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Loving the Fourteeners to Death

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LOVING THE FOURTEENERS TO DEATH

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Preface and Acknowledgements

Since I set foot on the summit of Quandary Peak at twelve years of age, I fell absolutely in love with climbing fourteeners. Over the years, this love has grown immensely deeper as I have spent day after day of my summer vacations wandering their unique and breathtaking trails. It is my deep love for fourteeners that not only led me to wholly recognize their endangerment and destruction, but also to create this work; for I have realized that if we do not drastically change the ways in which fourteeners are hiked, we will ultimately end up loving these mountains "to death."

I would like to thank all those who helped me foster my love for fourteeners, mountain climbing and adventure-going in general. Thanks to Katie Matarese for being my forever climbing partner and best friend, my parents for continually trusting in my decisions to set out on dangerous yet rewarding expeditions, and to all those who I have hiked with along the way.

Additionally, I certainly would not be where I am today without the help of Dr. Cath Kleier. From providing me with continuous life advice to research opportunities and everything in between, Dr. Kleier has undoubtedly been my number one support system throughout this journey. Finally, I must thank the Regis University Honors Department for encouraging me to answer life's difficult questions, the Colorado Fourteeners Initiative for being an invaluable resource, and all those who have edited and proofread this paper, including my peer writing circle mentors and reader, Allison Peters. To these wonderful individuals, I dedicate this piece of work.

Chapter One: Introduction

Heart pounding, lungs trembling, face stinging from the harsh rays of the sun, I sat on top of Ellingwood Point this past summer, marking the summit of my 36th fourteener. Of all my experiences on fourteener summits, I remember this one particularly well because it was unimaginably peaceful. I sat there in only shorts and a tank top, surrounded by my very closest friends, munching on cold pizza and admiring the 360-degree views of the Sangre de Cristo range. Although I remember each and every one of my 36 summit experiences, this one perfectly encapsulates the reason I love fourteeners so much.

Climbing fourteeners provides people with a goal that is both highly strenuous, but also exceptionally rewarding. We have all heard the over-used sayings and quotations about climbing or summiting mountains, such as "it is not the mountain we conquer, but ourselves" or, "only those who risk going too far can possibly find out how far they can go." Although incredibly cliché, most of these sayings could not be more accurate. We *do* primarily conquer ourselves, our fears, and our doubts when we climb. We *do* push our physical and mental boundaries as we risk going further. Yet, it has taken climbing many of these mountains for me to recognize the truth in these statements. Additionally, for individuals who choose to go out and hike more than just a single one, the idea of completing all of the mountains is very intriguing, as it is well known that we humans live to complete our checklists. If I am eventually fortunate enough to summit all 54 of Colorado's fourteeners, it will be one of my greatest life accomplishments.

My love for fourteeners also stems from the fact that they provide people with views like they have never seen before and may never see again in their lifetimes. I may be incredibly biased as a native Coloradoan, but I think that fourteener landscapes are some of the most beautiful in this world. Although I have not traveled to nearly all of the corners of the globe, from what I have seen of the natural landscapes of this earth, fourteeners undoubtedly offer some of the most breathtaking sceneries.

Admittedly, I am also in love with the physical aspect of climbing fourteeners, although I cannot explain precisely why. It is quite amazing to meet people of all shapes and sizes, backgrounds and ethnicities, atop these peaks on any summer day. From ultra-runners who take high altitude training to a new level by jogging up the switchbacks of the Collegiate Peaks, to out-of-staters who commit themselves to huffing up the last stretch of Bierstadt, hiking fourteeners offers individuals a unique experience in the outdoors—one that places them in the heart of the Colorado wilderness while in reality being only a couple of miles from a car. It is for these reasons, as well as many others, that people wake up at 4 am to drive to the base of a fourteener (or even at 11 pm as I have once done in the past), put on their headlamps and set out to conquer these mountains. In my mind, and in clearly many others, climbing any of them is a goal worth striving for.

Because of these reasons and more, nearly all 54 of Colorado's 14,000-foot peaks have become increasingly popular over the past couple of decades. Specifically, last year an estimated 311,000 people hiked fourteeners, which is three times as many people as were thought to be hiking them only a decade ago (Boster, 2017; Woodbury, 1999). Even

more surprisingly, over 674 people were documented to climb a single fourteener, Mount Democrat, in just one day (CFI, 2016). It is easy to become numb in the midst of these numbers and statistics, but I assure you that once you share your summit experience with over 100 other individuals, they become instantly realistic and extremely frightening.

Not only does this increase in popularity tend to diminish one's personal experience on fourteeners, but it also leads to other subsequent issues as well, as does what happens to any of the world's natural landscapes when they become overly popularized. For instance, the overcrowded trails have led to some extreme safety issues, especially on fourteeners that are considered difficult to climb. Nearly every year, even the most experienced climbers die hiking the "Hourglass" on Little Bear Peak—a vertical climb on loose, slick rock—usually by a falling rock which originates from hikers above (Flomberg, 2015). This past summer, five people died in a mere six weeks on Capitol Peak, a mountain which boasts one of the most dangerous climbs in the state due to a number of different technicalities (The Associated Press, 2017).

Apart from safety issues, the overcrowdedness of these mountains also presents substantial dangers to the wildlife of these ecosystems. Cardboard signs, which people take a picture with on the summit to mark their accomplishment on social media, as well as food, clothing, wrappers, and other garbage that people discard pollutes both the trails and summits of these mountains (Michels, 2017). Aside from depositing a great amount of trash, hikers add to a number of other ecological issues. For instance, it is not uncommon to see dogs off-leash, trampling extremely delicate vegetation or even hunting down native pika (*Ochonta princeps).* Those who choose to backpack partway up the

mountains cut down trees to make room for campsites as well as create fire-rings, leave behind waste and choose to feed nearby wildlife. Non-savvy hikers take shortcuts up the slopes and walk off designated trails, which inevitably leads to erosion. Not to mention, hikers discard countless wads of toilet paper as well as human feces in the areas around tree line, as they see it as their last time "to go."

As more and more people choose to hike fourteeners, these and many other human environmental impacts are beginning to pose serious threats to the once-untouched ecosystems. In fact, Lloyd Athearn, executive director of the Colorado Fourteeners Initiative, claims that, "hikers do more damage to the alpine environment per person per use than previously thought" (Fayhee, 2017). Hence, although these individual actions may seem somewhat insignificant in the grand scheme of ecological destruction, the reality is that they are being carried out by thousands of people, leading to grave environmental concerns.

These problems are also especially significant because fourteeners are home to some of the rarest species of both plants and animals in the world such as the pika (*Ochonta princeps),* rosy finch *(Leucosticte atrata),* marmot *(Marmota),* and ptarmigan *(Lagopus),* to name a few (National Forest Foundation, 2017). Additionally, the characteristic alpine environments of fourteeners are highly sensitive to change, due to the slow growth of high-altitude plants, which require centuries to develop (Botman et al., 1996; Vandvik, 2004; Hestmark, 2004).

Clearly, fourteeners experience an incredibly high level of destruction all while being highly sensitive to impact. So, it is natural to wonder what efforts have already

been made to alleviate the ecological damage on these mountains. Most people would think that the majority of work being done to protect these ecosystems would be overseen by the Forest Service or Bureau of Land Management, organizations that manage most of the Colorado territories within which fourteeners lie. Yet, because these organizations govern such large parcels of land and their budgets are unimaginably small for the amount of work they carry out, their focus on protecting the little amount of land on fourteeners remains a low priority.

Additionally, contrary to popular belief, the Forest Service is not primarily concerned with conservation or recreation, but instead is motivated to achieve "quality land management under the sustainable multiple-use management concept to meet the diverse needs of people" (National Forest Service, 2004). As an agency of the United States Department of Agriculture, the Forest Service must meet many needs (including wildlife development, supplying natural resources, energy development, managing livestock grazing), all of which fall under their "multiple-use management" strategy. In fact, one of their major aims is to provide "a variety of products to meet the needs of the Nation, including wood, forage, water, and energy" (National Forest Service, 2004). This is why the organization is most often known for their efforts in producing timber for use and mitigating wildfires, as these are some of their primary goals. This is not to say that the work the National Forest Service carries out is unnecessary and ecologically unimportant, but rather that the environmental needs of Colorado's fourteeners have consequently been addressed by other organizations.

The issue of ecological destruction on Colorado fourteeners has recently begun to be tackled by smaller organizations, which have sprung up in response to the overuse and degradation of many landscapes across the Rocky Mountains. As it turns out, most efforts have been made by the Colorado Fourteeners Initiative (CFI), a small group of individuals dedicated to protecting and preserving "the natural integrity of Colorado's 54 14,000 foot peaks through active stewardship and public education" (CFI, 2017), as well as other groups such as the Rocky Mountain Field Institute (RMFI), Sierra Club, and a few smaller organizations. The majority of work done by these groups is aimed at slowing and preventing the damage done to the wildlife by building trails that minimize erosion and other types of environmental degradation. Yet, their efforts come with a hefty cost.

2015 Colorado Fourteeners Statewide Report Card

Planned, Constructed 14er Summit Routes (Year Built)	Grade	Cost
Blanca Peak & Ellingwood Point. - *Lake Como**, (2011-12)	A	$
North Maroon Peak - *Approach, Northeast Ridge,* (2012)	A	$
Pyramid Peak - *Approach, Northeast Ridge,* (2005-06)	A -	$
Mount Harvard - *North Hornfork Basin,* (1999-2002)	A -	$
Humboldt Peak - *South Colony Lakes**, (1997-98)	A -	$
Windom & Sunlight Peaks, *Chicago Basin* , (2007, 2009-10)	B +	$
Mount Yale - *Denny Creek,* (2008-11)	B	$
Mount Evans - *Chicago Lakes & Summit Lake,* (2005-2006)	B	$$
Tabeguache Peak - *Jennings - "CLOSED",* (2002)	B	$
Capitol Peak - *Capitol Lake,* (2002)	B	$
Crestone Peak & Needle - *South Colony Lakes**, (2001-2005)	B	$
Mount Massive - *East Slopes,* (2006-2009)	B -	$$
Huron Peak - *Clear Creek,* (1998,2002)	B -	$$
Mount Bross - *Bypass,* (2008)	C +	$
Mount Massive - *North Halfmoon Creek,* (2003-05)	C +	$$
Quandary Peak - *East Slopes,* (2001-02)	C +	$$$
Mount Democrat - *Kite Lake,* (2008)	C	$$$
La Plata Peak - *Northwest Ridge,* (1995)	C	$
Mount of the Holy Cross - *Halfmoon Pass,* (2011-12)	C	$$
Mount Sneffels - *Yankee Boy Basin,* (2003-04)	C -	$
Uncompahgre Peak - *Nellie Creek,* (2008)	C -	$$$
Mounts Belford & Oxford - *Missouri Gulch,* (1995-96)	C -	$$
Wetterhorn Peak - *Matterhorn Creek,* (2004-05)	D +	$$$
Grays & Torreys Peaks - *Stevens Gulch,* (2000-02)	D	$$$
Missouri Mountain - *Missouri Gulch,* (2000-01)	D -	$$$
Mount Bierstadt - *Guanella Pass,* (1999-2002, 2014-15)	F	$$$$$$
Total Estimated Cost:		**$6 million**

Cost Notes and Legend:
1) Cost to bring route to ideal conditions, not including on-going maintenance.
$ = <$125,000
$$ = $125,000 to $249,999
$$$ = $250,000 to $499,999
$$$$ = $500,000 to $999,999
$$$$$ = $1,000,000 to 1,999,999
$$$$$$ = $2,000,000 and up

Unplanned 14er Summit Routes	Grade	Cost
Mount Elbert - *Black Cloud †*	C	$$$$
Quandary Peak - *Blue Lakes*	C	$$$$
Mount Princeton - *Radio Towers †*	C -	$$$$
Handies Peak- *Grizzly Gulch †*	C -	$$
Mount of the Holy Cross - *Notch Mtn. †*	C -	$
Mount Antero - *Baldwin Gulch*	D +	$
Handies Peak - *American Basin †*	D -	$$$
Mount Lindsey - *Lily Lake*	D -	$$$$$
Mount Elbert - *North †*	F	$$$$$
Mount Evans - *Guanella Pass*	F	$$$$$
Mount Shavano - *Blanks Gulch*	F	$$$$$$
Redcloud Peak - *Silver Creek †*	F	$$$$
La Plata Peak - *Winfield - SW Ridge*	F	$$$$$
Mount Columbia - *North Hornfork Basin*	F	$$$$$
Mount Elbert - *East Slopes †*	F	$$$$$
Snowmass Mountain - *Snowmass Creek*	F	$$$$$
Total Estimated Cost:		**$18 million**

Peaks/Routes to be Inventoried

Castle & Conundrum Peaks - *Castle Creek*
El Diente Peak - *Kilpacker & Navajo Basins,* (2014-15)
Mount Eolus & North Eolus - *Chicago Basin,* (2013, 16)
Kit Carson Peak & Challenger Point - *North Slope*,* (2014-15)
Mounts Lincoln & Cameron - *Kite Lake Loop*
Maroon Peak - *South Ridge,* (2013)
Pikes Peak - *Barr Trail & Crags Trail*
San Luis Peak - *Stewart & Cochetopa Creeks,* (2012-13)
Mount Sherman - *Fourmile Creek & Iowa Gulch*
Sunshine Peak - *Redcloud traverse*
Tabeguache Peak - *Shavano traverse*
Mount Wilson - *Navajo Basin & Rock of Ages*
Wilson Peak - *Rock of Ages*

Peaks/Routes That Will Not be Inventoried

Culebra Peak - Entirely on Private Land
Little Bear Peak - Too Hazardous to Maintain
Longs Peak - Maintained by National Park Service

Figure 1. Colorado Fourteeners Initiative 2016 Statewide Report Card reveals the estimated cost to repair and restore each of the surveyed fourteener trails, as well as their corresponding trail "grades" based on an analysis of 10 different factors such as extent of erosion and accessibility to natural rock sources (CFI, 2016).

In their 2016 Statewide Report Card (Figure 1) CFI estimated that at least $24 million dollars is needed to merely restore and construct current fourteener trails, not including repairing specific damage done to wildlife and their habitats (Blevins, 2015; CFI, 2016). Although the work these organizations carry out is necessary to assure that each hiker makes as little environmental impact as possible, it does not account for the damage that has already been done to fourteener environments.

Furthermore, no one is actually quite sure how bad the damage is, as hardly any research has been dedicated to assessing the destruction of these landscapes (Ciuti et al., 2012). Therefore, there is a great need for research concerning human impact on fourteeners because it will allow us to at least make an attempt at reversing the damage we have done to these environments in the past as well as prevent future harm. Using results from research experiments and comparative studies on fourteeners, we may inform policy makers as to what measures should be taken to decrease their future environmental degradation.

Former Colorado governor, Richard Lamm, once said that we humans may inadvertently be "loving the fourteeners to ruin," and I have certainly taken this statement to heart (Lamm, 2014; Woodbury, 1999). Clearly, both my own as well as many others' love for fourteeners is extremely strong. However, it is absolutely essential that we begin

to acknowledge when this love may be “too much” and instead start to find various ways that we might intervene so we do not end up loving them “to death.”

Because this is not only a pressing social issue, but a deeply personal one as well, I have chosen to investigate these ideas for my thesis, as well as work out a number of possible ways in which we may attempt to alleviate the anthropogenic problems on fourteeners. To accomplish this, I will first provide background information of current environmental health issues on fourteeners. Then, I will present my grant proposal to National Geographic, which aims at further understanding the relationship between human impact and environmental degradation on fourteeners. Next, I will propose various measures that might be taken to prevent further ecological destruction on these mountains, which will ultimately help to guide policy makers in making informed decisions in regards to how to best protect these precious landscapes. Lastly, I aim to reveal the significance of this topic to my own life and how furthering my knowledge about this topic continually encourages me to live in accordance with the Jesuit values.

Chapter Two: Aims of Grant Proposal and Biological Background

I have previously established how human-environmental impacts on fourteeners have become increasingly severe and that one of the main strategies to mitigate these problems might be to conduct research to assess human-environmental impacts and determine ways of protecting these environments in the future. In simple terms, I believe that research is the key to understanding what steps we should take to better protect fourteeners. Yet, merely conducting research is a relatively difficult task because one of the major problems is that we not aware of the current extent of damage on these mountains in the first place. Therefore, before we can decide what measures to take to prevent future destruction, we must assess the severity of the problem.

With this in mind, my advisor and research mentor, Dr. Kleier, and I organized a meeting with Colorado Fourteeners Initiative (CFI) earlier this year to learn more about some of the most pressing current issues regarding fourteeners. According to the CFI, one of the most demanding human-environmental concerns is the high level of fecal contamination caused by both dogs and humans. Although fecal pollution is a clear and observable issue on many of these mountains, we are not exactly aware of the severity and whether or not it is actually harming fourteener ecosystems. As Dr. Kleier and I wanted to conduct a specific research project on fourteeners, we began to explore this idea of fecal contamination and how we might be able to design an experiment that addresses these main questions.

To give you a little more background on the issue of fecal pollution of wilderness areas, it turns out that it tends to occur by the inadequate burial and disposal of human waste, especially at campsites and surrounding tree line (at least this is what we suspect, because these areas are the most private areas to "go") (Derlet & Carlson, 2006). Because of the extreme fragility of the soil on fourteeners, waste material can take large amounts of time to decompose. Additionally, the cold climate of the alpine contributes to the slow rate of fecal breakdown, as decomposition rates significantly decrease with lower temperatures (Burke et al., 2003; CFI, 2017).

These slow decomposition rates allow high levels of fecal matter to persist in the alpine environments, which presents a vast number of problems. For one, there is the issue of aesthetics, as visualizing improperly disposed feces can leave a negative impression on the individual's experience. Even more concerning, however, is that more than 100 species of bacteria, protozoans, and viruses commonly found in human feces are capable of causing illnesses (Cowgill, 1971; Derlet & Carlson, 2006). Exposed fecal matter can transmit these pathogens to humans through the air, upon direct contact or fecal-orally. Specifically, *Escherichia coli,* the most reliable indicator found in human feces, is commonly proven to be a threat to human health (APHA, 1998).

Furthermore, there is the extreme risk of water contamination by fecal pathogens after rainfall (Cilimburg et al., 2000). Upon exposure to rain, the rock fissures and underground channels in alpine ecosystems permit rapid water flow and are therefore capable of transmitting microbes extremely long distances (Potter et al., 1984). This is

particularly problematic because certain species of fecal coliform bacteria such as *E. coli* typically survive in drinking water for up to 12 weeks (Edberg et al., 2000).

It is not only those who climb fourteeners who have an increased risk of exposure to these pathogenic bacteria, but also the general public, because we obtain a majority of our water from these high alpine systems. As much as 20–25% of the global population depends on a supply of karst water (groundwater which flows through subterranean rock channels), with a significant amount originating from mountainous areas (Ford & Williams, 2008). Therefore, it is important that water is protected from microbial, chemical and toxic pollution for users both down and upstream.

Additionally, fecal microbes (mainly bacteria) can easily become airborne and have been documented to travel aerially for extremely long distances (Sanchez-Monedero et al., 2008; Bowers et al., 2013). In fact, in one major study conducted by researchers at the University of Colorado Boulder, it was found that one of the main sources of microbes in the air is actually bacteria derived from dog feces (Bowers et al., 2011). Thus, due to the high levels of human feces on fourteeners, it is reasonable to suspect that human fecal bacteria pollute the air in large quantities both on these mountains and in the surrounding areas. High concentrations of atmospheric microbes not only present a health hazard as common pathogens, but also have been known to trigger allergic asthma as well as seasonal allergies (Bowers et al., 2011).

To make matters worse, fecal contamination of water and soils on fourteeners presents issues to not only humans but also to the plants and animals that directly rely on these ecosystems. Alpine mammals drink directly from contaminated streams and often consume human fecal matter, and native plants can absorb pathogenic microorganisms as well as heavy metals from the soil. Thus, it is extremely important that we assess the levels of fecal contamination on fourteeners so we can deduce whether or not the extent of human impact is concretely harming their environments.

One of the ways we might begin to assess levels of fecal contamination on fourteeners is by looking for the presence of fecal indicator bacteria, as it is both redundant and highly difficult to test for all species. Indicator species are particularly helpful because determining whether they are present or absent offers a simple way of revealing the health of a certain ecosystem. For example, *Escherichia coli* and other fecal coliform bacteria are often used to indicate areas with high levels of fecal accumulation, even in alpine environments (Macpherson, 2005; Edberg et al., 2000). Scientists focus largely on *E. coli* because most other species of bacteria that are commonly found in the environment are not associated with fecal contamination and usually do not imply a health risk (Edberg et al., 2000).

Using *E. coli* as an indicator species is a relatively simple way to assess fecal contamination across fourteener landscapes and may lead to a further understanding of the severity of human-environmental impacts in these ecosystems. Additionally, measuring fecal contamination is relatively simple through the use of a Fecal Coliform Test, which measures the presence and abundance of *E. coli* and other fecal coliform

bacteria. Although *Escherichia coli* is the most reliable representative of the coliform group, intestinal enterococci and *Clostridium perfringens* are also frequently used as Standard Fecal Indicator Bacteria (SFIB).

The presence of Fecal Indicator Bacteria are associated with the decreased health of a water source, yet it is less widely accepted that their presence in soil systems is also harmful. In fact, the high level of nitrogen and phosphorus in fecal matter is widely assumed to promote plant growth, rather than inhibit it. It is true that *treated* fecal material (which has minor concentrations of both heavy metals and pathogenic microbes) tends to promote plant growth (EPA, 2000). Yet, untreated human waste has been shown to have negative effects on soil, food webs, and air quality, as it harbors pathogenic microbes, as well as high concentrations of heavy metals (Campos et al., 2015). One of the main concerns with untreated human feces on plant communities is the high prevalence of heavy metals (such as Cadmium, Copper, Chromium, Nickel, Lead and Zinc). These heavy metals have been shown to decrease plant root and shoot growth by inhibiting nutrient uptake and homeostasis (Jamali et al., 2007; Piršelová, 2011; Cele & Maboeta, 2016). Hence, treated fecal matter, otherwise known as “biosolids,” may in fact optimize plant growth and health, yet high concentrations of unprocessed fecal matter can have adverse effects on soil and the plant communities that directly rely on it, which may in turn harm entire ecosystems (Sharma et al., 2017).

Assessing the severity of fecal contamination on fourteeners and more specifically how it effects plant and animal biodiversity is necessary to begin understanding the overall human-eco dynamic on fourteeners. However, it is relatively easy to simply point

out various ecological issues on fourteeners, as I have done here. The more difficult aspect is designing and conducting an experiment to directly assess these problems. Therefore, I decided that rather than simply contemplating fourteener related issues, as many have done previously, I would take action and design a study.

Knowing that the issue of fecal contamination is extremely pressing and needing to be assessed, I decided I would write a research proposal that would speak to this problem. Early on, I decided to write and submit this grant proposal to National Geographic, as it is one of the leading organizations dedicated to the preservation and protection of our natural world. The next part of my thesis includes the sections of the actual grant, which was submitted to National Geographic in January of 2018, and explores the issue of fecal contamination on fourteeners and how we may go about assessing its severity.

Chapter Three: National Geographic Grant Proposal

Assessing the Levels of Fecal Contamination

On Colorado's 14,000-foot Peaks

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Abstract

Colorado's 54 peaks over 14,000 feet, otherwise known as fourteeners, have become increasingly popular hiking destinations throughout the past couple of decades, subsequently leading to high levels of ecological destruction. Yet, hardly any research has been done to assess anthropogenic impacts on the environmental destruction of fourteeners. Because of this, we aim to further understand the level of human impact on fourteeners by examining the severity of human fecal contamination, which has been noted to be one of the most significant anthropogenic-based ecological issues in these ecosystems. To do this, we plan to collect a variety of soil and water samples from a subset of Colorado fourteeners before conducting a Fecal Indicator test to determine the respective abundances of total fecal coliforms and *Escherichia coli*. We will then compare these values to the relative hiking frequencies of the mountains. Not only do we expect there to be a higher level of fecal contamination on frequently traveled fourteeners than less frequently hiked fourteeners, but also that many of the samples will exceed the limit of fecal bacteria suggested by the Environmental Protection Agency and World Health Organization. Because this is one of the first experimental research projects on fourteeners, the results will increase further understanding of whether or not human impact on fourteeners is significantly harming their ecosystems, and ultimately what should be done to mitigate these threats.

Introduction

Colorado is home to 54 peaks over 14,000 feet, more commonly know as "fourteeners" to in-state natives and tourists alike. Throughout the last couple of decades, these peaks have become increasingly popular hiking destinations. Specifically, last year, an estimated 311,000 people climbed fourteeners, which is three times as many people as were thought to be hiking them only a decade ago (Boster, 2017; Woodbury, 1999). Because of the extreme popularity of these trails, hikers have begun to alter the physical environments of these landscapes in innumerable ways—from trampling the highly delicate vegetation, to feeding wildlife, to creating short-cuts up the steep slopes, to camping high above tree line, to even discarding cardboard signs and other trash (Michels, 2017).

Although all of these issues pose adverse environmental concerns, Colorado Fourteeners Initiative (CFI), the primary nonprofit organization overseeing the protection of these peaks, suggests that one of the most prevalent issues concerning fourteeners is the high level of human fecal contamination. Coliform pollution of wilderness areas occurs through inadequate burial and disposal of fecal material, and tends to mostly occur near popular camping areas and surrounding tree line (Derlet & Carlson, 2006). Because the alpine soils on fourteeners are extremely fragile and exist in high, cold ecosystems, human waste tends to require extreme amounts of time to decompose (CFI, 2017; Burke et al., 2003).

Our research-based project aims at assessing levels of fecal contamination on a subset of Colorado fourteeners in order to determine whether or not human impact on

fourteeners is significantly impacting their ecosystems. Levels of fecal contamination can be assessed by the presence of certain indicator species, which offer a simple way of revealing the overall health of certain ecosystems. Specifically, fecal accumulation is measured using a Fecal Indicator test, which examines the levels of fecal coliform bacteria, enteric pathogens capable of causing human disease (APHA, 1998; Derlet & Carlson, 2006).

Measuring levels of fecal coliform bacteria in water is critical because as much as 20–25% of the global population depends on a supply of karst water (groundwater which flows through subterranean rock channels), with a significant amount originating from mountainous areas, and these microbes can survive in water for up to 12 weeks (Ford & Williams, 2008; Edberg et al., 2000). Not to mention, high numbers of hikers and backpackers directly rely on these alpine streams as a water source. Additionally, measuring levels of Fecal Indicator Bacteria in soils is essential because if left untreated, human fecal matter can have negative effects on food webs, air quality, and human health, as it harbors both pathogenic microbes and high concentrations of heavy metals (Campos et al., 2015).

Comparing total fecal coliform and *E. coli* counts between non-frequently and frequently hiked fourteeners will demonstrate whether or not fecal contamination is directly correlated to the amount of people who hike each mountain, as it is the only main differing component between the two groups. A visual observation of the various feces will also allow for a determination of the relative frequency of human and dog-related fecal contamination to that of the natural level resulting from solely alpine mammals.

Although the climbing of fourteeners has become increasingly popular over the past decades, no research has been conducted to demonstrate how human impact is negatively affecting Colorado fourteener ecosystems. Thus, this study aims to examine how high levels of human impact harm the environments of these peaks, specifically by assessing levels of fecal contamination. By collecting and analyzing a variety of soil and water samples collected from a subset of fourteeners throughout Colorado, we will be able to further understand the overall health of these ecosystems and to what extent human impact correlates with environmental degradation on fourteeners.

Ultimately, by comparing the levels of contamination with the hiking frequency of each peak, we will not only be able to determine if there is a positive correlation between hiking frequency and fecal contamination, but also further understand which fourteeners present the highest levels of ecological destruction. Specifically, we will be comparing our data against the current World Health Organization standards for drinking water (WHO, 2011), which gives various ranges of health risk categories (low risk <1, intermediate risk 1-10, high risk>10-100, very high risk >100 *E. coli* CFU/ 100mL). Additionally, we will determine if any peaks reveal fecal indicator bacteria levels that are over these suggested limits and therefore pose an environmental health risk for humans.

This project will help instruct land management organizations as to how these mountain landscapes can be better protected in the future, and the data we gather will guide policy makers as to how to make informed decisions regarding the current ecological state of Colorado's fourteeners. Assessing the level of human impact on

fourteeners is essential, as it is the first step in learning how to better protect these precious landscapes.

Protecting the alpine ecosystems these mountains support is vital, as they are not only incredibly fragile, but are also home to some of the rarest species of plants and animals in the world, such as pika (*Ochonta princeps),* rosy finch *(Leucosticte atrata),* marmot *(Marmota),* and ptarmigan *(Lagopus)* (National Forest Foundation, 2017). Also, these alpine environments are highly sensitive to change, due to the slow-growth of high-altitude plants, which require centuries to develop (Botman et al., 1996; Vandvik, 2004; Hestmark, 2004).

By physically impacting these ecosystems, humans may be unknowingly altering the behavior of animals, the makeup of dominant plant communities, and even the abiotic qualities of these alpine environments, all of which, in turn, might alter the course of ecological succession (Steidl & Powell, 2006). Clearly this is an important issue to consider, yet, given the fact that no research has been done on fourteeners, we can only suspect that increasing human impact on these mountains is harming their ecosystems. Since there is a great need for research assessing the ecological damage on fourteeners, and National Geographic is one of the most well-known organizations dedicated to the protection and preservation of our natural environment, this project aligns with the National Geographic mission statement and relates directly to other current research conducted by the organization, including a recently posted story regarding the problems of human waste around the world (Royte, 2017).

Additionally, there is little monetary support available to fund this type of research since the small amount of existing money dedicated to Colorado's fourteeners goes rightfully into building sustainable new trails, which decreases the amount of impact per user. Furthermore, this research topic is relatively specific as it attempts to combine scientific research with management practices and deals with assessing the ecosystem health of a small subset of mountains in Western Colorado, thus it is applicable to very few grants. However, this research falls perfectly within the guidelines for the National Geographic Biological and Environmental Sustainability Grant, because it aims at "informing tangible solutions that contribute to the conservation of natural resources" by developing a conservation action plan, implementing solutions to conservation issues and investigating threats to the natural environment. Not only is the issue of human impact on Colorado fourteeners pressing and urgent, the results of this study have implications to prevent further damage to critically endangered biodiversity. Although this project is relatively simple and straightforward, the results may provide much needed information about how humans are negatively impacting such delicate and valuable ecosystems.

How will your project fill gaps in our knowledge needed to effectively mitigate threats to wildlife?

The "Wildlife and Wild Places" lens seeks to support projects that attempt to "mitigate threats to Earth's life-forms" and improve our understanding of ecology. This project aims to accomplish both of these things. For one, it attempts to fill gaps in our knowledge of how the ecosystems on fourteeners are being negatively impacted by the

ever-increasing numbers of hikers. Because of scant previous research conducted on fourteeners, assessing the current level of damage is essential before we can determine what strategies we might use to mitigate threats to wildlife. It also seeks to improve knowledge of ecology, specifically in terms of the processes by which human feces can contaminate water and soil sources, and thereby how it might directly impact plant and animal life. Additionally, once we understand exactly how humans are altering fourteener ecosystems, we may be able to more effectively protect these environments by developing new management strategies.

Lastly, this lens supports projects related to research, conservation, education, and communication and that will "engage society and leverage action to protect the biological diversity of this planet." Our project seeks to do much more than just provide experimental research, as our results will also contribute to the discussion about how we may better educate recreationists so that we may conserve these natural landscapes for years to come.

Methods:

In the summer of 2018, we plan to collect both soil and water samples on five frequently and five non-frequently hiked Colorado fourteeners to determine if there is a correlation between hiking frequency and level of fecal contamination (Table 1). At least ten, 1-gram soil samples will be collected in sterile soil tins along the trail and around tree line, as well as near highly impacted/ camping areas. At least ten, 100mL water samples will be collected in sterile tubes near the highly impacted areas (ie. stream

crossings) as well as suspected campsites. We plan to record the GPS location of all of the sample sites, as well as record any visual observations of the feces of various animals (ie. dog, human, pika, bighorn sheep, marmot, etc).

Within 24-hours, the samples will be assessed for total fecal coliforms as well as *E. coli* using the membrane filtration test method outlined by the United States Environmental Protection Agency (U.S. EPA, 2002; U.S. EPA, 2012; Brenner et al., 1993). This test is often the preferred method of choice for measuring levels of both fecal coliforms and *E. coli* in water samples, as it is considered the most simple, cost-effective, and sensitive method allowing for the differentiation of total fecal coliforms and *E. coli* (Hallas et al., 2008; Maheux, 2015). Among many other methods, the membrane filtration method results in the lowest growth of atypic colonies and interference in *E. coli* count (Maheux, 2014).

Performing a Fecal Coliform test will only allow us to assess total levels of fecal contamination, meaning that we will not be able to differentiate the fecal coliforms contributed by different species. There are few methods available to determine only human-specific fecal contamination, all of which use PCR with primers specific for bacteria only found in human feces; yet, these approaches are still being improved, and they tend to be extremely difficult and not sensitive to low levels of contamination. Although testing for total coliform levels will not allow us to differentiate between human fecal contamination and that of native mammals, the results will still provide a general assessment of fecal contamination on fourteeners as well as a comparison between frequently used and non-frequently climbed peaks.

After sample collection, the soil samples will need to be diluted to an appropriate concentration that gives 20-80 colonies per plate (U.S. EPA, 2012). All samples will then be filtered through a 47mm cellulose ester membrane, which retains the bacteria, filtering out organic particulates. The membrane filter is then set in a petri dish that contains 5mL of nutritional growth medium (MI agar) selective for the growth of fecal coliforms and is incubated for 24 hours at 35 °C. Two enzyme substrates (IBDG and MUGal) are included in this medium. All fecal coliform bacteria possess the B-galactosidase enzyme, which allows them to break down the substrate MUGal, causing the colonies to fluoresce under UV light (366nm). Only *E. coli* bacteria possess the enzyme B-glucoronidase, which allows for the breakdown of substrate IBDG, causing the colonies to turn blue (Figure 2). After incubation, the colonies will be identified and counted, which will ultimately allow us to estimate the relative number of Colony Forming Units (CFUs) per sample.

We then plan to compare these estimated concentrations of fecal coliforms as well as *E. coli* with the current World Health Organization recommendations for drinking water (WHO, 2004). Additionally, we plan to compare the hiking frequency of each fourteener using data estimated by Colorado Fourteeners Initiative in 2016 using TRAFx recorders (CFI, 2016), with the resulting fecal contamination levels, as well as between the two different groups, frequently and non-frequently hiked.

The total fecal coliforms and *E. coli* CFU per 100 ml will be tested for normality (Shapiro-Wilk test) with non-normally distributed data analyzed by a Kruskal-Wallis analysis of variance test (KW-ANOVA) using Dunn's post hoc test for significance and Spearman-Rank correlation coefficient (rs). Normally distributed data will be analyzed

using ANOVA with Tukey's post hoc analysis and Pearson's correlation coefficient (r), as in Hallas et al. (2008).

Table 1. Selected fourteeners to be used in the study. Estimated hiking use data estimated by Colorado Fourteeners Initiative in 2016 using TRAFx recorders and infills from previous years and/or nearby peaks (CFI, 2016).

Most Frequently Hiked Fourteeners	Estimated Hiking Use
Mount Elbert	25,000-30,000
Grays/Torreys Peaks	20,000-25,000
Mount Bierstadt	20,000-25,000
Quandary Peak	15,000-20,000
Mount Evans	10,000-15,000

Least Frequently Hiked Fourteeners	Estimated Hiking Use
San Luis Peak	1,000-3,000
El Diente Peak	1,000-3,000
Uncompaghre Peak	3,000-5,000
Redcloud/Sunshine & Handies Peaks	3,000-5,000
Mount of the Holy Cross	5,000-7,000

Table 2. Proposed budget for the experiment.

Requested Grant Award: $36,000			
Item or Name	**Price**	**Quantity**	**Total**
Membrane Filtration Units (Filter Base & Funnel)	$250	1	$250
47mm Diameter, 0.45µm Pore-Size Cellulose Ester Membrane Filters	$150/ pack of 100 membranes	2 packs	$300
Longwave UV Lamp (366 nm)	$100	1	$100
Phosphate Buffered Dilution Water	$30/ package	1 package	$30
MI Agar	$250	1 dehydrated pack of 100g agar	$250
9x50mm Petri Plates	$60/pack of 100	2 packs	$120

Soil Trowels	$20 each	3	$60
Sterile Soil Sample Bags	$25/pack of 100	1 pack	$30
Sterile Water Containers	$40/pack of 100	1 pack	$40
Transportation Costs	Total driving time ~5 hrs/trip, gas ~$35 per car, 3 cars = $100/trip	10 trips at $100/trip= $1000	$1,000
Principal Investigator Stipend, Dr. Cath Kleier		Approximately 1 month salary	$5,000
Main Assistant Stipend, Bridgett Courtois		Approximately 2 month salary	$5,000
Student Field Work Stipends	5 Assistants at $12/ hr	10 hrs /day, 10 days= $600 each assistant	$3,000
CFI Employee Consulting & GIS Work	~20% of 36,000		$7,004
Statistical Analysis Consulting- Tim Trenrary & Kristofor Voss		Approximately 1 week salary	$1,000
Overhead Charge to Regis University	35.6% of 36,000		$12,816
			TOTAL= $36,000

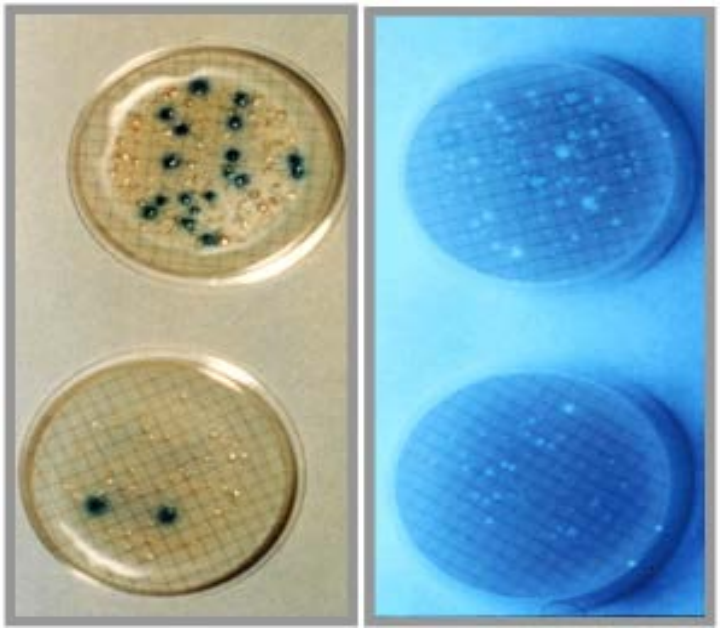

Figure 2. Sample image of bacterial colonies on MI agar. Left image shows *E. coli* colonies appearing blue under normal light. Right image shows total coliform colonies under long-wave UV light.

Results:

We expect there to be a higher level of fecal contamination on more frequently traveled fourteeners than less frequently traveled fuorteeners, and that many of the samples will be over the limit of both fecal coliforms and *E. coli* suggested by the World Health Organization. Although this study is relatively brief and straightforward, the results will indicate the degree to which humans have increased fecal contamination on fourteener ecosystems. If we find that human fecal contamination is exceptionally high, then we will need to put extreme care into developing strategies that limit the number of people who hike fourteeners or decrease the impact made by each person.

One of the most essential pieces of our research project is the ways in which we plan to use our data for educational purposes. Not only do we hope to publish our results in a scientific journal and present at various conferences, but also to share our results with both Colorado Fourteeners Initiative and the Colorado Mountain Club, two of the most well known sources dedicated to the conservation and protection of fourteeners and hiker education. Furthermore, we plan to have them published on their respective websites. In this way, our results may also be utilized by CFI Peak Stewards, volunteers who spend time conversing with hikers on fourteeners to better educate them about “Leave No Trace” guidelines. Undoubtedly, we also plan to share our results with the National

Forest Service, as many fourteeners lie within their territory, which will help to widely spread this information to other sources, such as the state government. Lastly, in order to communicate with the general public in Denver, we plan to disseminate our results to REI (Recreational Equipment Incorporated, a popular outdoor gear store) as well as submit newspaper articles to at least two local periodicals (*5280* and *The Denver Post*).

In summary, this project will allow for a quantitative assessment of the ways in which humans are negatively impacting fourteener ecosystems in Colorado. The results of this study will act as a resource to conservation groups, such as the CFI (Colorado Fourteeners Initiative), CMC (Colorado Mountain Club) and RMFI (Rocky Mountain Field Institute), by providing them with scientific-based information that they can use to educate people not only about these issues, but also about how we might be able to prevent them from occurring in the future. Additionally, we hope that by providing Colorado lawmakers with numerical data demonstrating how humans have negatively impacted some of the most symbolic landscapes in the state, they will consider allotting more funding to their protection. Finally, these results will also impact the Colorado hiking community by educating them about the current level of ecological destruction on fourteeners and how we may combat it.

Chapter Four: Future Action & Significance

Applying for this grant is just one of the first steps I have taken to help increase awareness of and eventually prevent future human-environmental issues on fourteeners. Regardless of whether or not we are awarded money to carry out this research project, it is important to consider other measures we might take in the meantime to prevent further ecological destruction on these peaks.

Determining what steps we should take to further protect fourteener ecosystems is perhaps the most difficult question I have had to consider throughout this process, specifically because I personally know the ways in which I have been positively affected and transformed by hiking fourteeners throughout the years, and would hate to see them restricted or limited. I would truly love for every human being to be able to experience the unmatched feeling standing atop at least one of the 54 peaks.

Yet, at the same time, I have experienced first-hand the devastating anthropogenic effects on fourteeners and inadvertently contribute to these environmental issues each time I set foot on a fourteener trail. In fact, all well-educated hikers who practice a "Leave No Trace" philosophy unintentionally disrupt the ecosystem merely by displacing dirt along the trail and involuntarily scaring off native animals.

In light of this, it is essential that I am able to come to my own answer to what should be done in response to this extreme level of ecological damage, as I have been wholly forced to see both sides of this argument. So, I will share my ideas and opinions

as to how we can best protect these precious landscapes while at the same time being able to still enjoy their beauty and wonder.

Previously, individuals have proposed various ideas to mitigate environmental destruction on fourteeners. From installing fee or permit systems, to shutting down heavily traveled fourteeners, to conducting restoration based research, to educating hikers on how to make less impact, there are many possible ways we might be able to mitigate the environmental threats faced by these peaks. Because there are both benefits and disadvantages to many of these strategies, I believe that utilizing a combination of these approaches will allow us to better protect fourteener ecosystems, while still allowing them to remain accessible.

The first idea that usually comes to mind when pondering how we might prevent further environmental destruction is by installing a fee or a permit system. The idea behind a fee strategy is that it might dissuade individuals from hiking due to the cost, thus decreasing total numbers of users. Ideally, money from fees can also go into restoring the damaged ecosystems. A permit system, on the other hand, strictly controls how many people can climb each mountain by a determined quota, thus directly decreasing the number of hikers.

Both fee and permit systems have previously been shown to be useful in lessening human-environmental impacts on a majority of West Coast peaks such as Mount Whitney and Mount Hood, as sheer numbers of people is obviously a large factor in increasing damage. CFI director Lloyd Athearn claimed that, “as someone who grew up and had formative climbing experience out in the Pacific Northwest ... frankly anyone from

Oregon, Washington, California, would be surprised that virtually all the peaks in this state are available without fees, without permits, without registration" (Rappold, 2010). Although much of the Eastern American landscapes are regulated in a similar way to those here in Colorado (in which it is free to enter National Forests but there are fees to enter National Parks), it is beneficial to see that these types of systems have already proven to be successful across West Coast territories. Furthermore, these proposed fees would likely not be substantial, as the Forest Service had previous plans to charge $10 for the hiking and $20 for camping in heavily used South Colony Basin in the Sangre de Cristo Range (Rappold, 2010).

Since it is possible that charging minor fees would not drastically alter the hiking frequency of fourteeners and may simply offer some extra revenue to restore and protect their ecosystems, many individuals, including Shawn Regan, former Olympic National Park ranger and researcher at the Montana Property and Environment Research Center, heavily support the idea of user fees to access natural resources. Regan believes that a fee system is the best way for these landscapes to maintain a "direct, consistent stream of revenue" (Langlois, 2017). As discussed previously, there really is no steady monetary source available for fourteener protection and restoration. Therefore, even if charging fees results in relatively small revenue for fourteeners, it would at least create funds that could be instantly available for necessary projects. Additionally, because this money would only come from those who directly use the lands, there would be no need for the federal government to get involved or state taxes to be increased, which logistically keeps things much simpler.

Based on this information, it seems like a fee system might be a promising way to mitigate environmental damage on fourteeners; however, there are many unforeseen issues with these types of systems. One obvious negative is that imposing a fee system might not successfully dissuade people from hiking, therefore, the level human impact may remain relatively the same. Yet, even if it did reduce the number of hikers, this would mean less money that hikers dedicate to tourism. Astonishingly, climbing fourteeners is estimated to provide $84 million for the Colorado state economy as hikers not only purchase gear and food in nearby towns, but also often choose to stay overnight in lodges close to the base of the peaks (Boster, 2017).

These types of systems can also be problematic because often the money obtained from the fees does not end up going into restoring damaged areas but rather into enforcing whether or not people have obtained a permit or paid their fee. In regards to our National Parks, only a mere 10% of the revenue obtained from entrance fees are dedicated to habitat restoration, while the remainder of the money goes into asset repairs, maintenance, visitor services, operations and administration (Repanshek, 2010). Although National Parks are admittedly run quite differently than fourteeners, this data just goes to show that installing fees on fourteeners might not actually significantly help in mitigating anthropogenic impacts.

Moreover, imposing a fee system on only the most frequently hiked fourteeners such as Mt. Bierstadt and Longs Peak might sound beneficial, but it may also just spread out hikers, leading them to drive beyond the Front Range to peaks that are not climbed as frequently. This raises the question of whether it is better to have a large amount of

ecological destruction concentrated in one area or spread out across various landscapes and environments. Generally, ecologists tend to follow the "confinement" principle, which describes how it is more beneficial for wildlife to have a large amount of impact concentrated in one area as opposed to a small amount of impact dispersed across many areas (Leung & Marion, 2000; Hampton et al., 1995, 2003; Cole et al., 2008; Kleier & Trenary, 2017). Multiple long-term studies have supported this idea, showing the effectiveness of the confinement principle on minimizing camping and hiking impact as compared to a dispersal strategy (Reid & Marion, 2004; Marion & Farrell, 2002). In this way, most landscapes can remain protected.

Furthermore, others are worried that installing a fee system may restrict certain people from being able to climb fourteeners. The Western Slope No-Fee Coalition (WSNFC) is one such group opposed to the idea of paying money to hike fourteeners, or anywhere in the wilderness, for that matter. President of the WSNFC, Kitty Benzar, states, "There are a lot of ways to manage the impacts that are more democratic, that are more fair to those with money and those without money. I don't think any wilderness should charge a general access fee. I think it's wrong to have to pay to go for a walk in the mountains" (Rappold, 2010). Benzar, like many others, does not believe that the ability to climb fourteeners or hike elsewhere in Colorado's National Forests should be restricted to anyone, especially by socioeconomic status.

Even if fourteener fees are not substantial, it is still likely that they may deter individuals from low-income backgrounds from hiking. Although no experiments have been conducted on fourteeners to support this idea, one study completed by the Forest

Service showed that approximately 50% of visitors who earned less than $30,000/year indicated that a $5 fee increase would lead them to either decrease their public-land use or travel to areas without fees (More & Stevens, 2000). Another 2017 study revealed how low-income individuals reported that they were willing to travel more than three times the distance to reach a fee-free National Park (Langlois). Although it is unclear whether or not these same trends would hold true in regards to installing fees on fourteeners, I would be incredibly disheartened if fourteener climbing opportunity was in any way limited by one's socioeconomic status.

Even if fourteener fees do not deter people from lower socioeconomic classes from hiking them, they may lead to other issues. In one of the only studies actually conducted on fourteeners from the *Journal of Environmental Management*, researchers found that installing fees on the most popular Front Range fourteeners would decrease their usage by over 20%, but would almost entirely be to substitution rather than income reasons (Loomis & Keske, 2009). In other words, fees would just encourage individuals to drive further to reach other fourteeners that don't charge fees. As I mentioned previously, a spreading out of hikers across the peaks is not exactly beneficial, as it will increase the extent of ecological destruction across more territories. This is yet another piece of evidence against imposing a fee system.

Lastly, even if fourteener fees do deter people from hiking them, the general idea of paying money to access public land is strongly opposed by many individuals. These people fear that charging money to hike fourteeners may be the beginning of a dangerous trend where "federal lands run less like a public resource and more like a commercial

enterprise" (Langlois, 2017). Like these individuals, this is precisely what terrifies me the most about installing fees on fourteeners. I worry that our public land will simply become an additional form of revenue for our government and that nature-based recreation will evolve into just another product to be purchased.

Although there are valid points on both sides of this argument, I tend to sympathize with those who oppose the creation of a fee system. Although sheer numbers of people is definitely a factor in increasing environmental destruction, it is not the bulk of the issue. Rather, the fate of these ecosystems rests largely upon the hikers themselves. For instance, a considerate group of 10 people who respect all "Leave No Trace" guidelines may make very minimal impact, while a group of four individuals who camp above tree line, scatter trash everywhere, and walk off trail, can highly damage the landscape. As you can see here, the extent of impact is not necessarily due to the number of people, but instead their level of responsibility and respect towards the landscape. It is entirely possible to build sustainable trails that make very little impact on the surrounding environment and are integrated with the landscape (Lambke, 2016). Thus, the objective is not necessarily to make less people hike fourteeners, but to have each person make less of an impact.

Moreover, on a personal level, I am not sure if I would have gotten into climbing fourteeners and in the process learned so much about both the outdoors and myself if I had been required to pay a fee to hike them. In fact, I think one of the most appealing things about fourteeners is that they provide access to some of the most gorgeous landscapes on Earth completely free of charge. Not only do I fear the creation of a fee-

system because it would put a monetary value on our lands, but also because most of the funds would likely be contributed to employing workers who administer fees rather than to protecting the landscapes themselves.

Nonetheless, if all hikers do not begin to take responsibility in making less impact on these mountains, I do not know if it is feasible to continue without charging fees and requiring permits. In order to keep the level of ecological destruction at a minimum, there must be some form of revenue available for restoring and protecting fourteeners, whether it be private funding or a minimal portion of the state budget. Without other sources of revenue, however, I would predict and agree with the creation of a fee system on fourteeners.

If it becomes absolutely necessary to charge fees to hike fourteeners, at least some data shows that individuals are actually relatively open to paying user fees.

In one of the few studies actually conducted on fourteeners, Keske and Mayer (2014) found that 62% of hikers were willing to pay a fee to climb the peaks. Furthermore, they discovered no significant difference between willingness to pay a fee of $20 or less and willingness to visit the site at no cost. I was particularly surprised by these results because they seem to contradict what was previously found regarding willingness to pay entrance fees for entrance to National Parks. In regards to fourteeners, it appears that hikers may be willing to pay fees to hike, whereas in terms of National Parks, it seems that individuals are not as likely to visit areas with higher fees. Whether this is due to the fact that the two areas experience visitors from different socioeconomic classes, that National

Parks already have a significant entry fee, or other reasons, at least it is clear that a majority of hikers are willing to pay.

Aside from a fee system, another proposed option would be to simply shut down the heavily traveled and badly damaged fourteeners, giving the mountains some much-needed time to restore. This introduces the idea that some fourteeners might just be "too far gone," meaning that without closing them down completely, they may never have enough time to be restored back to a state resembling their original one.

However, it is easy to imagine that a majority of people are not in favor of this idea either. Even strict environmentalists know that a backcountry trail can be built in such a way that each person makes very little impact (Lambke, 2016). As long as people follow the proper etiquette and guidelines, shutting a mountain down is somewhat unnecessary. Also, doing this might encourage people to seek out other environments to hike and explore, therefore spreading human impact to more areas.

Not to mention, closing down particular fourteeners altogether would raise a variety of other questions such as, "How might we enforce this rule?" and, "Are there any circumstances that certain individuals should be allowed to hike, such as if they offer a large sum of money?" People already have proven that they will pay lots of money to hike fourteeners, if need be. For instance, one privately owned fourteener in Southern Colorado, Culebra Peak, charges a hiking fee of $150 per person, and all available reservations for this summer are already booked (Cielo Vista Ranch, n.d.). Personally, I think the worst aspect concerning shutting down these peaks would be that it would

restrict the beauty of these mountains, which have offered myself, and many others, so much.

It does not appear that either implementing a fee system or closing down certain fourteeners would be proper approaches to avoiding further ecological destruction. In my eyes, emphasis should be placed on restoration, research, and education, as hikers can be taught to make less impact while climbing fourteeners.

In terms of restoration, utilizing certain techniques might allow the mountains to remain accessible while still being protected. Restoration ecology is commonly aimed at improving the makeup and establishment of native plant communities to restore the ecosystem from the ground up, but also can include increasing habitat areas for native birds and pollinators. One such example is utilizing turf transplants to restore old trails, a technique utilized by a research team I worked alongside this past summer.

Most alpine restoration is geared towards improving substrate stability and establishing proper soil conditions for plant growth as well as reestablishing native vegetation. Improving the substrate stability has been shown to be extremely important in alpine areas, specifically because they experience both heavy wind erosion and the annual thawing of permafrost (Hagen et al., 2014). Focusing on maintaining the soil conditions of the original landscape is also essential, as it dictates the growth and establishment of native plants. Lastly, rather than merely re-vegetating the ecosystem with any plant species, alpine restoration is centered on the reestablishment of a vegetal structure that is highly similar to the original plant community.

Some ecologists have proposed the idea of sowing seeds of native plant species into landscapes that need to be restored, yet there is disagreement over the long-term effects of this action. In one 20-year study, researchers found that artificial seeding may in fact help to increase total vegetation cover, but tends to alter the native levels of vegetation cover and species richness (Hagen et al., 2014). Thus, it is clear that many of these techniques have the potential to help restore damaged plant communities, but also that there is a fine line between restoring an ecosystem and changing it altogether.

Another major drawback of this approach is centered on the lack of research available on how to properly restore fourteener trails and habitats. This points to the dire need for research on fourteeners and other alpine environments in order to introduce and improve upon various restoration techniques. I have previously been a part of one such research group focused on developing and understanding current restoration techniques on fourteeners this past summer (Kleier & Trenary, 2017).

Specifically, our group collected data on the viability of cushion plants that had been previously transplanted into an old trail in an attempt to restore it. Unfortunately, we found that cushion plants do not transplant particularly well, potentially due in part to their large tap root systems, which allow them to acquire increased nutrients and water from the soil. Although the results were not what we expected, they are still valuable in contributing to our understanding of how we may better restore old trails, particularly by focusing on the transplantation of grass plugs as opposed to cushion plants. Though subtle, this distinction make restoring old or extremely widened trails much more successful. Ultimately, carrying out similar restoration-based experiments is essential to

formulating a better understanding of alpine restoration. Nevertheless, we will need much more than just a few studies to begin to successfully restore these alpine environments.

Apart from restoration and research, another obvious solution we might consider aims at preventing future damage to fourteener landscapes. This type of work consists of building sustainable trails to prevent erosion and is primarily carried out by the CFI and other likeminded organizations. Other prevention methods are focused largely on reducing levels of fecal contamination in the water and soils by installing latrines or implementing other strategies.

One of the more recently developed and especially promising techniques to prevent further ecological destruction to fourteeners and similar mountain environments is by providing "Wag Bags," human waste pack-out bags, in areas that experience high levels of fecal contamination. Wag (Waste Alleviation and Gelling) Bag kits contain gelling compounds that neutralize waste and absorb moisture from deposited urine and feces (MacDonald, 2008). The waste kits come with hand sanitizer and toilet paper, and can be disposed into any landfill. Wag Bags have been utilized to prevent further fecal contamination of multiple mountains in the West, such as Mt. Rainier, which has required their use since the 80s (Dwyer, 2017). As the state budget dedicated to staffing employees that mandate the protection of fourteeners and other wilderness areas diminishes, requiring the usage of Wag Bags may be a beneficial way to mitigate the issue of fecal contamination.

This and other prevention measures have the potential to lessen future environmental damage, keeping our mountains healthy and people happy. Nevertheless,

these methods have many unforeseen issues. For instance, although “Wag-Bags” are free and available, the question is, “Will people actually use them?” For a majority of mountains in the West, park rangers hand out Wag Bags to visitors when they pick up their hiking permits, so without a permit system, it might be hard to get them into the hands of all fourteener climbers. Additionally, providing them for free at the trailhead might be the only way to slow the rate of fecal contamination, yet each bag will cost the Forest Service approximately $2.40, so with the hundreds of people who hike fourteeners each day in the summer months, this could become a significant expenditure (Brasch, 2017).

Despite the issues presented by the usage of Wag Bags, I think their utilization on fourteeners would be more beneficial than detrimental. Although I would love to continue relying on catholes to dispose of human waste in these natural landscapes, with the amount of visitors fourteeners experience, I think we are far beyond this phase. Burying waste works well in “low use” areas where thick soil aids in decomposition, yet many fourteeners experience extremely high usage rates and much of their terrain is above tree line, in which there is a lack of rich organic soil to break down fecal matter (Cosmo, 2015). Not to mention, hikers often get lazy digging their catholes and end up just depositing feces on the surface of the soil, which presents a vast number of issues. Yet, even if hikers dig proper 6-8 inch deep catholes, their fecal matter can still take up to years to decompose in alpine ecosystems due to the extremely low temperatures and moisture levels (Herrel, 2011). Thus, although the use of catholes has been a suitable

method of disposing fecal matter up until this point, the ever-increasing numbers of hikers that fourteeners experience calls for additional action.

Admittedly, there will always be the question of whether or not people will choose to follow the rules if the usage of Wag Bags becomes mandatory. Yet, even if only few of the hikers comply, it will still lead to a decrease in environmental destruction, and ultimately encourage people to think a bit more about how to properly dispose of their waste in the natural world. Lastly, although supplying Wag Bags at fourteener trailheads might be a costly expenditure for the Forest Service, I believe it to be a necessary action towards protecting fourteener ecosystems. The relatively minor cost of each bag may help to prevent severe fecal contamination in the future, which could cost thousands of dollars to clean up.

Although the use of Wag Bags seems like a promising way to prevent future environmental destruction, little else is known about other methods we might use to prevent damage to the ecosystems of these peaks. Therefore, there is a great need for research to understand whether or not certain strategies will be successful. Research centered around prevention methods might aim to understand anything that could positively contribute to our knowledge and understanding of the current ecological issues on fourteeners or the various measures we might take in order to mitigate the effects of this destruction. For instance, it may be helpful to conduct surveys on 14ers.com, CFI.org, or even at the base of certain fourteeners, asking people whether or not they chose to use the “Wag-Bags” and why, for instance. This way, we may be able to better understand the motivations and opinions of people who hike fourteeners and alter our

prevention techniques based on their responses. Yet, not only is it important to conduct research aimed at prevention and restoration, but also at assessing the level of anthropogenic impact on these mountains. As I mentioned previously, before we are able to decide what we should do to protect our mountain ecosystems, we must attempt to understand which issues present the most harm to their environments.

The only major issue with conducting research is that it requires large amounts of time and money, both things that the Forest Service and CFI do not have. However, if the research is carried out by private organizations, it is much more feasible. Yet, finding sources of funding to support fourteener restoration is something the Forest Service and CFI have struggled with for many years, so it is clear that it is a difficult task. Thus, although I would encourage people to continue searching for organizations and corporations who are willing to financially help support fourteeners, it is essential that we first enter a phase of increased research on fourteeners. Obtaining concrete data illustrating how fourteeners are being harmed by humans is much more convincing than simply suspecting that people are negatively affecting these ecosystems. Hopefully, such data will force lawmakers, conservationist groups, and policy makers to directly address the issues, subsequently increasing their funding. This is why I have chosen to apply for a privately funded grant. Ultimately, if the results of my experiment indicate that there is in fact a high level of fecal contamination in the waters and soils of fourteener ecosystems, it will call for certain measures to be taken to directly combat these issues.

The final and perhaps best option to consider to protect Colorado's fourteeners would be to educate the public about the environmental issues they face and about how

people can make as little impact as possible while hiking. Educating hikers is probably one of the easiest ways to assure that each person makes as little impact as possible, and the outcome would be even more beneficial as hikers encourage other individuals to do the same. The LNT guidelines can be summed up into seven general tips: plan ahead, travel/camp on durable surfaces, dispose of waste properly, leave what you find, minimize campfire impacts, respect wildlife, and be considerate of other visitors (LNT Center for Outdoor Ethics, 2012). Yet ultimately, it is up to each and every individual to follow these guidelines. I am always alarmed by the number of hikers, especially those my age, who are incredibly careless when it comes to protecting the natural environment and observing "Leave No Trace" guidelines. For instance, in certain areas with special regulations (ie. no campfires), oftentimes the hikers will decide to have a fire regardless. Although there is no specific data on the extent to which people follow hiking regulations, I cannot count the number of times I have physically seen people create restricted fires, visibly discard trash, camp above tree line, hike off the trail, or feed wildlife, among other destructive actions.

In light of all this information, it is easy to see why such issues on fourteeners have been overlooked and remain unresolved. All of the possible solutions to solving the ecological crises on fourteeners seem somewhat problematic, and are "easier said than done." Nonetheless, it appears as if the most promising solutions lie not in increased fees and restrictions but rather in other methods such as research aimed towards prevention and restoration, as well as education-based techniques.

Prevention and education go hand-in-hand, for often we can prevent future ecological destruction by educating people about proper LNT guidelines. The Peak Steward Handbook offered by CFI is a helpful tool to educate hikers about how to hike safely and make the smallest possible amount of ecological impact (CFI, 2013). The handbook explains common hiking knowledge, such as the necessity of hikers to always remain on the trail to prevent erosion and to not cut up switchbacks. Additionally, the handbook instructs backpackers how to choose to camp on durable surfaces below timberline and to minimize campfire usage. Although seemingly obvious, it also includes other instructions such as carrying out your trash, not picking flowers, keeping control of your dog, and not feeding wildlife. Although they may seem like common sense, many of these actions are carried out much more frequently than you might think.

The most difficult aspect of educating hikers is actually getting this information into their hands. Although I would love for all fourteener users to read the entire LNT manual, it may be more efficient and feasible for the essential information to be at least printed on all trailhead signs. For instance, rather than simply including the topographic map and a few other warnings, I think all of the main signs should explain the fundamental LNT rules as well as provide free Wag Bags for mandatory usage. If possible, it would also be extremely beneficial to expand the Peak Steward program so that more volunteers can directly educate hikers (especially those who are caught breaking LNT guidelines).

Doing our part in following these guidelines and becoming more educated as to how to make less of an impact while hiking is the absolute least we can do to further

protect these peaks for years to come. Yet, as fourteeners are projected to become even more popular in the future, unless nearly every single hiker follows these guidelines, we will not be able to slow the damage being done to these valuable ecosystems. Although difficult to accept, the sad reality is that not everyone is going to immediately become a fourteener preservationist. Because of this, I foresee that the ways in which fourteeners are currently hiked and regulated are going to change significantly in the coming years. I would be surprised if fourteener hiking does not become highly regulated and restricted by rangers and permit systems, because despite the number of educated-hikers who choose to act respectfully towards these landscapes, it only takes a few groups of people to ruin these privileges for everyone.

Thus I cannot urge enough the importance of becoming an educated hiker and of following these LNT procedures, however annoying or meticulous they may seem. As a reminder, this is the very least a person can do to protect fourteeners—by taking responsibility for their own actions. Secondly, it is perhaps just as important to educate and inform both your own group members and other hikers about proper peak-stewardship actions.

I would also recommend that individuals who are more concerned with and interested in these issues to take one step further by signing up to conduct trail-work with CFI, or even by becoming a Peak Steward, a volunteer who spends a couple days each summer climbing fourteeners and educating hikers about LNT practices. Lastly, advocates for ecological preservation of fourteeners should become more involved in education by writing newspaper articles, posting on social media, and even writing to our

state legislature to ask for increased funding to protect them. Ultimately, by making these seemingly minor actions, we may at least spark the process of increasing respect for and decreasing harm towards our beloved fourteeners.

Chapter Five: Significance & Conclusion

Within this work, I have provided a background on the current ecological issues faced by fourteeners today. Specifically, I described one of the most prevalent concerns, the increasing level of human fecal contamination, and included my grant proposal to National Geographic, which aims at assessing the severity of this issue. Lastly, I spoke of the various solutions to the increasing environmental concerns on fourteeners and what each and every individual might do to help to combat these issues. Ultimately, my hope is that by doing these things, we may be able to "put the brakes" on environmental damage on fourteeners for a while, or at least lessen their destruction. Perhaps most importantly, by informing policy makers of our research, we may be able to make concrete changes in the ways in which fourteeners are climbed in the future.

At first it may seem like these suggestions apply only to a small number of people. For instance, some may wonder if non-Coloradoans, or people who don't enjoy spending their weekends hiking fourteeners, should even care about the issues these mountains face. Besides the fact that any one of these people might actually find themself hiking one some day, I believe it to be necessary for all individuals to care about this issue. It is not as if fourteeners are their own isolated systems, but rather that they are intrinsically connected with their surrounding ecosystems. If there is one thing that we have seen over and over in the realm of ecology, it is that everything—from dirt to soil to animals to microbes to sunlight to biomes—is interconnected, and the balances and

feedback pathways between them are highly delicate and indispensable to all life forms. Just as scientists saw how the entire ecosystem changed when wolves were reintroduced back into Yellowstone National Park (Beschta & Ripple, 2015), ecosystems are incredibly delicate and precisely balanced. Even the most minor ecological changes can have grave consequences for the plants and animals of a given environment.

So, it may seem relatively easy to simply "brush off" and not care about fourteener-related issues, especially if you are someone who isn't interested in hiking any of Colorado's 54 tallest peaks. However, I would claim that that is both narrow-minded and an uneducated stance to take. When fourteeners suffer, so do our mountain ecosystems, which ought to be preserved and protected at all costs. These precious environments not only act as a tailored home for plants, animals, and even humans, but also as iconic cultural representations and embodiments of nature for its own sake.

In the grand time-scale of the world's existence, our precious alpine landscapes have survived much longer than any group of humans (approximately 70 million years longer) and have the potential to live on for future generations if humans do not liberally impede their natural course of growth (NPS, 2016). Because these mountains have been around for such a long time and remain as some of the most beautiful places on earth, all people should advocate for their protection. Not to mention, the results from research conducted on fourteener ecosystems will allow landscapes and ecosystems across the globe to be better managed and protected. Thus, it is clear how all people have a stake in this issue.

Others will claim that although this is an important issue, it is not even close to being one of the most pressing environmental concerns in Colorado. These people ask, "Why should we dedicate funding to the protection of fourteeners when there are so many other ecological issues that are as equally problematic?" To these people, I would say that they are not necessarily wrong. Colorado's lakes and rivers are being overfished at extreme rates, once-protected areas are falling victim to deforestation, air pollution is becoming increasingly severe surrounding metropolitan areas, and entire populations of pine trees are being knocked out by beetles, not to mention a myriad of other ecological issues that are occurring throughout the state. Although I sympathize with these concerns and support funding to mitigate the affects of all of these issues, the difference is that a majority of these issues already have funding to support and research dedicated to them in the first place. The very little existing research and funding directly supporting fourteeners is the major reason why I specifically prioritize their protection and restoration.

Lastly, extremists will argue that if we are in complete support of protecting and preserving the environment that we should shut down all fourteeners. These people might raise the question, "Are human needs really more important than environmental needs?" To these individuals, I would say that shutting down all fourteeners would be an unnecessary action, because it is definitely possible to *both* protect their ecosystems *and* allow people to continue hiking them.

Hopefully, I have clearly illustrated that ecological issues on fourteeners are not only significant, but that they are in fact quite pressing and should be of concern to many

people. Finally, I will reflect on how climbing fourteeners and advocating for their protection has been quite significant to my own life journey, and inadvertently taught me to utilize and integrate some of the common Jesuit values into my life.

Chapter Six: Personal Reflection

Hiking a fourteener is about much more than just getting to the top of the mountain. The 54 rare peaks are state-wide symbols, remaining specks of natural beauty, and achievable aspirations. Although they have done little more than provided me with an environment to explore and discover, climbing fourteeners has undoubtedly taught me more about life than any other experiences I have had.

The process of researching this topic has been highly influential not only in terms of my future career goals, but also in the scope of my current Jesuit education. Within the next year, I will be applying to medical school to fulfill my lifelong dream of becoming a doctor. It is well known that good applicants are both well-rounded and care about a diverse set of topics. I could have easily chosen to research a medically based issue so that I could tie in my thesis with my future career goals, but instead I chose to study something that is highly important to me. Not only was this a better decision for me personally, but in hindsight should also be something that medical school admissions will consider as a plus. Contrary to popular belief, they like to see that students have unique passions and hobbies, as well as a "life out of school!"

Additionally, studying biology is not all about health and medicine, but equally about ecosystems and the environment. It is essential that biologists see both sides. As ecological issues become more of a concern in light of the increasing world population of the world and growing resource scarcity, it is likely that doctors and medical professionals will need to focus more on the ways in which human health is being

impacted by our environment. Public environmental health concerns, such as what our National Geographic grant aims at assessing, will likely become even more relevant. Furthermore, the overall process of writing a grant, conducting fieldwork and creating experiments in the lab is not only beneficial as an aspiring scientist, but also as a qualified medical school candidate. Perhaps most importantly, the experience of writing this thesis has helped me tie together my Jesuit education, as it has taught me to incorporate all six of the Jesuit values—unity of mind and heart, *Cura personalis*, men and women in service of others, *magis*, contemplatives in action, and *Ad Majorem de Gloriam*– into my own life.

Studying this topic has united my "heart," the passion I have for climbing fourteeners, with my "mind," my intellectual and career aspirations. In the process, it has made me a more well-rounded person, demonstrating my mastery of *Cura personalis*, or "care of the whole person." In a sense, it has also led me to become a woman in service of others, because my efforts aim to protect this world so that it may remain beautiful for generations to come! Seeking to protect fourteeners has helped me to pursue the *magis*, or the "more," that Jesuits seek to uncover throughout their lifetimes. There is no doubt that this topic is my "more"—what I deeply desire to change for the betterment of this world. Also, it has led me to consider what it means to be a "contemplative in action," the Jesuit value which emphasizes the need for both contemplation and action in order to combat worldly issues. Going through the process of physically creating and writing the grant forced myself to go beyond merely pondering these ideas and instead go study them in nature. And lastly, this process has led me to fully realize *Ad Majorem Dei Gloriam*, or

"the greater glory of God," as it is when I climb fourteeners that I recognize God's goodness and powers more than any place on Earth! From watching the sunrise over the mountains and valleys at 14,000 feet, to hiking and camping alongside some of my best friends in the most beautiful landscapes, to learning continual lessons from Mother Nature, I have undoubtedly never felt more overwhelmed by His presence.

References

American Public Health Association. (1998). Standard methods for the examination of water and wastewater (20th edition), *American Public Health Association.*

The Associated Press. (2017). 5th climber in 6 weeks dies on Colorado's Capitol Peak. Retrieved from https://www.usnews.com

Beschta, R. L., & Ripple, W. J. (2015). Divergent patterns of riparian cottonwood recovery after the return of wolves in Yellowstone, USA. *Ecohydrology, 8*(1), 58-66. doi:10.1002/eco.1487

Blevins, J. (2015). Colorado Fourteener Initiative says trails need $24 million. Retrieved from http://denverpost.com

Boster, S. (2017). Study: Colorado's 14ers more popular than initially estimated. Retrieved from http://gazette.com

Botman, B., Atkin, O., & Lambers, H. (1996). The causes of inherently slow growth in alpine plants: An analysis based on the underlying carbon economies of alpine and lowland *Poa* species. *Functional Ecology, 10*(6), 698.

Bowers, R. M., Sullivan, A. P., Costello, E. K., Collett, J. L., Knight, R., & Fiereri, N. (2011). Sources of bacteria in outdoor air across cities in the midwestern United States. *Applied & Environmental Microbiology, 77*(18), 6350-6356.

Bowers, R. M., Clements, N., Emerson, J. B., Wiedinmyer, C., Hannigan, M. P., & Fierer, N. (2013). Seasonal variability in bacterial and fungal diversity of the near-surface atmosphere. *Environmental Science & Technology, 47*(21), 12097-12106. doi:10.1021/es402970s

Brasch, S. (2017). Conundrum hot springs has a poop problem, so you may have to bag your business. Retrieved from http://www.cpr.org/

Brenner, K., Rankin, C., Roybal, Y., Stelma, G., Scarpino, P., & Dufour, A. (1993). New medium for the simultaneous detection of total coliforms and *Escherichia coli* in water. *Applied and Environmental Microbiology*, *59*(11), 3534-3544.

Burke, I., Kaye, J., Bird, S., Hall, S., Mcculley, R., & Sommerville, G. (2003) Evaluating and testing models of terrestrial biogeochemistry: The role of temperature in controlling decomposition. *Models in Ecosystem Science*, 254–271.

Campos, M., Medina, L., Fuentes, N., & García, G. (2015). Assessment of indicators of fecal contamination in soils treated with biosolids for growing grasses. *Universitas Scientiarum, 20*(2), 217. doi:10.11144/javeriana.sc20-2.aifc

Cele, E. N., & Maboeta, M. (2016). A greenhouse trial to investigate the ameliorative properties of biosolids and plants on physicochemical conditions of iron ore tailings: Implications for an iron ore mine site remediation. *Journal Of Environmental Management*, *165:* 167-174.

Cielo Vista Ranch. (n.d.). Climbing/Hiking Procedures. Retrieved from http://cielovistaranchco.com/climbing-procedures/

Cilimburg, A., Monz, C., & Kehoe, S. (2000). Wildland recreation and human waste: A review of problems, practices, and concerns. *Environmental Management*, *25*(6), 587-598. doi:10.1007/s002670010046

Ciuti, S., Northrup, J., Muhly, T., Simi, S., Musiani, M., Pitt, J., & Boyce, M. (2012). Effects of humans on behaviour of wildlife exceed those of natural predators in a landscape of fear. *PLoS ONE,* 7(11). doi:10.1371/journal.pone.0050611

Cole, D., Foti, P., & Brown, M. (2008). Twenty years of change on campsites in the backcountry of Grand Canyon National Park. *Environmental Management*, *41*(6), 959-970. doi:10.1007/s00267-008-9087-5

Colorado Fourteeners Initiative (CFI). (2016). Estimated hiking use days on Colorado's 14ers. Retrieved from http://www.14ers.org

Colorado Fourteeners Initiative (CFI). (2016). 2015 Colorado fourteeners statewide report card. Retrieved from http://www.14ers.org

Colorado Fourteeners Initiative (CFI). (2016). 2016 Year end report. Retrieved from http://www.14ers.org

Colorado Fourteeners Initiative (CFI). (2017). Our work. Retrieved from http://www.14ers.org

Cosmo. (2015). How the AT works: What happens after you poop in the woods. Retrieved from https://thetrek.co/

Cowgill, P. (1971). Too many people on the Colorado River. *The Environmental Journal,* 45:10–14.

Derlet, R. & Carlson, J. (2006). Coliform bacteria in Sierra Nevada Wilderness lakes and streams: What is the impact of backpackers, pack animals, and cattle?. *Wilderness and Environmental Medicine*, *17*(1), 15-20.

Dwyer, O. (2017). Oh, Crap!. *Backpacker*, 21.

Edberg, S., Rice, E., Karlin, R., & Allen, M. (2000). *Escherichia coli*: The best biological drinking water indicator for public health protection. *Journal of Applied Microbiology, 88*(S1). doi:10.1111/j.1365-2672.2000.tb05338.x

Environmental Protection Agency (EPA). (2000). Biosolids technology fact sheet: Land application of biosolids. Retrieved from https://www3.epa.gov/npdes/pubs/land_application.pdf

Flomberg, D. (2015). Top 5 hardest Colorado fourteeners to climb. Retrieved from http://denver.cbslocal.com

Ford, D. & Williams, P. (2008). Karst hydrogeology and geomorphology. *Chichester: John Wiley & Sons. 45*(7), 1189.

Hagen, D., Hansen, T., Graae, B. J., & Rydgren, K. (2014). To seed or not to seed in alpine restoration: Introduced grass species outcompete rather than facilitate native species. *Ecological Engineering*, *64*255-261. doi:10.1016/j.ecoleng.2013.12.030

Hallas, G., Giglio, S., Capurso, V., Monis, P., & Grooby, W. (2008). Evaluation of chromogenic technologies for use in Australian potable water. *Journal of Applied Microbiology*, *105*(4), 1138-1149. doi:10.1111/j.1365-2672.2008.03842.x

Hampton, B., Cole, D. N., Absolon, M., & Reed, T. (1995). Soft paths: how to enjoy the wilderness without harming it. *Stackpole Books.*

Herrel, K. (2011). Decomposition of human waste. Retrieved from https://www.backpacker.com/gear/decomposition-of-human-waste

Hestmark, G., Skogesal, O., & Skullerud, Ø. (2004). Growth, reproduction, and population structure in four alpine lichens during 240 years of primary colonization. *Canadian Journal of Botany*, *82*(9), 1356-1362. doi:10.1139/B04-068

Jamali, M. K., Kazi, T. G., Arain, M. B., Afridi, H. I., Jalbani, N., & Memon, A. R. (2007). Heavy metal contents of vegetables grown in soil irrigated with mixtures of wastewater and sewage sludge in Pakistan using ultrasonic-assisted pseudo-digestion. *Journal Of Agronomy & Crop Science*, *193*(3), 218-228. doi:10.1111/j.1439-037X.2007.00261.x

Keske, C. & Mayer, A. (2014). Visitor willingness to pay U.S. Forest Service recreation fees in new west rural mountain economies. *Economic Development Quarterly*, *28*(1), 87-100. doi:10.1177/0891242413506744

Kleier, C. & Trenary, T. (2017). Revegetation success of plugs with and without cushion plants in an alpine restoration project on Mount Yale, CO. *Ecological Society of America Annual Meeting*, Portland, OR.

Lambke, K. (2016). Sustainable Trails. Retrieved from https://mylandplan.org/content/sustainable-trails

Lamm, R. (2014). Richard Lamm: Loving Colorado's fourteeners to ruin. Retrieved from https://www.denverpost.com

Langlois, K. (2017). The price of a national park fee hike. Retrieved from http://www.hcn.org/issues/

Leave No Trace Center for Outdoor Ethics. (2012). The leave no trace seven principles. Retrieved from https://lnt.org/learn/7-principles

Leung, Y., & Marion, J. L. (2000) Recreation impact and management in wilderness: A state-of-knowledge review. United States Department of Agriculture, 23–48

Loomis, J. & Keske, C. (2009). Mountain substitutability and peak load pricing of high alpine peaks as a management tool to reduce environmental damage: A contingent valuation study. *Journal Of Environmental Management*, *90*(5), 1751-1760. doi:10.1016/j.jenvman.2008.11.024

MacDonald, D. (2008). You Can Take It With You. *Backpacker*, *36*(5), 37-38.

Macpherson C., Gottstein, B., & Geerts, S. (2000). Parasitic food-borne and water-borne zoonoses. *Revue Scientifique et Technique,* 19: 240-258.

Maheux, A., Dion-Dupont, V., Bisson, M., Bouchard, S., & Rodriguez, M. (2014). Detection of *Escherichia coli* colonies on confluent plates of chromogenic media used in membrane filtration. *Journal of Microbiological Methods*, *97*51-55. doi:10.1016/j.mimet.2013.12.008

Maheux, A., Dion-Dupont, V., Bisson, M., Bouchard, S., Jubinville, É., Nkuranga, M., & Rodriguez, M. (2015). Multiparametric comparison of chromogenic-based culture methods used to assess the microbiological quality of drinking water and the mFC method combined with a molecular confirmation procedure. *Journal of Water and Health*, *13*(1), 67-72. doi:10.2166/wh.2014.059

Marion J., & Farrell, T. (2002) Management practices that concentrate visitor activities: Camping impact management at Isle Royale National Park, USA. *Journal of Environmental Management*, 66:201–212

Michels, A. (2017). Cardboard signs creating a trash mess on Colorado's 14ers. Retrieved from http://kdvr.com

More, T. & Stevens, T. (2000). Do user fees exclude low-income people from resource-based recreation?. *Journal Of Leisure Research*, *32*(3), 341-357.

National Forest Foundation. (2017). Find your fourteener. Retrieved from https://nationalforests.org

National Forest Service. (2004). USDA Forest Service fiscal year 2004 president's budget. Retrieved from https://www.fs.fed.us/budget_2004/mission.shtml

National Park Service (NPS). (2016). Geologic activity. Retrieved from https://nps.gov

Odonkor, S. & Ampofo, J. (2013). *Escherichia coli* as an indicator of bacteriological quality of water: An overview. *Microbiology Research, 4*(1), 5-11. doi:10.4081/mr.2013.e2

Piršelová, B. (2011). Monitoring the sensitivity of selected crops to lead, cadmium and arsenic. *Journal Of Stress Physiology & Biochemistry*, *7*(4), 31-38.

Potter, L., Gosz, J., & Carlson, C. (1984). Water resources in the southern Rockies and high plains. *Eisenhower Consortium #6*, 331.

Rappold, R. (2010). Days of free fourteener climbing may be ending. Retrieved from http://gazette.com

Reid, S.E., & Marion, L.J. (2004) Effectiveness of a confinement strategy for reducing campsite impacts in Shenandoah National Park. *Environmental Conservation,* 31:274–28

Repanshek, K. (2010). Entrance fees generate hundreds of millions of dollars a year for national park service. Retrieved from https://www.nationalparkstraveler.org/

Royte, A. (2017). Nearly, a billion people still defecate outdoors; Here's why. Retrieved from https://nationalgeographic.com

Sánchez-Monedero, M., Aguilar, M., Fenoll, R., & Roig, A. (2008). Effect of the aeration system on the levels of airborne microorganisms generated at wastewater treatment plants. *Water Research*, *42*(14), 3739-3744. doi:10.1016/j.watres.2008.06.028

Sharma, B., Sarkar, A., Singh, P., & Singh, R. P. (2017). Agricultural utilization of biosolids: A review on potential effects on soil and plant grown. *Waste Management*, *64*117-132. doi:10.1016/j.wasman.2017.03.002

Steidl, R. & Powell, B. (2006). Assessing the effects of human activities on wildlife. *George Wright Forum*, 23, 50-58.

United States Environmental Protection Agency (US EPA). (2002). Method 1604: Total coliforms and *Escherichia coli* in water by membrane filtration using a simultaneous detection technique (MI medium). Retrieved from http://nepis.epa.gov

United States Environmental Protection Agency (US EPA). (2012). 5.11 Fecal bacteria. Retrieved from https://archive.epa.gov

Vandvik, V. (2004). Gap dynamics in perennial subalpine grasslands: Trends and processes change during secondary succession. *Journal of Ecology*, *92*(1), 86-96. doi:10.1111/j.1365-2745.2004.00842.x

Woodbury, R. (1999). Peak Season. *Time*, *154*(2), 50.

World Health Organization (WHO). (2004). Guidelines for drinking-water quality 4th edition. Retrieved from http://apps.who.int