2017

Crested Butte

LOVING IT TO DEATH

Class papers
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Introduction

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Known as "the gateway to the Elk Mountains", Crested Butte and its surrounding area are the ancestral home of the Native American Utes and sources of natural resources and beauty. The town was incorporated in 1880. Within a few years, Crested Butte had become a coal mining "company town" and mining of the area's extensive bituminous and anthracite coal deposits grew over the next decade.

This time period was also the beginning of the Colorado Silver Boom, which was fueled by a combination of the 1878 Bland-Allison Act and the 1890 Sherman Silver Purchase Act. In 1893, the boom became a bust when the Sherman Silver Purchase Act was repealed and silver prices plummeted (Bryan, 2012). Overnight, thriving mining towns became ghost towns. Crested Butte, however, survived due to its coal mining and coke production. By the turn of the century, Crested Butte boasted the third largest coal mine in Colorado and was producing the highest quality coal in the state (Crested Butte, 2017). However, its glory days were short lived. By the early 1950s, coal mining ceased and the railroad removed its tracks. Crested Butte's population and economy declined.

Perched at an elevation of 2,708 m, Crested Butte lies in the Elk Mountains 43 km north of Gunnison, connected by Colorado State Highway 135. The Slate River flows between Mount Crested Butte, Mount Emmons, and Whetstone Mountain. Its tributary, Coal Creek, runs through the 2 km^2 town center of Crested Butte. The Slate River forms the headwaters for the Colorado River; therefore, everything that flows through – and into – the Slate River is of high significance. Like many Colorado waterways, Coal Creek and the Slate River received contaminated runoff and leaching from the abandoned mines.

In 1962, two developers opened a new ski area featuring Colorado's first gondola. Over time, the area grew into what is now known as the Crested Butte Mountain Resort. This development triggered the area's economic transition from mining to tourism. Eventually, an entirely new town named Mt. Crested Butte was developed to accommodate luxury condos, vacation homes, and large hotels. The Crested Butte area is now a year-round vacation destination for visitors of all ages and interests, with endless opportunities ranging from snow sports to mountain biking, river running to rock climbing, hiking to wildflower watching, plus many festivals and events. Correspondingly, the area's population has also expanded. From 1960 to 2010, Crested Butte grew from 289 residents to 1,487, while the town of Mt. Crested Butte grew from nothing to 819 residents, and Gunnison County grew from 5,477 to 15,324 residents. In 2014, the Crested Butte Mountain Resort reported more than 350,000 skier days (Gunnison County, 2014

p. 12) and – for the first time ever – Gunnison County recorded more visitors in the summer than in the winter (Tilton, 2015).

Seasonal visitors and vacation homes bring significant sales and tax revenue to Crested Butte. However, their enjoyment of recreational areas – and the development needed to support their enjoyment – has created a noticeable impact on the region. Crested Butte is not the only tourist town in Colorado to feel the effects of commercial success. The surge in popularity has been exacerbated in recent years by social media attention. Now that Crested Butte has been "discovered", its residents and surrounding ecosystem are struggling under the load. The open spaces and recreational land do not have the ability to simply expand capacity to accommodate the growing demand. This is having a deleterious effect on the region, some of which may not be entirely reversible.

The objective of this report is to evaluate the ecological impact of Crested Butte's mining past, and its tourist-industry present and future. While the impacts examined in this report may appear dire, it should be noted that there are signs of positive change. For example, since 1977, a grass-roots group known as the High Country Conservation Advocates has successfully opposed all attempts to mine Mount Emmons ("Red Lady"), just outside the town of Crested Butte. In October 2016, it struck a preliminary deal to permanently remove mining claims from Mount Emmons and return about 9,000 acres of land to the Forest Service (Blevins, 2016). Under this agreement, the current mining rights owner will continue treating tainted water flowing from a long-defunct lead and zinc mine on the mountain. In November 2016, Crested Butte voters overwhelmingly approved Ballot measure 2A, agreeing to let the town borrow $2.1 million to permanently prevent mining on Mount Emmons.

Organizations such as the Crested Butte Land Trust and the Gunnison Ranchland Conservation Legacy work tirelessly to protect and steward open lands for vistas, recreation, wildlife and ranching, and to purchase conservation easements to protect agriculture. Similarly, the Crested Butte Mountain Bike Association plans, creates, and maintains over 450 miles of bike trails. The Rocky Mountain Biological Laboratory in Gunnison County studies ecosystems that replenish the world's air, water and food supply to better understand and help influence environmental policy at all levels of government and within many private sector industries. The Crested Butte Mountain Resort, whose success revitalized the region, now endeavors to preserve the Gunnison Valley's natural beauty and rural landscapes (Crested Butte Mountain Resort, 2017). It recognizes that its long term economic success depends upon a healthy, diverse, and resilient natural environment. The resort donates funds to the aforementioned organizations. In 2016, it partnered with Western State Colorado University to develop a Strategic Sustainability Plan (Kotowski, 2016).

Preserving cultural heritage is also important to the residents of Crested Butte. Since 1972, the entire town has been a historic district. In 1974, part of the town was listed on the National Register of Historic Places, and in 2002, the boundaries of that district were expanded. In 2005, due to its commitment to preservation, the town earned an award from the Colorado Historical

Society. In 2008, Crested Butte was listed as one of the National Trust for Historic Preservation's Dozen Distinctive Destinations (Encyclopedia Staff, 2017). Although preserving cultural heritage *per se* does not guarantee ecological remediation, its importance to the residents of Crested Butte suggests their willingness to preserve the surrounding outdoor spaces.

This report investigates a variety of issues related to the human impacts upon the region, such as mining, snow sports, mountain biking, hiking and golf. Throughout the report, authors have coupled primary research with interviews and field studies to provide perspectives and insights that are both scientifically grounded and socially informed. Through a balanced approach, this report aims to guide productive discussions and educated decisions regarding land use, environmental protection, and development in the Crested Butte area.

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Wildlife

Fracking in Gunnison County

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Abstract:

Since its invention, fracking has become a very controversial method for natural gas extraction. Despite this controversy, as the demand for energy increases, so does oil and gas infrastructure. Fracking and the extraction of other nonrenewable energy sources are often solely associated with global climate change. While these industries do negatively affect the climate, they can also cause severe, local environmental impacts such as water contamination, habitat loss and fragmentation, and decreased biodiversity. This paper takes a closer look at the impacts of hydraulic fracking and how they affect the town of Crested Butte, Gunnison County and the greater Rocky Mountain Region.

Introduction:

Gunnison County is known far and wide for its outdoor recreation. Tourists flock to this region from all over the globe for its world class fishing and skiing, and the abundant flora and fauna. The region's economy has grown to depend on the preservation of the landscape for these activities, yet this pristine area is currently being threatened by natural gas extraction. According to the Colorado Oil and Gas Conservation Commission, fracking became a regular technique for oil and gas extraction in Colorado in the early 1970s and has since flourished. In 2014 alone, 3.67 million acres of federal land were leased for natural gas and crude oil development (Ballotpedia, n.d.).

To understand the impacts of hydraulic fracking, it is important to first understand the fracking process itself. To create a fracture in rock formations, highly pressurized, "frack fluid" is injected into a wellbore. After the cracks are created, natural gas and petroleum can flow freely. The frack fluid used is made up of water, a proppant, and a concoction of chemicals. The proppant, typically aluminum oxide or sand, prevents the cracks from closing when the hydraulic pressure is removed from the wellbore and is permeable enough that frack fluid, gas, and oil can flow through it.

Impacts of Fracking on Water:

One of the most threatening impacts of fracking is on water quality. Frack fluid, along with water and a proppant, contains a concoction of chemicals that each serve a different purpose such as corrosion inhibitors, gelling agents, or pH adjusting agents. This toxic mix becomes even more environmentally hazardous when it is pumped into the ground and comes into contact with the heavy metals that exist naturally deep in the shale. Frack fluid that remains underground can contaminate groundwater that is used in wells. Frack fluid that returns to the surface, called flowback, flows into nearby water sources if it is not properly contained. This is especially problematic because most water treatment plants do not have the equipment to remove the contaminants from fracking flowback (Greenpeace, n.d.). Both groundwater and surface water contamination can have serious consequences.

A 2011 study done in Pennsylvania and New York examined methane contamination in drinking wells in relation to natural gas extraction sites. While methane was detected in 85% of all the wells samples, the concentrations were significantly higher in sites close to natural gas wells. The amount of methane detected near active sites was not only an average of 17 times higher than the concentration of methane near inactive sites, it also was concentrated enough to qualify for the Department of the Interior's defined action level for hazard mitigation (Osborn et al., 2011). Methane contamination is only one of the many concerns regarding the toxic concoction used to extract natural gas. This contamination is both a public health concern and can significantly impact the surrounding ecosystems.

Gunnison County is home to some of the best fly fishing in the Rocky Mountain West. Downtown Crested Butte is lined with one angler shop after another. Having abundant, healthy fish populations requires a healthy riparian ecosystem and plenty of insects to feed on. Aquatic macroinvertebrates are good bioindicators of water quality because of their wide range of pollutant tolerance and the fact that they are relatively stationary organisms compared to other aquatic organisms such as fish. Species can be used to develop Indices of Biological Integrity (IBI) to show ecological complexity. Aquatic macroinvertebrate IBIs calculated in sites without fracking have been found to be significantly higher than those in sites near fracking. Abiotic factors of these ecosystems, such as pH, are also affected which in turn can harm the biotic elements present (Lutz et al., 2016). The benthic critters present in aquatic ecosystems are the backbone of the fishing industry in the Crested Butte region; without a food source, the fish cannot survive.

It is not only important to look at water quality, but also water quantity. If the flowback escapes into a small body of water, the contaminants would be in a much higher concentration than if released into a large body of water where the contaminants would be diluted. Additionally, if too much water is drawn for frack fluid, it can lead to a shortage which can drastically impact agriculture, lower surface water levels and lead to aquifer depletion (Burton Jr., 2014).

Impacts of Fracking Infrastructure:

As the demand for domestic energy increases, so does the infrastructure for natural gas production. While many studies examine how fossil fuels affect biodiversity via climate change, it's important to look at how fracking sites themselves affect biodiversity. Both the sites and the roads leading to them contribute to habitat loss and fragmentation, noise and light pollution, and the introduction of invasive species.

Habitats in fracking zones are affected by well pads, transmission lines, surface pipelines, roads, and constant noise and lights which keep wildlife at bay. As energy use increases, economic pressure will drive development into increasingly remote places, requiring more miles of roads, pipelines and transmission lines (Jones et al., 2015). This web of infrastructure leads to habitat fragmentation which limits species colonization, restricts access to mates and food, hinders interspecies interactions and causes edge effects (Primack et al., 2016). While natural gas actually requires less on site infrastructure than energy sources such as hydroelectric power or coal, the majority of its impacts come from fragmentation. This is because gas wells are geographically more scattered than other energy sources (McDonald et al., 2009).

One way fracking infrastructure poses an environmental hazard is through the introduction of invasive species. The combination of disturbed soil from construction and vehicle traffic provides the perfect opportunity for nonnative species to flourish. Propagules from plants can arrive on site by attaching to vehicles or by residing in soils that are brought in for construction (Nentwig, 2008).

Few studies have been done to quantify the effects of noise and light pollution from fracking sites yet their impacts on wildlife are not insignificant. The US Government Accountability Office found a grand total of 4,406 gas and oil wells concentrated in only 105 of the country's 575 National Wildlife Refuges. Light pollution can negatively affect wildlife by disturbing the rest, mating and feeding patterns of species (Burton Jr et al., 2014). During production, fracking sites are loud. Compressor stations and pumping stations produce a significant amount of noise, as well as the disturbance caused by occasional flaring and vehicle traffic. This constant noise is a disturbance to both livestock and wildlife, as well as residents of the area and recreationalists (Burton Jr et al., 2014).

One misconception of Environmental Impact Assessments required by the National Environmental Policy Act is about the displacement of ungulates, hooved mammals such as mule deer. It is commonly believed that the displacement of these animals caused by infrastructure is temporary and that they eventually become habituated and return to an area once the construction is over and production is underway. However, a recent study published in 2017 proved this wrong. For 17 years, researchers tracked mule deer near natural gas extraction sites throughout development, production and reclamation stages. Even as wells moved into further stages, the mule deer did not adjust to the disturbance at all, staying an average of 1 kilometer further away from well sites in comparison with ungulates before the development occurred. This reduced amount of available habitat and critical winter range directly affects mule deer and over the 17 year study, populations decreased by 36% despite serious mitigation efforts (Sawyer et al., 2017).

Other ungulates, such as elk, are affected as well. A study done in Wyoming, which shares a border with Colorado, examined elk locations both prior to and during natural gas development. It found that elk presence in high use areas that now have natural gas infrastructure was reduced by 43% in the summer and 50% in the winter. While completely eliminating the impacts of this infrastructure is improbable, steps can be taken to reduce the negative effects. Reducing daily traffic would help lessen the impacts of vehicle presence on wildlife, as well as reducing human presence via the improvement of automated technology (Buchanan, 2014).

Impacts of Fracking on Climate Change:

While we can see the immediate effects of natural gas on water and wildlife, the effects of climate change caused by fossil fuels like natural gas can seem distant. Yet climate change is already affecting Gunnison county. Deforestation that occurs to make room for fracking infrastructure not only affects wildlife by removing habitat, but changes the local climate. Forest soils are typically moist but when no vegetation is present to provide shade they dry out and become barren. Also without vegetation, the temperature changes between night and day in the region become more drastic. This disruption changes niches, releases sequestered carbon and provides an opportunity for invasive species to proliferate (Meng, 2016).

Fracking not only affects the local climate, but the global climate as well through greenhouse gas emissions. Often, fracking is compared to coal power plants in terms of carbon dioxide emissions, which natural gas produces less of. Yet methane emissions from natural gas extraction are often not included in these calculations (Burnham et al., 2011). Methane as a greenhouse gas is less prevalent than carbon dioxide, but it is much more effective at trapping radiation. Natural gas and oil production are the largest sources of methane emissions in the US and without methane potency incorporated into environmental impact analyses, natural gas gains an unearned reputation as a "cleaner" energy source (Meng, 2016).

According to the Colorado Department of Local Affairs, 35% of Gunnison County's economy relies on tourism (Colorado Department of Local Affairs). In Gunnison county, for the most part, that tourism is centered around outdoor recreation; and outdoor recreation is being seriously impacted by climate change. The scenic forests of Colorado are being adversely affected by the spread of the bark beetle, which is caused by rising temperatures year round. Cold winters used to keep beetle populations low but as global warming increases, so will bark beetle outbreaks (US Forest Service, n.d.). Within Gunnison county lies Crested Butte, known as the wildflower capital of Colorado.

Yet studies at the nearby Rocky Mountain Biological Lab show declines in some species of flowers dues to progressively earlier snow melts (Miller-Rushing et al., 2009). Additionally, earlier snow melts and rising temperatures affect Crested Butte Mountain resort, where thousands of people flock every year to ski and snowboard. The list of ways climate change impacts outdoor recreation goes on. Limiting fracking operations in Gunnison county will not immediately reverse global warming. However, no global issue is solved overnight, and unless regions do their bit to slow emissions, they will be contributing to the tragedy of the commons.

New Fracking Operations in Gunnison County:

Dave Neslin, the executive director of the state oil-and-gas commission, in 2011 said "There has been little development in Gunnison County, but there is certainly potential there" (Denver Post, 2011). In the time since he stated that, natural gas development in the region has increased greatly. The Upper North Fork Valley in the Gunnison County is currently in the process of receiving 150 wells on 35 pads, a development that was just approved by the Bureau of Land Management in October, 2017. According to Matt Reed, the Public Lands Program Director of High Country Conservation Advocates, this new fracking operation has been an "out of sight, out of mind" issue for many citizens of Crested Butte because the site of these proposed wells, while still within Gunnison county, is in a different watershed (M. Reed, pers. com., October 13, 2017). The proposed North Fork Valley fracking site lies directly upstream of Delta County, which holds the highest concentration of organic farms in Colorado (5280: Denver's Mile High Magazine, 2017). Much outcry has come from Delta County organizations about the possibility of irrigating crops with contaminated water. It also is a concern for wildlife corridors connecting the North Fork to the Crested Butte region (M. Reed, pers. com., October 13, 2017).

The majority of the pads will be on private land, but these are "islands" of private land surrounded by expanses of scenic forests on public land. The proposed fracking sites in Gunnison County interfere with summer transition zones for mule deer and elk as well as 2,100 acres of essential winter range for mule deer and 8,000 acres of documented winter concentration zones for elk. This area also provides habitat for several species of birds listed as Birds of Conservation Concern by the US Fish & Wildlife Service such as the northern goshawk and the purple martin as well as the bluehead sucker fish, a species of interest to Colorado Parks & Wildlife (Colorado Parks and Wildlife, 2017).

This proposed development is concern to both anglers and hunters, the latter being one of the most publicly vocal groups against the proposed fracking sites. Hunting in both Delta County and Gunnison County bring in millions of dollars to communities each year (M. Reed, pers. com., October 13, 2017). Between the two counties, approximately 912 jobs are related to fishing and hunting, and within Gunnison county alone, fishing and hunting related jobs make up 4.6% of the total jobs in the county (BBC Research & Consulting, 2008). Disrupting wildlife with fracking infrastructure poses a serious threat to these industries.

While many groups are publicly opposed to the proposed fracking sites in the Upper North Fork Valley, the project is far enough along that it has moved beyond the official period of public input. Any chance to halt the construction of these wells would have to be accomplished through litigation (M. Reed, pers. com., October 13, 2017).

Conclusion:

Although fracking has been in practice for several decades, areas that were once deemed inaccessible can now be developed for natural gas extraction because of changing technology. So it is unknown what areas will come under threat as new techniques develop. Fracking jeopardizes clean water, wildlife habitat, outdoor recreation and the global health of our planet yet it is advertised as a promising energy source by the current federal administration. This step backwards in the pursuit of clean energy can best be countered by local efforts, which Gunnison county is lucky enough to have a lot of. Conservation organizations like the Crested Butte Land Trust and High Country Conservation Advocates as well as concerned citizens are working together to preserve the sensitive and rich ecosystems within the region.

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Mining impacts in Crested Butte, Gunnison County

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Abstract:

This paper investigates impacts of mining near a small town in the Rocky Mountains of Colorado. Multiple research articles demonstrated that current and abandoned mines have negative impacts on soil, water, and organisms that inhabit the affected area. Coal and metal mines contaminate environment through acid mine drainage and release of heavy metals. Impacts include reduction in pH value and increase in the level of soluble heavy metals in both aquatic and terrestrial ecosystem. These lead to lower species diversity and a change in the structure of the biological community. Moreover, mining contributes to higher rates of erosion and degradation. Additionally, the metal cadmium, copper, lead, and arsenic, which are produced and released from mining activity harm human health. Restoration projects such as the Peanut mine reclamation could restore mining sites to reduce pollution, increase aesthetic value and educational opportunities.

Introduction:

Mining is the extraction of coal and minerals from ores in excavation sites (mines). It is an inevitable process that provides raw materials for commodities people use in day to day life. However, countless scientific studies have revealed negative impacts of mining practices to both the environment and human health. This paper will investigate the impact of mining with a focus on Crested Butte.

Crested Butte (CB) locates in the North part of Gunnison County. Formerly, it was the Ute Indians who dwelled in the area. However, due to the extensive mineral deposits, miners (mostly European-Americans), were attracted to the Gunnison region, and as a result, CB was established and grew. For example, the discovery of gold deposits in 1859 drove a large population of miners into the region. Around 1860, CB began the mining industry. In the 1880s, the CB community was around 400, and it increased to 1,604 people in 2016.

Mining in CB was mostly in coal, gold, silver, and molybdenum. Coal mining began roughly in the 1860s and accounted for a large sector of the local economy. Silver mines started around the same time but mostly in the Western region of Crested Butte. In 1893, all silver mines ceased and depressed the economy of many surrounding towns. However, the coal mining industry supported the CB community through this period.

One of the renowned coal mines was the Big Mine under the CF&I (Colorado Fuel and Iron). This mine lasted 58 years until it was shut down in 1952 due to the conversion of railroads for other uses, the introduction of gas and electricity, and better substitution for CF&I. Eventually, mining became a part of the history of the town as tourism grew due to the establishment of the ski area at around 1962. Nowadays, Crested Butte is named the "The Wildflower Capital of Colorado," hosting a wide range of outdoor activities such as skiing, hiking, mountain and dirt biking, fishing, and rock climbing ("History of Crested Butte", n.d.). In 2012, tourists spent $150.6 million, which fueled 1,870 jobs in CB (Gunnison County Colorado, 2014). Nevertheless, with a long history of mining and surrounded by 10,317 mines, Crested Butte, experienced-and possibly still experiencing- significant environmental impacts ("Mines near Crested Butte, Colorado", n.d.).

Impacts of mining on water:

Undoubtedly, mining at an industrial scale causes many impacts on ecosystems, especially on stream ecology. One of the pollution produced from sulfur-containing-mines is called acid mine drainage (the leaching of acidic water from mines) which alters the chemistry of the stream and turns water to a brownish-yellow. It usually occurs in coal, iron and gold mines where the mineral pyrites are present. Pyrites and metal sulfides react with oxygen and water to produce sulfuric acid, which reduces the pH value of the river. The brownish-yellow color is caused by the metal oxide precipitations ("What is Acid Mine Drainage", n.d.). Typically, a low pH of water increases the solubility of existing metals in the water such as aluminium and iron. After these metals become soluble, they undergo oxidization at the surface of fish gills, and in the end become insoluble which damage fish gills. Fish gills are critical to the species because they are responsible for respiration, osmoregulation, and removal of ammonium. Gill damage can lead to hypoxia, high concentrations of ammonium in the blood, and abnormal ion regulation in fish. Some of the soluble metals can be taken into the fish body, accumulate in the liver, kidney, and spleen, and impair the functions of these organs (Slaninova et al., 2014).

Having said that mining causes low water pH and a high level of dissolution of existing metals, it also adds additional metals to the water. To make the situation worst, large quantities of dissolved metals are also released directly from mines into the river. As such, there is a high concentration of soluble metals which can poison aquatic organisms and alter the biological community. A study on the effect of heavy metal to benthic organisms in Arkansas river in Colorado suggests that mayflies, stoneflies, beetles, and orthocladiinae are significantly affected by metals. This is shown by the low abundances of these organisms presented in water with higher zinc concentrations. Caddisflies and blackflies can also be affected, but the food abundance overtakes the impacts of pollutants. In general, these sensitive organisms cannot tolerate water that is polluted with heavy metals, and reduction of these organisms therefore cause changes in the composition and interactions of a stream community (Clements, 1994). Another study also suggests similar impacts on the aquatic organism but focus on mayflies and stoneflies, found that these two organisms are most affected by high metal concentrations (Courtney & Clements, 2002). Although these studies are specific to the Arkansas River, they are also applicable to Crested Butte, since Arkansas river also experienced mining activities and is located in Colorado. Therefore, the stream ecosystems are likely to be similar, so does the pollutants from mines. In fact, a water quality survey suggested high zinc concentrations in the water streams in Crested Butte (Gurdak et al., 2002), similar to what happened in Arkansas river. Hence, similar impacts on the aquatic organisms may occur.

Heavy metals, such as copper, also affect trout. Trout is the most common capture by fly fishers. A study suggests the mortality of trout is inversely correlated with the concentration of copper in the stream, with only one exception- the rainbow trout (John et al., 2009). An increased concentration of copper would, therefore, damage the fly fishing industry. In CB, fly fishing is a large part of recreation. As the economy of CB is heavily relying on the tourism sector, every opportunity of outdoor recreations should be protected to maintain a sustainable economy.

High concentration of metals in the water can also be detrimental to human health. Metal includes lead, cadmium, copper, and arsenic can accumulate in stream water and biomasses. When human consume organisms and water, these metal enter the human body. It has been found that long term ingestion of high concentration of lead can lead to neurological problems, such as encephalopathy (the degeneration of neural Schwann cells), anaemia (a blood disease), Vitamin D deficiency, and increase blood uric acid. Overconsumption of cadmium leads to kidney stones, bone fractures, osteoporosis, diarrhoea, and a higher risk of cancer. Copper in high concentrations would cause oxidative cell damages, diarrhoea, neural disorder, Wilson's disease, and liver disease. For arsenic, ingestion in high concentrations can cause anaemia, copper deficiency, abnormal cardiac functions, chromosomal abnormalities, type-2 diabetes, neurological disorders, hypertension and cancer (Zahra et al., 2017). Indeed, heavy metal possesses a significant threat to human health.

One might argue that such a problem might not exist in Crested Butte. However, it is far from the reality. In the Gunnison County, a water quality survey conducted between 1989 and 1999 suggested a high aluminium, cadmium, copper, lead, manganese and zinc concentration in the water stream, where historical mining practices present. Trace elements, elements that are usually present in small quantities and are essential for normal growth in organisms, including iron, copper, zinc, and molybdenum, are found to be higher in the downstream of mining sites. Accordingly, it is evident that water quality had been affected by mining practices and possibly remains to be a serious concern (Gurdak et al., 2002).

Another aspect of water contamination by minings is groundwater. A 2009 study done in Italy showed that mining could increase the concentration of dissolved sulfate, zinc, cadmium and lead in aquifers of lead and zinc mines. It also showed that the level of contamination is determined by the rate of aquifer discharge (Cidu et al., 2009). Potentially, the aquifer in the CB region may also be contaminated. According to statistics from the water investigation report of the Gunnison river shed, there were 9 sites out of 39 groundwater samples, exclusively near CB, had manganese concentrations higher than the EPA standard of 50 mg/liter. Since CB region experienced intensive mining practices, the high manganese concentration was likely a consequence of mining. Additionally, all 39 samples contained radon, produced from the natural radioactive decay of uranium, are higher than the maximum potable water contamination level of U.S EPA standard-300 picocuries per liter (Gurdak et al., 2002). This could be a result of the uranium mines surrounding the area. In general, groundwater in CB has been moderately contaminated.

Impacts of mining on surrounding terrestrial ecosystems:

Not only is water affected by mining, the surrounding terrestrial ecosystems also experience substantial impact. First of all, mining harms biodiversity and changes the ecosystem. Similar to the effects in streams, high level of heavy metals and low pH values are detected in the soil near mining sites. The metal accumulates in vegetation and biomagnifies up the food chain. For example, cadmium poisons and alters physiology, health, demographics and distributions of organisms. Willows obtain cadmium from soil, and herbivores including moose, mule deer, beaver and snowshoe hare obtain high levels of cadmium when they ingest the willow (Larison, Likens, Fitzpatrick & Crock, 2000). Species that cannot endure a high cadmium level will gradually reduce in population size as other species, who are usually invasive and more tolerant of metal contamination, take over the region. As such, toxic elements from mine tailings enter the food chain and alter the composition of the ecosystem. In India, a study on the ecological impacts of coal mining was done and found that ecosystem resources are degraded, and habitats are destroyed. The native vegetation and opens up the space for colonization of invasives. Without proper management, the invasive species may spread and threaten the region around the mine (Goswami, 2015). In Crested Butte, a similar phenomenon occurred. Research conducted in CB surveyed 5 mining sites: the East River Valley, the Slate River Valley, Paradise Basin, Virginia Basin and Mount Emmons. Here coal and silver were the primary mining product. A higher number of invasive plants were found in the mining region. 36 out of 130 species observed species were invasive and mostly present in mining sites. The most common invasive species is the *Matricaria perforata*. Regarding species diversity, the mining sites were lower compared to the control site. For instance, the control site is 43% richer and 66% denser in species than that of the mines. Other impacts on vegetation discovered include shorter plant height, fewer flowers and lower pollination rate (Little, 2009). Evidently, mining has dramatically altered the biodiversity in the CB area.

Beside a lower biodiversity, erosion also stands out in the various number of negative mining impacts. One of the methods used to create coal mine is strip mining which clears up vegetation and decimates lands for the purpose of accessing underground ores. Sometimes, explosives are used to open up the ground. These destructive actions will remove topsoil and expose the land to actions of water and wind, which increases the rate of erosion. Abiotic conditions are altered. Consequently, the environment becomes degraded and is no longer suitable for native vegetation. In this case, the value of the land also reduced due to the lack of natural scenery, poor soil quality and fewer minerals (“About coal mining impacts”, n.d.).

A Case Study of Mine Restoration:

After a mine becomes inactive, the land is reconsidered for other uses. However, standing on the barren ground with piles of tailings, sparsely growing plants and brownish water flowing through, there is almost nothing people can gain from the land without rehabilitation or restoration efforts. There was a successful case of a mine reclamation project on the Peanut mine in Northern CB. Peanut mine was a coal mine which became inactive in the early 1900s. A mill operated in the area after the mine was shut down from the early to mid 1970s. Piles of tailings and refuses were left over in the region. After 1990, when tourism began to dominate the town's economy, calls for reclamation increased. In response to the demands from the public, a partnership formed between the Inactive Mines Reclamation Program and Peanut Mine Inc, a corporation established and funded by Crested Butte Land Trust after it brought the Peanut mine. Fundings from the United State Environmental Protection Agency ($200,000) Colorado Department of Public Health and the Environment ($70,000), and the Gates Foundation ($50,000) supported the project. The reclamation began in 2005. Actions included removing of coal and silver waste, constructing drainage channels, applying organic material (cow manure), establishing shrub patches, plotting seeds of grass and forbs, planting triticale (a fast growing wheat), and adding weed-free straw mulch. Volunteers helped to plant 4,500 trees in 2005. Trees including willows, Quaking aspen, Blue Spruce, Engelmann Spruce were planted. The reclamation was successful. The ground cover in 2009 became 78.9% with around 47% of the vegetation non-noxious. Sagebrush dominated the area along with wax currant, Douglass rabbitbrush, blue spruce, Engelmann spruce, and quaking aspen. The reclaimed area now provides educational opportunities and high aesthetic value. In 2008, the project received an Excellence award in Abandoned Mined Land Reclamation National Award from U.S. Office of Surface Mining (Renner, 2011).

Conclusion:

This paper has used many scientific research articles related to the topic of mining impacts to assess the potential problems in Crested Butte. To sum up, mining greatly increases the level of soluble heavy metals in both aquatic and terrestrial ecosystems. High concentration of heavy metals in water harms fishes and kills metal-sensitive organisms, thus destroying the equilibrium of a biological community. In addition to that, the metals cadmium, copper, lead and arsenic produced and released from mining pose significant threats to human health. On terrestrial ecosystem, heavy metals bioaccumulate in organisms and biomagnify up the food chain and result in low biodiversity. Furthermore, the population of native vegetation is suppressed and lead to high invasive species. Moreover, strip mining clears vegetation and exposes the land to erosion. Despite all the negative impacts generated by mining practices, restoration projects, such as the

Peanut mine reclamation, could help restore mining sites to mitigate pollution. Consequently, the restored land gains higher aesthetic value and provides more educational opportunities.

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Social and environmental analysis of solar and wind power potential in rural Colorado

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Abstract:

In 2004, Colorado passed one of the country's most aggressive Renewable Portfolio Standards initiative in order to reduce reliance on fossil fuels and combat climate change. Nonetheless, most of Colorado's electricity needs are still met by fossil fuels, though this is declining as green power projects are becoming more effective and financially feasible. In this paper, the state's suitability for small- and large-scale solar and wind development is evaluated, with a focus on Crested Butte and the greater Gunnison County area. Additionally, ideological barriers to renewable energy development are analyzed, focusing of the challenges of implementing projects in small, rural communities, particularly those located in the Mountain West. Environmental problems associated with renewable energy development in the mountain and desert Southwest are also analyzed. The research suggests that Colorado is best suited for small-scale wind farms and solar panels constructed on preexisting buildings. Future renewable energy legislation must not be framed as just an environmental issue, but also an economic and democratic issue. This would incorporate the values and concerns of many conservatives that typically oppose these "greenie" laws.

Introduction:

Wind and solar power in the United States provided 9% of energy needs in 2015, with 82% from fossil fuels and 8% from nuclear power. Even with advancements in technology and policies making renewables more feasible, numerous obstacles remain (Holechek et. al., 2015). Nevertheless, many communities continue to implement renewable energy practices. For example, in 2004 Colorado became the first state to pass Renewable Energy Standards (RES) on the general ballot – a measure that sought to diversify the state's electricity portfolio – with subsequent amendments and legislation strengthening this policy. As of 2013, the law required investor-owned utilities to generate 30% of their electricity from renewables by 2020; larger, cooperative utilities to generate 20%; and all other sources to generate 10 %: approximately 25% of Colorado's electricity sales overall (Hannum et. al., 2017; Colorado Energy Office, 2017). Though an important step in renewable energy development, the mandate passed without the support of many rural counties; rather, the large, urban districts pushed the law through (State of Colorado, 2004).

One Colorado county of note is Gunnison. Gunnison County voted for the measure unlike many rural areas (State of Colorado, 2004). As such, Gunnison is an interesting place to study renewable energy practices, particularly the town of Crested Butte – a former mining town that transitioned to a recreation town in the 1960s with the opening of what eventually became Crested Butte Mountain Resort (Town of Crested Butte, 2017). Gunnison County Electric Association (GCEA) offers residents green power for purchase at one block each (100 kWh) for $0.12 extra per month. Residents are incentivized to conserve energy through a program that allows them to offset 100% of their power usage with renewables with their monthly bill calculated based on individual energy usage. GCEA also runs a community solar garden, the Doyleville wind turbine, and electric vehicle charging stations (partnered with Crested Butte). The state of Colorado, as of 2016, installed over 925.8 MW of solar energy while 17.3% of the state's electricity was generated by wind power. Both energy sectors employed at least 6,000 people each (GCEA, 2017; Colorado Energy Office, 2017). Plentiful sunshine and wind in Colorado favors the growth of solar and wind power above other energy developments, allowing the state to eventually rely on renewables instead of fossil fuels. However, there are numerous ideological and environmental barriers that need to be addressed – particularly in small, rural communities – before Colorado can eliminate its reliance on fossil fuels.

Wind and Solar Suitability:

Crested Butte is situated in a section of the Rockies with a collection of areas rated with high wind potential (see Appendix Fig. 1). Since Gunnison County encompasses mostly federally protected land (wilderness areas, national forests, etc.), development of these lands for large commercial wind farms is not feasible. Additionally, many of the best suited areas are located in sensitive sub-alpine and alpine regions (Janke, 2010). As such, the future of wind power in Crested Butte is limited to small-scale projects. Many could be located close to ski resorts or similar facilities in high alpine environments that could use wind energy to run ski lifts and offset other electrical uses. Crested Butte Mountain Resort (CBMR) could work on a wind farm project in partnership with Nunatak Alternative Energy Solutions – a local renewable energy company that specializes in small-scale projects that understands the needs and values of Crested Butte residents in regard to land development (Nunatak, 2017). The numerous ranchlands located in Crested Butte and in the greater Gunnison area could also serve as potential sites for small-scale wind farms due to their exposed topography. Ranchers can use these wind farms to generate extra income for themselves; however, conservation easements placed on many of these private properties complicate plans for ranchland wind farms.

Solar power in Gunnison County, and specifically Crested Butte, is in a similar situation to wind power: the county is even less suitable for solar farming than wind farming (see Appendix Fig. 2). However, Colorado receives over 250 days of direct sunlight, or total direct insolation, with little variance across the state. Therefore, solar power in Colorado is suited for local or individual usage – houses, businesses, even traffic lights – due to the lack of suitable land and infrastructure for giant solar farms like those in Nevada (Crescent Dunes, Copper Mountain, Nevada Solar One) (Janke, 2010). CBMR could also utilize solar to power ski lifts and other facilities in conjunction with wind power in case weather causes one to underperform; any extra power produced could be sold back to the electricity grid (Holechek et. al., 2015). Again, Nunatak would be the preferred company to work with for aforementioned reasons.

Ideological and Attitudinal Barriers:

Though Crested Butte moved away from mining decades ago and transitioned to a tourism-based economy – advertising both its outdoor recreation and sustainable practices – the residents give some surprising pushback against renewable energy projects (Town of Crested Butte, 2017; Benjamin Swift, Crested Butte resident, pers. comm., 2017). This is notable given that many people in Crested Butte are college-educated and have a vested interest in reducing climate change to preserve the environment for its recreation/tourism-based economy (U.S. Census Bureau, 2015). However, there are numerous reasons why small western mountain towns, even liberal towns, can be resistant to green energy projects.

The first and probably most popular reason for opposition pertains to the landscape. Mountain town residents form their identity around the landscape and do not want development, wind turbines or otherwise, to obstruct or mar the view. For towns that rely on tourism, such unnatural structures are seen by some residents as hurting the local economy because turbines would affect the aesthetic value of the Rockies (Olson-Hazboun et. al., 2016). In this case, careful planning taking into account the need for renewable energy and preservation of the landscape can sway opponents of local wind farms. This is especially true for Crested Butte, a town known as "Colorado's Last Great Ski Town" and "The Wildflower Capital of Colorado", where any manmade alteration to the landscape will draw the ire of the townspeople and visitors: even new recreation trails can divide the town (Dave Ochs, Executive Director of Crested Butte Conservation Corps, pers. comm., 2017). Essentially, Crested Butte's environmental values are difficult to deal with as love for nature is not something that can be reconciled with facts and statistics; an affinity for the landscape is an emotional attachment to something beyond the realm of human societal constructs.

Another reason why renewable energy projects are not well-received in rural towns, even those that would greatly benefit from clean energy, is that renewable power is framed as an environmental issue (a "greenie, tree-hugger" problem). This obviously does not align with many rural towns' conservative views on environmental topics, especially their skepticism of human-caused climate change and the scale of fossil fuel pollution. Local renewable energy projects framed in an economic light would be much better received by conservative small towns. Support for renewable energy is not strongly correlated with people's environmental beliefs; economic and democratic factors are more important indicators of a town's support for clean energy projects (Olson-Hazboun et. al., 2016). An example of this is Georgetown, Texas, a conservative town in the middle of oil country that is one of the first cities to be 100% wind powered. The shift to green energy was not made with environmental ethics at the forefront, rather it was almost entirely an economic decision: wind and solar power are more predictable and plentiful and prices do not fluctuate as wildly as gas and oil (Shapiro, 2017).

Although political ideology is not as important in Crested Butte's view of local renewable energy projects, in other rural Colorado mountain towns where conservative ideals are the norm, great care must be taken in crafting legislation for green power. Many conservative counties opposed the 2004 energy mandate because they resented the exercise of big government power. However, if policies are written and framed as reducing government waste, creating jobs, stimulating struggling oil and mining towns, and giving local communities control over energy policies –appealing points to conservatives – the political chasm is mostly bridged between those with strong environmentalism values and those with strong individualism values (Hess et. al., 2015).

Environmental Impacts:

Although renewable energy development is an important step in mitigating the effects of climate change, conserving natural resources, and controlling pollution, it is still land development. As such, there are environmental concerns with developing green energy, from land use to resource use.

As mentioned in Section 2, many of the lands suitable for wind power cannot be used because of their sensitive environmental structure and remoteness. Wind farms, due to their large size and current operational design, create some very visible issues. Notably, the spinning blades can threaten birds. Although some case studies note that the threat of wind turbines to birds is negligible, in other places large numbers of bird deaths have been reported and have spurred further studies on the wind farm threat (Kellett, 1990). This suggests that the danger posed by wind turbines to birds is dependent on the location, the bird species, and the design and planning of the wind farm. However, unlike solar farms, wind farms take up relatively little space for the amount of energy they produce, so many habitat corridors could be maintained with minimal fragmentation even with extensive turbine development (Holechek et. al., 2015).

On the other hand, large-scale solar farms that can support urban centers – typically the biggest energy consumers in a state – are much trickier. Although they are a constant and reliable source for desert regions, the large area required for their construction creates problems with habitat fragmentation and degradation (Janke, 2010). Most of the Rockies and desert Southwest are protected and development is prohibited or permits are difficult to obtain. Even on land open for development, desert habitat is fragile and sensitive to disturbance, so the intensive construction of solar farms can greatly damage these environments. For example, an estimated 769,230 ha of the threatened Agassiz's desert tortoise (an ecological engineer) habitat will be directly and indirectly affected by a proposed USSEDO (utility-scale solar energy development and operation) solar project. Additionally, the water used for cooling the photovoltaic systems strains the already limited water resources for desert regions (Lovich & Ennen, 2011). Additionally, a significant portion of Colorado is too mountainous to construct solar farms. However, photovoltaic panels can be attached to existing human structures without further disturbance to the natural landscape (excluding the mining for the metals needed to build PV panels). Essentially, though renewable energy projects are less damaging than fossil fuels and nuclear, construction of wind and solar sites still requires extensive research and analysis on the ecological functions of the land and how development will alter the region before projects begin.

Conclusion:

Crested Butte and the greater Gunnison County exemplifies the complications of renewable energy in rural mountain towns, demonstrating the need to reconcile both the aesthetic worth and energy needs of these areas. Colorado should allow communities more control over energy policies and development; this allows for local input and tailored projects that fit specific needs of the individual, town, or county. Small-scale wind farms and PV panels on preexisting buildings are the most feasible methods for reaching Colorado's RES goals. Additionally, renewable power cannot be framed as purely an environmental issue if further legislation is to gain public support; green energy must also appeal to the economic and democratic values of those where environmental ethics are not a priority. Finally, the notion that solar and wind farms are a panacea to the state's (and country's) fossil fuel addiction must be changed. Renewable power can damage the environment just like fossil fuels and nuclear power, though typically on a lesser but still significant scale. Renewable energy, especially solar and wind, has enormous potential in Colorado, and as long as planning of energy projects encompasses environmental, ideological, and economic factors, the state is on track to dramatically reduce its reliance on fossil fuels while maintaining a strong economy and protecting its natural lands.

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Appendix:

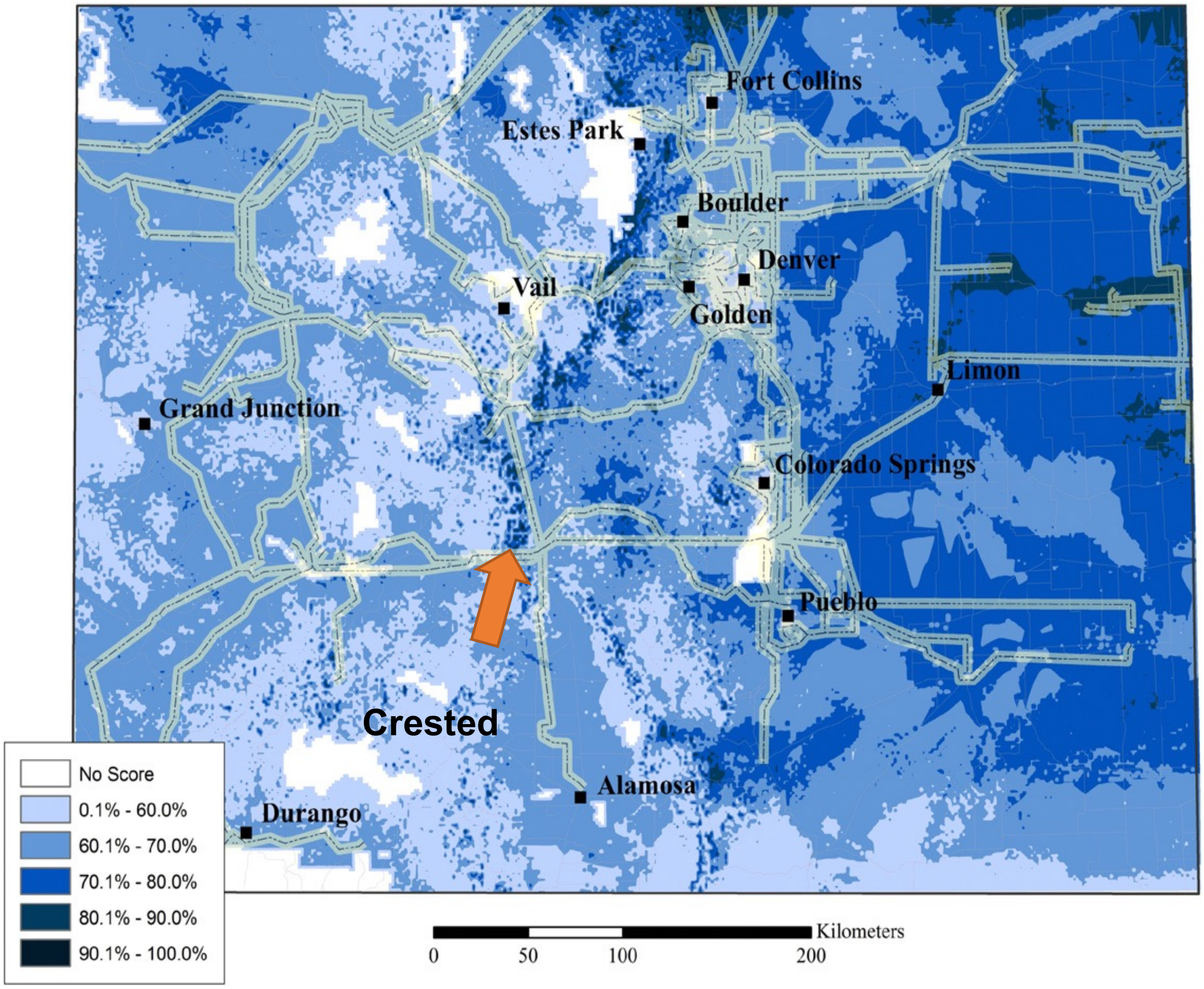

Fig. 1. Ideal wind farm locations based on GIS criteria. Dark areas indicate high wind potential.

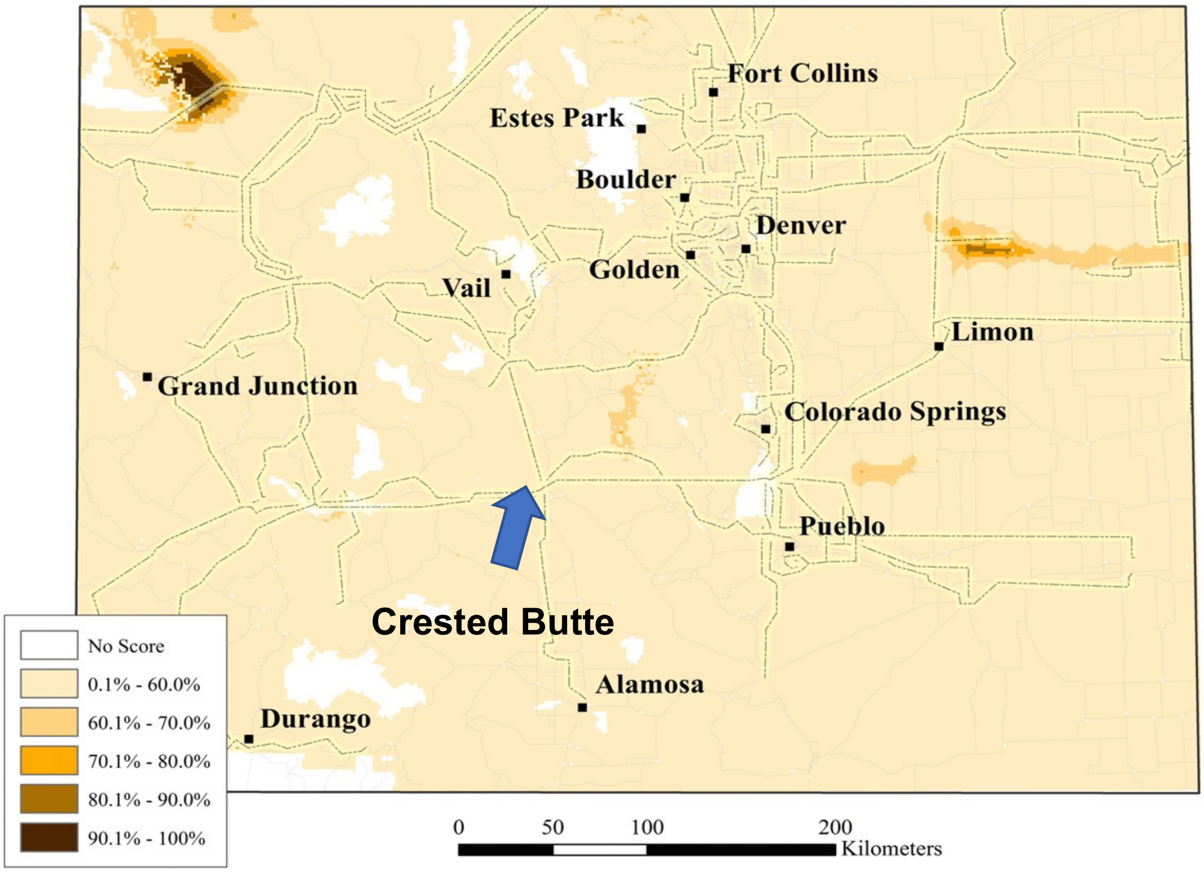

Fig. 2. Ideal solar farm locations based on GIS criteria. Dark areas indicate high solar potential (for large farms).

The Impacts and Evolving Practices of Cattle Ranching

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Abstract:

In the modern day, meat and especially beef is appreciated and consumed in large quantities by many societies and cultures worldwide. With the United States being one of the top consumers, it is important to take into consideration what the environmental repercussions are in the process of bringing that juicy burger to our plate. There are different methods of raising cattle, the two most widespread being ranching and concentrated animal feeding operations (CAFOs). The focus of this paper is on ranching and the grazing of cattle because it is the prevailing practice in Colorado and other Southwestern states. The paper will discuss the history of ranching in Colorado, its environmental impacts, and sustainable and smart practices to recognize and mitigate them.

Introduction:

Through careful monitoring and management, ranching can have positive environmental impacts such as providing an intermediate amount of disturbance as a result of grazing as well as providing fertilizer in the form of dispersed manure. If grazing is not managed properly, however, it has a wide variety of negative environmental impacts not inherently obvious, but important to understand and mitigate. Some impacts are on a larger scale such as overgrazing and eutrophication, the influx of too many nutrients into a water source, whereas other impacts are more localized such as the threat to sage grouse habitats in the East River watershed (Beck 2000). Cattle ranching is an integral part of our society, so to ensure its future success and well being of the human race, we must take into consideration its environmental impacts and apply smart, sustainable practices to preserve integral ecosystems and species.

Ranching in Gunnison County and Colorado:

Ranching has been a driving force of the economy of Gunnison County for over a century and is appreciated by the locals for its economic benefits and preservation of open spaces. During the 1880s when the Gunnison County mines were in full swing, farms and ranches were created in the valleys. After the Meeker Massacre in 1879, the Tabeguache Utes were relocated to the Uintah Reservation in Utah and the valley was made vacant for agriculture by the white settlers. At the time, cattle and sheep ranching were the most profitable practices in the valley and by 1900, they had surpassed mining as the biggest economic driver of the county. In 1900, Gunnison County created an annual tradition called Cattlemen's Days that hosts a rodeo to celebrate the county's agricultural history (Encyclopedia nd).

The first influx of cattle ranching into Colorado was in 1866 by Texan cowboys for three reasons: the availability of grasslands, the removal of the native Utes, and the nutritious nature of the grasses. At first, ranchers used open rangeland for grazing. They had spring rounds to brand calves and release the cattle into the mountains and fall rounds to bring them back to the valley for the winter. Eventually these open land grazing practices were substituted for more localized methods such as those of the ranchers in Gunnison County during the mining era (Fuqua nd).

When the Colorado College Conservation Biology class met with the Crested Butte Land Trust during our visit to the area, we were informed that the people of Crested Butte and Gunnison County have historically appreciated agriculture as both an economic sector and as a way to preserve open lands. This perceived public appreciation of agriculture was supported in a study conducted in the years of 1996, 2001, 2006, 2011, and 2016 by the Colorado Department of Agriculture. In 2016, they surveyed 1,000 people and asked them a variety of questions having to do with land, food prices, and other subjects. In one of the questions, they asked surveyees which of four reasons for maintaining agricultural land and water use in Colorado was most important to them. Open spaces ranked number one with a 60% response rate followed by production, jobs, and heritage in order. In the four other years of the study, the importance of ranchlands to maintain open spaces also had very high response rates with a peak of over 70% in 2001. Other questions in the survey also indicated that the public attitude in Colorado is predominantly positive towards cattle ranching and agriculture, and most people appreciate the role that both of these industries play in environmental and economic spheres (Chriestenson 2016)

Environmental Impacts:

Cattle ranching can have many positive influences on the economy and people's perception of the natural environment. The actual impacts it has on the environment, however, are oftentimes not those that are commonly perceived or even considered by most people. With responsible grazing management, the negative impacts of ranching can be mitigated and there is even potential for some positive impacts. Unfortunately, in many cases ranchers do not properly manage their cattle which can create a cascade of negative environmental impacts that may damage whole ecosystems, and reduce the potential for future cattle ranching in a given area.

A study conducted by Tichenor et. al assessed and contrasted the environmental impacts of grass fed (GF) versus dairy beef (DB) cattle ranching practices. It found that many negative impacts came from GF beef, for example, global warming potential, agricultural land use, and eutrophication potential. The unit they used to determine the extent of the impacts was 1 kg hot carcass weight or HCW (Tichenor 2017). This unit is based on the weight of a fresh carcass after its head, organs, feet, tail, hide, and blood have been removed which is typically about 60% of the live weight (*Canadian* nd). The global warming potential for GF is 33.7 kg CO2-eq per kg HCW which is significantly higher than DB at 12.7 kg. In terms of agricultural land use, GF uses about 122m squared per kg HCW which is a large land commitment and subsequently has a sizeable impact, whereas DB only uses 17m squared. The eutrophication potential for GF is 184.8g of phosphate per kg HCW and only 75.6g for DB (Tichenor 2017). These specific impacts are all higher for GF than DB, however, this is not to say that DB doesn't have its own wide ranging negative impacts.

Some grazing impacts that are localized to Gunnison County are found in the sagebrush steppes as well as the subalpine forests. In the sagebrush steppes, Beck et. al did a study that analyzed both the positive and negative impacts of cattle grazing on sage grouse habitat. It found that trampling of sagebrush by herds leads to its decreased growth rate and subsequently less grouse habitat. On the other hand, when the cattle graze the areas surrounding the sage, it creates less competition allowing for a higher growth rate and creating more grouse habitat in some places. The authors also discovered that secondary succession and elevated disturbance caused by grazing can negatively affect grouse habitat by encouraging the growth of weedier plants. These new, weedy plant communities provide opportune habitat for ground squirrels which were shown to be a leading factor in sage grouse nest destruction in a study conducted by Giesin (Beck 2000).

The second dominant ecosystem in Gunnison County is the subalpine forest which is typically dominated by ponderosa pine at low elevations and by douglas fir, grand fir, and western larch at higher elevations. In 1984, Zimmerman and Neuenschwander did a study in the foothills of the Bitterroot Mountains of Idaho in which they compared grazed and ungrazed sections of forest. One area had been grazed heavily between 1925 and 1941, at which point a large exclosure was built to exclude cattle but not deer or elk. When the study was conducted a few decades later, the grazed ponderosa pine stands had twice the amount of young trees compared to the ungrazed stand within the exclosure. The conclusion the authors came to is that livestock grazing is the most influential aspect in creating the right conditions for a high success rate in young tree growth, which leads to a decrease in the overall fitness of the forest ecosystem. Another author who did a similar study in 1951 came to the conclusion that the decreased amount of competition from grasses caused by grazing allowed for small trees to be more successful. In cases such as these, when forests have more trees and less ground vegetation, they are more prone to spreading disease and being ravaged by wildfire (Belsky 1997).

As demonstrated by both localized and broad ranging studies, cattle ranching and grazing can have a variety of positive and negative impacts on ecology. In most cases, the negative ones, such as extensive land use and overgrazing, outweigh the positive ones, such as intermediate disturbance that helps maintain biodiversity. This makes it all the more important to raise the public's awareness of these issues and implement sustainable grazing practices.

Smart and Sustainable Practices:

Sustainable grazing practices are essential for the long term prosperity of ranching and the conservation of ecosystems and ecological processes that we humans and many other animals depend on. Two ways to improve rangeland sustainability are consistent, responsible grazing and Land EKG monitoring (the term EKG is based on the electrocardiogram test which is given to monitor the heart's electrical activity).

In Colorado, a study conducted over 42 years observed the variation in species diversity in exclosures under three conditions: no grazing, grazing of only wild animals, and mixed grazing between wild and domestic animals. The exclosure with no grazing had the most shrub cover but the lowest species richness because there was too much competition and certain plants dominated large areas. The exclosures with wild and mixed grazing, on the other hand, had intermediate disturbance and a higher species richness. The authors concluded that grazing by both domestic and wild animals had noticeable influences on the plant community structure as well as the ecosystem processes (Manier 2007). The results of this study demonstrated that grazing can have positive impacts on the restoration and succession of ecosystems.

To increase these positive impacts, however, it is important to take into consideration responsible grazing practices. In 2010, the Department of Agriculture created a five year plan called the Grazing Land Conservation Initiative (GLCI) Strategic Plan. Its vision was to maintain sustainable grazing lands to provide for a healthy environment and its goals included providing guidance to landowners to implement conservation programs. Upon request, landowners could receive research management systems which were reports providing conservation options through an analysis of soil, water, air, plant, and animal resources (*Natural Resources*). In efforts to protect the ranchlands and the environment, this type of outreach is necessary to help organizations and individuals understand what responsible grazing entails.

Land EKG monitoring was developed by Charley Orchard in 1994 to improve understanding about whether the ecological health of grazing lands were improving or degrading. It is a helpful tool for many parties, including ranchers, scientists, and conservation organizations to evaluate rangeland health and make effective and sustainable management decisions . Before Orchard established this method, 60% of holistic management practitioners exercised some fashion of monitoring but most of them did not understand the significance of the numbers they gathered, and thus were not able to use their results in making decisions. To implement the Land EKG method, it is necessary to set up permanent transects of 200 feet and have four established points within each transect. Then at each point, photos are taken and 5 square feet of the soil surface are inspected for four ecosystem processes: the mineral cycle, the water cycle, the plant community, and the energy flow. Many subcategories are examined under each category. For example, to determine the water cycle, gullies, crusting, density of plant cover, and erosion are taken into consideration. Orchard noticed that much of the time ranchers tried to protect their transects from influences such as fire, new grazing patterns, or changes in management. The idea of Land EKG monitoring is to guide management strategies based on constant developments in environmental and management factors so he encouraged ranchers to leave their transects to natural devices (Orchard nd). By innovating this new approach to monitoring and better understanding natural and human influences on rangelands, Orchard prompted an awareness amongst ranchers and the public that can serve as a foundation for the development of more environmentally friendly and sustainable ranching practices.

Conclusion:

For many decades, scientists have done research regarding the impacts of cattle grazing on the environment and strategies such as Land EKG monitoring have been developed to facilitate rangeland conservation. The scientists' findings have included negative impacts on watersheds and rivers such as eutrophication from fertilizers and manure, excessive land use and habitat destruction, and region specific impacts such as destruction of sage grouse habitat in the East River Watershed of Colorado. With this broad base of research and knowledge available, it is up to land managers and the public to put it to good use. Now is the best time to continue creating and implementing smart management techniques so that we can preserve our priceless natural environment and continue to provide for a thriving cattle industry.

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The Impacts of Climate Change on High Alpine Ecosystems of the Rocky Mountains

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Abstract:

Climate change as a driving factor for species migrations, changes in ecosystems, and extinctions is well documented. Many studies and articles discuss this possibility. Ecosystems that have evolved under particular conditions have the potential to be affected severely by these changes, as their flora and fauna have evolved over thousands of years to inhabit these particular environments. The high Rocky Mountains represent a unique environment that has the potential for massive biological losses from climate change. Climate change will cause the lower limit of species ranges to be pushed upwards to cope with the warming and will have widespread effects on the biological makeup of alpine ecosystems. The already present isolation associated with alpine ecosystems will be exacerbated as ranges are pushed upwards, and species will face challenges associated with genetic isolation and fragmentation. Combined with the shifting climate, the isolation leaves ecosystems little chance of surviving large scale climate changes.

Introduction:

Most often when addressing climate change in the United States, the ocean and the cities lining the coasts receive the majority of concern. With rising sea levels, this worry is quite warranted. Yet, on the other end of the spectrum stand the high mountains. Each area represents extremes-the highest and lowest points. Perhaps from some perverse duality then rises the fact that both of these areas stand to lose immense amounts of biological value as our climate changes, and both areas will be some of the first to be drastically affected by the warming of the planet. Crested Butte and its area hold true to this role.

There are many complex factors associated with climate change that lead to changes in ecosystems and species extinction. At some point, almost every ecosystem will feel the effect of climate change. The uniqueness of this impact on the Colorado Rockies is that the organisms that reside in the alpine will be the first to feel these effects because of their particular physical and biological traits. The Rocky Mountains represent an intensely variable climate that has frigid temperatures in the winter, warm summers and a short growing season. In addition to these strains are droughts, disease, and intense weather. All of which creates a habitat that is both sensitive and incredibly well adapted to deal with its environment. Compounded upon the fragility of the alpine ecosystem is the isolation of the high alpine. As temperatures warm, species inhabiting lower ranges will be forced upwards, furthering isolation. This leads to fragmentation as the lower end of the alpine environments change in their biological and physical makeup. As a result a host of other issues associated with isolation such as genetic drift, inbreeding, and loss of genetic diversity will occur. The strain put on the high alpine from climate change and the increasing isolation of alpine populations will make the Rocky Mountain ecosystem particularly susceptible to extinctions.

Ecological and Niche Specificity of Alpine Organism:

As a general rule, everything is more intense at higher elevations. Winters are extremely cold. There is less atmosphere to protect flora, so they must find a balance between photosynthesis and tolerating UV radiation. Winds and weather patterns are also more intense, with larger thunderstorms striking daily during the summer and snowpack that is usually many meters thick. In order to cope with the intense climate of the alpine tundra, species have had to develop many specific adaptations to live. Many alpine mammals, for instance, have adapted their hemoglobin function to cope with high altitude and avoid hypoxia (Storz 2017). Aspen bark has adapted to contain chloroplasts, and during the early spring can be responsible for a high percentage of the total photosynthesis (Pearson, 1958). This gives the deciduous tree the advantage that it needs to grow and be competitive in such a short season. Other trees, like the Engelmann spruce and the Bristlecone pine, have a phenotype entirely different than their lower elevation relatives. They form krumholz at high elevation or take on stunted and misshapen forms to cope with high winds and severe weather. Similarly, alpine flowers have adapted to grow close to the ground to avoid the winds that ravage the higher elevations and conserve more energy, showing the incredibly specific attributes organisms have adapted to in order survive in such an unforgiving area. Additionally, the Engelmann Spruce and the Subalpine fir have ranges from 9000 ft. to tree line (US National Park Service). These trees have adapted to a very specific high elevation habitat, and as temperatures warm and the climate changes the potential decrease in the size of their range could be devastating.

Changes in Tundra Ecology from Climate Change:

Studies of climate change on the high alpine environment are scarce and certain aspects of it are little understood. However, climate change effects have been studied in tundra environments in the far north tundra. These environments are very similar to those found on high mountain slopes, with the main difference being a much higher altitude on the Rocky Mountain slopes. With this constraint in mind, arctic tundras represent a way for us to examine effects on other tundras as well.

Species facing climate change can do three things: adapt, shift ranges, or go extinct. Sage is able to shift its range in response to climate changes. This typically lower elevation plant becomes much more frequent on sites that are exposed to an increase in average temperature over a long period of time (Perfors et al. 2003). Another study analyzing plots of land in the tundra environment found that climate change increases shrub height as well the abundance of evergreens. Moreover, it found that there was an increase all around in the frequency of shrubs, forbs, and rushes in these plots and a decrease in bare ground, all of which is possibly linked to increased summer temperatures (Elmendorf et al, 2012). This demonstrates how, as a result of warming, lower elevation species can become more prominent at higher elevations, and how plant cover can change in tundra environments.

Changes in the makeup of plants, specifically the trend of more plants that a have higher cover, could force out many of the small and historically plentiful alpine plants. These plants would only be able to grow in higher regions where shrub growth was still restricted and would cause a significant loss of habitat for high alpine organisms. Similarly, it has been shown that temperature is the limiting factor for the upper ranges of conifers (Ettinger et al, 2011), as well as willows, which are also limited by summer temperatures in their rate of growth and their elevation (Forbes et al, 2012). An increase in summer temperatures could cause the expansion of the ranges of these species into the alpine. This would functionally push treeline up the slopes and cause less alpine environment and more competition for alpine plants. Because alpine ecosystems can't move upwards, and the rate of anthropomorphic climate change makes any adaptations to climate unlikely, extinction eminent for unprotected alpine ecosystems.

Sky Islands and Island Biogeography:

The specificity of the flora and fauna puts them in a dilemma as the climate changes. Many other creatures can either migrate uphill to higher elevations to cope with the changes or shift their range. Alpine organisms are already at the "top" and have nowhere to go to seek refuge from the changing climate. Moreover, these organisms, especially in the form of plants, are not able to traverse the lower sections and valleys of mountain ranges because of how specific their niche adaptations are. Similarly, other animals like the pika, can't overcome the isolation of mountains. For a pika, which only lives on the rocky scree of high alpine slopes, it is unlikely to traverse the lush valleys thousands of feet below in search of new habitat. As temperatures rise, alpine organisms' ranges will have nowhere to go but up. This accentuates the already existing island-like nature of the high alpine, creating islands that are smaller and farther away from each other.

To understand the ramifications of this the island biogeography model must be taken into account. This model, created by Robert H. MacArthur and Edward O. Wilson in 1967, was formulated with islands in the traditional sense, but works equally well with any isolated area, like a mountain. The model states that the extinction and colonization rates of an island are primarily affected by its distance from the mainland and its size. Islands that are closer to the mainland will have a greater influx of colonization. Additionally, islands that are larger will be able to host and maintain a greater number of organisms and have a higher biodiversity. Inversely, a smaller island will have a higher extinction rate. Combining these ideas, a small island close to the mainland will still have relatively high biodiversity because as species go extinct new ones will arrive. Larger islands far from shore will also be biodiverse because, while fewer new species are arriving on the island, there are also fewer species going extinct. At the extreme low end of the biodiversity spectrum are small isolated islands, which can be expected to have the least biodiversity.

It has been shown that some species are unable to share genetic material between high altitude environments (Kramer et al 2010). This essentially creates sky islands, in which the large changes in environmental and physical characteristics isolate individual alpine ecosystems. Sky islands act in the same way as a normal island except for one key difference: sky islands are isolated by areas of lower elevation or non-traversable areas between them, whereas marine islands are isolated by water. Plants that rely on insects as pollinators are particularly susceptible to isolation from sky islands compared to plants that are pollinated by hummingbirds (Kramer et al 2010). Additionally, climate change has been shown to fragment pika populations (Stewart et al. 2017) demonstrating that sky islands act as isolating mechanisms for larger mammals as well. Islands have always been identified as areas of particular risk for extinction and loss of biodiversity. The primary issue with the mountain sky islands is that as the effect of climate change becomes more prevalent the islands will increase in distance from each other and decrease in their size. This phenomenon will cause genetic isolation and extinction.

Susceptibility to Extinction and loss of Biodiversity:

There are a host of issues facing all ecosystems as human actions cause a global rise in temperature. The uniqueness of the alpine tundras in the Rocky Mountains is that they are in a position to feel the full brunt of these changes, they will be some of the first ecosystems to be affected because of their sensitivity, and organisms residing in the ecosystems will be poorly prepared to handle changes because of their isolation. Alpine ecosystems have a host of features that make them more susceptible to extinction. Islands habitats, small population sizes, few populations, narrow ranges, limited dispersal ability, and specialized niche requirements have all been identified as factors that make extinction more likely to occur (Primack et al. 2016). Alpine ecosystems embody most, if not all, these factors. Moreover, as ranges are pushed higher by climate change, populations that can only exist at high elevations will become more isolated and face problems associated with isolation like genetic drift, inbreeding and overall loss of genetic diversity. This, in combination with the drastic changes in climate predicted in the next hundred years, will put tremendous strain on alpine environments with little hope of them being able to cope with the change.

Conclusion:

When trying to manage climate change impacts in the Colorado Rockies, it is important to understand that there is a host of different issues associated with climate change facing alpine ecosystems, and in response, any efforts at conservation must be multifaceted. As such, monitoring is key to success of climate change conservation in the alpine. Areas like the Rocky Mountain Biological Institute (RMBL) near Crested Butte are invaluable for the long-term monitoring and data they have. The establishment of more sites like RMBL will be key in the future. Truly though, the only sustainable way to help alpine tundras is to stop all human activities associated with climate change. However, this is unlikely to happen, so management should focus on minimizing impacts. Focus should be put on trying to protect all alpine tundras with some form of conservation easement or state as well as federal designation. Special focus should be put on areas that represent a bridge between sky island environments. Conservation efforts should also be focused on areas that have high volumes of land above tree level and high connectivity between alpine environments, in order to minimize effects from island biogeography. In these areas special efforts should be made to avoid any excessive levels of human contact and any human activities that contribute to fragmentation. Ultimately though, our efforts on a local level can only hope to slow the inevitable destruction of pristine and beautiful alpine habitats.

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Invading Colorado's Most Prized Landscapes: Impacts of Noxious Species

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Abstract:

Colorado is home to hundreds upon hundreds of non native noxious weed species. With some of the most famous mountainous landscapes in the country, the state is visited by many tourists and recreationists whose activities inadvertently fuel the spread of these invasive species. Many endangered species like the Green Back Cutthroat Trout are threatened with extinction because of the ability of many noxious species to out compete native species. The propagation of invasive species must be combatted through diverse community efforts including public education, travel/transportation precautions through vulnerable regions, and the implementation of mitigation tactics in the coming years.

Introduction:

A wide range of human activity has impacted the natural environment of the Rocky Mountains for over 150 years. The development of towns and cities, industrial manufacturing, mining, livestock agriculture, and forest fires all have caused well documented harm to the ecology of the region. While the environmental impacts of each of these human activities must be researched and addressed by all stakeholders, the consequences of the introduction of invasive and non native plant and animal species by human beings is often under-appreciated as another major threat to the biodiversity and ecosystems of the Rocky Mountains. During the Columbian Exchange, in the 15th and 16th centuries there was a widespread transfer of plants, animals, and microbial pathogens between the American and European continents. Since then the Rocky Mountain region has been wrought with ecological issues stemming from the introduction of hundreds of alien species. While many of the invasive species found in the United States date back many years, human mediated dispersal of weeds endures in the modern day. Invasive species have many more indirect impacts on ecosystems that can often be overlooked. For example, hemlock woolly adelgid-an invasive insect that kills hemlock trees- also impacts native trout species in streams due to shifting stream conditions like temperature and shade. Meanwhile, another invasive species-white pine blister rust-impacts the Clarke's nutcracker through destroying their natural food source the whitebark pine. (Sutherland, 2010) These kind of impacts can have major domino effects leading to trophic cascades and decimation of species. Education and control strategies are necessary to preserve the remaining healthy ecosystems and native food webs of the natural world.

Impact of Invasive Plant Species:

Invasive plant species cause a variety of ecologically damaging impacts to the ecological system they occupy. First, they can outcompete native species which can lead to extinctions and decreased biodiversity. Noxious species can also financially impact stakeholders in agricultural settings. Invasive species lead to more homogenized habitats that lack native species diversity necessary for a healthy ecosystem. While much attention is paid to the competition between native and non native species for water, sunlight and nitrogen, pollination is another key source of competition. Invasive species tend to outcompete native species for pollinators. (Martin, 2004) This phenomenon has been studied in the Crested Butte region of Gunnison by researchers at The Rocky Mountain Biological Laboratory. Their focus of the study was on the invasive plant species *Linaria vulgaris*, originally introduced to Gothic as an ornamental flowering plant, and the native species *Potentilla pulcherrima*. Both are yellow flowering plants pollinated by bumblebees. These two species have a similar range and flower at the same time in the season making them ideal for assessing pollination competition. Ultimately, the study concluded that bumblebees visited *Potentilla pulcherrima* 588 times when *Linaria vulgaris* was not present and only 459 times when the *Linaria vulgaris* was present. (Martin, 2004) Clearly invasive species and are a threat to native species continued viability into the future. However, non native plant species are not the only issue facing the ecological systems in the Rockies.

Impact of Invasive Animal Species:

Exotic, invasive insects are increasingly problematic in modern times fraught with warming temperatures and increased globalization. The Emerald Ash Borer was first found in Colorado in 2013, 11 years after it was first detected in the United States in Michigan. (Colorado State Forest Service) This insect kills Northern American Ash trees and does not experience predation from any other species. The Emerald Ash Borers burrow into tree bark and cut off the flow of nutrients and water to different parts of the tree. Around 15% of Colorado's trees in the forests of the Front Range are Ash. The most common means of spreading this species is through the transportation of firewood and other Ash tree products. (Colorado State Forest Service) Colorado forests are especially vulnerable because of the ease with which the beetle can be spread and the shear number of trees that are susceptible to the impact. The Colorado Forest Service suggests chemical treatments, tree removal and replacement to control the infestations.

Another one of Colorado's most problematic invasive animal species is the Northern Pike Fish. The Northern Pike are large in size, often weighing up to 30 pounds. They were introduced into Colorado river systems in the 1950s and are a huge threat to native and endangered fish species in the state due to their large appetites. They pose such a major threat to the survival of native fish that Colorado Parks and Wildlife initiated a twenty-dollar reward to fishermen who catch the invasive species in the Green Mountain Reservoir. (Colorado Parks and Wildlife) The species was recently introduced to the reservoir illegally by fishermen interested in stocking the body of water. The Northern Pike presence in the reservoir is particularly worrisome due to the potential for some of the fish to escape into the Colorado River and threaten some of Colorado's most endangered species including the Colorado pikeminnow, humpback chub, razorback sucker, and bonytail. (Colorado Parks and Wildlife)

Human Mediated Spread of Invasive Species:

With the huge environmental toll caused by invasive species in Colorado, it is important to develop mitigation strategies to limit the ways in which human beings further the spread of invasive species into this region. Vehicles, animal agriculture, clothing, pets, and recreational activities all contribute to the dispersal of invasive weeds. In fact, in an experiment conducted in Freiburg, Germany, scientists determined that mountain bikes can act as mechanisms for seed dispersal. This has the potential dangerous effect of spreading invasive species to new regions and disrupting natural food webs. While most seeds detach from mountain bike tires within 5-20 meters after their attachment, some seeds can remain on tires for up to 500 meters. (Weiss, 2010) In cases of wet conditions seeds were even more likely to travel farther distances on bike tires. This means that bikes can be responsible for introducing species to completely new habitats. Bike trails often start at roadways which presents the problem that seeds transported on cars can then be transported deep into backcountry regions by bicyclists. Suggestions to mitigate the impact of mountain bikes include public educational efforts aimed to support the cleaning of mountain bikes prior to beginning a ride in a new habitat, and focusing weed control efforts at trailheads. (Weiss, 2010) Furthermore, bikers should avoid riding in wet regions or following a heavy rainfall. Hiking boots also often transport seeds great distances. Seeds can travel up to 5000 meters attached to hikers' boots. (Ansong, 2015) Public education efforts to minimize these impacts must be considered in Crested Butte, where native species of wildflowers are prevalent but also vulnerable to out competition by alien species.

Another way humans play a role in the spread of noxious species is through forest rehabilitation projects. Due to years of fire suppression policy in Colorado, many forests are considered too dense and therefore extremely vulnerable to forest fires and insect infestations. In response to this issue, many thinning operations have been conducted in forest regions. In order to access the sites for these projects roads have been constructed. These roads have been found to be havens for noxious species and the means by which noxious seeds are dispersed into forest land. (Birdsall, 2012) The regions that have had thinning or burning operations tend to be more likely to experience the proliferation of invasive or non native species. Furthermore, when major fires do occur due to past fire suppression, many native vegetation and seeds can be decimated leaving room for the growth of invasive species. (Sutherland, 2010) The Crested Butte Mountain Resort has engaged in some forest thinning operations in partnership with the Forest Service in recent years. While these projects are often necessary to maintain healthy forest habits, the resort ought to closely manage and monitor regions that could be susceptible to weed growth after the operations.

Another unpredicted human mediated introduction of noxious species is, ironically, through control projects dedicated to clearing the invasive Tamarix insect species. In a study conducted in Southwestern river regions physical removal of the Tamarix resulted in rapid secondary invasions of other weed species that occurred within zero to three years while bio control treatment (introduction of a beetle) resulted in secondary invasions in five or more years. (González, 2017) Usually, ecosystems have a variety of subordinate invasive species that, given the chance, will proliferate in the disturbed region previously occupied by the dominant species. Initially, the proliferation of Tamarix along rivers was a result of the construction of dams and water practices of the twentieth century, but today, it is from this new challenging secondary growth. Tamarix disrupts the riparian habitats by causing a shift in floodplains, salt accumulation, and a change in soil microbial communities. (González, 2017)

Invasive Species and Control Practices in Crested Butte, CO:

Crested Butte is treasured by individuals worldwide for its plentiful native wildflowers and its pristine ecosystems. With the growing tourism and recreation in the region, the native flora and fauna are threatened with overuse, the introduction and spread of non native, and invasive species. Invasive weeds have the potential of wiping out the diverse wildflower populations and creating a monoculture that lacks healthy biodiversity. To combat this threat, Crested Butte developed a noxious weed management plan. The town also created a noxious weed advisory board with the following charter: “to develop a Weed Management Plan for the integrated management of designated noxious weeds; To declare noxious weeds and any state noxious weeds designated by rule to be subject to integrated management; To recommend to the Crested Butte Town Council that identified landowners be required to manage noxious weeds on their property.” (Town of Crested Butte Noxious Weed Program) The board also aims to educate property owners about noxious species, monitor public and private land for weed levels, and determine regions in particular need of weed removal efforts. Board members come from various organizations in the regions including a representative from the Crested Butte Land Trust, the community school, the Parks and Recreation Department, and the town council. The board has created a noxious weed watch list detailing the physical identification traits of the species, how to educate the public about it, and how to control its spread. Some major noxious species in the Crested Butte region include Dalmatian toadflax, Canada thistle, Absinthe wormwood, and Russian Knapweed among a number of others. (Town of Crested Butte Noxious Weed List) The town has specific chemical, cultural, and mechanical control methods they suggest for each individual species. For example, the Dalmatian toadflax can be controlled by use of the defoliating moth, *Calophasia lunula*, a root boring moth, Eteobalea intermediella, herbicide spraying, or seeding disturbed areas surrounding the invasive species with native grasses such as Thickspike Wheatgrass or Streaband Wheatgrass. (Town of Crested Butte Noxious Weed Program) A key role of the Crested Butte Noxious Weed Board is educating the public about what common landscaping plants are actually incredibly invasive. Shockingly, Dalmatian toadflax is sold in nurseries and found in home gardens which demonstrates the need for further education of the public.

Conclusion:

The state of Colorado Colorado represents the majestic home of the Rocky Mountain West, with its beloved native wildflowers, forests and incredible vistas. Crested Butte is a microcosm of the Rocky Mountains, rich in natural beauty as well as biodiversity. With Colorado's population booming and its tourism expanding, its natural wonders are in danger. Outdoor recreationists are trampling native species and spreading non-native invasive seeds farther into the previously untouched backcountry. Meanwhile, noxious insect infestations are killing trees at accelerating rates due to human mediated spread of infected tree wood products. Unknowingly, many Coloradans are planting noxious non native plants in their yards, fueling the proliferation of these dangerous species. Efforts to educate the public must be significantly expanded in order to preserve this precious ecosystem. The threat of noxious, non native flora and fauna must be addressed with the same energy as other environmental dangers.

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Human Impact on a Rising Population of Aggressive Beetle Species

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Abstract:

For almost two decades, populations of aggressive beetle species across Colorado have been steadily increasing. The state of their growth is now considered to be at epidemic rates, as their ecosystems cannot provide enough food forcing their spread. The impact of these populations extends far beyond the rising tree mortality rate; the patches of dead standing trees left in their wake may also be increasing the risk of fire, erosion, flooding, and other catastrophes within these fragile ecosystems. The conditions causing this population explosion can be to linked back climate change and other human-inflicted ecosystem impacts. This dramatic increase is having detrimental impacts on forest ecosystems, which could impact human recreation and development.

Introduction:

When thinking about Colorado, generally the first image to come to mind is towering mountains and luscious forests as far as the eye can see. In reality, the picturesque landscape is marked by barren scars of dead trees upon the hillsides. These standing patches are dead trees are due to a rising population of aggressive phytophagous insects, specifically bark beetles. Bark Beetles are currently the most destructive insects in western coniferous forests, causing 90% of insect-caused tree mortality and 60% US loss of wood growth (Forest Service 2010). Gunnison County has only recently begun to see the impacts of these insects. In 2016, the Spruce Beetle colonized the western portion of Gunnison National Forest. Their spread has not yet reached the Crested Butte area, but will surely impact the town in coming years. Their damage could possibly impact many industries within the town valued for its natural beauty. This dramatic increase is attributed to other major environmental changes, specifically rising temperatures and more frequent and intense droughts. This indicates that the insect epidemics in Colorado's forests are yet another effect of climate change.

Aggressive Beetle Characteristics and Recent Spread:

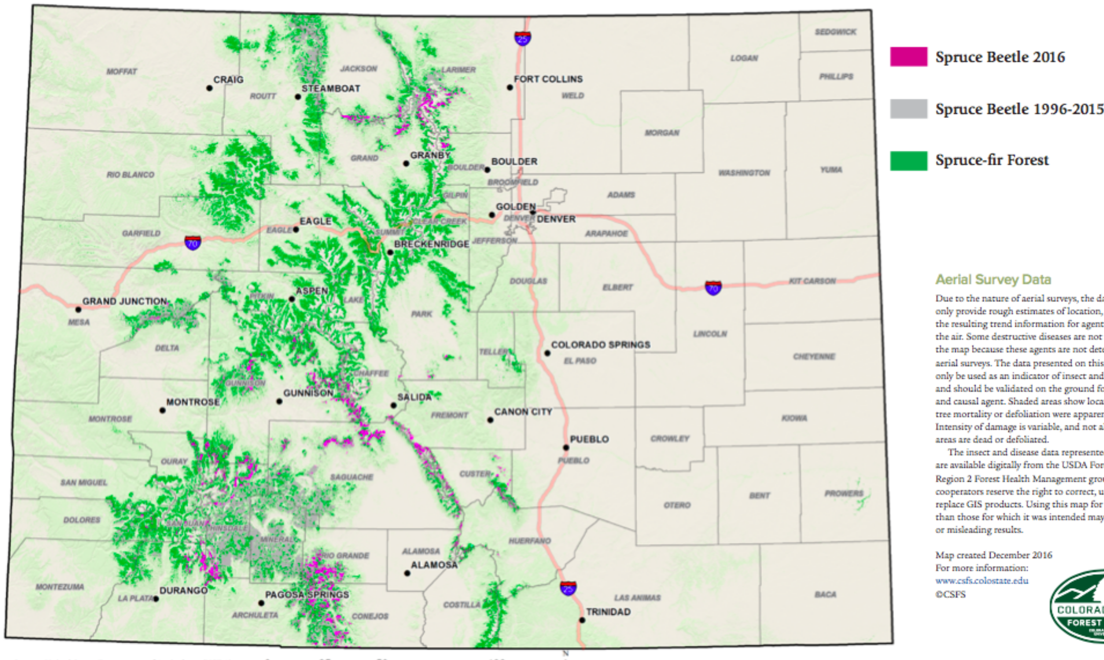
Despite their negative reputation, aggressive beetles are typically considered a natural and vital tool for maintaining ecosystem health. Most beetle species progress through four life stages, egg, larva, pupa, and adult, all of which are spent in the bark of trees which provides their food source of phloem (Forest Service 2010). However, adults are capable of migrating to different trees. The lifespans of these organisms are typically short, usually less than two years, which contributes to their ability to evolve quickly (Hansen 2010). Bark Beetles are a type of phytophagous insect, or insects that feed on vegetation or plant material. They are considered an "aggressive" species, meaning they naturally cause mortality through their feeding habits (Hansen 2010). Insects in this category create disturbance events, facilitating a competitive environment within their habitats in order to increase biodiversity and overall strength of an ecosystem. Bark Beetles share this category with many insects such as worms and engravers.

Recently, bark beetles have been defined by their overly destructive role and aggressive spread in habitats across the US. The most destructive bugs in Colorado are native, and only pose an unnatural threat due to unusual climate conditions. A high beetle population can have dangerous direct and indirect impacts. Aside from decreasing the population of healthy trees, their presence can weaken a tree's defenses and increase its susceptibility to pathogens, such as the associated root disease caused by the Western Balsam Bark Beetle (State of CO Forest Report). Aggressive insects also create fuel for wildfires, which can result in problems for the watershed including flooding and erosion (Potterf 2017).

Bark Beetles are the most prevalent threat facing Colorado forests. Perhaps the most notorious species is the Mountain Pine Beetle, which inhabits Ponderosa, Lodgepole, Whitebark, Limber, and bristlecone pine species. Engelmann and Blue spruce species are also impacted when outbreaks are large (Forest Service 2010). Their flexibility in prey has helped the Pine Beetle establish itself historically as the most aggressive beetle in west, already having killed more than 70,000 square miles worth of trees (Lemonick 2013). However, the Mountain Pine Beetle is on the decline after almost two decades of destruction, in recent years their spread has decreased and populations now remains fairly localized (State of CO Forest Report). There are several other species of Bark Beetles active in Gunnison county, such as the Douglas-fir beetle which impacted 19,000 acres of Colorado forest in 2016 (State of CO Forest Report 2016).

Although the Mountain Pine Beetle has a fearsome reputation, the Spruce Beetle is currently the largest threat to western Colorado forests. This insect effects Engelmann and occasionally blue spruce, and they form new generations every 2 years (Forest Service 2010). This population has earned the spot of most destructive in Colorado for the past 5 years; in the last decade, these beetles have affected over 1.7 million acres of forest, 350,000 acres of which were Engelmann Spruce (State of CO Forest Report 2016). In past years, the Spruce Beetle has been active mostly in the southwestern part of the state and some sections of northern forests. However, this insect is starting to spread to the central part of the state.

Spruce Beetle Activity in Colorado Forests, 1996-2016



Data Source: United States Department of Agriculture (USDA) Forest Health Technology Enterprise Team (FHTET)

Aerial Survey Data

Due to the nature of aerial surveys, the data on this map only provide rough estimates of location, intensity and the resulting trend information for agents detectable from the air. Some destructive diseases are not represented on the map because these agents are not detectable from aerial surveys. The data presented on this map should only be used as an indicator of insect and disease activity, and should be validated on the ground for actual location and causal agent. Shaded areas show locations where tree mortality or defoliation were apparent from the air. Intensity of damage is variable, and not all trees in shaded areas are dead or defoliated.

The insect and disease data represented on this map are available digitally from the USDA Forest Service, Region 2 Forest Health Management group. The cooperators reserve the right to correct, update, modify or replace GIS products. Using this map for purposes other than those for which it was intended may yield inaccurate or misleading results.

Map created December 2016
For more information:
www.csfs.colostate.edu
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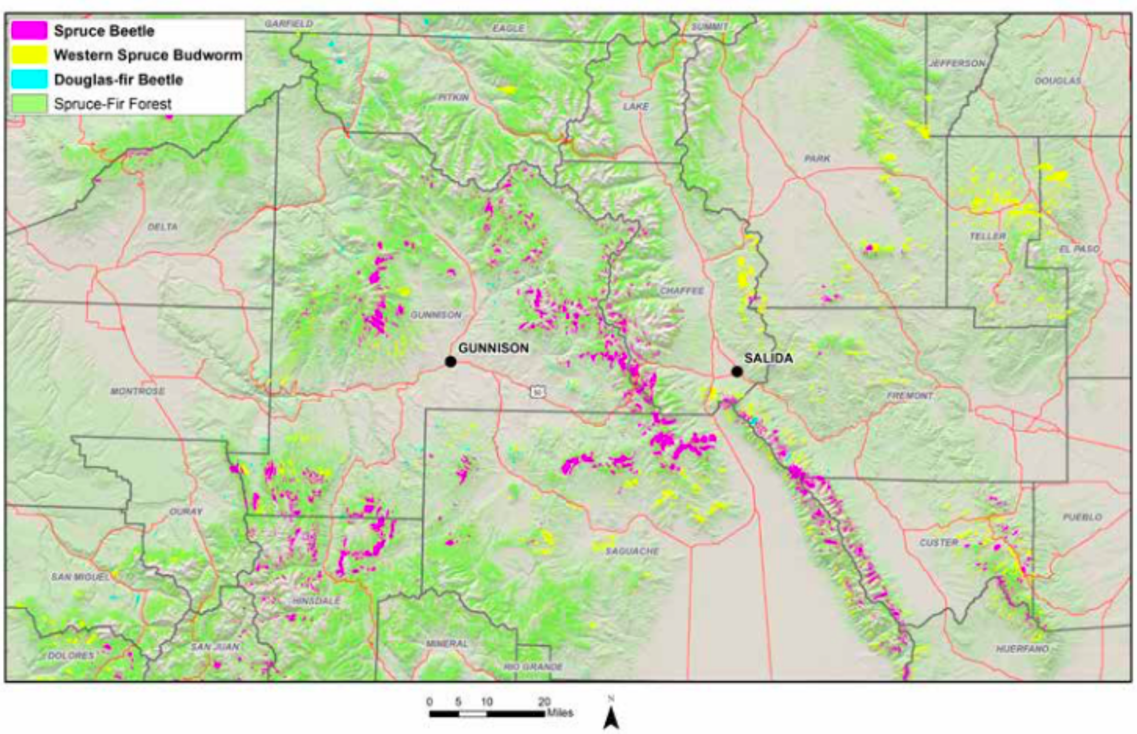
Spruce Beetle, Western Spruce Budworm and Douglas-fir Beetle Impacts in the Gunnison/Salida Area



Other varieties of phytophagous insects also cause massive destruction. The Western Spruce Budworm population is responsible for the destruction of over 226,000 acres of Douglas fir. Douglas-fir Tussock Moth is also present, but their population is rapidly collapsing due to disease (State of CO Forest Report 2016). The invasive Ash Borer also poses a threat. Although the species has been fairly contained to areas near Boulder, CO, organisms have recently begun to expand beyond their previously defined habitat boundaries. Other than bark beetles, the Western Spruce Budworm is currently the only notably active insect in Gunnison county.

Characteristics and Conditions of an Epidemic:

A bark beetle''s role in an ecosystem is typically as a tool of succession. Insects and diseases are necessary for healthy forest ecosystems; they target trees in mature, overly dense forests in order to clear space for new young trees (State of CO Forest Report 2016). This process not only promotes species diversity, it helps strengthen the forest since healthy trees have a higher resistance to ailments and fire. The insects prevent climax forests while environmental circumstances keep their population size at a healthy level. Most healthy trees are naturally equipped with defenses against beetles such as chemical repellants, so the insects only kill unhealthy, weak trees (Lemonick 2013). Temperature is also a factor in keeping a balanced population; annual winter freezes kill off a portion of larvae and assist the decline of older generations (Hansen 2010). A larger percentage of healthy trees also affects the feeding patterns of bugs. The likelihood of a tree to be attack decreases the farther it is from an infestation, so fewer trees are likely to be affected in healthy ecosystems (Potterf 2017). In a perfectly balanced and unaffected ecosystem, aggressive beetle species would not be viewed as destroyers but a natural and healthy part of the environment.

However, these insects can easily become dangerous if the state of their population shifts from an endemic state to an epidemic one. Epidemics are brought on by an increase in the insect's food source; in this case an increase in unhealthy trees. Dramatic climate events and ecosystem changes create homogenous areas of disturbed or stressed trees, decreasing the healthy percentage of a forest (Potterf 2017). As a result, beetles are able to move from tree to tree more easily. The combination of easier and increased targets for infestation creates a positive feedback loop allowing the beetle population to explode. In an epidemic state, the insect population cannot be sustained by only the weak trees of the forest. After this quick expansion, beetles typically will use up the food supply extremely quickly. When there are not enough sickly and old trees to support the population, they turn to atypical prey. The probability of a healthy tree to become infested significantly increases with a higher population of beetles because with more assailants, the natural defenses of trees are easily overcome (Potterf 2017).

In recent decades, the population of aggressive phytophagous insects has inarguably exploded. This population boom is occurring for several reasons. Insects have been exposed to new habitat niches and are expanding to fit this new space, which involves spreading to higher elevations and to new forest ranges where trees are more susceptible and may not contain natural defenses. Aggressive beetles are also remaining active for longer portions of the year than ever before, and their activity increases every season (Lemonick 2013). The increasing vulnerability of trees also is a prime factor for population growth. Stressed trees are easier to invade because they are weakened, meaning the threshold number of beetles necessary for a successful takeover of a tree is reduced (Hansen 2010). Conditions that create tree stress such as drought are becoming more frequent and dramatic.

Humans attributions to these conditions:

The effects of human intervention and climate change have also had a profound impact on the health of forest ecosystems. The State of Colorado Forest Report listed 2016 as continuing the yearly trend of higher temperatures. Climate change has and will continue to increase conditions associated with tree mortality and correlates with a high occurrence of fire, drought, and insect outbreaks (Halofsky 2017).

Through years of wildfire prevention, humans have protected forests to the point of maturity, establishing climax forests. A climax forest is defined as a region of old established trees that prevent younger and healthier trees from growing, therefor preventing the increase of diversity and natural succession (Halofsky 2017). These types of habitats occur when the process of succession is halted or unable to occur. Older trees decrease in health and are not replaced by younger, healthier trees more able to fend off disease and invasion, decreasing the overall health of the forest. Because of this, beetle outbreaks are more likely to occur in mature forests (Forest Service 2010).

One of the biggest resulting issues resulting from climate change is a lack of water. Colorado's increasing population and rising demand is increasing stress on local water systems, and a larger percentage of the state's water is being directed to growing cities and communities. Severe moisture limitations create ecological disturbances that reduce forest growth at lower elevations (Halofsky 2017). Earlier snow melt is also leading to premature spring runoff and lower summer stream flow, projected to decline anywhere from 20%-40% in coming years (Halofsky 2017). Water yields in the Rockies are also expected to decrease, as warmer temperatures will likely reduce the accumulation of snowpack in the winter and therefore limit the amount of mountain runoff (Halofsky 2017). In addition, the state's natural supply of water is being directed to agricultural efforts in the eastern plains (Colorado State University 2007). These conditions are contributing to water shortages and more frequent droughts, one of the largest causes of tree stress.

In addition, rising temperatures have created opportunities for bark beetles to increase in territory and population. In the past, cold winters killed off a large percentage of Colorado's phytophagous insects. Without these yearly freezes, beetles are not held in check by cold that usually kills larvae, and they are surviving in far greater numbers (Lemonick 2013). Generations used to replace each other as one died off and another was born, but with longer lifespans allowed by rising temperatures they are overlapping (Lemonick 2013). Warmer and longer seasons now also allow new niche habitats to be created for the bugs. Higher temperatures and lacking soil moisture may cause timber species to shift locations, exposed to conditions they do not have defenses for such as root disease and insect invasion (Halofsky 2017). With the shift of their food source, the insects are also moving to higher elevations and encountering new populations of trees that have no natural defenses against them.

Prevention Tactics and Future Implications:

The first step to prevention is adequate monitoring of forests and their conditions. Every year, the Colorado State Forest Service conducts an "Aerial forest health survey," in which they map and classify the intensity of the current year's damage in all of Colorado's forests (State of CO Forest Report 2016). This survey is the primary survey of insect damage, and is extremely useful to predicting their future spread. The population of the pests can also be controlled by direct combat methods. The Forest Service defines direct control as activities such as burning, debarking, and solarization; actions that are effective at reducing population (Forest Service 2010). Unfortunately, the effects of this process are only temporary and do not usually work well in epidemic stages of invasion as they do not prevent further spread.

One of the most effective ways to control these epidemics is indirect; the health of forests must be restored. This process would include reducing tree stress and increasing forest resilience. Several methods are already in use by the forest service, such as reducing the density of dry forests through clearing, prescribed fires, and planting drought and disturbance resilient species (Halofsky 2017). Water protection is also a necessary step for maintaining health of our forests. Almost 86% of Colorado’s water is used for agriculture and channeled to the eastern plains, an area that naturally receives only 20% of the state’s annual precipitation (Colorado State University 2007). This redirection of water prevents trees from receiving the amount they need to prevent stressful conditions.

Conclusion:

Colorado's beautiful forests are largely affected by human created ecosystem changes. Bark beetles are native and have a natural role in their ecosystems. However, because of human-caused changes to their environments, these insects are now influencing their habitats to a dangerous degree. Human disturbances and intervention are increasing damaging conditions that help further the spread of aggressive phytophagous insects. In order to prevent further outbreaks on this scale, it is necessary to acknowledge the damaging effects of human impact and on ecosystems. The best prevention for incidents such as this massive epidemic is to combat climate change and drought. With the insect population continuing to grow dramatically, it may be too late to prevent large scale damage. In time, the beetle population will die off due to limited food resources or disease, but by that point they may have successfully changed the forested landscape of Colorado as we know it.

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Burn, Baby Burn: Wildfire Management in the Southern Rockies

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Abstract:

Recent wildfire events throughout the world have highlighted the consequences of residential development in the wildland-urban interface (WUI) including hundreds to thousands of homes burned during a single wildfire or, more tragically, firefighter and homeowner fatalities. Despite substantial progress in wildfire management techniques, wildfires continue to threaten life and property in the Southern Rockies. This paper explores how wildfires have been managed throughout history to the modern day, and how wildfire management has impacted forest ecosystems

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Introduction:

Crested Butte had their first wildfire scare of 2017 on June 28 up the Slate River Valley. According to Crested Butte Fire Department, the fire was human-caused and not as a result of lightning. Campers up the valley on USFS land dug out their fire pit but they ended up not thoroughly extinguishing the campfire. High winds kept the embers alive, eventually blowing them into dry foliage. The fire that ignited rapidly climbed a cliff, catching trees on fire as it spread. The Forest Service responded to promptly, using a helicopter to drop 40 tanks of water, and ultimately containing the fire to about a half an acre. ere. Although the fire was rapidly contained, it served as a stark reminder of the fire danger the residents of Crested Butte face. Human's have an enormous impact on wildfires, from providing an ignition like the campers in the Slate River Valley to ultimately containing a blaze. Although wildfires threaten entire communities, they are also an important ecological process that we must live with. Reducing the number of human-caused fires is not enough not mitigate the risk wildfire's pose-- the majority of fires in Colorado are caused by lightning. Managing wildfires is our best tool to protect lives and property, but also carries our greatest impact on this natural process.

Ecological Significance of Wildfires:

The ecological benefits of wildfires often outweigh their negative effects. A regular occurrence of fires can reduce the amount of fuel build-up, lowering the likelihood of a potentially large, high-intensity wildfire in the future. Fires kill invasive plants that compete with native species for nutrients and space and remove undergrowth, allowing sunlight to reach the forest floor and support the growth of native species. The ashes that remain after a fire add nutrients to the soil for trees and other vegetation. Fires can also control pest insects by killing off the older or diseased trees and leaving the younger, healthier trees. In addition to all of the mentioned benefits, wildfire is essential for the regeneration of certain species. Lodgepole pine, which is a dominant species in some sub-alpine forests around Crested Butte, have serotinous cones that produce hundreds of thousands of seeds. Sealed with a dense resin, the closed cones may remain on the tree for decades until a fire sweeps through. Fire temperatures of 45-50 degrees Celsius or higher melt the resin, allowing these cones to release their seeds (Lotan, 1976). The bare soil and fresh ashes produced by a wildfire provide an excellent seedbed for lodgepole pine seedlings to grow in the open sunshine.

Although wildfires are typically ecologically beneficial, they have the potential to severely damage aspects of an ecosystem. In some cases, invasive plant species may overtake a burned area, preventing succession from occurring for native species(Hunter et al, 2006). Additionally, fire can cause soil damage, especially by burning organic material in the soil that helps to protect the soil from erosion. When organic material is removed by an especially intense fire, erosion can occur. Heat from intense fires can also cause soil particles to become hydrophobic, causing rainwater to run off the soil rather than to infiltrate it, further contributing to erosion (Martin et al, 2001).

Fire Suppression:

Before the middle of the 20th century, most forest managers believed that all fires should be suppressed. By 1935, the U.S. Forest Service's fire management policy stipulated that all wildfires were to be suppressed by 10am the morning after they were first spotted. In the 1960s, policies governing wildfire suppression began to change as ecological studies recognized fire as a natural process necessary for new growth. Today, policies advocating complete fire suppression have been exchanged for those who encourage wildland fire use, or the allowing of fire to act as a tool to maintain healthy ecosystems. Nevertheless, over 50 years of fire suppression continues to have an effect on fire regimes in the Rocky Mountains, particularly in dry, low elevation forests dominated by ponderosa pine. In subalpine forests, like those surrounding Crested Butte, the impacts of fire suppression have been minimal. Subalpine forests burn rather infrequently, though often at a much higher intensity than dry forests. Historic fire-return intervals in subalpine forests range from 50 to 300 years (Arno 1980). In many cases, historic fire-return intervals for subalpine forests are longer than the period of time since fire-suppression policies were implemented. Wildfire-suppression activities have not yet measurably altered the structure and composition of the subalpine forests since they have, in general, not missed fire cycles like the dry forests have (Smith and Fisher 1997).

Modern Wildfire Management:

The National Cohesive Wildland Fire Management Strategy, published by the Department of Agriculture and Department of the Interior in 2014, outlines three main goals of wildfire management: resilient landscapes, fire adapted communities, and safe and effective wildfire response (Dept. of the Interior, Dept. of Agriculture, 2014). Prescribed burns are the primary tool used to prevent extreme fires and restore ecosystems to their natural fire regimes. Prescribed fires reduce hazardous fuel build up on the forest floor, minimize the spread of invasive insects and disease, recycle nutrients back to the soil, and drive succession. When prescribing a burn, specialists take into consideration temperature, humidity, wind, moisture of the vegetation, and conditions for the dispersal of smoke. These fires are therefore safer for firefighters to manage and can be more beneficial to the forest than naturally occurring wildfires.

Thinning is another tool used to managed wildfires and is often done in conjunction with prescribed burns. In some instances, firefighters may do silvicultural thinning (i.e., logging of small-diameter trees) to reduce the fuel loads so prescribed fires can be effectively controlled. However, the scientific community is not in agreement that thinning on its own is an effective method to manage wildfires. In some instances, thinning intended to reduce the fire hazard appeared to have the opposite effect. Though it reduces fuel loads, thinning also allows more sunlight and wind to reach the forest floor. The net effect is often reduced fuel moisture and increased flammability (DellaSala et al, 2001). Moreover, mechanical treatments fail to mimic the ecological effects of fire, such as soil heating, nutrient cycling, and altering forest community structure.

Wildfire Threat and Management Strategies in Crested Butte:

As more people leave the front range in favor of mountain communities like Crested Butte, Colorado's wildland-urban interface has grown significantly. Wildland-urban interface, or WUI, is any area where land is developed close to, or within, natural terrain and flammable vegetation where high potential for wildland fire exists. As of 2012, the wildland-urban interface covers 6.6 million acres of land in Colorado, and is home to over two million people (Colorado State Forest Service). In Crested Butte, like in many other WUI communities, mitigating the risks of wildfire is a complex, community-wide issue.

Gunnison County's Community Wildfire Protection Plan classifies the wildfire risk in downtown Crested Butte as "moderate." Downtown is a small urban area surrounded by wildland fuels, predominantly grass and shrub mix. The grasses, both native and invasive, are perennial and build up a fuel bed every year that they are not burned. The grass regrows quickly with a fire return rate of 5-10 years. Any fires that do spark up have the potential to spread rapidly, but prolonged fire activity is unlikely. To the town's advantage, riparian areas located on three sides of the downtown area limits fire activity directly adjacent to the community. To further protect the area, Gunnison County recommended expanding and improving defensible space along the town's exposed western edge. Defensible space is created by removing vegetation and debris surrounding homes and business to prevent them from igniting and to give firefighters ample space to extinguish the flames (Hakes, 2017). When linked between properties, defensible space can protect an entire community.

While wildfire is only of moderate concern in downtown Crested Butte, the community Trappers one mile west is at extreme risk. The community is covered by heavy timber, predominantly lodgepole pine, spruce, and fir. Although fine surface fuels are sparse in subalpine forests like this, ladder fuels are abundant. Shade-tolerant fir and spruce trees have many lateral branches, which easily carry fire up into the canopy. By contrast, shade-intolerant lodgepole pines have few lateral branches, but these trees tend to grow in very dense stands that thin over time, contributing to abundant dead ladder fuels (Schoennagel et al, 2004). Steep slopes will also increase rates of spread. However, due to the long fire return interval in this forest type, a preceding multi-season drought and high fire weather day will be necessary for an ignition source to produce sustained fire. To mitigate the risk of a destructive wildfire in Trappers, the county recommended employing several management techniques including defensible space around homes, fuel thinning along the evacuation route, and a fuel break. Similar to defensible space, fuel breaks are established by clearing a line of vegetation to slow or stop the flames and provide a safe zone for firefighters to battle a wildfire. An unintended consequence of extensive fuel break construction and maintenance may be the establishment of nonnative plant species (Merriam et al, 2006).

Conclusion:

The ways in which we manage wildfire have changed significantly throughout history and will inevitably change in the years to come as climate change poses the threat of more frequent and intense wildfires. In addition to rising temperatures and longer drought, climate change has allowed populations of pine bark beetle to grow out of control. Though they haven't yet entered the Crested Butte area, these pests could make managing wildfires more difficult in the near future. The only way we'll be able to effectively manage fire and reduce our impact in the coming years is through continued research and educating the public.

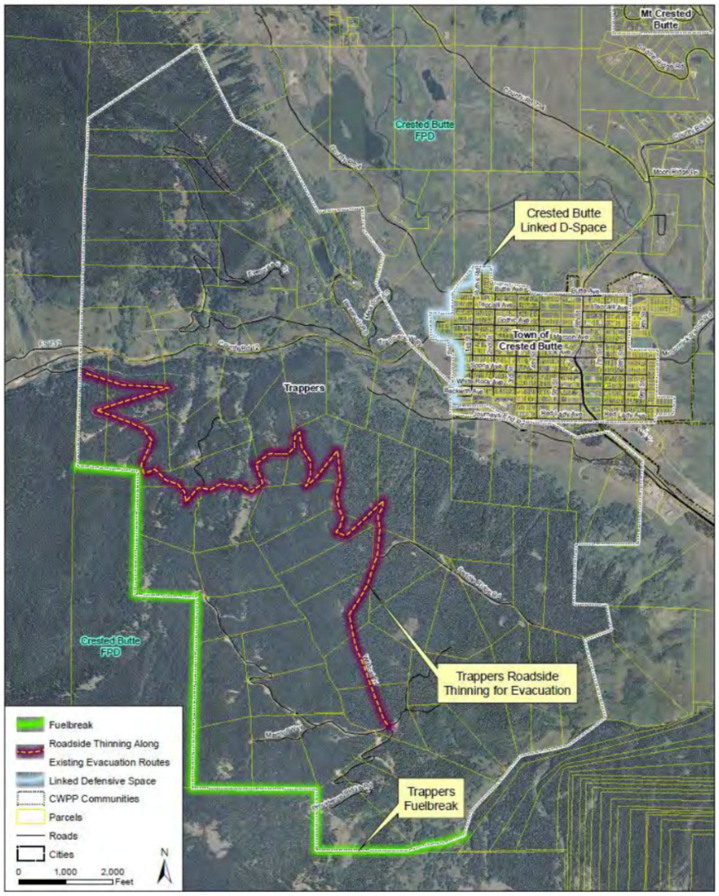

Figure 1. This map from the Gunnison County Community Wildfire Protection Plan models several different wildfire management techniques to implement in Crested Butte.

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Impacts of Golf Course Development and Management on Biodiversity

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Abstract:

Golf course development consistently coincides with ecosystem upheaval. Such transformation of natural systems was examined in order to determine the ramifications on the biodiversity content within those systems. Analysis of different golf course locations revealed that courses employing appropriate management strategies, including habitat maintenance and native vegetation installation, often functioned as havens for biodiversity. However, research indicated that the biodiversity content of golf courses must be considered in relative terms, as a course may have superior ecological value to alternative types of human development but not to other land varieties, namely pre-existing natural habitat. These findings held validity in analysis of golf courses developed within the Rocky Mountain West as well. As consequence, golf course locations and management strategies must be carefully considered in order to minimize environmental impacts and thus preserve, or even enhance, the biodiversity content within different ecosystems.

Introduction:

Human activity has transformed the natural world and its ecosystems in an extensive and irreversible manner. The rate of this impact is continuously increasing as well, further complicating a distressing situation. All things considered, these environmental alterations are of an unprecedented scope. The notion that certain species play a role as ecosystem engineers, organisms that affect other biota via their alterations to the abiotic environment, is accepted throughout the field of ecology. Humans are thought to be the most dramatic of ecosystem engineers, modifying and destroying natural habitat to suit their desire for resources, recreation, and development. Other types of organisms adjust ecosystems to suit their needs as well, but no species has been as thorough or globally encompassing in its actions as humans have been. Society's desire for further development is one of the driving factors behind this environmental alteration, but development often comes at the expense of the natural world. For instance, the construction of roadways has had a detrimental effect on fauna, flora, and abiotic environmental factors through anthropogenic influences, such as edge effects and habitat fragmentation. While they may appear to be relatively low impact, many roadways essentially function as barriers to gene flow, biodiversity, and environmental health, profoundly deteriorating habitat quality (Oxley, 1974).

The golfing industry is a specific subdivision of recreational development that has detrimental environmental effects. Golf courses necessitate the transformation of a chosen ecosystem into an entirely different ecosystem, which is a substantial shift for the biota within it. The destruction of natural habitat to introduce a new golf course habitat is often a damaging action which harms native species and, in severe cases, can even result in extirpation. This is not to say all new golf course development is undesirable, however. Often times, the establishment of a new, usable habitat can be beneficial if the original habitat was not natural or lacked biodiversity. While they further human impact on the natural world, the construction and use of a golf course can be either beneficial or detrimental to biodiversity, depending on chosen location and course management strategies.

Location: High vs Low Anthropogenic Impact:

The location of a golf course relative to other human developments is essential in evaluating its ecological value. The identity of both the location on which the golf course will be developed and the surrounding location following its construction must be considered in analyzing ecological value. Desirable locations to establish courses are in areas of high anthropogenic impact. These areas are often previously altered by humanity, contain a large concentration of humans, or continue to have their landscapes altered by development in some manner. Such landscapes are preferable for golf course development due to their natural environment often being already destroyed or harmed, meaning golf courses provide an opportunity for biodiversity to be restored. The ecological value of a golf course must be considered relative to other potential land uses as well. Golf courses built in urban areas which otherwise would have been sites for further housing development are a preferable option in terms of biodiversity content, for instance. Urbanization coincides with habitat loss and degradation for the vast majority of species. One such species is the round-tailed muskrat, a species of concern in Florida. As it is typically a wetland species, its occurrence was found to be negatively correlated with urban land cover, as urban land cover represented further habitat loss (Faller, 2016). Golf courses are large green areas which have potential to harbor significant biodiversity and provide opportunities for those species affected, such as the round-tailed muskrat, to thrive. One quantitative synthesis study even concluded that golf courses had a higher ecological value in 64 percent of cases compared to other green-area land uses, such as parkland and agricultural land (Colding, 2009). Golf courses within more populated urban centers, such as Colorado Springs and Denver, can often serve as hotspots for biodiversity, attracting both urban species and species poorly adapted to human influence.

Not all golf courses are built in areas of high anthropogenic influence, though. Course development often occurs in areas of low anthropogenic impact as well, destroying natural habitat and diminishing ecological value. Such golf courses are detrimental to biodiversity, as they result in the imbalance of natural ecosystems as native species struggle to adapt to the unfamiliar environment and sudden human influence. Golf course development in the Rocky Mountain West often causes ecosystems to suffer in this manner. With an abundance of natural habitat still intact within the Rockies, companies often find that it is easiest to purchase relatively undeveloped land

and transform it into a golf course, resulting in damaging ecosystem upturn. This is often the case in smaller mountain towns within the Rockies, such as Crested Butte. To encourage ecosystem stability and environmental sustainability, future golf course developers should aim to establish courses within modified habitat, urban centers, and other areas of high anthropogenic impact.

Habitat: Gain, Loss, & Fragmentation:

Golf courses influence the habitat available for numerous species through their transformation of original landscapes. Golf courses can either provide or destroy habitat, depending on their location and course maintenance strategies. Habitat fragmentation and loss can be major issues when golf courses are developed on the ranges of territorial predatory species. Due to their wide range, solitary predators such as cougars and bobcats often suffer from habitat loss when courses are developed. This loss can include an outright elimination of usable habitat or a fragmentation of usable habitat by the golf course itself. The effects of habitat fragmentation are often amplified in these two cats as a consequence of their natural tendency to avoid humans as well. This sudden reduction in habitat can cause these species to struggle in finding food, as they are adapted to utilizing a large area in search of prey, rather than one fragmented by human development (Crooks, 2001). The loss or significant decline of these predatory species can often lead to trophic cascades, or dramatic changes in ecosystem structure due to the loss of a top predator. These cascades cause ecosystem imbalance and are particularly harmful to biodiversity. Trophic cascades pose potential issues in Rocky Mountain states, where top predators like wolves, cougars, and bobcats play a valuable role in maintaining ecosystem balance and are particularly vulnerable to human impacts. Mountain towns are often in close proximity to relatively untouched habitat, and thus trophic cascade potential should be a consideration when choosing golf course locations.

Golf courses often serve in providing usable habitat for a wide variety of species to thrive as well. Intricate course management plans are essential in maintaining a healthy ecosystem which is capable of supporting significant biodiversity. Amphibians such as freshwater turtles are capable of flourishing in golf course wetlands. Despite their often artificial nature, these wetlands typically hold the same ecological value as natural wetland ecosystems and serve as valuable habitat for painted turtles and other amphibian species (Winchell, 2015). This is an especially beneficial aspect for biodiversity conservation, as 43 percent of amphibian species worldwide are believed to be declining, mostly due to human influences (Desonie, 2007). Viable habitat for aquatic organisms can be increased by careful management tactics, such as decreasing use of fertilizers and pesticides, and using less intense pesticides in course maintenance. These chemicals, often in the form of nitrates, runoff into water sources and can impact water quality and the turtles themselves. This management strategy can also benefit species who prey on wetland organisms, such as red-tailed hawks, as such harsh chemicals can adversely impact the hawk following predation. Populations of red-tailed hawks have been on the rise since they hit their low point due to harmful pesticide usage in the 1960's, and they often use golf courses as habitat for nesting and hunting. The over 15,000 current golf courses in the United States were essential for red-tailed hawks to use in their recovery, and the hawks are now considered by the IUCN Red List of Threatened Species to be a species of least concern. (Morrison, 2016). Golf course wetlands serve as habitat for a variety of other birds as well, including other raptors like the peregrine falcon, and water birds, such as the double-crested cormorant, and the great egret (White, 2004). Wetlands serve as valuable habitats on Rocky Mountain golf courses as well. Wetland habitats have been on the decline for hundreds of years in the Southwest due to human impacts ranging from eutrophication processes to large-scale water usage. Establishing new wetlands can help to mitigate the regional decline of the biome, and provide havens for the species which inhabit it. The establishment of wetland habitats via golf courses can help to preserve endangered Rocky Mountain amphibians such as the Boreal toad and Northern cricket frog. All factors considered, golf courses can be either beneficial to biodiversity by providing habitat for certain species, or harmful to biodiversity by taking habitat away from certain species, depending on course location and management practices.

Location; Golf Course Landscapes:

The typical golf course landscape is not suited to the Southwestern ecosystem and climate, and it often imposes non-native species onto a Southwestern landscape, which causes a variety of problems for resource usage and biodiversity. Western golf courses often plant grass species which are better suited to the American Northeast for usage reasons, in spite of the climatic difference. This results in excessive water usage, especially in desert climates. The average golf course in Palm Springs, a city located adjacent to an area known as the Palm Desert, uses about one million gallons of water per day. For comparison, the average family of four uses 400 gallons of water per day (Adler, 2007). While this problem is not as severe in the Rocky Mountains, it is still true that water sources must be depleted in order to water golf courses. Though some species may be able to prosper with a lower water level, species that rely on a high water level in those water sources are affected adversely. For instance, while predatory water birds may thrive in the new conditions since the lower water table makes it easier for them to find prey, the populations of fish species which rely on a high water table to provide cover from those water birds may decline. This type of shift in environmental conditions can sometimes be severe enough to imbalance an ecosystem.

Non-native plant species used in roughs and greens often cause consequences to local biodiversity due to the fauna being unable to adjust to foreign conditions. The short blade height on a course can cause problems for animals that rely on taller grass to hide from predators, for instance. These non-native grass species can be replaced with native species if tradition is compromised. Planting native grass may slightly decrease the quality of a course, but it will increase biodiversity by providing habitat for native species and helping some environmental balance remain established despite ecosystem upheaval. Courses with primarily native vegetation content have been shown to possess greater ecosystem health and stability (Davis, 2014). Both in the often drought-ridden California and in the Rocky Mountains, caring for native plant species will decrease detrimental environmental effects, since native species will be able to survive more easily without excessive watering and fertilizer usage. To change California's dark green fairways into course "brownways", fairways with natural, brown Californian vegetation, would have a decisively positive effect on biodiversity and overall ecosystem health (Davis, 2014).

Conclusions:

Natural ecosystems possess unambiguous superiority over golf courses in terms of biodiversity. Still, golf courses are not exclusively a danger to biodiversity. When properly cared for, golf courses can serve as artificial biodiversity hotspots in locations which lack biodiversity or have high levels of anthropogenic impact. In the future, the locations of golf courses must be carefully selected and their conditions must be carefully managed in order to preserve the ecological value and biodiversity within ecosystems. Continuing to destroy natural habitat without considering the repercussions is unsustainable. Future golf course development must take into account the natural world, and minimize environmental impacts by considering the manner in which the course is maintained and used.

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To Ski or not to Ski: Ski Slopes Effects on a Mountain Ecosystem

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Abstract:

Ski resorts are becoming increasingly popular in the Rocky Mountains. The ski industry is a complex industry involving customers, waste management, energy, and water. With resort skiing on the rise, the effect it has on the environment is crucial to investigate. This paper reviews research concerning the impacts of skiing on the mountain ecosystem. Although skiing is an economic driver for the Rocky Mountain region, it negatively affects the global environment. The development and management of ski slopes impacts vegetation and wildlife; this paper explores these issues in Crested Butte.

Introduction:

Skiing has long been a mode of winter transportation and only relatively recently has become a recreational activity. As downhill skiing started gaining popularity, ski resorts began popping up all over the world and the United States. Today there are over 1,800 ski resorts around the world. Any form of popular recreation comes with impacts on the economy and the environment, both positive and negative. Ski resorts, such as Crested Butte Mountain Resort (CBMR) in northern Gunnison County, offer an economic benefit to the local government and citizens by providing jobs, tourism, and increased real estate values. As more and more tourists come to Crested Butte every year (Fig 1 – removed from public document), the real estate prices increase dramatically. The average price of a house or condo in Crested Butte in 2014 was approximately $683.8k, while the average price of a house or condo in Colorado in 2014 was approximately $240k. This gives a sense of the impact a ski resort can have on a small mountain town. All these seemingly positive effects can have negative outcomes on the local community and the environment.

Local citizens are finding it difficult to afford their homes in Crested Butte because the real estate prices around them are skyrocketing. CBMR has offered some of their private land to the city for a housing development, called Bush Creek, to provide affordable housing for seasonal workers and locals that cannot afford to live near the mountain or in town. However, this could possibly hinder the community socially by separating the tourists from the locals. Not only do ski resorts affect economic and social aspects of a community, they also affect the global environment and the ecosystem in which the ski resort is located. Traveling to ski resorts requires transportation whether it be car, plane, or both. Skiers rely on fossil fuels to get to the mountains and the resorts rely on fossil fuels to keep their facilities running for customers. Skiing also has a significant impact on animals and plants because high-elevation ecosystems are easily susceptible to change.

The development of ski resorts involves (in addition to housing, lodges, roads etc.) clearing vegetation on a mountainside, keeping those areas clear for skiing (ie. snow grooming), and making artificial snow. The creation and maintenance of ski slopes creates fragmented forests. Although there are many different impacts skiing can have, this study will address the environmental impacts of ski slopes, both immediate and long term.

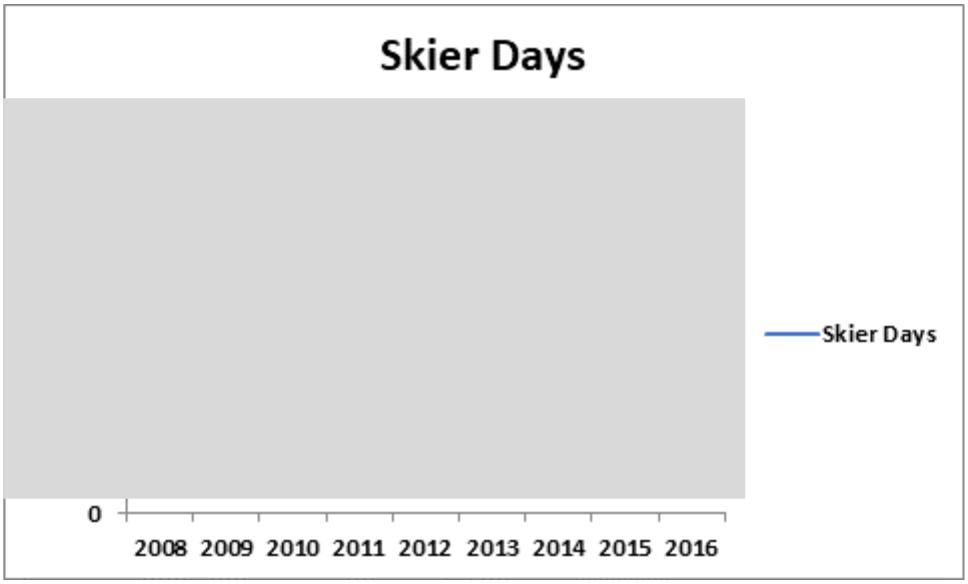

Fig 1. Number of skiers at Crested Butte from the 2008/9 season to the 2015/16 season. Skiing has increased over the past few years (CBMR Data, provided by Matt Feier, not for public consumption).

Impacts of Ski Slope Creation on the Mountain Ecosystem:

When a ski resort decides to implement a new slope, two methods can be used. The first is to construct a slope by cutting down trees and mowing vegetation; this is known as the clear method. The second way ski resorts can create a slope is the machine-grading method. Graded slopes are initially created using the clear method and then are cleared a second time using machine-grading to remove boulders and tree stumps and even out the terrain, which removes the natural vegetation and most of the organic topsoil.

A study done in the Lake Tahoe region of California looked at the impacts of ski slope construction on ecosystem properties (Burt & Rice, 2009). This study sampled plots in cleared ski slopes, graded ski slopes, and untouched reference forests near the ski slopes. Plots were measured for plant community composition, diversity patterns, and soil characteristics (both physical and chemical). In cleared ski slopes there was a greater covering of perennial herbs, subshrubs, and shrubs; all plants typical of a mid-successional community. In graded ski slopes there was a greater cover of graminoids and annual herbs; all plants typical of an early successional community. In the reference forests there was a greater tree cover, a compositional trait indicative of late successional or a climax community. Cleared ski slopes had a greater species diversity than graded runs and reference forests (Burt & Rice, 2009). This difference can be explained by the intermediate disturbance hypothesis which states that species diversity is maximized when there is an intermediate amount of disturbance. Graded ski slopes had a higher introduced species cover and richness due to the management practice of seeding for erosion control. The need for erosion control can be seen by the visible-erosion class (Class 1-no erosion, Class 5- lots of erosion) measure of 2.6 on graded runs. The visible-erosion class was 0.8 and 1.4 classes higher than cleared runs and reference forests, respectively (Graph 1). This difference can be explained by the soil depth, amount of compaction, and water-retention capacity on graded runs all being significantly lower than on cleared runs and reference forests due to the way the slope was altered with a machine.

According to the Forest Service environmental assessment of CBMR in 2007, the removal of native vegetation, disturbance of soil surfaces, alteration of slope angles, and the addition of snowmaking has the potential to increase soil erosion and decrease the stability of mountain trails. Although graded areas in this study had a high species cover and richness, most of the plants used for erosion control were nonnative plants. Planting nonnative species has a negative effect on ecosystems because they compete with the native species for nutrients and resources. Both methods of constructing a slope, clearing and grading, have impacts on biodiversity and ecosystem properties, yet the grading method is more negatively impactful.

Graph 1. Results from a study about ski slope disturbance on ecosystem properties. Graded ski cause the most disturbance (Burt & Rice, 2009).

	Disturbance level		
Response variable	Graded ski runs	Cleared ski runs	Reference forests
Plant community composition			
Cover graminoids (%)	26.4[a]	4.5[b]	0.8[c]
Cover annual herbs (%)	2.7[a]	1.0[b]	0.3[c]
Cover leguminous herbs (%)	2.2[a]	0.8[a]	0.7[a]
Cover perennial herbs (%)	7.1[a]	13.9[b]	6.8[a]
Cover shrubs (%)	3.4[a]	26.6[c]	10.0[b]
Cover subshrubs (%)	0.1[a]	2.6[c]	1.2[b]
Cover trees (%)	3.7[a]	5.5[a]	51.6[b]
Diversity patterns			
Shannon-Weiner species diversity, H'	1.4[b]	1.7[a]	1.1[c]
Species richness†	13.0[ab]	15.3[b]	10.8[a]
Introduced richness	2.5[a]	0.1[b]	0.0[b]
Functional richness	4.5[ab]	5.1[b]	4.0[a]
Cover introduced plants (%)	19.7[a]	0.2[b]	0.0[b]
Total vegetative cover (%)	43.5[a]	51.8[ab]	62.1[b]
Soil physical characteristics			
Visible-erosion class	2.6[a]	1.8[b]	1.2[c]
Cover bare ground (%)	48.4[a]	23.2[b]	6.3[c]
Cover litter (%)	4.3[a]	16.3[b]	57.7[c]
Depth to compaction (cm)	8.4[a]	18.8[b]	17.1[b]
Soil depth (cm)	13.8[a]	31.3[b]	30.2[b]
Soil chemical characteristics			
Total nitrogen (mg/g soil)	1.4[a]	2.5[b]	2.2[b]
Total carbon (mg/g soil)†	32.8[a]	63.9[b]	64.3[b]
C:N ratio	23.6[a]	28.2[b]	31.7[b]
Soil water-holding capacity (% at 0.3 ATM)	19.0[a]	20.9[b]	22.3[b]
Cation-exchange capacity (meq/100 g)	12.4[a]	17.0[b]	17.5[b]

Impacts of Ski Slope Use on the Mountain Ecosystem:

Construction of ski slopes alters the landscape but so does the use of the ski slopes by skiers. Snow-grooming and skiing compact the snow cover. Snow acts as an insulator to the vegetation and when it is compacted, thermal insulation as well as the gas capacity of the snow are decreased (Rixen et al., 2003). This can cause vegetation to have frost damage, oxygen deficiency, infection by fungi and pathogens, and delay in development and mechanical damage to the plant tissue (Cernusca, 1989). The result of these outcomes is a change in plant composition and decreased biodiversity (Rixen et al., 2003). Artificial snow use also changes vegetation composition. Due to the effects of climate change, the majority of ski resorts (including CBMR) make artificial snow. Water for artificial snow is normally taken from lakes and streams which contain more ions and nutrients. Lake and stream water have a different pH than rainwater (Rixen et al., 2003). This makes it easier for more nutrient- and moisture-demanding vegetation species to thrive on the slope. This is important because alpine and subalpine vegetation provides for animal species in the area during non-winter months. When the vegetation is altered, these animals are affected.

Forest Fragmentation caused by Ski Slopes:

Construction of ski slopes splits an intact forest into smaller fragments. According to a 22-year investigation in the Amazon about fragmentation, forest fragments typically contain a limited amount of flora and fauna because smaller plots have fewer species and less habitat diversity than larger areas (Laurance, 2001). A reason for this is because many animals are sensitive to fragmented areas. Fragmented areas are at risk due to edge effects. The smaller an area is, the closer the protected area is to the edge. Edges create a disturbance on the biota of the area due to higher wind exposure, temperature variation, sunlight access, and recreation encroachment. An example of this can be shown by a study done in 2007 that looked at the effects of ski slopes on grassland bird communities (Fig 2). The biodiversity of bird species was much lower on ski slopes than on a natural grassland nearby (Rolando et al., 2007). An explanation for this is the lack of diverse vegetation due to construction and use of ski slopes, which would lead to a decreased number of insects and ultimately fewer birds. Breaking up an intact forest decreases the species richness in forest areas adjacent to ski runs due to edge effects.

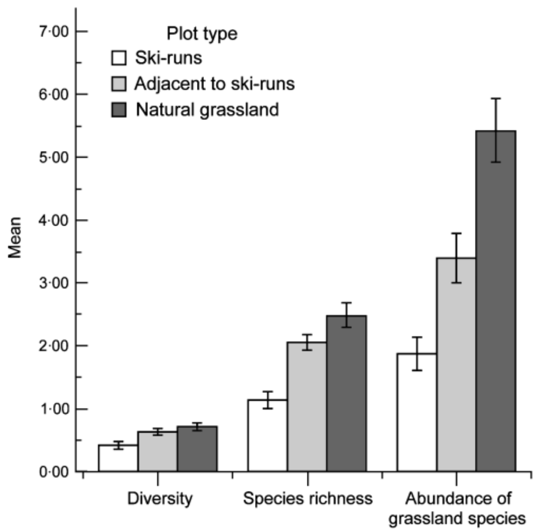

Fig 2. Differences in diversity, richness and abundance of grassland bird species between plot types. There is more diversity, richness, and abundance in natural grasslands than ski-runs or areas near ski-runs (Rolando et al., 2007).

Crested Butte Mountain Resort's Mitigation Tactics:

As shown in this paper, the creation and use of ski slopes has a negative impact on the mountain ecosystem. CBMR is a for-profit company, however they are working to include sustainability measures in their business plan. One example of this is recycling and starting a composting program. Another example is that they have been working with the Forest Service to replace their aging trees and kick start succession. In June, 2017, CBMR planted 600 new Engelmann Spruce trees with the Forest Service in the Double Top Glades. This reforestation project is expected to help promote forest diversity, stimulate stand succession and help ensure the forest's (and the resort's) long term health and durability.

As more tourists come each year, mountain resorts are forced to build more and more infrastructure to compensate. CBMR is a perfect example of a thriving mountain resort trying to expand. In 2009, an expansion proposal sent by CBMR to the Forest Service requesting to expand their ski resort to an adjacent mountain, Snodgrass Mountain, was rejected. Although Snodgrass Mountain is part of CBMR's land permit, the Forest Service (influenced by the public) told CBRM to focus expanding on their mountain first before looking to expand to another. A few years later, in 2012, CBMR came out with a new proposal, the Teocalli Expansion. The Teocalli Expansion seeks to expand to the backside of the mountain. This proposal is currently still under review. According to Matt Feier, Director of Planning, CBMR is not going to machine grade their new ski slopes if the Teocalli Expansion gets approved (machine grading is the most impactful construction method) (M. Feier, personal communication, October 12th, 2017). This is a perfect example of a mountain resort trying to make more money but being aware of their impacts and doing what they can to reduce them without lessening their profits. Prioritizing profit and customers over environment, with any for-profit company, is inevitable. Policies and public pressure (ie.

Snodgrass Mountain Expansion) are ultimately the most effective way to prevent further degradation on ski mountains.

Conclusion:

Skiing attracts millions of people to Colorado every year while having it has large impacts on mountain communities, both positive and negative. Many ski resorts in Colorado are located in what were historically mining towns or rural areas that would rarely get visitors. Ski resorts therefore offer their communities a stable economy by bringing in tourists. Although this may help economically, it hinders the surrounding ecosystems. Ski resorts put a large burden on the environment but skiing is not going to stop any time soon. It is important for ski resorts to be aware of the impacts, like CBMR, and do what they can to mitigate them.

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The impact of snowmaking at ski resorts on the local ecosystem

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Abstract:

Snowmaking has become popular for resorts to satisfy the need of customers since the early 1970s, but at the same time, this process has many negative impacts on local ecosystems. No doubt, the production of artificial snow will postpone snowmelt and increase the input of water into the soil. Moreover, snowmaking not only affects local environment from the physical aspect. First, water resources resorts used for snowmaking will affect soil, microorganisms, and vegetation by increasing soil pH. To produce artificial snow, resorts pump water from nearby rivers, lakes, or other groundwater sources, which have different pH compared with natural precipitation. Second, snow additions may affect plants and microorganisms. In Crested Butte Mountain Resort (CBMR), SnowMax is added into water to make it easier to form ice crystals. SnowMax accelerates this process through adding dead bacteria bodies into the water. The use of Snomax will reduce the number of plants and organisms since it enables liquid to freeze at a higher temperature. According to reports from several national institutions, Snomax does not present any pathologic impacts on human, though it may cause allergy to some sensitive individuals. This paper will focus on the impacts of snowmaking on the local ecosystem.

Keywords: pH, soil, microorganisms, vegetation, snow additives, health.

Introduction:

Resorts are growing as popularity of the sports increases. They have to deal with more people, and open for longer to increase profits. Furthermore due to climate change, reliability on artificial snow making is increasing. Since it allows more reliable opening time for resort and usable slopes for busiest period. Resorts get water from river, incorporate additives, place additional snow on top of hillside, and all this has impacts that are not well understood. Purpose of this paper is to examine these impacts.

In 2001, about 90 % of resorts in the United States relied on snowmaking (Rixen, 2003). Since climate is impacting the amount of snow received by resorts, as a result, resorts located less than 1500m in elevation cannot get enough snow to operate in winter(Rixen, 2003). Besides, to satisfy customers' need, resorts need snowmaking to get enough snow at the very beginning of winter seasons. Thus, even in Crested Butte Mountain Resort (CBMR), which is located between 2,778 m and 3,710 m in elevation, snowmaking is extensively employed.

Winter tourism is an important economic sector in Crested Butte. Last winter, about 450,000 people visited CBMR. In November and December, the resort practices 24-hour snowmaking for both months no matter what the weather is to meet the needs of the busy period at the end of December. The continuous snowmaking consumes tons of electricity and water. CBMR gets the water they need from the neighboring East River. Thanks to a senior water right, they can pump up to 2686 gallons of water per minute. During Colorado students' trip, CBMR director said, last year, 8.8 million gallons of water were pumped for snowmaking, and over half of the electricity used by the entire area of Crested Butte and CBMR was consumed by the resort. Much more snow than necessary was made because of the heavy snowfall.

In the spring, the amount of water input to the slopes from snowmelt also increases because of the employment of artificial snow. According to a Swiss study, which measured the water input from artificial and natural snow, water input produced by snowmaking (750mm) doubled compared with 400mm produced by natural snow (Stoeckli&Rixen, 2000). Thus, the production of artificial snow may affect local hydrology heavily.

For long-term economic benefits, CBMR works closely with the Forest Service and conservation organizations. Every two months, a third party organization will take a river read of the East River, the head waters of which are located near the resort. Last year,6,000 trees were planted by the resort to protect the local environment and compensate for the trees they had previously cut down for ski slopes. Every year, 1% of day pass fees are donated to the Crested Butte Land Trust. Dirt transfer is forbidden to prevent potential introduction of invasive species to the environment. Garbage classification and recycling are carefully managed. However, snowmaking has some inherent negative effects to local ecosystem as well as the pleasure it brings.

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pH:

To meet the need of water for snowmaking resorts mainly pump water from nearby rivers, lakes, and other surface water resources. These surface waterresources resorts used is exposed to soil and sediment, and farther susceptible to the minerals which can dissolve into water, resulting in a pH value generally between 6 and 8 (Henderson& Henderson, 2008). While the pH value of natural precipitation is slightly acidic due to the interaction between carbon dioxide and water. Some heavily polluted areas, like Vermont, may have a pH value much lower than 5.6, the dividing point of common and acid rain.

A measurement conducted in British at Giant Brook and Coleman Brook supports the distinct pH of natural precipitation and man-made snow. The average pH values of these two streams were 5.88 and 6.06 respectively. Coleman Brook, where artificial snow was made, had greater acidity during autumn time due to autumn rainfall. The seasonal varied pH value in Coleman Brook proved that the difference in pH value in spring at two spots was caused by snowmaking, not by soil differences (Henderson, E. & Henderson, K., 2008).

Another research done by Henderson et al. directly compares the different pH values of natural snow and artificial snow in two ski areas in Vermont. According to this study, average hydrogen ion concentration of artificial snow was 1.5μM (μmol/L), one-tenth of that of natural snow (Henderson, E. & Henderson, K., 2008). In this case of measurement, artificial snow samples mixed with some natural snow indicated that the pure man-made snow was much more basic. The great quantity of high pH water used in snowmaking brings some problems to local environment: it will increase soil pH and then gradually affect microorganisms, ecological processes, and vegetation types.

Microbial communities alter according to the acidity of the soil. Microorganisms all have their favorite pH. For example, *Nitrosospira* cluster 2 dominated soil of 4.9 pH but bacteria population declined as pH increased, *Nitrosopira* cluster 3 dominated soil of 7.5 pH and bacteria population decreased as pH decreased (Nicol et al., 2008). These ammonia-oxidizing bacteria (AOB) conduct ammonia oxidation, which is the first and rate-limiting step of nitrification. By affecting the growth and activity of AOB through changing soil pH, the efficiency of nitrogen cycling is also affected (Zhu et al., 2015). As nitrification process slowed at the beginning point, even though the gross amount of nitrogen does not change, its availability decreases and farther limits the growth of plants. Nitrogen is the composition of many organic compounds, like protein, nucleate, and chlorophyll. Since protein is the main component of cells; nucleate is essential to constitute the body and maintain life activities; chlorophyll is indispensable substances for photosynthesis; nitrogen is the primary factor which limits plants' growth. As a result, the changed soil pH due to artificial snow will have a negative impact on microorganisms and vegetation growth.

Snowmelt from artificial snow contains different ion composition compared with snowmelt from natural snow. Water from groundwater sources is enriched in minerals, including Ca^{2+} Na^{+}, K^{+}, Cl^{-}, Mg^{2+}, SO_4^{2-}, NH_4^{+} and NO_3^{-} (Rixen&Stoeckli&Ammann, 2003). Most of them are vital to plants. Besides these ions surface water may carry, its higher pH value will reduce the aluminum ion it holds (Henderson, E. & Henderson, K., 2008).

According to a study done at Giant Brook and Coleman Brook, inorganic aluminum concentrations of snowmelt from natural snow at Giant Brook was nearly twice of those in snowmelt from man-made snow at Coleman Brook (Henderson, E. & Henderson, K., 2008). That is because, in a weak basic solution like ammonium hydroxide, the aluminum ion will react and form $Al(OH)_3$ precipitation with hydroxyl ion, in a strong acid solution like NaOH solution, aluminum will exist in AlO- form instead. The decrease of Al^{3+} has a positive influence on plants growth. Based on past studies, the most evident impact of aluminum ion on plants is restricting the elongation and cell division of roots. When the nutrients in the current area covered by roots are used up, plants cannot obtain enough resources they need. As the volume of water and nutrients plants absorbed decrease, photosynthesis efficiency also decreases. Finally, plants' output and seed quality decline (Tong & Ding, 2008). Thus, compared with natural precipitation, water used in snowmaking is beneficial to vegetation growth to some degree at the same time and will change original local vegetation.

Vegetation types change directly due to the changed soil pH. Some plants prefer acidic soil, like plum trees, while some plants prefer basic soil, like fig.Besides that, changed soil pH value also affect vegetation types through changing microorganism communities and ion composition in the soil.

Snomax:

Artificial snow is produced with water and compressed air. CBMR has a pump house to pump water from the East River and adds Snomax into the water. Then, compressed air and water are transferred to snow guns. These snow guns spray small droplets broke by compressed air, producing ice crystals.

Snow additives are products with ice nucleation activity (INA). INA enables snow production at a higher temperature by adding nucleuses into the water. There are two essential requirements for snow formation: water-vapor saturation and having a nucleus of condensation. Natural snow forms with condensation nucleus like sea salt, sulfuric acid or nitrogen particles in the air. Without these nucleuses, water vapor in the air will only liquefy when the relative humidity goes over 500% (Zhou, 1997). By providing more available nucleus, snow additives enable snow production at up to -3 °C instead of temperature less than -7 °C (Rixen, 2003).

Snomax is a controversial snow additive. It is made based on the bacterium *Pseudomonas syringae*'s proteins. *Pseudomonas syringae* is a very special bacterium. They attack plants through making them frozen. In winter, tissues of plants without antifreeze proteins still remain in liquid state. When this liquid frozen, frost damage occurs. Generally, frost damage happens when the temperature between -4 and -12 °C. However, the *Pseudomonas syringae* triggers liquid to freeze at a higher temperature, as high as -1.8 °C (Maki &Galyan& Chang & Caldwell, 1974). When the condition does not allow them to freeze plants, they can live as saprotrophs, absorbing nutrients from dead organisms (Hirano & Upper, 2000). Their ice-forming property retains even when they are dead. Snomax is made of extracted proteins from dead *Pseudomonas syringae* bacterium.

On its company's home page, the company, Advanced Genetic Sciences in Berkeley, California, declares that their product is made of naturally-occurring substance, human, and plants contact with this bacterium frequently and thus will not bring any negative effects to the environment. It also says researches on the possible impacts of Snomax also did not show any negative results (Snomax). However, some scientists warn that this chemical additive has indefinite effects on human (Boyle, 2015). The use of Snomax is banned in Austria and Germany, but still widely used worldwide, including the United States and Switzerland. Hydrologist Carmen de Jong is one scientist who tested Snomax. According to her research, various studies showed the very negative effects Snomax has on human health. About 400 different types of plants are also affected (Boyle, 2015).

The use of INA agents not only make leaves more susceptible to frost damage but also limits insects ability to survive through subzero temperature. One study compared the ability of nematode juveniles in water with Snomax and without Snomax under subzero condition was done (Wergin et al., 2000). When temperature went below zero, water with Snomax inside was frozen while the control group remained in the liquid phase. Approximately 10% of all juveniles with Snomax survived after 30 minutes, while 43-91% survived in the controlled group. The result showed that these juveniles all have some degree of ability to survive under super cooling environment without additional ice nucleation. The introduction of INA was lethal to most juveniles.

However, different from the negative impacts some scientists criticized, the report from the French Agency for Environmental and Occupational Health Safety (Afsset) assessed Snomax does not have any negative impacts on human health (Lagriffoul et al., 2010). An exhaustive literature search confirmed that Pseudomonas syringaecannot cause any infections in humans. That is because this bacteria cannot survive above 32 °C. Therefore, they are not able to multiply in human bodies at all. Moreover, two strains of *Pseudomonas syringae* (ESC-10 and ESC-11) are used to store fruits for over 10 years under the US Environment Protection Agency (EPA). The toxicity studies conducted by the US Food and Drug Research Laboratories prove that the usage of Snomax will not cause any serious hyper-sensitization. Research about whether Snomax will cause an anaphylactic reaction is insufficient. In conclusion, *Pseudomonas syringae* does not present any infectious, toxic, or allergenic danger to human, but may cause allergy to some individuals.

Conclusion:

The excess water used for snowmaking results in a decrease in soil pH, which affects nitrification rates and biological communities inhabiting the soil. Changes in soil microorganisms also affect vegetation types. Snomax, which is used in CBMR, is very controversial. Some assert Snomax will have negative impacts on the local environment, including killing nematode juveniles and intensifying frost damage to plants. However, some believe Snomax will not affect ecosystems because it is made of a natural material which exists in great number worldwide. Reports from several national agencies also prove that Snomax will not have any negative effects to human. Further studies are still needed for mitigating impacts of snowmaking on the local ecosystem.

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Water in the ski industry: A look at the impacts on water bodies

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Abstract:

The ski business is the biggest attraction for tourists in Crested Butte. However, not many people are aware of the impacts of ski resorts on adjacent water bodies. Runoff snowmelt deposits sediment on the ponds, lakes, streams and/or rivers located at the base of ski mountains. Snowmelt from ski slopes carries more sediment because, usually, they lack as many obstacles to slow down water and drop sediment on the mountain instead of the nearby water bodies. In addition, the industry of snowmaking affects the peak flow of rivers and streams and the size of lakes and ponds where water is obtained and drained. In the case of Crested Butte Ski Resort, the water is obtained from the East River, north of the mountain. This research goes into detail on the impacts on water ecology surrounding ski resorts, explores the importance of these impacts, and gives possible solutions for CBMR and other ski resorts.

Introduction:

Skiing is a practice known as early as the prehistoric man 5,000 years ago, as shown by human rock paintings. Hunters would travel from central Asia's Altai region to the northwest and northeast chasing elk and reindeer (Lund et al., n.d.). Several centuries later, during the Middle Ages, Scandinavians used skis for farming, fighting and hunting. By the 18th century, units of the Swedish Army were trained and skilled on skis for fighting and competing (Lund et al., n.d.). Currently, in Crested Butte, Colorado, the primary attraction for tourism during the winter season is the Crested Butte Mountain Resort. The ski industry attracted 415,000 people during the winter season to the mountain. This influx of people throughout the year impacts the use of water in the Gunnison County. The biggest impacts on water bodies are the ski runs of mountain resorts. Once the season ends, the snowmelt either evaporates, seeps into the ground, and, most of it, drains to the nearby water bodies, such as ponds, lakes, streams, or rivers, and changes the morphology of them.

Impact of Snow Drainage on Rivers:

Many ski resorts draw and drain water from/to nearby rivers. A study performed by Gabrielle David evaluated streams near resorts in the White River National Forest, which surrounds Breckenridge, Vail, and Keystone ski resorts in Colorado (David et al., 2008). David tagged the streams close to the mountain resort as project streams and the streams away with little to no development as reference streams. David compared the project streams' amount of sediment, bank stability, bank undercutting, bank height, wood load, pool residual depth, sediment size, and vegetation structure. The results proved that project streams had a higher percentage of fine sediment, smaller pool residual depth, and a higher percentage of unstable banks than reference streams (David et al., 2008).

The cause of this difference between project and reference streams is the machine grading of ski runs. When the snow melts and turns into water on the ski runs, it flows downwards from the mountains and carries sediment. Sediment carried by the snowmelt reaches the streams and fills the pools. Additionally, it can also erode the shape of the stream, decreasing the biodiversity by reducing the quality of habitat for species and making the stream more prone to floods. A healthy stream gradually shapes inwards creating this shape '_/', while an unhealthy stream has flat side banks '|_|'.

An example of an unhealthy stream is Sand Creek in Divide. The ranchers in the area changed the distribution of the creek by driving away the beavers and creating a man-made dam blocking off water access to a ditch that ran parallel to the creek and irrigated a meadow (Beardsley, 2015). This dam channeled all the water running down from the mountains, along with the sediment, into the stream, which caused severe erosion and the loss of habitat. In addition, during seasons of rain, the stream also floods, further deteriorating the banks (Beardsley, 2015). This alteration could also occur to adjacent streams of mountain resorts if not controlled. The primary victims of this habitat deterioration would be species which reside in the area and inside the river, possibly decreasing the habitat for fish and other aquatic life.

This issue with sediment could also occur on project streams surrounding mountain resorts. Many species and habitats protected by public lands could be affected by this erosion. Pools would not be able to hold as many key species such as insects, fish, and beavers, possibly creating a trophic cascade and decreasing the biological diversity and evenness of the water body.

Snowmaking:

Another impact on water bodies due to a resort's usage is the practice of snowmaking. Ski resorts pump water from nearby rivers, ponds, or other sources of water. This water is then pumped to a facility where it is injected with a biodegradable product and sent out to the ski runs through pipes. The pipes connect to snow guns which, when activated, spray artificial snow. This process goes throughout the winter season depending on the resort, usually going from early November to early April. Ski resorts pump between 50 to 400 million gallons of water a year to produce artificial snow (Flynn, 2013). For example, creating enough snow for one day at a Lake Tahoe ski resort uses about 400,000 gallons of water (Laurie, 2015). Liberty Mountain Ski Resort in Pennsylvania can pump 5,200 gallons of water per minute, yielding 312,000 gallons in an hour ("Snowmaking 101," n.d.). The substantial amount of water taken by resorts could potentially drain water sources if not monitored. The variation of water levels can also affect wildlife in the area and in the water by constantly changing the suitable habitat of species.

Artificial snow and natural snow are structurally different and, combined, affect the peak flow of drainage streams. Mark, the Assistant Mountain Manager at the Crested Butte Mountain Resort, says that natural snow drops from the sky and is made from water vapor, which allows moisture to leave the snowflake and decreases its density. On the other hand, manmade snow drops and forms nearly ten feet away from the ground from water droplets, making the snowflake denser and compacting in the ground. Regarding snowmelt, two events can occur: the snow melts faster because of the direct sunlight due to lack of trees in the ski runs, or it delays snowmelt nearly 4 weeks after the season is over because of the higher density (David et al., 2008). Both events affect the peak flow of adjacent water bodies/ drainages to the ski resorts. According to the Colorado Parks and Wildlife, peak flow is important for conserving the reproductive habitat for fish and aquatic life (Colorado Parks and Wildlife, 2017).

Crested Butte Ski Resort and its Water Usage:

CBMR draws its water for snowmaking from the East River from November until the 1st of April. When weather allows it, they will attempt to make snow for a total of two months. However, the U.S. Forests Service only allows CBMR to use the East River when the level of cubic feet per second is above 5 cfs. To enforce this number, the U.S.F.S checks on the cfs level of the river every two weeks once the season starts. Normally, on a good day during the winter, the river will be flowing at 17-18 cfs, which yields 2,696 gallons of water per minute for snowmaking. Last season, the CBMR used about 88 million gallons of water. The number of gallons of water used for snowmaking decreases every year at Crested Butte due to more snowfall every year. However, the amount of annual snowfall is unpredictable in the future.

Unfortunately, the effect of the drainage of snow and sediment on streams and rivers near Mt. Crested Butte is unknown. There are no studies on the water bodies adjacent to the ski resort. The two primary bodies of water possibly affected by the drainage of this snow are the East River and the Slate River. In addition, to combat the fluctuation of annual peak flow in rivers, the CBMR spreads the snow throughout the ski runs to allow the snow to melt faster. This practice allows for the peak flow of the rivers and streams to stay steady through the seasons.

Solutions:

Some possible solutions to avoid the disturbance of water habitats already exist. In Massachusetts, Wachusett Ski Resort created a "snowmaking pond," which intercept snow runoff and drainage water from the mountain and is then reused to make snow. This process also filters sediment coming from the mountain and diverts it away from the Wachusett Lake. When Spring arrives and the snowmelts, most of the water ultimately returns to the Wachusett Lake without the sediment ("A closer view of Wachusett mountain," n.d.).

Another uprising trend is the use of treated wastewater. If water from the ski resorts is reused without entering the water bodies, the impacts could be significant for adjacent streams, ponds, and rivers. Starting with the controversial Snowbowl in Arizona in 2012, the practice has now spread to ski resorts across the country and even internationally (Coffey, 2015). In Australia, Mount Mahon planned to decrease water used from streams for snowmaking in a year from 50 million gallons to about 30 million gallons. The resort attempted to do this by replacing the 20-million-gallon gap with treated wastewater. The question is, where does the water go? Further impacts of the treated wastewater should be evaluated in future studies to see its impact on waterbodies. Even though the water is treated, residues can still remain in the wastewater at small levels.

Conclusion:

The impact of ski resorts on water ecology is important because every year ski resorts are more frequented and exploited. The sediment impact and changes of flow because of snowmelt and snowmaking can have an acute impact on the habitat of species. Further monitoring and studies should be made to protect water bodies and their aquatic life. While Crested Butte's ski resort has certain practices to prevent leaving a footprint on the surroundings of Mt. Crested Butte, there are still other solutions that could help prevent further deterioration in the area, such as a "snowmaking pond" similar to that of Wachusett Mountain. Another area where ski resorts, like Crested Butte, could improve is further studying the long-term impacts of snowmelt runoff in the base area of the mountains. Overall, the ski industry is impacting the surrounding water habitats with their snow management.

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Sustainable Mountain Biking in Crested Butte

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Abstract:

Since the 1980's, mountain biking has been growing in popularity all over the country; expanding its borders as the industry's technology gets more advanced. For smaller mountain towns with mountain biking destinations, the social and ecological impacts of mountain biking have not gone unnoticed. This paper synthesizes scientific research in order to explore the impacts biking has on vegetation, soil composition, erosion, habitat fragmentation, and the social dynamics of mountain bike destinations. It will also seek to explain how the methods of conservation used by conservation organizations in the town of Crested Butte minimize the ecological and social impacts of the sport of mountain biking, while providing a memorable experience for the recreationists.

Introduction:

Mountain Biking is a relatively new activity. While the sport was only established in the early 1980's when the first mountain bikes were brought to the market, its popularity has exploded in recent years. According to a survey done by the International Mountain Bike Association, the number of mountain bikers reached around forty million in 2001, and has gradually increased since then. As technology has advanced in the biking industry, bikes have become more capable of taking beginner riders to harder trails, and social media such as Strava -which lets you map any ride with GPS and compete with others- have allowed enthusiastic bikers to reach new areas. Despite the new technology, bikers are still limited to certain trails, which are usually maintained by the government in charge of that certain park, or nonprofit organizations, such as local chapters of the International Mountain Bike Association. New trails are always needed as mountain biker populations increase in parks. Unfortunately for the sake of conservation, parks and park managers cannot always get the funding needed to open new trails and do restoration work on others. The growing numbers of bikers has far exceeded the trail infrastructure, concentrating the ecological impacts to certain areas (Chavez, 1993).

In the Rocky Mountains and the American Southwest, mountain biking is extremely popular due to the recreation oriented trail systems and the views the mountains provide. Many smaller mountain communities, such as Crested Butte, are having issues keeping up with the tourists brought to the areas in search of fantastic mountain bike trails. Luckily, non-profit conservation organizations in Crested Butte work together to build and maintain sustainable trail networks that attempt to minimize damage done by bikers to the environment. In Crested Butte, trail work is an activity that unites the community while bolstering productivity at the same time.

Ecological impacts overview:

While the impacts of an individual mountain bike ride may not be noticeable, the increasing popularity of the sport has led to an influx in the amount of trail users; magnifying the physical impact bikers have on the trails. According to frequent studies, mountain biking increases soil density, which leads to other ecological impacts. When bikes pass over a section of trail, weight is concentrated in a small area, and the soil from that area becomes extremely dense and hard over time. In a study done in Ontario, mountain bikes were ridden repeatedly in a controlled manner over a section of trail about five hundred times. The data collected from the trail showed that there was about a 75% decrease in species richness, a 75% decrease in vegetation cover, and a 30% increase in soil exposure. This may seem like a big impact on the ecosystem, but in reality, the study found that no impacts to vegetation or soil occurred more than thirty centimeters from the center of the trail (Thurston & Reader, 2001). Therefore, bikers can minimize damage by staying on the trail. Compaction of soil also leads to higher amounts of erosion. When a trail on a hillside is hardened, water running down after a storm will speed up on the concrete-like dirt, with no vegetation to naturally absorb the water. This increases erosion of the trail and harms the vegetation and water below the trail when sediment is carried downhill. Erosion that runs along the trail in deep tire tracks or skid marks will cause deep ruts and dangerous, rocky conditions for users of the trail. Usually these damaged sections are those that are used as uphill trails by bikers because when going uphill, a biker will exert much more torque when pedaling, which can loosen sediment. However, when going downhill, bike wheels exert much less torque and have less impact on the trail than hiking, horseback riding, and motorized vehicles (Seney & Wilson, 1994). Despite the lack of force put on the ground when going downhill, irresponsible practices such as skidding or going off the trail to avoid an obstacle can actually be harmful to the plants and the stability of the sediment on the trail. In addition to these reckless practices, building illegal trails is done to add adrenaline to a ride, because illegal trails can host obstacles that may be too much of a liability for legal trails. These poorly built trails and non-sanctioned fall line trails (trails that run straight down the slope) have no means of water diversion and will cause harmful erosion as well (Marion, 2006; Pickering & Norman, 2016).

The disturbance of wildlife is another negative impact of mountain biking. Just like roads, trails can fragment a habitat and create an edge effect for fauna. For example, a 2009 experiment shows that in the presence of mountain bikes, North American Elk are more likely to move as a group away from the disturbance right after it occurs. In comparison to the control group of elk, the movement following a bike going by was premature to their usual morning movement. Consequently, the elk were recorded eating for a longer time to make up for the extra movement they had to make. This means that the elk had to use more energy traveling and eating than they otherwise

would have without the disturbance. Although the elk returned to the spot following a bike going by, they still showed a negative reaction to mountain biking (Anthony, et al 2009).

The practice of shuttling is a preeminent concern in Crested Butte. Shuttling is when a car or truck transports bikes and riders to the top of a trailhead so that the riders can descend without having to climb the hill. It is usually repeated multiple times. Shuttling has a plethora of damaging impacts to fragile ecosystems. Usually bikes are shuttled on dirt roads or fire roads in order to access the trail. This involves a substantial amount of driving, increasing the possibility that the vehicle is doing damage to a montane ecosystem as it goes up the mountain. According to Dave Ochs, in Crested Butte, so many bikers use shuttling that parking lots overflow and tourists are forced to park on the side of the road, on top of vegetation.

Social Impacts:

Mountain bikers have not made a great rapport with the trail user community. As bikers flood trails previously only used by hikers, conflicts have occurred, making bikers appear aggressive and disrespectful. The interactions between the two groups have been studied multiple times. This conflict can be tracked down to the group's perspectives of the other group. According to a survey taken in 2001, hikers are more likely to experience unacceptable behaviors from mountain bikers while mountain bikers were less likely to experience unacceptable behavior with hikers. The same study decided that a higher percentage of hikers have social conflicts with mountain bikers, meaning they feel threatened by them or worried that they are degrading the environment. This feeling was one sided: mountain bikers in the study had no concerns with hikers (Carothers, et al 2001; Watson et al 1991).

Other groups have qualms with mountain bikers too. In Crested Butte, the so-called birthplace of mountain biking, the popularity explosion of cycling tourism has enraged a sizable proportion of ranchers and citizens. According to Dave Ochs, director of the CBMBA (Crested Butte Mountain Bike Association), ranchers have become irate with mountain bikers going through their private land -which is legal because of trail easements- but leaving their gates open and letting cattle escape. Some of the citizens of Crested Butte, even some who have been mountain biking in Crested Butte since the eighties, are not responding positively to the arrival of thousands of new mountain bikers over the summer. The trails get more crowded and part of the tourist population does not respect trail etiquette, ruining the experience of recreation for others.

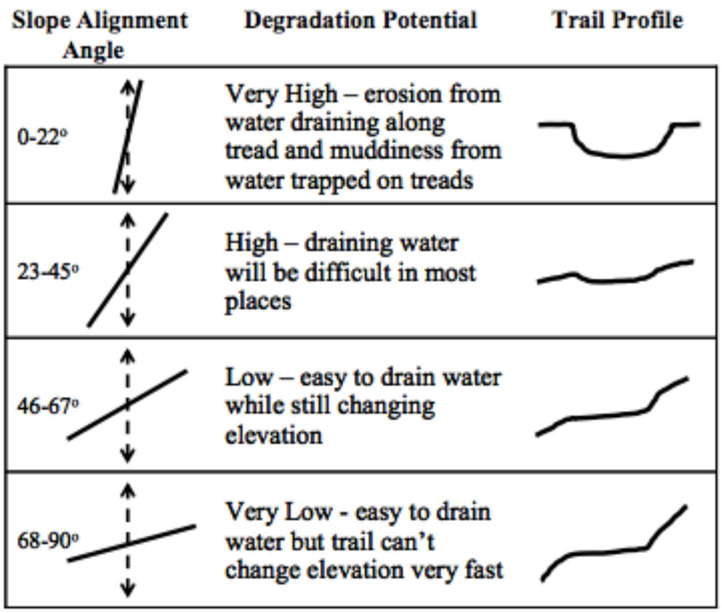
Management in Crested Butte:

Organizations such as the CBMBA, Crested Butte Land Trust (CBLT), and Crested Butte Conservation Corps (CBCC) work to minimize the damage done by trail use and outdoor recreation on the ecosystem of Crested Butte. CBLT has over 250 miles of single track trails. Some of that they own, and some they have worked with the government and landowners to place trail easements on. A trail easement is a stipulation on a land deed stating that a trail can go through that private land, and it is accessible to the public. By having trail easements CBLT is able to provide more trail to disperse the effects of biking. It also discourages bikers from illegally poaching land for trails because there are more public trails offered. CBCC and CBMBA work closely with the public to build trails and lobby to provide more access to trails and make the relationships between townspeople, ranchers, and recreationists more pleasant. A notable example of this is a project CBMBA did recently to make ranchers happier with mountain bikers. Since mountain bikers leaving ranch gates open was a big issue, CBMBA replaced gates with rollovers. The rollovers allowed recreationists to get over the fence, but kept the cattle inside. The CBCC also recently rerouted a trail to satisfy a single homeowner so they could have a symbiotic relationship with a someone who owns a lot of land. Projects like these that are done by mountain bikers will help mend social relationships with the town and other recreationists, and can help the environment. Non-profit groups should continue to do these projects for the future of mountain biking. It is possible that if mountain bikers can prove themselves as not being harmful, and have good relationships with others, the sport may be accepted in more areas to disperse the sheer numbers of bikers and the impacts on the environment.

Making Trails Sustainable in Crested Butte: CBMBA trail Building:

The organizations mentioned above are doing an excellent job of making trails more sustainable and preventing extreme amounts of damage by bikers and other recreationists. In Crested Butte, the CBMBA does all of the trail work using volunteers and hand tools. The specific methods that CBMBA uses to build trails help keep impact from trail use minimal.

In a presentation, Dave Ochs talked about a project the CBCC and CBMBA recently participated in. The project consisted of building two new parallel trails on a piece of land that was recently acquired. Even though the trails, “Lupine one” and “Lupine two”, are wide paths meant for everyone, they were built by volunteers from the town with no power tools. The Lupine trails were built to be strategically wide –both being about three feet in width. The width of the trail and the lack of technically difficult sections on the trail gives beginner riders a new trail to try that they can ride without having to get off and walk or go around obstacles. The fact that no machines were used to cut this wide trail is very important. Machinery and the vehicles used to transport machinery create bad erosion from the amount of torque and the weight the machines produce, which displaces sediment and tears up plants that hold the ground together when water runs over it. (Seney et al, 1994; Anthony et al, 2009). Using machines also creates habitat fragmentation from the loud noise they make. Just like the elk that did not habituate to loud ATV noises, the fauna near the trail would be frightened by the loud machinery and leave their habitats. Simply using humans however does not have this effect because, according to Anthony et. al.s' study on Elk, foot traffic promotes the least amount of negative reaction from elk (Anthony et al, 2009). Furthermore, the trail was bench cut to prevent erosion. Bench cutting is a process where a trail is cut along the side of a hill so that it is level (see figure 1)



Slope Alignment Angle	Degradation Potential	Trail Profile
0-22°	Very High – erosion from water draining along tread and muddiness from water trapped on treads	
23-45°	High – draining water will be difficult in most places	
46-67°	Low – easy to drain water while still changing elevation	
68-90°	Very Low - easy to drain water but trail can't change elevation very fast	

Figure 1 (Marion, 2006) -- The bottom two images represent a bench cut. When water goes down the hillside, it can easily continue over the trail without becoming a single flow or moving faster. Bench Cutting is a very universally used technique for trail building to prevent erosion.

The CBMBA also recently rerouted an existing trail called the Budd trail. The original trail was on flat ground, and had been badly eroded. The trail was closed and blocked off and seeds were planted. According to Ochs, the trail would barely be visible in a few years. His method is moving a trail before it gets too degraded to ever support life again. The new trail was also moved so that it followed the contour of the meadow it was in. Instead of just staying along the bottom of the hill, it went up and down along the natural curve. According to the International Mountain Bike Association (IMBA), a trail should always follow the contour of the hills and use grade reversals so that water never collects on the trail. (Boone et al, 2006)

Ideas for Future Sustainability

Even though the mountain bike organization in Crested Butte is able to rally the citizens to volunteer with trail building, it is still underfunded. Volunteers are tremendous for completing projects in small amounts of time, but with better funding, organizations like the CBMBA and CBCC could hire more professionals, more staff, better tools and additional equipment, and have funding for projects such as the ranch gate rollovers. According to Ochs, it is time for the mountain bikers to start paying for the right to use trails. In fact, he believes that all recreationists should pay a tax, added on to the sale price of any recreational equipment, that goes to conservation organizations. This idea shares similarities to current taxes on permits, and the sales of permits for hunting, fishing, and dirt biking. Although this idea may anger some recreationists, it is a small price to pay to be able to take advantage of the environment, and would help fund conservation considerably, insuring more pristine and healthy trail systems for mountain bikers and all other recreationists.

Conclusion:

In Crested Butte, citizens and conservationists trust nonprofit organizations including the Crested Butte Mountain Bike Association, Crested Butte Land Trust and Crested Butte Conservation Corp to build and maintain trails that can withstand the hordes of bikers that flood the town every summer. These organizations are well versed when it comes to trail building, using techniques like bench cutting, contour shaping, trail relocation and plenty of others to subdue the effects of erosion, vegetation loss, reckless and immature riding, and shuttling on the ecosystems of Crested Butte. Since these organizations are not well funded, they rely on volunteers. While volunteers do exemplary work, officials in the organizations are hoping that in the future, mountain bikers, or recreationists in general will have to pay for permits just like fishermen, hunters and motorcycle riders so that conservation organizations have more money for projects. Until then, the current nonprofits will have to continue the invaluable work they do to diminish ecological impacts of biking, while making the trails exciting for users.

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Impact of Hikers on Vegetation Biodiversity and Implications for the Town of Crested Butte, Colorado

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Abstract:

As the number of trail users increases near Crested Butte, Colorado, so too do the impacts sustained by vegetation. These impacts include a change in vegetative cover, species composition, prevalence of invasive species, species richness, and overall biodiversity. In many cases, the intensity and duration of trail use can make these impacts permanent and detrimental to the well-being of the area's vegetation. In turn, this degradation of a natural resource may lead to restrictions on land use and a loss of economic opportunities for the town. As a town reliant on nature-based tourism for its economy, a loss of natural resources would be catastrophic. This report seeks to outline the probable effects of trail use on Crested Butte's vegetation, as well as to propose a management plan based on the research of others.

Introduction:

Crested Butte, Colorado, offers a wealth of attractions for recreationists. It is the "Wildflower Capital of Colorado," holding a Wildflower Festival each July to celebrate the title. According to Michelle Bivens, executive director of the festival, three to five thousand hikers come each year to see the fields of flowers, which include over 60 types of native blooms (M. Bivens, pers. com., October 16, 2017). Joshua Futterman, an employee at Travel Crested Butte, said that the valley also boasts upwards of 1,000 miles of trails (J. Futterman, pers. com., October 16, 2017). These trails are accessible to hikers, and sometimes mountain bikers, ATV riders, and horseback riders, too. Within the past few years, the popularity of these activities has exploded, with hundreds of thousands of visitors making the trek to the mountain town each year. With so many visitors taking to the trails around Crested Butte, resulting impacts on the surrounding landscape are inevitable. The impacts can be observed in the form of changes in vegetative cover, species composition, prevalence of invasive species, species richness, and overall biodiversity. Over time, these impacts can become detrimental to the well-being of the vegetation and can cause lasting damage to the local ecosystem. This would not only impact the well-being of the ecosystem, but the well-being of the economy in Crested Butte as well. Summer tourists, who often come to the town specifically for its outdoor recreation opportunities, are some of the primary drivers of the economy, spending roughly \$800 to \$1,000 during their visits (Tilton, 2015). If the ecosystem becomes so degraded that tourists are no longer attracted to the area, the economic losses sustained by Crested Butte would be devastating. The question then arises, how can trails and visitors be managed best to prevent deleterious effects on the region's plant life, while maintaining the outdoor opportunities that attract tourists?

No published research exists yet that is specific to the impact of trail users on vegetation in the Crested Butte area. However, a plethora of studies have been conducted on the topic elsewhere in this country and other countries as well. These studies can serve as important cautionary tales for the town of Crested Butte because they can predict the impacts that are being sustained by the area's vegetation. The studies cited in this paper were conducted in environments similar to Crested Butte—montane, subalpine, and alpine environments—making them reliable predictors. Research shows that much of the vegetation disruption that takes place along an established trail is the result of trampling, which occurs when hikers walk on top of various plants on or near trails. Trampling can occur for a variety of reasons, such as when hikers walk several people across on singletrack trails, or leave the established trail to avoid oncoming traffic, muddy sections, puddles, or other obstacles in their way.

Impacts on Vegetative Cover:

One prominent effect of trampling is a decrease in vegetative cover. A 2007 study done in Mt. Robson Provincial Park, British Columbia, looked at the different impacts vegetation endured in a high-use versus low-use trail system. The study revealed that the high-use trail, which attracted 4,000 backpackers per year, had significantly less vegetative cover than both the low-use trail, which received 400 backpackers annually, and the control plots, which were not hiked on (Nepal & Way, 2007). Another experiment regarding the impact of trampling on vegetative cover was conducted in six montane and grassland communities in western Montana. Relative vegetative percent cover loss was measured after three seasons of experimental trampling. In areas with 1,200 simulated hikers per season, the relative loss was roughly 80-85%. When the number of simulated hikers rose to 1,600, the percentage reached upwards of 90% (Cole, 1987). This data has troubling implications for the Crested Butte area, where trails experience the traffic of several thousand visitors per summer—far more than the number simulated in this study. According to Matt Feier, director of planning at Crested Butte Mountain Resort, the resort alone receives more than 100,000 visitors each summer, who utilize the resort's 25 miles of trails (M. Feier, pers. com., October 5, 2017). The Lower Loop Trail attracts similar attention, with over 100,000 users annually (H. Peterson, pers. com., October 4, 2017). Based on the research done by Cole, it is safe to predict monumental losses in vegetative cover with this volume of use if efforts are not made to minimize the effects of trampling.

Impacts on Species Composition:

Species composition has also shown to be altered when trails are trampled by visitors. Many researchers have noted an increase in graminoids following the repeated trampling of an area, as well as a decline in woody plants, which tend to be eliminated from trampled areas altogether. This is due to the fact that graminoids are both more resistant and resilient to trampling relative to other plant types because they have protected meristematic tissues as well as tough and flexible vegetative parts. Woody plants are less flexible, and therefore are often damaged beyond the point of repair when trampled on (Cole, 1981).

Additionally, ruderal species are far more prevalent along trailsides than in undisturbed areas. Ruderal species are those that are first to colonize disturbed lands, making them highly suited for areas trampled by trail users. In a study conducted in the front range of Colorado, it was found that ruderal species constitute 37% of groundcover along trailsides, but only 10% of groundcover in areas 20 meters away from the trail (Potito & Beatty, 2005).

The creation of trails in areas with dense tree cover also alters species composition because the clearing of trees and shrubs that is necessary to create trails lets in more sunlight. This allows sun-tolerant species to outcompete shade-tolerant species that previously thrived there (Cole, 1981).

The introduction of invasive species is another potential impact on species composition that results from extensive trail use. In the study done by researchers Potito and Beatty in the front range of Colorado, invasive species made up 15% of groundcover in a transect that ran alongside the trail, but only 5% of a transect that was located 20 meters away from the trail (Potito & Beatty, 2005). These findings are supported by the study conducted by researchers Nepal and Way in British Columbia, where two species of invasive species were observed on the highly-used trail, but none on the off-trail control plots (Nepal & Way, 2007). Crested Butte is already experiencing problems with invasive species near trails. *Linaria vulgaris*, or yellow toadflax, is a species that thrives on disturbed lands and outcompetes native vegetation, making it both ruderal and invasive. It is very prevalent along the Upper Loop Trail in Crested Butte (D. Ochs, pers. com., October 16, 2017). Toadflax poses a major threat to the native wildflower species that attract visitors from around the country each summer because it can easily outcompete them in disturbed areas along trailsides. Other problematic invasive species in the valley include several species of thistle, knapweed, and yellow sweetclover ("Town of Crested Butte," n.d.).

Decrease in Species Diversity:

A study conducted in Los Palancares y Tierra Muerta, a natural monument in Spain, found plant biodiversity to be significantly lower near trails than in untrampled areas. The Shannon Diversity Index of the vegetation located 10 meters away from a highly used trail was 0.35, versus an index of 1.31 in an untrampled area (Lucas-Borja et al., 2010). Cole's study of the impact of trampling in western Montana yielded similar results about species richness. The number of species that went locally extinct increased as the number of simulated hikers increased. In certain grassland communities, species richness declined by over 60% when 1,600 hikers were simulated (Cole, 1987). This substantial loss of species diversity is alarming, especially for high-traffic areas in Crested Butte such as the Lower Loop trail and the Crested Butte Mountain Resort trail systems. As a town reliant on its natural resources for tourism activities, Crested Butte cannot afford to lose its vegetative diversity. If a large proportion of native wildflower species disappear, so will the annual Wildflower Festival and the revenue it generates. Festival participants pay anywhere from $15 to $250 for each program they take part in (M. Bivens, pers. com., October 16, 2017). With over 3,000 participants annually, those figures add up. When the revenue generated from hotel stays, restaurant visits, and shopping excursions are also taken into account, it is clear to see the economic value of the wildflowers and the attention they garner.

Best Management Practices:

As seen in the Montana trampling experiment, performed by Cole, plants that have undergone intense trampling will take more than one season to recover—and will potentially require several years to do so (Cole 1987). A study done in the Tasmanian alpine predicted it could even take upwards of ten years for full recovery to happen once trails have been used by 500 hikers (Whinam & Chilcott, 2003). Therefore, it is not practical to create a management plan for Crested Butte revolving around temporarily closing trails to allow them to recover. The volume of visitors is simply too high in the Gunnison County area for that method to be of benefit, because closure times would have to be a decade long. Instead, it would be in Crested Butte's best interest to concentrate the impact of trail users on a high-use trail system rather than try to disperse the impact among many trails.

When it becomes absolutely necessary for a new trail to be built, it is imperative that the prospective area's vegetation types be considered. In order to minimize vegetation disruption, trails should be constructed in open areas where graminoids are prevalent when possible, rather than in forests. As previously stated, graminoid plants are the most resistant and resilient to trampling (Cole, 1981). Conversely, forest-floor vegetation, such a woody shrubs and erect forbs, is very vulnerable to trampling and thus is more likely to be eliminated if a trail is constructed near it (Cole 1981). Forest-floor vegetation is especially susceptible to alteration when sunlight is introduced, too. When it is necessary for a trail to run through a section of forest, tree and shrub removal should be kept to a minimum, and the trail should be made as narrow as possible to encourage a more limited range of impact (Cole 1981).

In addition to considering where and how new trails should be built, it is important that the community of Crested Butte also seeks to change the behavior of hikers. One method of doing this is through the implementation of signage on popular trails. Such signage would educate hikers on the ecological dangers of straying from the trail, and encourage them to minimize their impacts. A study done in 2017 on the efficacy of educational and site management actions to reduce off-trail hiking in urban-proximate areas concluded that the most effective means of reducing off-trail hiking is through a combination of signage and personal contact with a trail steward at the trailhead. This method reduced observed off-trail hiking from 25.9% to 0%. The installation of signage at trailheads and along trails (Fig. 1) without personal contact was also successful, reducing the off-trail rate from 25.9% to 6.5% (Hockett et al., 2017).

Figure 1: Signage placed at trailhead in an effort to minimize off-trail hiking and decrease impacts of trampling on vegetation (Hockett et al., 2017)

The goal of educating hikers about their impacts is to remove the need for closure of trails or limiting their use. Both Crested Butte locals and visitors alike have a great love for their trails and recreation opportunities, and to restrict them for the sake of vegetation health would be a shame. Prevention measures such as education and signage will hopefully be sufficient to ward off the need to close trails or restrict their use.

Conclusion:

The community of Crested Butte, Colorado, is heavily reliant on natural resources for its economic well-being. Visitors come from far and wide to see the town's impressive array of wildflowers and to hike the hundreds of miles of scenic trails the area has to offer. With the influx of visitors, though, Crested Butte's vegetation is under threat. Studies have shown that heavily-hiked trails can experience dramatic losses in vegetation coverage—even on the order of a 90% loss (Cole, 1987). Species composition is also altered when hikers trample vegetation on and along trails. The prevalence of graminoids increases, while woody plants are often extirpated from the trailside. Ruderal species have also been seen to increase, taking advantage of disturbed areas and often establishing a monoculture. Similarly, invasive species such as yellow toadflax thrive along trailsides, and have already proven to be a problem in Crested Butte along the Upper Loop Trail. These factors combine to lead to an overall decline in species richness and diversity.

However, despite all of the challenges presented by trampling, it is possible to manage natural areas in a way that they can be both protected and enjoyed by users. Management tactics include constructing trails such that their impacts are minimized, and using signage to educate users about the importance of reducing trampling. Measures such as these are a significant step towards ensuring continued trail accessibility for hikers and other outdoor enthusiasts alike, so that they can enjoy the natural beauty that Crested Butte has to offer for years to come.

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The Impacts of Human Presence on Wildlife

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Abstract:

Human presence has a profound effect on wildlife. It can sensitize animals to humans, leading to overreactions that drive animals to avoid humans. Alternatively, animals can get used to this presence. This can lead to bolder prey animals that put themselves at risk of predation by more threatening predators. On the other hand, prey animals can rely on humans for protection against predators, taking advantage of a 'human shield.' These problems are especially relevant to Crested Butte because its economy relies on activities that take place in nature, which causes more interaction between humans and wildlife. While it is impossible to prevent humans from causing change in wildlife behavior and temperament, it is possible to limit it by only allowing humans access to small, select sections of protected areas.

Introduction:

While humans and their activities pose many direct and visible negative threats to organisms, the mere presence of humans also has a profound, if less noticeable effect on the behavior of wildlife. These problems grow as the human population grows, resulting in further encroachment on formerly wild lands. Human visitation of terrestrial protected areas reached 8 billion in 2015, meaning that the human impact on animals living in these areas are increasing (Balmford et al., 2015). Crested Butte, a tourist town in a county where 82% of the land is public, is an ideal subject for this paper because its economy is driven by activities that increase human presence in areas rich in wildlife. Skiing, mountain biking, hiking, fishing, and hunting are popular forms of recreation in this small mountain town, and it draws visitors from around the world. The contact created by these activities leads to either sensitization or habituation to humans. While this change in behavior may not seem like a big deal, this problem brings up a question that is core to environmental ethics: how much do we value animals unaffected by humans?

Sensitization:

Sensitization is a phenomenon whereby animals change their behavior to avoid human contact. Is more common in situations where humans pose a direct threat to wildlife, such as in areas where hunting is common. However, it occurs even when humans pose no threat. For example, in a study in an Indonesian national park, researchers compared the behavior and distribution of animals in two regions. Human traffic in the Ketambe region consisted of a dozen researchers at most, while the Bengkung region was undisturbed. They found that animals would go out of their way to avoid areas trafficked by humans. Moreover, they found the sun bear to be nocturnal in the Ketambe region, despite being diurnal in most cases, including in the Bengkung region (Griffiths 1993). This behavior is especially concerning for animals living near ecotourist towns like Crested Butte because of the sheer amount of human contact they are subject to. On top of all the non-threatening forms of recreation, hunting is popular in Crested Butte and in the surrounding area. The habitats of animals that sensitize shrink rapidly as an ever-increasing stream of humans encroach on their homes.

Habituation:

In cases where humans do not directly threaten wildlife, animals more commonly habituate to humans. Birds and rodents feast on human refuse and ungulates consume crops. This behavior leads to frequent contact with non-threatening humans, resulting in changes in temperament. For example, a study of marine iguanas in the Galapagos compared the release of corticosterone among iguanas in tourist sites with those in undisturbed sites. Corticosterone is a glucocorticoid that helps animals cope with stressful situations, and the amount they release is a good indicator of their level of stress. They found that iguanas with more contact with humans have the same initial corticosterone levels as those living in undisturbed areas while having about half as much as chronically stressed iguanas. However, iguanas in tourist sites show less of a response to human stressors than those living in undisturbed areas (Romero et al., 2002). A similar study found that Magellanic penguins with little human contact experience physiological stress as a result of the presence of humans. This stress was also measured through the release of corticosterone. Confronted with the same stimuli, penguins regularly exposed to tourism do not perceive humans as a stressor. However, those exposed to an intermediate level of contact with humans did not seem to habituate to humans over time (Fowler 1999). This is the most detrimental type of contact an animal can have, as they will continue to fear non-threatening humans, wasting time fleeing from danger that does not exist. It is better for animals that have regular contact with humans to learn that humans do not pose a direct threat, leaving them with more time not spent fleeing.

Other studies use the distance at which prey animals flee from predators, known as the flight initiation distance (FID), as a measurement for the boldness of an animal. On an urban to rural gradient, a study found that urban fox squirrels develop lower FIDs than rural ones in response to humans. More importantly, this study is one of the only studies that suggest that this lessened response to humans can transfer to other predators. They found that the lower FIDs of urban fox squirrels also extends to their behavior towards red-tailed hawks and coyotes (McCleery, 2009). Similarly, a study on dik-diks, a small ungulate native to parts of Africa, found that human-tolerant dik-diks are unable to distinguish between threatening and non-threatening sounds. This suggests that animals living in more pristine areas may be more negatively impacted by the presence of humans (Coleman et al., 2008). All these studies point towards keeping humans contained in small sections of protected areas, if they need access at all. Heavily concentrating the presence of humans when in the wild allows a small fraction of animals to be extremely habituated to humans while preventing a majority of wild animals from having contact with humans. More importantly, it would minimize the number of animals subject to an intermediate level of contact with humans. This is one reason why the prevention of the ski resort's expansion to Snodgrass Mountain was so important. It forced the ski resort to concentrate tourism on Crested Butte Mountain. With the public's call for more trails, and with the role organizations such as the Crested Butte Mountain Bike Association and the Crested Butte Ski Resort play in the creation of new trails and ski runs, it is important to be mindful of the lasting impacts humans have on the behavior of the fauna of the region.

Another example of the unintentional impact humans have on wildlife concerns human urine and sweat. Mountain goats in Glacier National Park occasionally venture away from the safe cliffs to obtain essential minerals. However, they can get the same minerals from human urine and sweat while also taking advantage of the protection from predators a human presence provides: the 'human shield' effect. Predators are less likely to be present in areas where humans are present. Mountain goats are 18 times less likely to bed in cliffs if they are near humans because they can get the same protection merely by staying close to the humans. Conversely, the predators that rely on mountain goats for food are 27 times more likely to be present at a natural mineral site than an anthropogenic one (Sarmento et al., 2017). This study demonstrates the need for proper facilities for human waste. By removing anthropogenic minerals, mountain goats will have less of an incentive to stay in human infested areas. Dave Ochs of the CBMBA recognizes the problems of improper waste disposal firsthand. The trails of Crested Butte are notorious for the toilet paper that line their trailheads. While his concerns lie more with aesthetics of the trail, this study demonstrates the importance of considering the less noticeable impacts of human negligence.

A study in Sweden found that brown bears also take advantage of the 'human shield' effect. While brown bears are not the most obvious example of a prey animal, females and their cubs are often preyed upon by larger male bears. This explains why brown bears often appear near human settlements. Not to take advantage of better or more readily available food, an idea known as food conditioning, but to take advantage of the protection humans provide from predators (Elfstrom et al., 2014). This habituation of prey animals to humans is beneficial to prey animals in the short term because instead of overreacting in response to unharmful stimuli, they focus on other aspects of their wellbeing by instead allocating their time and energy on activities such as scavenging.

In fact, habituation can be an intentional management practice for the health of wildlife when previously undisturbed animals are suddenly exposed to humans. This occurs with the construction of a new trail or the opening of an area to tourism. However, this becomes a problem in the long term if the human presence, and thus, the 'human shields' are not permanent. With tourism, humans may only be present during the day and during the summer. When humans leave, prey animals may be less equipped to survive without the security that the presence of humans provides. They may retain the boldness they acquired in the presence of humans, which becomes a disadvantage if the 'human shield' disappears. Daniel Blumstein compares this to the story of the boy who cried wolf. Prey animals learn that what they used to perceive as threatening, no longer is, but if their 'human shield' disappears, the animals might not be prepared when a real threat comes along (Blumstein, 2016). While no studies have been published on the 'human shield' effect in Crested Butte, it is most likely subject to this problem because much of its tourism is seasonal. Although most areas are accessible year-round, the ski runs are most heavily used during the winter while trails are most trafficked during the summer.

Conclusion:

The presence of humans has lasting negative impacts on wildlife. Depending on the circumstances, increased human contact can lead to sensitization or habituation. These impacts suggest that the best way to minimize the effects of humans on wild animals is to concentrate human visitors, when in the wild, into small sections of protected areas. Doing so ensures that animals frequently in contact with humans will be fully (not partially) habituated, will limit the number of animals that have intermediate contact with humans but do not habituate, and maximize the number of animals that do not come into contact with humans at all. When such drastic measures are impossible, it is important to try to minimize the lasting effect humans have on the areas they visit. This can mean creating outhouses to prevent the creation of accessible anthropogenic mineral sites. Better yet, visitors should always adhere to the Leave No Trace principles when in the wild. While ideal for wildlife, implementing and enforcing such policies will prove to be a challenge with the increasing popularity of ecotourism and the growth of the world's population as a whole. More than anything else, this issue is a moral one. How far are humans willing to go in pursuit of fun, knowing the drastic impact it will have on wildlife? While this problem may not seem as detrimental as other, better known environmental disasters, it is vital that humans consider this issue while time remains. What is the value of a truly wild animal?

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