWS assumes that their grazing maintenance closely mimics that of historical bison (*Bison bison*) grazing and movement patterns throughout the Centennial Valley prior to near-eradication in the 1800's through hunting and westward expansion (USFWS, 2023). Historically, bison were the primary grazers in the Great Plains region and the western United States (Kohl *et al*., 2013). While historical bison grazing and habits are often compared to those of contemporary cattle, the two species differ in all behaviors, including grazing, bedding, and movement/migration (Kohl *et al*., 2013). Unlike bison, cattle tend to remain close to water sources, posing unique challenges when attempting to exclude them from riparian zones (Helzer,

2014). Kohl *et al*. (2013) found that cattle spent a higher proportion of time grazing (45-49%) than bison (26-28%) and spent longer periods in the immediate vicinity of a water source. Bison also traversed the landscape at 50-99% higher rates than cattle, covering much larger forage patches (11,690 hectares) than their distant cattle relatives (615 hectares) (Kohl *et al*., 2013).

Given the fact that bison and cattle are not ecologically equivalent grazers, and that cattle are more likely to graze and remain near water sources, the question must be asked: How do land managers and agencies keep cattle from degrading riparian and aquatic habitats within our public lands? One obvious choice is to fence certain areas so that cattle cannot trample or erode them. Fencing can be an effective alternative, yet it may adversely fragment an ecosystem, especially when barbed wire is used (Nusslé *et al*., 2017). This also becomes nebulous when dealing with wildlife refuges, especially those that fall within Wilderness boundaries, where human alteration is strictly discouraged (Wilderness Act, 1964). Grazing, or any alteration of Wilderness areas by human processes, should be strictly forbidden, in accordance with the original document passed into law. Wilderness areas are among the nation's most pristine ecosystems, and the disruption of natural processes affects not only the immediate area but also the entire ecosystem. The cessation of livestock grazing in Wilderness areas is of utmost importance for the conservation and preservation of these fragile habitats.

Stocking rates into grazing units must be based on animal unit months (AUMs), or the amount of forage a mature cow and calf consume in a 30-day period (approximately 354 kg dry weight) (Charnley *et al*., 2018; USFS, 2014). In RRLNWR, grazing rates have historically ranged from 0.31 to 0.85 AUMs per acre, with an annual mean of 4,165 AUMs (USFWS, 2023). Actual rates vary by site, season, and weather conditions, with some rates as low as 0.02 AUMs per acre and others as high as 2.17 AUMs per acre (USFWS, 2023). With active and vigilant

monitoring, set standards of a reasonable 0.5 AUMs may be achieved, and once that allotment is reached in the season, the head of cattle must be returned to the rancher's own private property.

Another option is to allow longer periods between grazing activities, or perhaps less-intensive grazing, both of which may be addressed in lease agreements that dictate how many head, how long they are allowed to graze, and exactly where grazing takes place (Helzer, 2014). Periods of rest between grazing allotments must also be standardized, with additional safeguards for particularly sensitive areas, such as riparian zones. Currently, rest periods of two to three years are granted to severely grazed units within RRLNWR (USFWS, 2023). This is arbitrary, however, and is determined by both the Refuge staff and management officials. To promote vegetation growth and minimize disturbance, a minimum of three years should be allowed for each unit to recover adequately (Davis & Cutting, 2014; Nusslé *et al*., 2017). Added safeguards, such as a minimum of five years rest in units with less than 5% invasive graminoid cover, to help prevent the spread of non-natives into otherwise pristine areas (Davis & Cutting, 2014). For units with riparian zones, a minimum of five years rest should also be enforced to promote adequate recovery and to protect streambank integrity (Davis & Cutting, 2014).

In addition to these recommendations, early growing-season grazing should be limited to units that do not include immediate riparian and other ecologically valuable zones used for spawning, nesting, and brood-rearing in the spring and early summer (Davis & Cutting, 2014; Whelham *et al*., 2013). In addition to mimicking bison activity, some advocates argue that cattle grazing also reduces wildfire intensity by minimizing the amount of light fuels that can allow a fire to spread (USFWS, 2023). This action, called targeted grazing, utilizes cattle grazing to reduce vegetation to a predetermined stubble height, creating fuel breaks (USDA, n.d.). There are, however, severe and opposing downsides to using cattle as wildfire deterrents. In addition to

increased trampling and decreased soil porosity, cattle grazing may exacerbate the spread of invasive grasses and weeds within an ecosystem (Molvar *et al*., 2024). Invasive grasses and weeds require a disturbance event to gain a foothold, and the reduction of native vegetation to stubble offers a window to invasion (Molvar *et al*., 2024). Species such as cheatgrass (*Bromus tectorum*) die in the early summer months, creating vast amounts of wildfire fuel compared with more fire-resistant native species such as bunchgrasses (Molvar *et al*., 2024). Intense wildfires have been found to negatively affect existing salmonid numbers post-burn, with some cases so severe as to completely eradicate the juvenile and resident adult populations (Rieman *et al*., 1997). Although wildfires are a natural part of the disturbance regime, they influence aquatic ecosystems in a wide variety of ways, including heating, abrupt changes in water chemistry, erosion, and debris loading (Rieman *et al*., 1997). Sudden changes in a salmonid-supporting stream likely exacerbate conditions for already fragile populations. As a natural phenomenon, wildfires cannot be completely eradicated, therefore the mitigation of high-intensity wildfires by the removal of cattle grazing, and thus their effects, is the next best alternative. Natural, low-intensity wildfires provide overall protection against potentially extreme, destructive high-intensity fires while also having minimal detrimental effects on salmonids within the watershed (Wu *et al*., 2023).

CHAPTER FOUR

Conclusion

In my review of contemporary livestock grazing practices across western public lands, and based on the findings of many others, I strongly reaffirm that stricter regulations are necessary to preserve our shared landscapes and wildlife. Through degradations such as riparian removal, excess nutrient inputs, increased erosion and sedimentation, and the displacement of native species, among others, the negative effects of cattle grazing far outweigh the positive economic impacts for the few who are privileged enough to benefit. Excluding riparian zones, decreasing stocking rates and intensities, and increasing resting periods between grazing are all applicable strategies to reduce detrimental impacts on public lands. It is my opinion that all cattle grazing within particularly sensitive and resource-rich areas, such as designated Wilderness and National Wildlife Refuges, should be abolished.

America's many wildlife refuges are a pillar of public land success, preserving valued ecosystems and the species which call them home. Today, more than 850 million acres of both land and marine environments are protected within the refuge system, providing habitat for more than 220 species of mammals, 700 species of birds, and 1,250 species of fish, reptiles, and amphibians (O'Mara, 2025). Welcoming more than 67 million visitors annually, these refuges provide immeasurable opportunities for both humans and wildlife to thrive (O'Mara, 2025). Despite the successes of the National Wildlife Refuge system, our public lands remain in peril of exploitation for commercial gain by the very agencies sworn to protect them. Actions such as cattle grazing within refuges across the nation not only subvert the values on which they were founded but also offer precedents for further degradation and fragmentation of some of the last remaining natural strongholds. It is up to the public to act and voice their opinions to sway our

elected officials and those who manage these areas, so they can continue the mission of preservation and conservation in our most treasured landscapes. The offices of the United States Fish and Wildlife Service, Bureau of Land Management, and Forest Service must always accept criticism and comments from their constituents to remain relevant in their management practices and uphold the desires of those who entrust them to protect our natural resources. Using the information provided in this paper, it is my hope that the public, including those who recreate in and enjoy public lands (and even those who do not), will recognize the detrimental effects of continued grazing practices and express their concerns vehemently.

REFERENCES CITED

American Fisheries Society. (2015). *The Effects of Livestock Grazing on Riparian and Stream Ecosystems* (AFS Policy Statement No. #23). https://fisheries.org/wp-content/uploads/2015/05/policy_23f.pdf

Armour, C. L., Duff, D. A., & Elmore, W. (1991). The effects of livestock grazing on riparian and stream ecosystems. *Fisheries*, *16*, 7–11.

Beschta RL, Platts WS, Kauffman JB. (1991). Field review of fish habitat improvement projects in the Grande Ronde and John Day River Basins of eastern Oregon. BPA, Division of Fish and Wildlife, Portland, OR. 1991;DOE/BP-21493-1. 53 pp.

Beschta RL. (1997). Riparian shade and stream temperature: an alternative perspective. Rangelands 19: 25–28.

Big Sky Fishing. (n.d.). *Map of Red Rock Lake National Wildlife Refuge in Montana*. Retrieved April 28, 2026, from https://www.bigskyfishing.com/scenic-drives/map-red-rock-lake.php

Bisson PA, Dunham JB, and Reeves GH. (2009). Freshwater ecosystems and resilience of Pacific salmon: habitat management based on natural variability. Ecol Soc 14: 45.

BLM. (n.d.). *Rangelands and grazing: livestock grazing.* Retrieved March 10, 2026, from https://www.blm.gov/programs/natural-resources/rangelands-and-grazing/livestock-grazing/about

Carothers, S.W. (1977). Importance, preservation, and management of riparian habitats: an overview. In R.R. Johnson and D. A. Jones (eds.), Importance, preservation, and management of riparian habitat: a symposium. USDA Forest Service General Technical Report RM-43.

Charnley, S., Gosnell, H., Wendel, K. L., Rowland, M. M., & Wisdom, M. J. (2018). Cattle grazing and fish recovery on US federal lands: Can social–ecological systems science help? *Frontiers in Ecology and the Environment*, *16*(S1). https://doi.org/10.1002/fee.1751

Clary, W.P., Kinney, J.W. (2002). Streambank and vegetation response to simulated cattle grazing. *Wetlands* **22**, 139–148. https://doi.org/10.1672/0277-5212(2002)022[0139:SAVRTS]2.0.CO;2

Davis, S. C., & Cutting, K. A. (2014). *Creating Grazing Habitat Management Strategies for a National Wildlife Refuge*. Montana State University. https://www.montana.edu/extension/coa/2015reports/DavisReport.pdf

Donovan, M., & Monaghan, R. (2021). Impacts of grazing on ground cover, soil physical properties, and soil loss via surface erosion: A novel geospatial modelling approach. *Journal of Environmental Management*, *287*, 112206. https://doi.org/10.1016/j.jenvman.2021.112206

Earnst, S. L., Ballard, J. A., & Dobkin, D. S. (2005). Riparian songbird abundance a decade after cattle removal on Hart Mountain and Sheldon National Wildlife Refuges. *In: Ralph, C. John; Rich,*

Environment Waikato Regional Council. (2004, May). *Effects of livestock grazing on wetlands: Literature review*. https://www.waikatoregion.govt.nz/assets/WRC/WRC-2019/TR04-16.pdf

Fleischner, T.L. (1994). Ecological Costs of Livestock Grazing in Western North America. Conservation Biology, 8: 629–644. https://doi.org/10.1046/j.1523-1739.1994.08030629.x

Goss, L. M., & Roper, B. B. (2018). The relationship between measures of annual livestock disturbance in western riparian areas and stream conditions important to trout, salmon, and char. *Western North American Naturalist*, *78*(1), 76–91. https://www.jstor.org/stable/26779968

Guertin, S. (2009). *Comprehensive Conservation Plan Red Rock Lakes National Wildlife Refuge*. U.S. Fish and Wildlife Service. https://www.govinfo.gov/content/pkg/GOVPUB-I49-PURL-gpo15385/pdf/GOVPUB-I49-PURL-gpo15385.pdf

Helzer, C. (2014, January 21). Bison good, cattle bad? *The Prairie Ecologist*. Retrieved on March 25, 2026, from https://prairieecologist.com/2014/01/21/bison-good-cattle-bad/

Holecheck, J. L., & Galt, D. (2000). Grazing intensity guidelines. Rangelands, 22(3), 11-14. 10.2458/azu_rangelands_v22i3_holecheck

Kauffman J. B., Thorpe A. S., & Brookshire E. N. J. (2004). Livestock exclusion and belowground ecosystem responses in riparian meadows of eastern Oregon. Ecol Appl 14: 1671–79

Kauffman, J. B., Beschta, R. L., Lacy, P. M., & Liverman, M. (2022a). Livestock use on public lands in the western USA exacerbates climate change: Implications for climate change mitigation and adaptation. *Environmental Management*, *69*(6), 1137–1152. https://doi.org/10.1007/s00267-022-01633-8

Kauffman, J. B., Coleman, G., Otting, N., Lytjen, D., Nagy, D., & Beschta, R. L. (2022b). Riparian vegetation composition and diversity shows resilience following cessation of livestock grazing in northeastern Oregon, USA. *PLOS ONE*, *17*(1), e0250136. https://doi.org/10.1371/journal.pone.0250136

Knopf, F. L., R. R. Johnson, R. Rich, F. B. Samson, & R. C. Szaro. (1988). Conservation of riparian ecosystems in the United States. Wilson Bulletin 100: 272–284.

Knoppf, F. L., & R. W. Cannon. (1982). Structural resilience of a willow riparian community to changes in grazing practices. Pages 198–207 in J. M. Peak and P. D. Dalke (eds.), Wildlife-livestock relationships symposium: proceedings 10. University of Idaho Forest, Wildlife and Range Experiment Station, Moscow, Idaho.

Kohl, M. T., Krausman, P. R., Kunkel, K., & Williams, D. M. (2013). Bison versus cattle: Are they ecologically synonymous? *Rangeland Ecology & Management*, *66*(6), 721–731. https://doi.org/10.2111/REM-D-12-00113.1

Miller, B. (2024, May 17). Groups sue over grazing agreements in Red Rock Lakes National Wildlife Refuge. *Daily Montanan*. https://dailymontanan.com/2024/05/17/groups-sue-over-grazing-agreements-in-red-rock-lakes-national-wildlife-refuge/

Molvar, E.M., R. Rosentreter, D. Mansfield, & G.M. Anderson. (2024). Cheatgrass invasions: History, causes, consequences, and solutions. Hailey, ID: Western Watersheds Project, 128 pp. Retrieved on March 30, 2026, from https://westernwatersheds.org/wp-content/uploads/2024/03/Molvar-et-al-2024-Cheatgrass-Monograph-opt.pdf

National Archives. (2021, July 29). *Homestead Act (1862)*. https://www.archives.gov/milestone-documents/homestead-act

Nusslé, S., Matthews, K. R., & Carlson, S. M. (2017). Patterns and dynamics of vegetation recovery following grazing cessation in the California golden trout habitat. *Ecosphere*, *8*(7), e01880. https://doi.org/10.1002/ecs2.1880

O'Mara, C. (2025). *National Wildlife Refuges: A Haven for Animals and for Us*. National Wildlife Federation. Retrieved on March 30, 2026, from https://www.nwf.org/Magazines/National-Wildlife/2025/Fall/Conservation/National-Wildlife-Refuges#:~:text=The%20National%20Wildlife%20Refuge%20System%20is%20the,additional%2022%20percent%20proposed%20in%20early%202025

Ohmart, R. D. (1996). Historical and Present Impacts of Livestock Grazing on Fish and Wildlife Resources in Western Riparian Habitats. In *Rangeland Wildlife* (pp. 245–279). The Society for Rangeland Management. https://www.fs.usda.gov/rm/boise/AWAE/labs/awae_flagstaff/Hot_Topics/ripthreatbib/ohmart_histpresimplivestock.pdf

Peterjohn, W.T. and Correll, D.L. (1984). Nutrient Dynamics in an Agricultural Watershed: Observations on the Role of A Riparian Forest. Ecology, 65: 1466-1475. https://doi.org/10.2307/1939127

Platts, W. S. (1978). Livestock interactions with fish and aquatic environments: problems in evaluation. Transactions of the North American Wildlife Natural Resources Conference 43:498-504.

Ratz, D. (n.d.). Arctic Grayling — *Thymallus arcticus*. Montana Field Guide. Montana Natural Heritage Program and Montana Fish, Wildlife, and Parks. Retrieved on March 25, 2026, from https://FieldGuide.mt.gov/speciesDetail.aspx?elcode=AFCHA07010

Rieman, B., Lee, D., Chandler, G., & Myers, D. (1997). Does Wildfire Threaten Extinction for Salmonids? Responses of Redband Trout and Bull Trout Following Recent Large Fires on the Boise National Forest. *Fire Effects on Rare and Endangered Species and Habitats*.

Roni P, Beechie TJ, Bilby RE, *et al*. (2002). A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. N Am J Fish Manage 22: 1–20

Shoemaker, W. (2024, May 14). *Defending Montana's Red Rock Lakes National Wildlife Refuge from Grazing Mismanagement*. Advocates for the West. https://advocateswest.org/defending-montanas-red-rock-lakes-national-wildlife-refuge-from-grazing-mismanagement/

Smith, R.J. (1977). Conclusions. In Proceedings of a seminar on improving fish and wildlife benefits in range management. Biological Services Program, US Fish and Wildlife Service, Washington, DC, FWS OBS-77/1.

Strassmann, B. I. (1983). Grazing programs on federal rangelands and refuges: consequences for wildlife, beef production, and fossil fuel use. MS thesis, Cornell University, Ithaca, New York, 167 pp.

Taboada, M. A., Lavado, R. S., Svartz, H., & Segat, A. M. L. (1999). Structural Stability Changes in a Grazed Grassland Natraquoll of the Flooding Pampa (Argentina). *Wetlands*, *19*(1), 50–55. https://doi.org/10.1007/BF03161732

The Nature Conservancy. (n.d.). *High divide headwaters*. Retrieved April 14, 2026, from https://www.nature.org/en-us/about-us/where-we-work/united-states/montana/stories-in-montana/montana-high-divide/

Torgersen CE, Price DM, Li HW, *et al*. (1999). Multiscale thermal refugia and stream habitat associations of Chinook salmon in northeastern Oregon. Ecol Appl 9: 301–19.

UCL. (2012, March 27). *DNA traces cattle back to a small herd domesticated around 10,500 years ago*. UCL News. https://www.ucl.ac.uk/news/2012/mar/dna-traces-cattle-back-small-herd-domesticated-around-10500-years-ago

University of Minnesota Extension. (2023). *Grazing and pasture management for cattle*. Retrieved January 26, 2026, from https://extension.umn.edu/pasture-based-dairy/grazing-and-pasture-management-cattle

USDA. (n.d.). *Targeted Grazing for Wildfire Fuel Breaks*. U.S. Department of Agriculture Climate Hub. Retrieved on March 26, 2026, from https://www.climatehubs.usda.gov/hubs/northwest/topic/targeted-grazing-wildfire-fuel-breaks

USFS. (2014). Draft environmental impact statement: proposed revised land management plans for the Malheur, Umatilla, and Wallowa-Whitman national forests. Portland, OR: USFS Pacific Northwest Region 6.

USFWS. (1986). *Red Rock Lakes National Wildlife Refuge*. U.S. Fish and Wildlife Service. https://npshistory.com/brochures/nwr/red-rock-lakes-1986b.pdf

USFWS. (2008). *Cooperative Land Management*. 50 CFR 29.2 226. https://www.govinfo.gov/content/pkg/CFR-2008-title50-vol6/pdf/CFR-2008-title50-vol6-sec29-2.pdf

USFWS. (2008). *Cooperative agriculture.* Retrieved March 11, 2026, from https://www.fws.gov/service/cooperative-agriculture

USFWS. (2011). Conserving the Future: Wildlife Refuges and the Next Generation. USFWS. https://www.fws.gov/sites/default/files/documents/FinalDocumentConservingTheFuture.pdf

USFWS. (2022). *Red Rock Lakes National Wildlife Refuge.* https://www.fws.gov/refuge/red-rock-lakes.

USFWS. (2023). *RRL NWR Grazing CD Final Signed.* Retrieved March 11, 2026, from https://www.fws.gov/media/rrl-nwr-grazing-cd-final-signedpdf

USFWS. (2024). *Finding of no significant impact (FONSI) and decision to implement beaver dam notching in Red Rock Creek, Red Rock Lakes National Wildlife Refuge.* https://www.fws.gov/media/finding-no-significant-impact-fonsi-and-decision-implement-beave-dam-notching-red-rock-creek

Warren, J. & Cutting, K. (2010). Breeding strategy and organochlorine contamination of eggs in lesser scaup (*Aythya affinis*). Ecotoxicology (London, England). 20. 110–8. 10.1007/s10646-010-0561-5.

Western Watersheds Project. (2025, December 17). Court approves plan to revisit livestock grazing at Red Rock Lakes National Wildlife Refuge. Retrieved March 20, 2026, from https://www.westernwatersheds.org/2025/12/court-approves-plan-to-revisit-livestock-grazing-at-red-rock-lakes-national-wildlife-refuge/

Western Watersheds Project. (n.d.-a). Public lands ranching. Retrieved March 11, 2026, from https://westernwatersheds.org/public-lands-ranching/

Western Watersheds Project. (n.d.-b). The history of public lands grazing. Retrieved March 10, 2026, from https://westernwatersheds.org/the-history-of-public-lands-grazing/

Whelham, N. J., Warren, J. M., & Frisina, M. R. (2013). Effects of cattle grazing on small mammal communities at Red Rock Lakes National Wildlife Refuge, Montana. *Intermountain Journal of Sciences*, *19* (1-4 December), 9–21. https://arc.lib.montana.edu/ojs/index.php/IJS/article/view/630

Wildearth Guardians & Western Watersheds Project v. USFWS (United States District Court for the District of Montana). (May 15, 2024). https://dailymontanan.com/wp-content/uploads/2024/05/Red-Rock-Lakes_Grazing_Complaint_Filed.pdf

Wilderness Act. (1964, September 3). Public Law 88-577 (16 U.S.C. 1131-1136) 88th Congress, Second Session. https://www.nps.gov/subjects/wilderness/upload/W-Act_508.pdf

Wilderness Connect. (n.d.). *Red Rock Lakes Wilderness*. Retrieved April 22, 2026, from https://wilderness.net/visit-wilderness/default.php

Wu, X., Sverdrup, E., Mastrandrea, M. D., Wara, M. W., & Wager, S. (2023). Low-intensity fires mitigate the risk of high-intensity wildfires in California's forests. *Science Advances*, *9*(45), eadi4123. https://doi.org/10.1126/sciadv.adi4123

Zaimes, G. N., & Schultz, R. C. (2015). Riparian Land-Use Impacts on Bank Erosion and Deposition of an Incised Stream in North-Central Iowa, USA. *CATENA*, *125*, 61–73. https://doi.org/10.1016/j.catena.2014.09.013