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Recreation Ecology of Colorado Fourteeners: An Assessment of Trail Usage and Impacts

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RECREATION ECOLOGY OF COLORADO FOURTEENERS:

AN ASSESSMENT OF TRAIL USAGE AND IMPACTS

by

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ABSTRACT

RECREATION ECOLOGY OF COLORADO FOURTEENERS:

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The popularity of climbing Colorado's 14,000 ft. peaks, or "Fourteeners", has risen dramatically in recent years, raising important sustainability and management questions. Moreover, groups managing the peaks operate with major capital constraints so their efforts need to be informed, prioritized, and efficient. This paper gauges the dynamics of trail usage, explanatory variables, and recreational impacts across all 58 Fourteeners, and details evaluation adjustments that minimize error and produce results in-step with the resource management framework. Relative to a baseline study completed in 2005, substantial changes occurred in trail usage and impact dynamics. The greatest changes were concentrated on peaks previously least impacted, and in the San Juan Range, which is furthest from the largest population center in the state. After improving upon the methodologies of the baseline study, several new variables that explain trail usage were uncovered, and a new combination of impact features were used to determine that the most heavily impacted peaks in the state are concentrated in the Tenmile/Mosquito Range. Findings provide insight into how to prioritize reconstruction efforts, build a system for monitoring trail usage and impacts, and evaluate the efficacy with which both are addressed by management.

DEDICATION

This project is dedicated to my wife, Ashley, whose unwavering love and support have long been the wind in my sails. Also to my family: Wendy and Randall Terry, Kate Williams, Emily Ewing, Michael Ewing, and Meagan Terry. They are the assemblers of my passion for science and the outdoors. An extra tip of the cap goes to my father, Randall, and brother, Michael. When the going got tough, they guided me to the terminus. Last, but certainly not least, this project is dedicated to my border collie, Gemma, whose endless energy and companionship in the mountains were inspiring on a daily basis.

ACKNOWLEDGMENTS

A special thanks goes to my committee director, Dr. Carl Reese, for guiding me through the development and execution of this project. His background was the example I needed to have the audacity to blend personal with academic goals in the mountains. Many thanks go to Drs. David Cochran and Grant Harley for their invaluable counsel, time, and interest. If not for that fateful day in the biogeography lab when Dr. Harley mentioned a previous study done in the mountains of Colorado, I may still not have a project.

Much appreciation goes to Dr. Jon Kedrowski for having the creativity to conceive of the original project upon which this one was founded. Many thanks to the CMC Historian, Woody Smith, for helping me orient myself in the archives. Lastly, a huge debt of gratitude is owed to Shelby Arnold, the American Mountaineering Museum Director, and Brenda Porter, the Director of Operations for the Colorado Mountain Club, for kindly granting me access and workspace.

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LIST OF ABBREVIATIONS

CFI	Colorado Fourteener Initiative
USFS	United States Forest Service
VPY	Visitors Per Year
CMC	Colorado Mountain Club
AMC	American Mountaineering Center
DD	Direct Distance to Denver
DPR	Direct Distance to the Nearest Paved Road
TL	Trail/Route Length
Class	Technical Classification
THE	Trailhead Elevation
TS	Trail Spurs Per Mile
SB	Switchbacks Per Mile
SBN	Switchbacks Needed Per Mile
FR	Fire Rings Per Mile
%DW	Percent of Trail as Double Wide
%4WD	Percent of Trail as Four-Wheel Drive
%ELNT	Percent of Elevation Gain with No Trail
%TMNT	Percent of Trail Miles with No Trail
%RMNT	Percent of Route Miles with No Trail or Markers
RMFI	Rocky Mountain Field Institute
iFEDI	Interim Fourteener Environmental Degradation Index
FEDI	Fourteener Environmental Degradation Index

RAMCF	Relative Annual Mountain Climbing Frequency
AAC	American Alpine club
RP	Efferculty
NDD	Network Distance to Denver
NDPR	Network Distance on Unpaved Road
RTL	Round Trip Length
TEG	Total Elevation Gain
C4	Class IV Segment
FTII	Fourteener Trail Impact Index

CHAPTER I

INTRODUCTION

Problem Statement

The Rocky Mountains span from New Mexico in the southern United States to northern British Columbia in Canada, the crescendo of which lies in the heart of Colorado, where 58 summits[1] eclipse the 14,000 feet threshold (Figure 1). For perspective, the only other states containing peaks of equal stature are California, Washington, and Alaska; however, their respective 14, 1, and 21 'Fourteeners' (moniker denoting peaks >14,000 f.a.s.l) pale in comparison.[2]

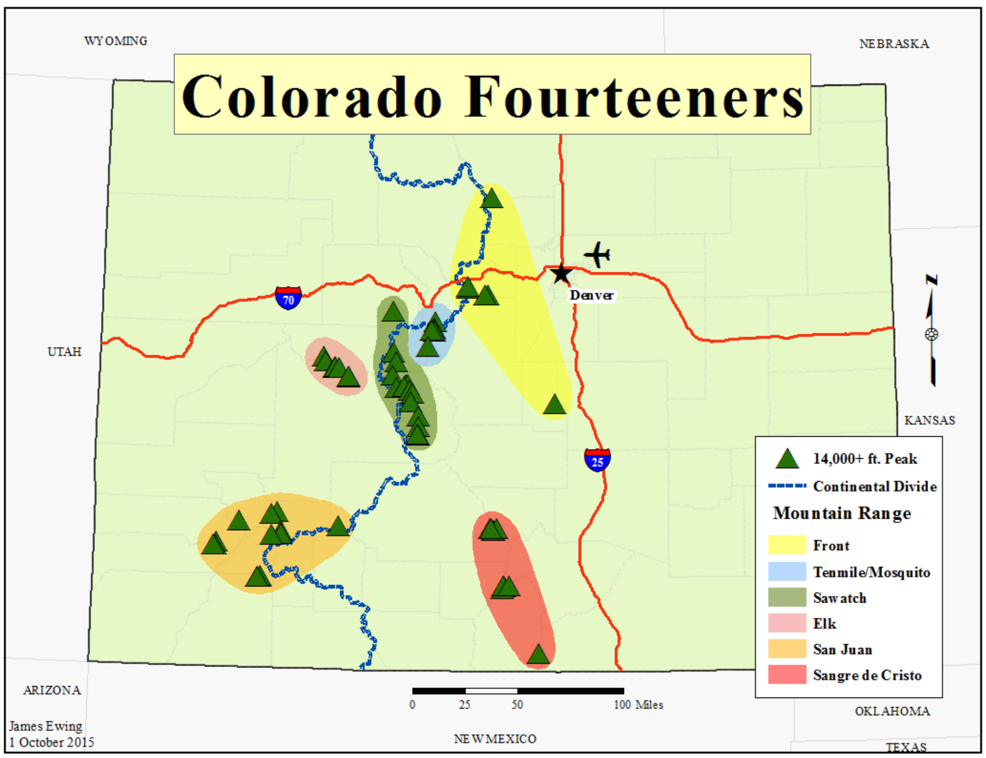


Figure 1. Distribution of Colorado Fourteeners and mountain ranges.

[1] Count varies due to differing definitions of what distinguishes a peak from a sub-peak. Usually 300 feet of topographic prominence plays a critical role.
[2] In terms of quantity, not size; Alaska and California have peaks higher than Mt. Elbert, the pinnacle of Colorado.

Since 1920, when Carl Blaurock and William Ervin pioneered the concept, a subculture has been forming around “peak-bagging”, or summiting, Fourteeners (Bueler 2000). Composed of a spectrum of people ranging from seasoned mountaineers to altitudinal greenhorns, the Fourteener subculture has grown exponentially in recent years, resulting in a considerable influx of outdoor enthusiasts to the Colorado Rockies. Coupled with massive state population growth and a new era of connectivity, this growing wave of eco-tourists means an unprecedented number of people are peregrinating Fourteener trails; conservative estimates suggest an alarming half-million hikers visit every year[3] (Roach 2011; CFI 2015a). While the standard routes of some Fourteeners remain in good condition, others appear to be bursting at the seams with recreational use and impacts, raising important sustainability and management questions for these fragile and once-pristine alpine environments (Figure 2).

To quell the impacts, organizations like the Colorado Fourteener Initiative (CFI)—a collection of nonprofit and public organizations supplemented by volunteers—have been working to preserve and restore trails and proximal areas. Despite their valiant efforts, these groups are overburdened by capital constraints (e.g., people, funding, information), and could be overmatched by the rate at which Fourteeners are being impacted. As the ranks of peak-baggers continue to swell, effective and well-informed management strategies have never been more important.

The most basic raft necessary to survive the deluge of impacts is a thorough understanding of trail usage and recreational impact dynamics across all 58 Fourteeners. Acquiring empirical purchase as to how both dimensions have changed over time, and

[3]The half-million figure is “conservative” because it is at least a decade old.

furnishing a robust methodology for ongoing evaluation, may be pivotal in mending and preventing impacts by helping managers focus resources where they are needed most. Hopefully such an understanding will lead to the development of a proactive management plan that addresses the main leak, improper overuse, as opposed to reactive impact acupuncture.

Figure 2. Marked difference between a healthy, sustainable trail segment and another with braiding, erosion, and excessive width. The left photo is from the Chicago Basin on the approach to the Windom Group, the most remote Fourteeners in Colorado. The right photo is from Bierstadt, which resides 38 miles from Denver as the crow flies.

With that in mind, the overarching goals of this study were to provide the CFI, and Fourteener community at-large, with an assessment of the degree, distribution, and evolution of trail usage and recreational impacts on Colorado Fourteeners. The approach employed was to create a cross-section of trail usage and impacts following a previous methodology as closely as possible (i.e., Kedrowski 2006, 2009) and comparing results.

Then the evaluation methods and input parameters were refined to produce a synopsis suggesting where managers ought to focus resources. The specific questions designed to achieve the research goals were:

1. How have the dynamics of trail usage and recreational impacts changed?
2. How can the input parameters and methodologies for evaluating the dynamics of trail usage and recreational impacts be improved to produce better results for resource managers?

In what follows, the second chapter provides an overview of, and contextualization within, previous Fourteener-specific research and recreation ecology. The third chapter describes the study area. Chapter IV details the procedures of the latitudinal analyses. Chapter V delivers the results and discusses study error and limitations. The sixth chapter suggests adjustments to the evaluation approach that should improve the results. The seventh chapter synthesizes all the results and discusses future research opportunities. Finally, Chapter VIII concludes the paper by connecting the broader implication dots for this line of inquiry.

Study Significance

Singular to this project is a population-encompassing temporal analysis of trail usage and recreational impacts on Colorado Fourteeners, the comparable results of which allow for better prioritization of husbandry efforts. This sidesteps the hamstrung utility of the oft-implemented individual case-study approach, the results of which have little practical utility for resource management. Maximizing the efficacy and efficiency of the understaffed, low-budgeted groups obliged to shepherd Fourteeners will serve to protect and restore the integrity of these fragile alpine environments and maintain the quality of recreation experiences for the future, both of which are requisite fundamentals to nursing the development of a healthy Fourteener sub-culture that contributes considerably to local economies.

This study also connects research and data collection to the existing theoretical framework of recreation ecology, which gives future work a robust point of reference from which to operate, synchronizes research with management practices, and creates an opportunity to evaluate the efficacy of management practices in general.

CHAPTER II

LITERATURE REVIEW

Previous Work

The existing body of literature relating specifically to Colorado Fourteeners is meager, but improving. Several studies focus on cultural processes of the "peak-bagging" subgroup (Blake 2002, 2008). Others deal with the socioeconomic ramifications of climbers (Loomis and Keske 2009; Lohman 2010). Finally, a portion of this deficient literature focuses on trail impacts (e.g., Hesse 2000; Kedrowski 2006; Loomis and Keske 2009; Lohman 2010; Vaughn 2011), a tiny slice of which discusses the dynamics of trail usage (i.e., Kedrowski 2006, 2009). The lack of published research can be attributed to the nascent popularity of "peak-bagging", and to the fact that the CFI and United States Forest Service (USFS) conduct internal research with seemingly no intentions of publishing or sharing their work. Perhaps more importantly, however, is the untidiness with which Fourteener research is filed away within a larger body of literature; it lacks an established connection to the methodologies and frameworks of more deeply rooted, mature topics of study.

Moreover, researchers studying recreational trail usage and impacts face some unique challenges. First, a standardized system for gathering trail usage data statewide does not exist (Kedrowski 2006, 2009). Efforts to understand the dynamics of trail usage have been sporadic with little potential for methodological advancement. Without these data it is impossible to assess to what degree increased trail usage contributes to recreational impacts, despite the ostensible logical connection. Strikingly, only one study has dredged into the matter with any depth (i.e., Kedrowski 2006, 2009).

Based on this literature, the following rough sketch of annual trail usage over the last few decades surfaced: in the 1980s, Fourteeners had roughly 25,000 visitors per year (VPY; Vickery quoted in Kelly 1994); during the 90s, figures are between 50,000-200,000 VPY (Kelly 1994; Hesse 2000); since the early 2000s, estimates have ranged between 200,000-500,000 VPY, the upper threshold of which is used most often today (Kenworthy 2001; Blake 2002; Kedrowski 2006, 2009; CFI 2015a).

A proxy source of trail usage, the number of Dr. Colorados,[4] is equally variable and indicative of rising trail usage; there were about 300 in the mid-80s, and around 3,000 by 2011 (Bueler 2000; Roach 2011). Underscoring the variability, the Colorado Mountain Club's (CMC) flagship journal, *Trail & Timberline*, suggests only 1,627 people have earned the Dr. Colorado title (T&T 2014). The point is no one knows how many people are climbing Fourteeners, but scuttlebutt consistently suggests trail usage has increased dramatically.

In addition to the lack of readily available trail usage data, the wide geographic distribution of the peaks makes comparative studies exceedingly difficult. This, among other factors, means a localized case-study approach has typified past research (e.g., Hesse 2000). Although this design is fruitful in terms of providing descriptions regarding the state of particular trails, it fails to relate trail usage data to impacts, and does not provide a relative assessment as a collective group. Managers need comparative data for all Fourteeners to prioritize peaks based on restoration and protection needs.

Lastly, a barrage of physical and mental challenges accompanies mountain fieldwork. One must be willing and able to hike or climb over harsh terrain while

[4] Title earned by people that have summited all Colorado Fourteeners.

making sound backcountry decisions, as mountain weather is infamously capricious. These challenges, among others, perhaps contribute to the lack of depth to the literature. The scarce research notwithstanding, a seminal work by Kedrowski (2006) laid the foundation for comparatively assessing trail usage dynamics and recreational impacts for all 58 Fourteeners, which will serve as the springboard for this study.

Study Springboard

In the summer of 2005, Kedrowski (2006, 2009) compiled trail usage data for the temporal range of 1995-2004 by counting signatures on summit registers of all peaks archived in the American Mountaineering Center (AMC) in Golden, CO. These data were then collated and classified into groups for testing factors that could potentially explain where and why people climb certain peaks. The five variables for which data were collected and tested for explanatory significance included:

1. Direct distance to Denver (DD; quantitative, primary): Euclidean distance from the summit to the Colorado State Capitol Building.
2. Direct distance to the nearest paved road (DPR; quantitative, primary): Euclidean distance from the summit to the nearest paved road.
3. Trail/route length (TL; quantitative, primary): Network distance from the trailhead to the summit along the standard route.
4. Technical classification (Class; qualitative, secondary): Qualitative rating describing movements necessary to complete the standard route (Table 1).
5. Trailhead elevation (THE; quantitative, primary): Elevation of the standard route trailhead.

Table 1

Technical classifications for climbing routes on Colorado Fourteeners (Roach 2011)

Technical Route Classifications for Colorado Fourteeners
Class 1 - Trail hiking or any hiking across open country that is no more difficult than walking on a maintained trail. The parking lot at the trailhead is easy Class 1, groomed trails are midrange Class 1, and some of the big step-ups near the top of the Barr Trail (Pikes Peak) are difficult Class 1.
Class 2 - Off-trail hiking; usually means bushwhacking or hiking on a talus slope. Hiker is not yet using handholds for upward movement. The rating Class 2+ is occasionally used for pseudo-scrambling when the hiker uses hands but does not need to search very hard for handholds. Most people can downclimb Class 2+ terrain facing out. Class 2+ movement is sometimes called *scampering*.
Class 3 - The easiest climbing category usually referred to as *scrambling*. The climber looks for and uses handholds for upward movement; basic climbing movements as opposed to walking. Although handholds are used, they are not very difficult to find. Occasionally putting a hand down for balance while crossing a talus slope does not qualify as Class 3. Many people feel the need to face in while downclimbing Class 3.
Class 4 - Within the realm, but on the outskirts of technical climbing. The climber does not just use handholds, but must search for, select, and test them. The climber is beginning to use muscle groups not involved with hiking, those of the upper body and abdominals in particular. The movement is more focused, thoughtful, and slow. Many people prefer to rappel down a serious Class 4 pitch rather than downclimb.
Class 5 - The interior of technical climbing. The climber uses a variety of climbing techniques, not just cling holds. Movement may involve leg-stemming, cross-pressure with arms, pressing down on handholds, edging on small holds, smearing, chimneying, jamming, and heel hooks. A lack of flexibility will be noticeable and can hinder movement. Movement usually totally occupies the climber’s mind. Most people rappel down Class 5 pitches.

Interestingly, if unsurprising, Fourteeners further from Denver and paved roads with longer, more technically challenging routes, starting at lower elevations, were found to have fewer climbers. Extending the scope of the study, the following absolute and potential trail impact data (all primary) were gathered from all 58 standard routes:

1. Trail spurs per mile (TS; quantitative)

2. Switchbacks per mile (SB; quantitative)
3. Switchbacks needed per mile (SBN; quantitative)
4. Fire Rings per mile (FR; quantitative)
5. Percent of trail as double wide (%DW; quantitative)
6. Percent of trail as four-wheel drive (%4WD; quantitative)
7. Percent of elevation gain with no trail (*%ELNT*; quantitative)
8. Percent of trail miles with no trail (*%TMNT*; quantitative)
9. Percent of route miles with no trail or markers (*%RMNT*; quantitative)

These data were analyzed, normalized (Equation 1), and then used in conjunction with the trail usage data to create what was dubbed the Interim Fourteener Environmental Degradation Index (iFEDI).

$$\text{Variable} = \frac{\text{(Actual Value-Minimum Value)}}{\text{(Maximum Value-Minimum Value)}}$$

Equation 1. Normalization method used to build indices with trail impact and explanatory variables.

Potential impacts (i.e., variables 7-9 in italics above) were earmarked because their effect on the index values was determined to be dependent upon trail usage. The underlying logic was that route segments without a formally marked trail generally lead to increased trail spurs for peaks with *High* usage, and those with *Low* usage are actually less impacted without a trail. Therefore, potential variables were engineered to affect each peak's index value accordingly via the following equations:

$$\text{iFEDI}_{\text{high}} = \left(\frac{\text{TS-SB+SBN+FR+\%DW+\%4WD}}{6}\right) + (\%ELNT + \%TMNT + \%RMNT)$$

Equation 2. Interim Fourteener Environmental Degradation Index for peaks with *High* trail usage.

$$\text{iFEDI}_{\text{mod}}=\left(\frac{\text{TS-SB+SBN+FR+\%DW+\%4WD}}{6}\right)+\left(\frac{\%ELNT+\%TMNT+\%RMNT}{3}\right)$$

Equation 3. Interim Fourteener Environmental Degradation Index for peaks with *Moderate* trail usage.

$$\text{iFEDI}_{\text{low}}=\left(\frac{\text{TS-SB+SBN+FR+\%DW+\%4WD}}{6}\right)-(\%ELNT+\%TMNT+\%RMNT)$$

Equation 4. Interim Fourteener Environmental Degradation Index for peaks with *Low* trail usage.

Getting into the details of equation mechanics, the six normalized absolute variables, found in the left set of parenthesis, were averaged regardless of trail usage. The absolute variables, save switchbacks (SB), were determined to negatively impact the resulting index value; switchbacks generally indicate healthy, sustainable trail construction so the variable was subtracted, lowering the overall index value (Table 2). Again, the three normalized potential variables, in the right set of parenthesis, affected the index values according to trail usage. If the peak was determined to have *High* usage, the sum of the normalized potential variables was added to the average of the normalized absolute variables (Equation 2). If trail usage was *Moderate*, the average of the normalized potential variables was added to the average of the normalized absolute variables (Equation 3). For low trail usage, the sum of the normalized potential variables was subtracted from the average of the normalized absolute variables (Equation 4). Thus, high iFEDI values indicate peaks more severely impacted than those with lower values.

Table 2

Effects of impact indicators on iFEDI (adapted from Kedrowski, 2006)

Impact Indicators	Equation Abbreviation	Absolute	Potential	iFEDI Effect
Informal Trails/mi	**IT**			**+**
Switchbacks/mi	**SB**			**−**
Switchbacks Needed/mi	**SBN**			**+**
Campsites/mi	**CS**			**+**
% Double Wide	**%DW**			**+**
% 4WD road	**%4WD**			**+**
Elevation gain markers only	***%ELNT***			**+ or −***
Trail miles markers only	***%TMNT***			**+ or −***
Route miles no markers	***%RMNT***			**+ or −***

*Based on trail usage groups

The results of the iFEDI allowed for ranking and comparing peaks based on trail usage and empirically observed impacts. In general, peaks closer to Denver and paved roads with shorter, less difficult routes starting at higher elevations (i.e., more accessible peaks) suffered greater impacts than those on the other sides of the continua.

Finally, the study added the explanatory variables to the mix to create what was christened the Fourteener Environmental Degradation Index (FEDI), which allowed ranking and comparing peaks based on all three dimensions (Figure 3). Similar to the iFEDI, the explanatory variables were normalized (Equation 1), and treated as potential so trail usage determined how they affected the resulting index values:

$$FEDI_{high}=[(iFEDI)+(DD+DPR+TL+Class+THE)]$$

Equation 5. Fourteener Environmental Degradation Index for peaks with *High* trail usage.

$$FEDI_{mod}=\left[(iFEDI)+\frac{(DD+DPR+TL+Class+THE)}{5}\right]$$

Equation 6. Fourteener Environmental Degradation Index for peaks with *Moderate* trail usage.

$$FEDI_{low}=[(iFEDI)-(DD+DPR+TL+Class+THE)]$$

Equation 7. Fourteener Environmental Degradation Index for peaks with *Low* trail usage.

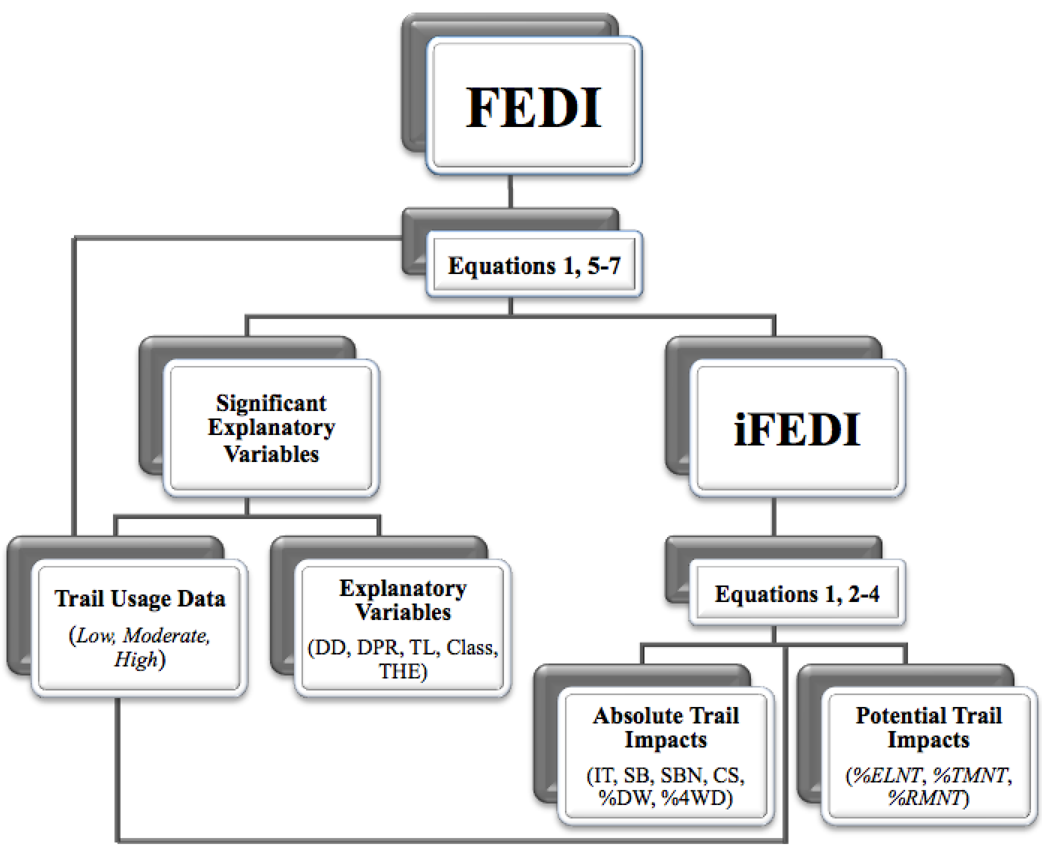


Figure 3. Conceptual framework for trail usage, explanatory variables, impact indicators, and indices adapted from Kedrowski (2006).

The FEDI values for peaks with *High* trail usage were calculated by adding the iFEDI values to the sum of the five corresponding normalized explanatory variable data points (Equation 5). For *Moderate* peaks, the iFEDI value was added to the average of the corresponding normalized explanatory variables (Equation 6). The FEDI for peaks with *Low* trail usage was determined by subtracting the sum of the corresponding normalized explanatory variables from the iFEDI (Equation 7). Again, higher FEDI values denoted more severely impacted peaks.

The results of the FEDI bolstered the findings of the iFEDI; peaks further from Denver and paved roads with longer, more technically challenging routes starting at lower elevations had lower index scores, indicating their need of restoration ought to be prioritized behind higher scoring peaks.

Kedrowski's (2006, 2009) study is important for several reasons: it established a methodology for gathering and analyzing trail usage for all Fourteeners; uncovered variables that explained those data; delineated and measured trail impact variables; defined a methodology for creating indices that rank the peaks based on various combinations of the dimensions above; and perhaps most importantly, created a baseline by which changes in trail usage, explanatory variables, and impacts can be measured over time. Also, because the data were collected and evaluated for the entire population of peaks by a single researcher, resource managers should no longer have to grapple with comparing results across inconsistent data collection and evaluation methods to inform their efforts.

This study stands specifically on the shoulders of Kedrowski (2006, 2009) to create a longitudinal comparison of trail usage, explanatory variables, and trail impacts, and then attempts to fine-tune the input parameters and formulae for creating the indices. With the spike in "peak-bagging" popularity over the last 10 years, the dynamics of how many, where, and why people climb Colorado Fourteeners, and the degree to which peaks are being impacted, are likely quite different. To firm up the foundation, and provide broader context, this work must be couched within recreation ecology.

Recreation Ecology

As previously mentioned, Fourteener research has not been connected to a well-developed body of literature, which has prevented its focus and growth. However, an extant, mature body of literature called 'recreation ecology'— wherein researchers study human impacts in wilderness areas— has methodologies, designs, and frameworks directly relevant to Fourteener research. The geographic focus of recreation ecology in the U.S. has been in the northeast, around the Appalachian Trail, and in regions of Montana (e.g., the Bob Marshall Wilderness and Bitterroot Mountains). In what follows, the broad research designs and methods of recreation ecology will be introduced, and the present study will be contextualized within this literature.

According to Cole (1987) and Leung and Marion (2000), there have been essentially four recreation ecology study designs: descriptive surveys (cross-sectional), comparisons of used sites to a control (observational/experimental), longitudinal natural experiments, and longitudinal simulated experiments (experimental). In a descriptive survey design, the researcher estimates or measures recreation impacts to assay overall site health (e.g., Cole et al. 1997; Kedrowski 2006). The comparative design allows the researcher to evaluate impacts by comparing measurements taken from an afflicted site to a control site (e.g., Hall and Kuss 1989; Marion and Leung 1997). In the longitudinal natural experiment design, measurements are collected before and after the inception of a management action/policy to evaluate changes in impacts due to action (e.g., Doucette and Kimball 1990; Marion 1995). Lastly, the longitudinal simulated design is identical to the natural; however, measurements are temporally situated around the application of a prescribed impact remedy (e.g., Cole 1995; DeLuca et al. 1998). These research designs have been applied to what are essentially the topical foci of recreation ecology: effects of trampling, trail and campsite impacts, and impact “indicators and indices” (Leung and Marion 2000, p 27).

Trampling studies almost invariably employ a longitudinal simulated experiment design because the goal is to understand how levels of trail usage affect the magnitude of impacts, how trampling influences vegetation, and the degree to which different kinds of trampling impact recreation sites (Leung and Marion 2000). Although trampling studies represent a considerable portion of recreation ecology research, the results of which are certainly relevant to recreational impacts on Fourteeners, this line of inquiry falls outside the scope of this paper. Put simply, the conclusions drawn by trampling research serve as underlying assumptions; namely, that increased trail use leads to increased impacts. Owing to their peripheral relevance, the particular research methods of this topic will not be discussed further.

Research methods for studying trail impacts can be organized by three categorical approaches: reconnaissance, sampling-based, and census-based (Leung and Marion 2000). Under the reconnaissance approach, the most often used methods are condition class assessments and imagery analyses. The former method requires the researcher to assign trails to defined descriptive classes based on qualitative observations (e.g., Cole et al. 1997), and the latter entails trail identification and evaluation using remotely sensed imagery. Within the sampling-based category there are point sampling and quadrat analysis techniques. Both of these methods require a sampling scheme wherein data are collected at a series of points (point sampling; e.g., Cole 1991) along the trail or within quadrats (point-quadrat; e.g., Hall and Kuss 1989). Lastly, within the census-based category there are sectional and problem assessment methods. The former involves dividing the trail into segments for evaluation, and the latter incorporates a thorough inventory of defined impact issues over the entire trail (e.g., Leung and Marion 1999).

Research regarding recreational impacts at campsites generally employs a “reconnaissance” or “multiple-indicator approach” (Leung and Marion 2000, p 30). The reconnaissance approach is similar to that of assessing trail impacts in that it can be further sub-divided by methods that involve either assigning defined condition classes to campsites (e.g., Marion 1995), or evaluating campsite photographs (e.g., Magill 1989). Within the multiple-indicator approach there are the ratings and quantitative measurement methods. The former involves bestowing a rating for select impact variables on each campsite (e.g., McEwen et al. 1996), as distinct from the latter, which requires the researcher to gather quantitative data for each impact variable (e.g., Marion and Cole 1996). Campsite impact studies are particularly important because these areas are often the most degraded (Leung and Marion 2000). Similar to trampling, the results of campsite impact studies will serve as assumptions; namely, that camping produces a certain degree of negative impacts in virtually all circumstances. Again, camping impact studies are tangentially related to the current objectives, but their results serve as foundational assumptions.

Research regarding impact indicators and indices has grown in recent years because both are efficient in terms of informing resource managers in a timely, cost-effective way (Leung and Marion 2000). Indicators, or features, are monitored variables that have been found to reflect recreational impacts. Indices, or some combination of indicators, are used to streamline the articulation and interpretation of results for resource managers. According to Leung and Marion (2000), impact indices can be organized by four categories based on what each intends to represent: the degree of impacts (e.g., Cole 1993), spatial distribution and extent of impacts (e.g., Cole et al. 1997), site resource summary (e.g., McEwen et al. 1996), and site sensitivity to impacts (e.g., Cole 1995). The impact indicators (i.e., observed impact variables) and indices employed here are designed to reflect the degree, distribution, and extent of recreational impacts on Fourteeners.

Summary

To summarize, this paper is essentially a revised repeat study of Kedrowski (2006, 2009). The research design and methods employed are a hybrid of those previously mentioned for recreation ecology. Properly situated in the four designs, this is a longitudinal natural experiment and descriptive survey. The topical focus includes trail impacts and indicators/indices. Again, several underlying assumptions are the fruits of trampling and campsite impact studies; namely, that trail use and camping activity are positively correlated with negative impacts. Within the aforementioned trail impact study approaches, this research corresponds with the reconnaissance and census-based categories; more specifically, condition class and problem assessment methods were employed because defined impacts on all standard routes were inventoried and used to assign classes. Then, the results were abridged by way of a composite index representing the degree of impacts, and by extension, the spatial distribution and extent of impacts throughout Colorado.

This design and methodology was chosen for several reasons. First, the study should inform resource management with concise results that allow for legitimate comparison among peaks. Second, the methodology avoids errors associated with other sampling schemes and introduces an element of consistency as a single researcher made the census-based observations of impacts for all the peaks. Lastly, in following the methodology of Kedrowski (2006), the results offer a longitudinal comparison of the dynamics of trail usage and recreational impacts, which can inform restoration efforts and perhaps provide insight into the effectiveness of management strategies. In what follows, specifics of the study area and methodology will be laid out.

CHAPTER III

STUDY AREA

Lexicon

To avoid confusion, some definitional housekeeping must be done. First, a key component of this study was to determine trail usage for all 58 Fourteeners in Colorado. Within the confines of this study, "trail usage" is represented by the number of summit-register names counted and collated for every peak according to the rules set forth below, which is equivalent to Kedrowski's (2006, 2009) "relative annual mountain climbing frequency" (RAMCF). The goal here is not to misrepresent the boundaries of this study, but instead to increase its readability.

Secondly, many of the peaks do not have a traditional "trail" leading to the summit, but instead have segments demarcated by cairns or nothing at all. For convenience, the terms "route" and "trail" are often conflated because the distinction between the two serves no purpose unless explicitly stated (e.g., potential impact variables 7-9).

Lastly, several naming conventions will be altered to better fit the lingua franca of recreation ecology. For example, the ensuing trail impact variables will be referred to as impact indicators or features. The goal is to disconnect this research from environmental-specific topics of study in the strict sense of the word because the scope does not encompass anything like biodiversity. Furthermore, two impact indicators will be renamed: trail spurs (TS) will become informal trails (IT), and fire rings (FR) will become campsites (CS); both are defined the same way, just with tidier labels.

Colorado

The majority of Fourteener climbing is concentrated near the urban corridor east of the Front Range where roughly 80 percent of Colorado's 5 million+ residents reside (U.S. Census 2010). The 58 peaks over 14,000 feet in elevation are sprinkled across six sub-ranges situated in central and western Colorado (Figure 5). The elevations range from the 14,433' rooftop of Mt. Elbert to the 14,001' summit of Sunshine Peak. The standard routes include technical classifications ranging anywhere between the Class I North Slopes of Grays Peak to the harrowing Class IV "Hourglass" couloir of Little Bear Peak and the "knife-edge" of Capitol Peak (Roach 2011; Figure 4). Colorado's booming population increase of 53 percent over the last two decades coupled with roughly 40 percent of tourists visiting the mountains means the number of people climbing Fourteeners will continue to increase exponentially (CFI 2015b).

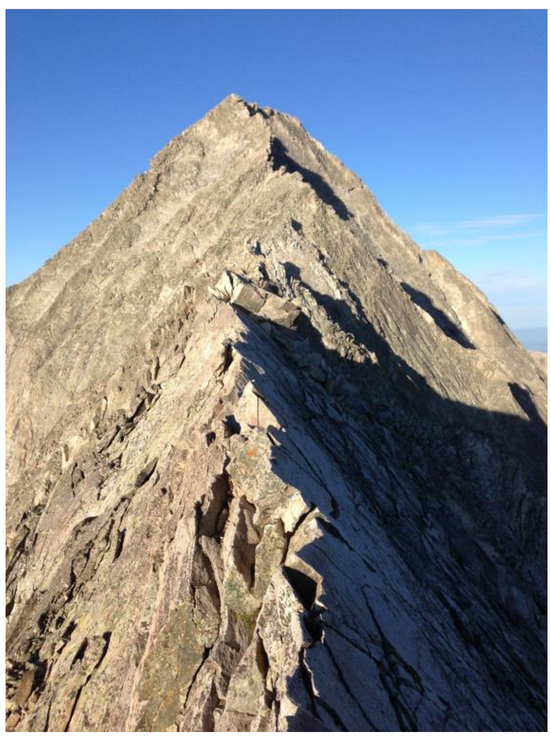


Figure 4. The famous knife-edge section of Capitol Peak in the Elk Range.

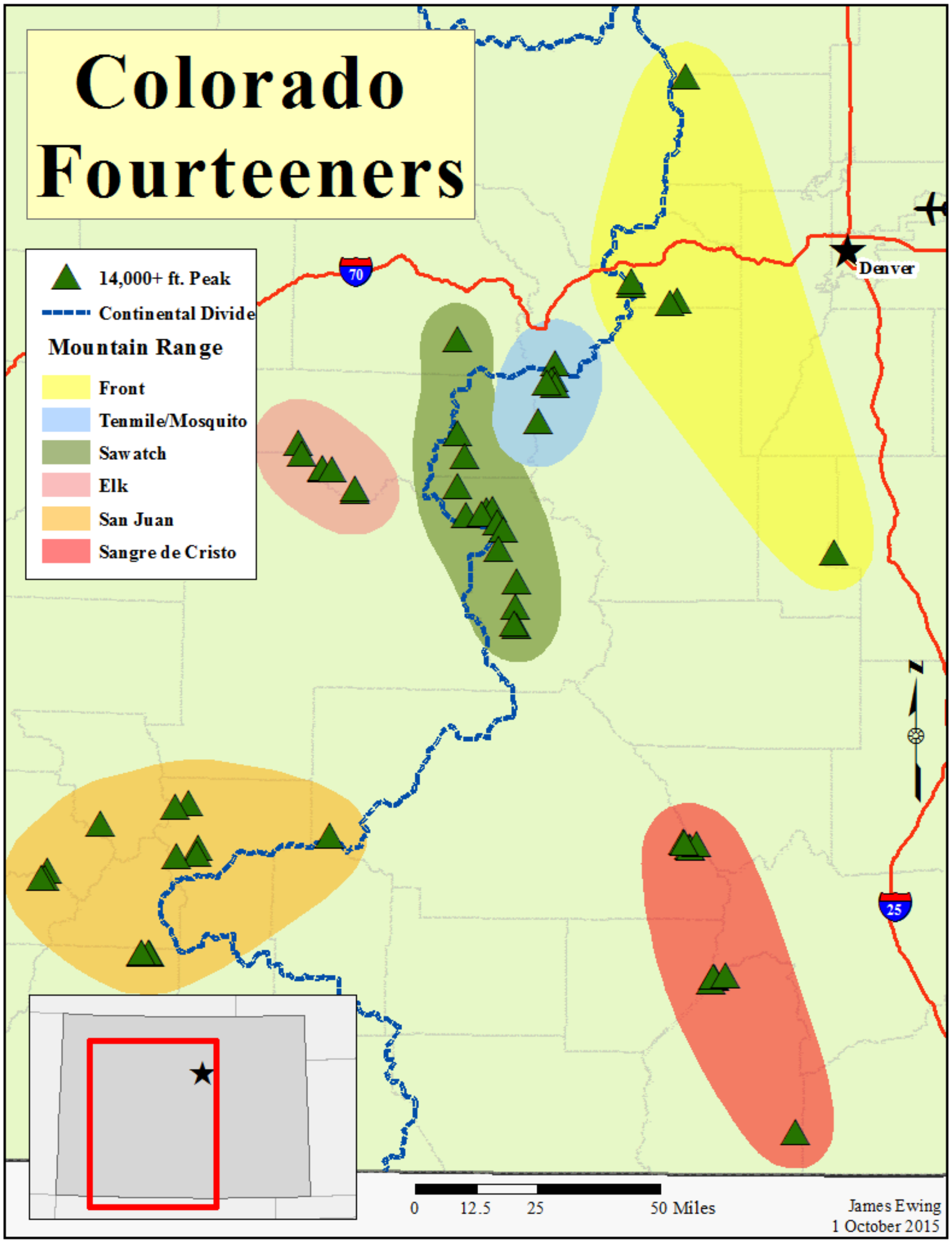


Figure 5. Distribution of Colorado Fourteeners and regional sub-ranges.

Vegetation Zones

The diverse landscapes covered by Fourteener routes can be broadly organized into five altitudinal vegetation zones – semi-desert shrublands, foothills, montane, subalpine, and alpine (McMulkin et al. 2010). The relevant portion of the semi-desert shrublands reaches up to about 8,000 feet, and is primarily located in the San Luis Valley west of the Sangre de Cristo Range (McMulkin et al. 2010). The transitional foothills zone, dominated by deciduous shrubs and Piñon-Juniper woodlands, reaches as high as 8-10,000 feet, and is wedged between the semi-desert shrublands and the higher montane zone (McMulkin et al. 2010). The montane zone extends up to about 10,000 feet, and is composed primarily of pines, Douglas-fir and aspen (McMulkin et al. 2010). Moving higher in elevation, there are the spruces, firs, and pines of the subalpine zone that extends up to treeline around 11,400 feet (McMulkin et al. 2010). Finally, the alpine zone stretches upward from treeline to the summits, and predominantly consists of herbaceous plants and woody shrubs that can withstand the harsh environment and short growing season (McMulkin et al. 2010). All routes cross the alpine and subalpine zones, and most begin in the montane zone; only a handful dips into the foothills and semi-desert shrublands (e.g., Lake Como Road to the Blanca Group).

Generally speaking, ecosystem fragility increases with elevation. Alpine soils in the Colorado Rockies can take up to 1,000 years to generate a single inch, and plants grow up to 1,000 times slower than those at lower altitudes (CFI 2015c). Thus, heavy usage on unsustainable routes has long-lasting impacts that can take centuries to recover. Putting the common vegetation zones aside, each range has singular characteristics.

Mountain Ranges

The Front Range is Colorado's longest, stretching 175 miles between the border of Wyoming and the Arkansas River Valley west of Pueblo (Roach 2011). The six Fourteeners in the Front Range are the most accessible and most often climbed in the state (Figure 8). Two Front Range peaks have paved roads to the summit (i.e., Pikes and Evans).

The Tenmile/Mosquito Range roughly extends between Frisco and Trout Creek Pass from north to south, and from Colorado 9/US 285 to Colorado 91/US 24 from east to west. The Continental Divide latitudinally bisects this range into the northern Tenmile and southern Mosquito portions (Figure 9). The six Fourteeners of the Tenmile/Mosquito Range have high trailheads, easy routes, and are very accessible from the east.

The Sawatch Range stretches for 80 latitudinal miles between I-70 and Monarch Pass on US 50 (Figure 10). There is a single paved range crossing on Colorado 82 over Independence Pass. The fifteen Fourteeners of the Sawatch are the most of any range, and include four of the highest peaks in the state. The fairly gentle standard routes of the Sawatch are accessible and see a lot of activity as the area is a popular tourist destination for whitewater rafting and summer retreats. The well-known Collegiate Peaks are a subgrouping of five Sawatch Fourteeners named after universities.

The Elk Range is located southwest of Aspen and Colorado 82 (Figure 11). Five of the seven peaks in this range, perhaps most famously the Maroon Bells, are composed of exceedingly crumbly, red sedimentary rock that makes for dangerous climbing (Figure 6). The granite of the other two is solid, but long approaches and airy exposure guard their summits. The sheer beauty of the Maroon Bells-Snowmass Wilderness area provides a stark contrast to the dangers above; half of Colorado's most technically challenging Fourteeners reside here.

Figure 6. Crumbly, red sedimentary rock on the Maroon Bells Traverse in the Elk Range.

The San Juan Range covers over 4,000 square miles in southwestern Colorado, including six wilderness areas (Figure 12; Roach 2011). The thirteen San Juan Fourteeners are out of reach for the weekend warriors of Denver. The rugged remoteness combined with quaint and interesting towns like Telluride, Ouray, Silverton, and Lake

City makes for one of the most awe-inspiring landscapes in Colorado. Access to the standard routes of the San Juan Fourteeners includes circuitous driving, long, rough dirt roads, and a lift from the Durango and Silverton Narrow Gauge Railroad (Figure 7).

Figure 7. The Durango and Silverton Narrow Gauge Railroad provides climbers access to the Windom Group deep in the San Juan backcountry.

The Sangre de Cristo, or blood of Christ, Range is only 10-20 miles wide and stretches for 220 miles from Salida to Santa Fe, NM (Figure 13; Roach 2011). The portion containing peaks of interest is framed by Westcliffe and Crestone to the north, the New Mexican border to the south, the Wet Mountain Valley and Huerfano Park to the east, and the San Luis Valley and Great Sand Dunes National Park to the west. The ten Fourteeners of the Sangre de Cristos have some of the most challenging standard routes in the state, and the Crestone Conglomerate makes for unique, interesting climbing (Figure 14).

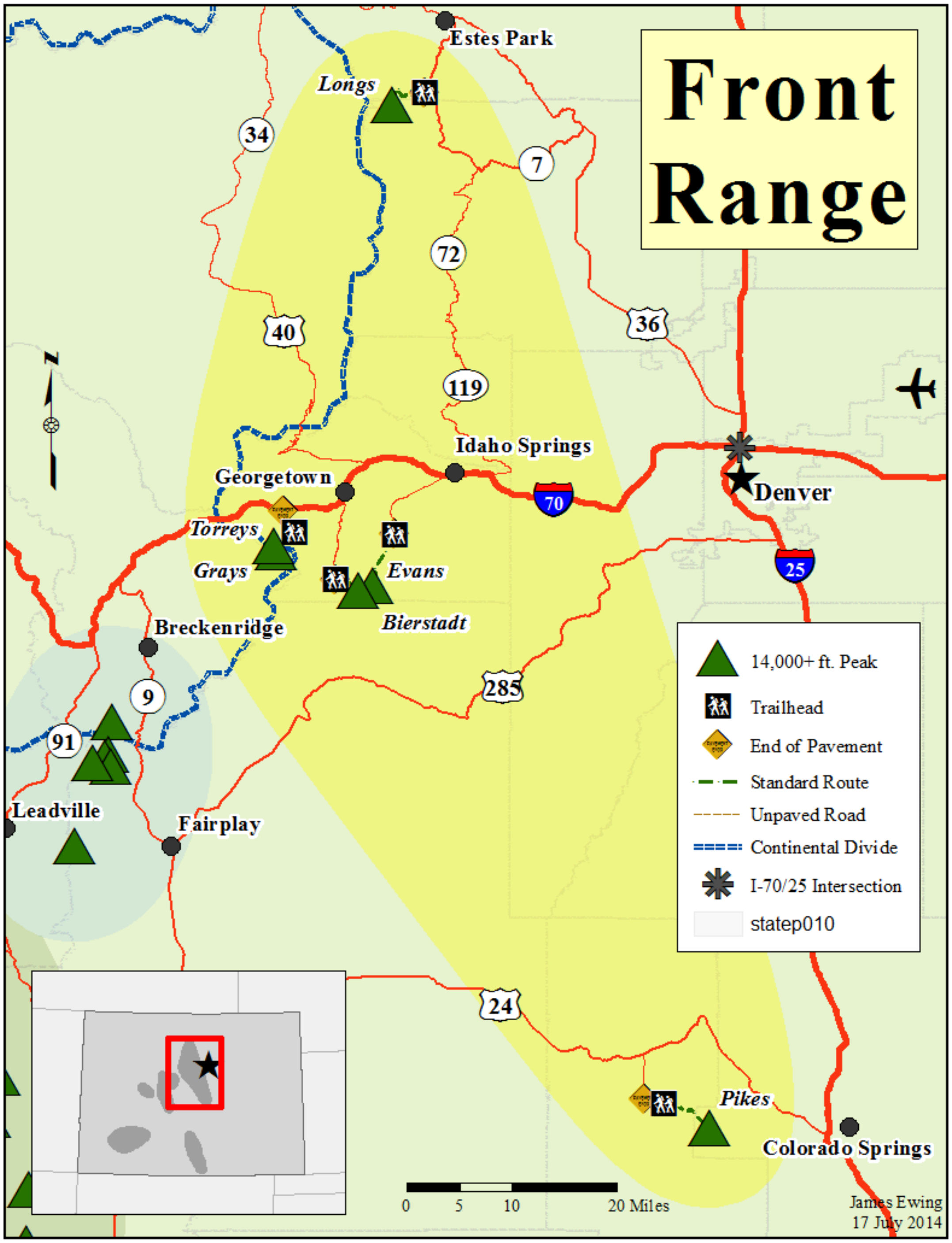


Figure 8. The Front Range houses Longs Peak, the only Colorado Fourteener located north of Interstate 70 and within the boundaries of a National Park. Pikes Peak, the southernmost of the Front Range, hosts the annual Pikes Peak International Hill Climb, an automobile and motorcycle race along the summit road.

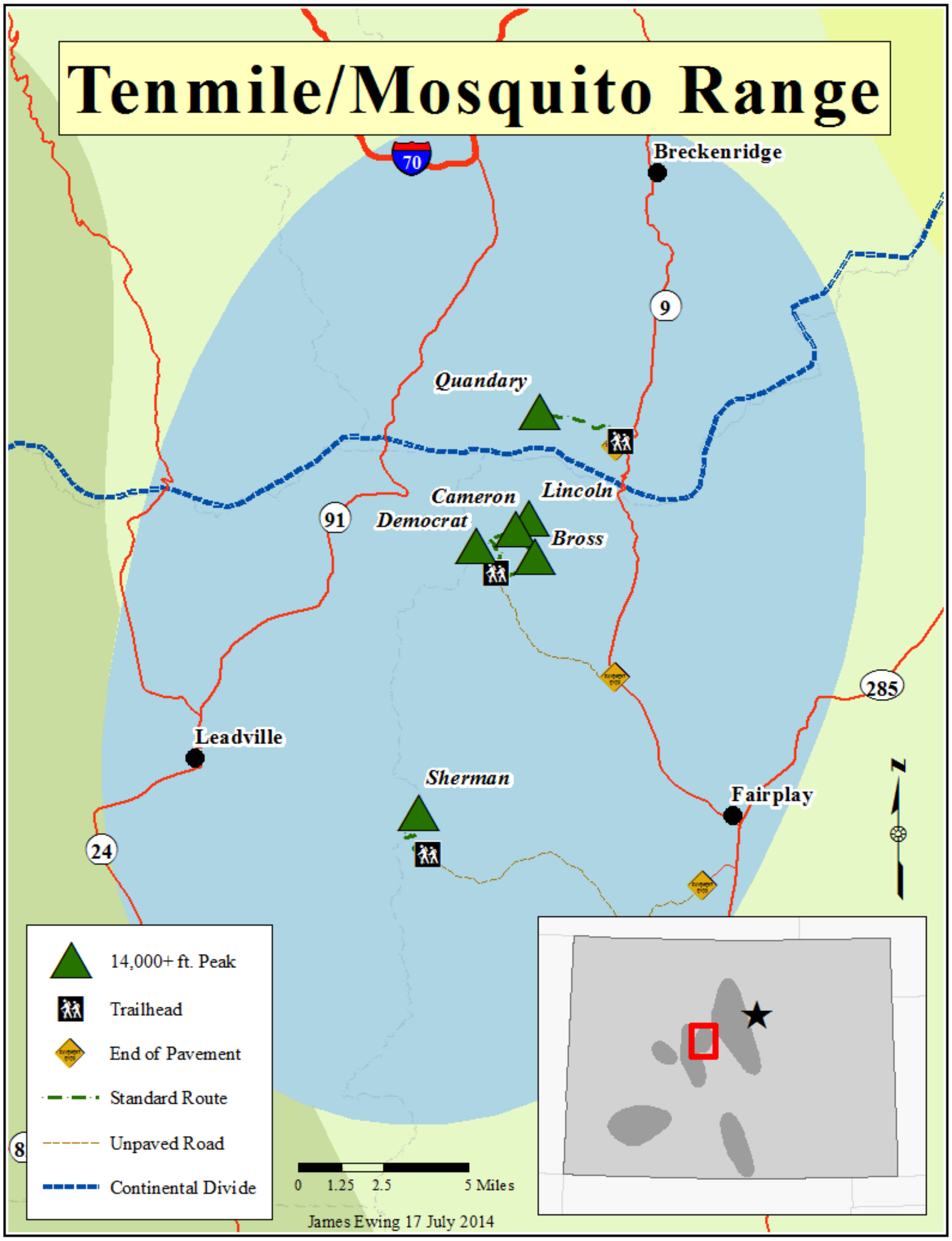


Figure 9. The Mosquito Range Fourteeners south of the Continental Divide are littered with remnants of mining activity. The Lincoln Group has an easy and popular combination route known as the Decalibron, which offers peak-baggers four summits in a day trip from Denver. Interestingly, Mount Bross, the southeastern peak of the cluster, is the centerpiece of an ongoing access dispute as the summit is on private land.

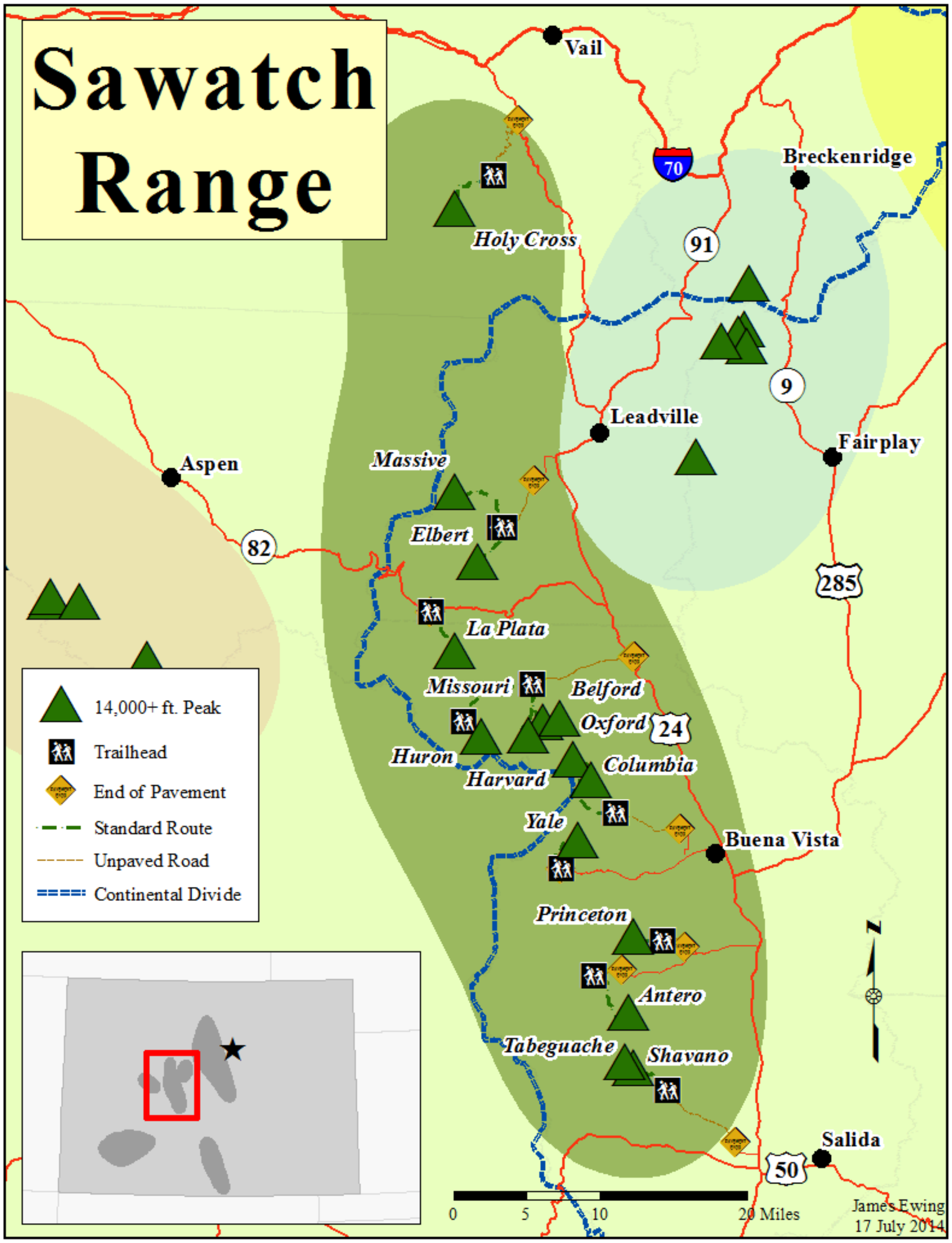


Figure 10. The Sawatch Fourteeners are east of the Continental Divide, save the northernmost Mount of the Holy Cross. The east-facing cross-shaped couloir for which the peak is aptly named fills with snow and is visible from even the westernmost Fourteeners of the Front Range on a clear day. The pinnacle of Colorado, Mt. Elbert, is the first peak north of Colorado 82.

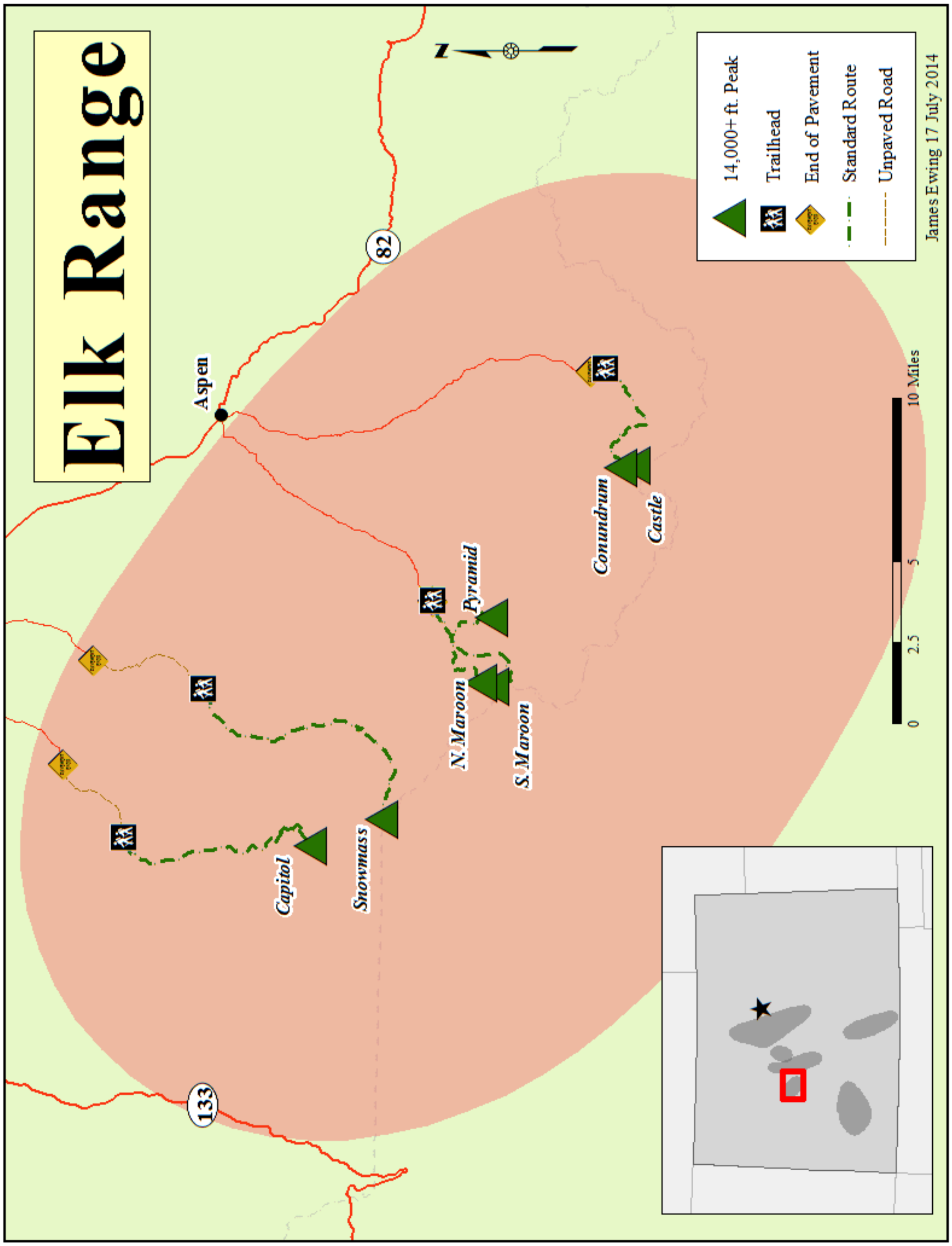


Figure 11. The Elk Range has some of the most beautiful and dangerous Fourteeners in Colorado. The central cluster of peaks includes the Maroon Bells, often regarded as perhaps the most photographed mountains in the state. Despite their close proximity to Aspen, most of these peaks are not viewable from Colorado 82.

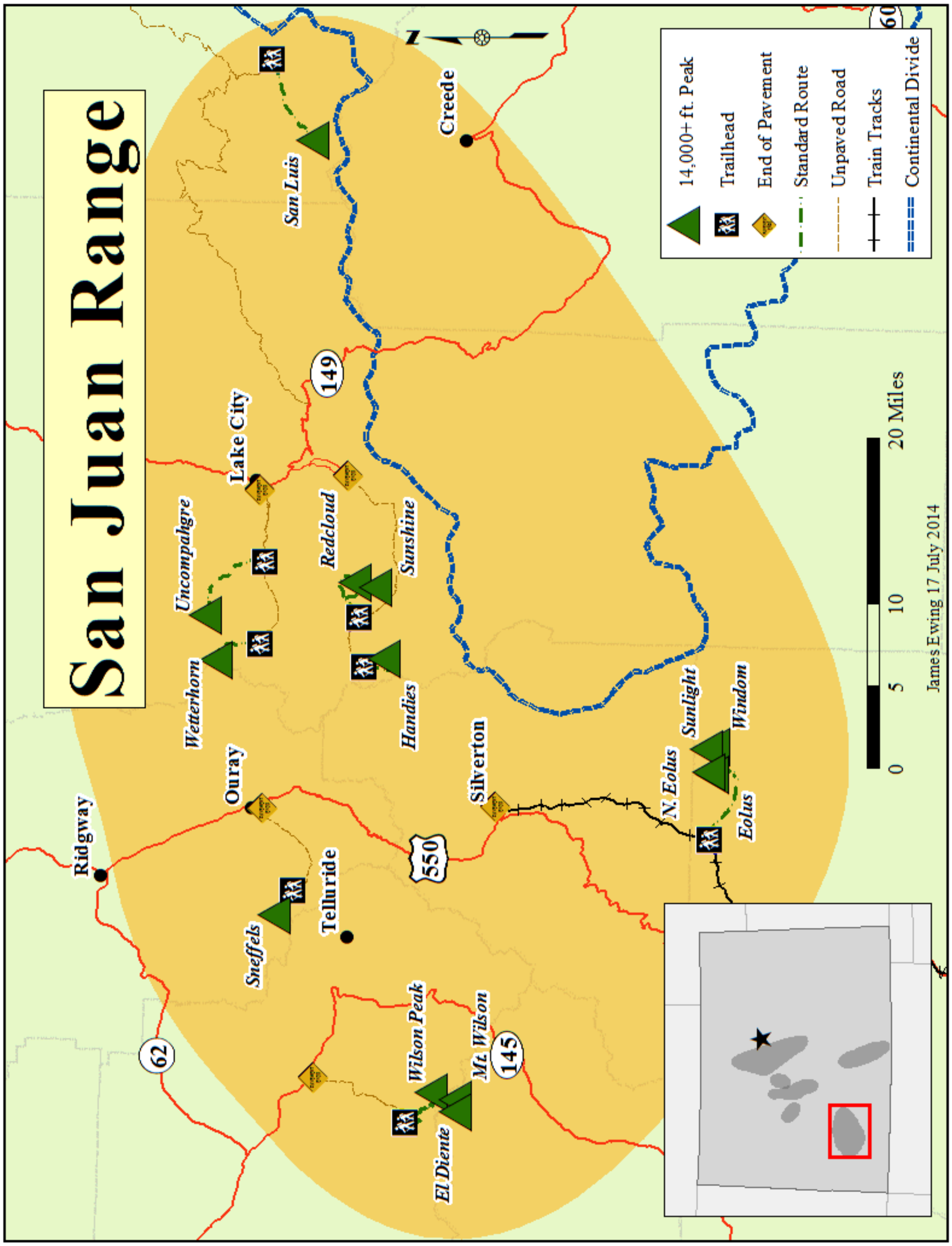


Figure 12. The Fourteeners of the San Juans cover a vast expanse west of the Continental Divide. Interestingly, the standard route for the Windom Group includes a train ride from Silverton to the trailhead. Owing to its isolation and simple standard route, the easternmost peak, San Luis, could be the least climbed Fourteener in Colorado.

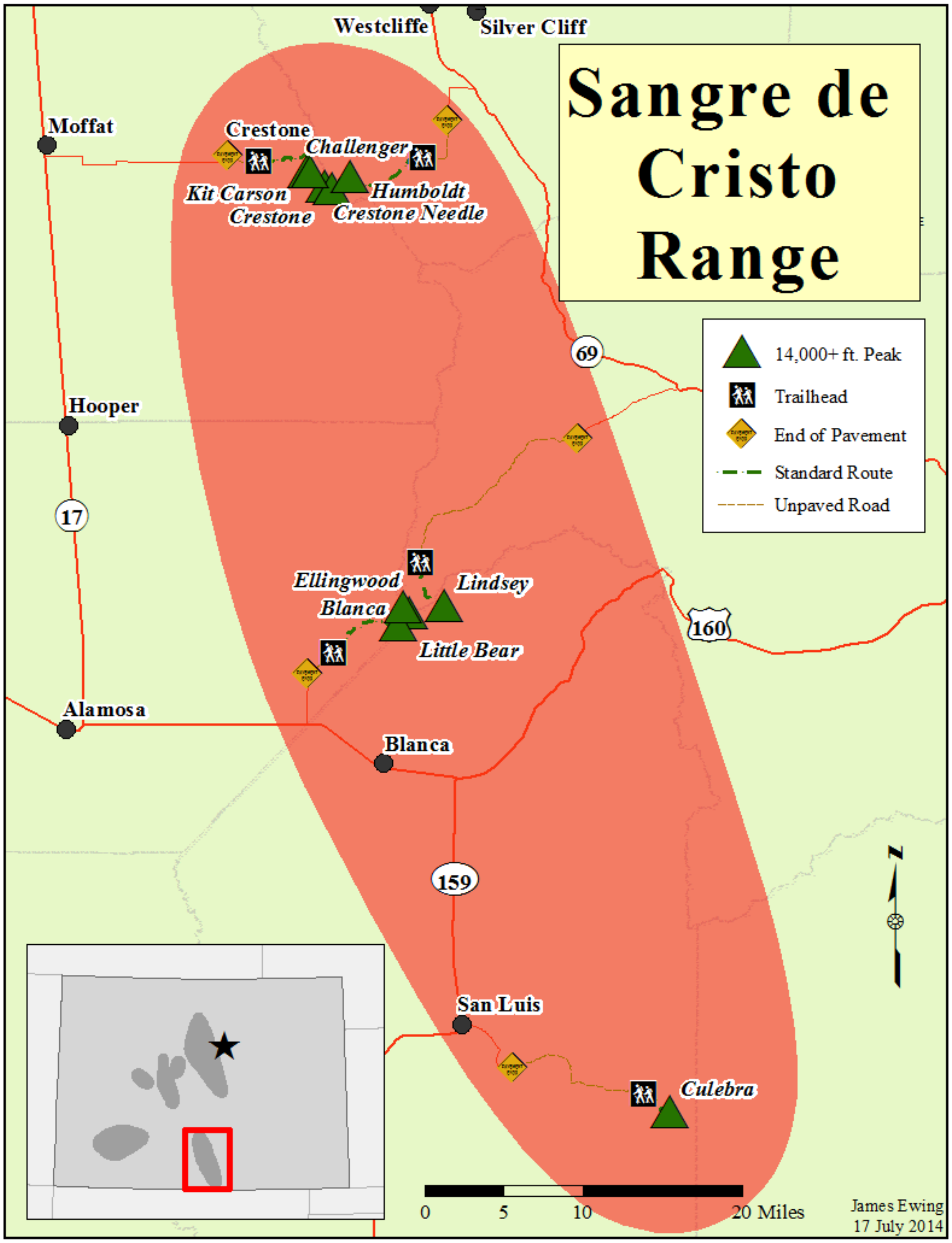


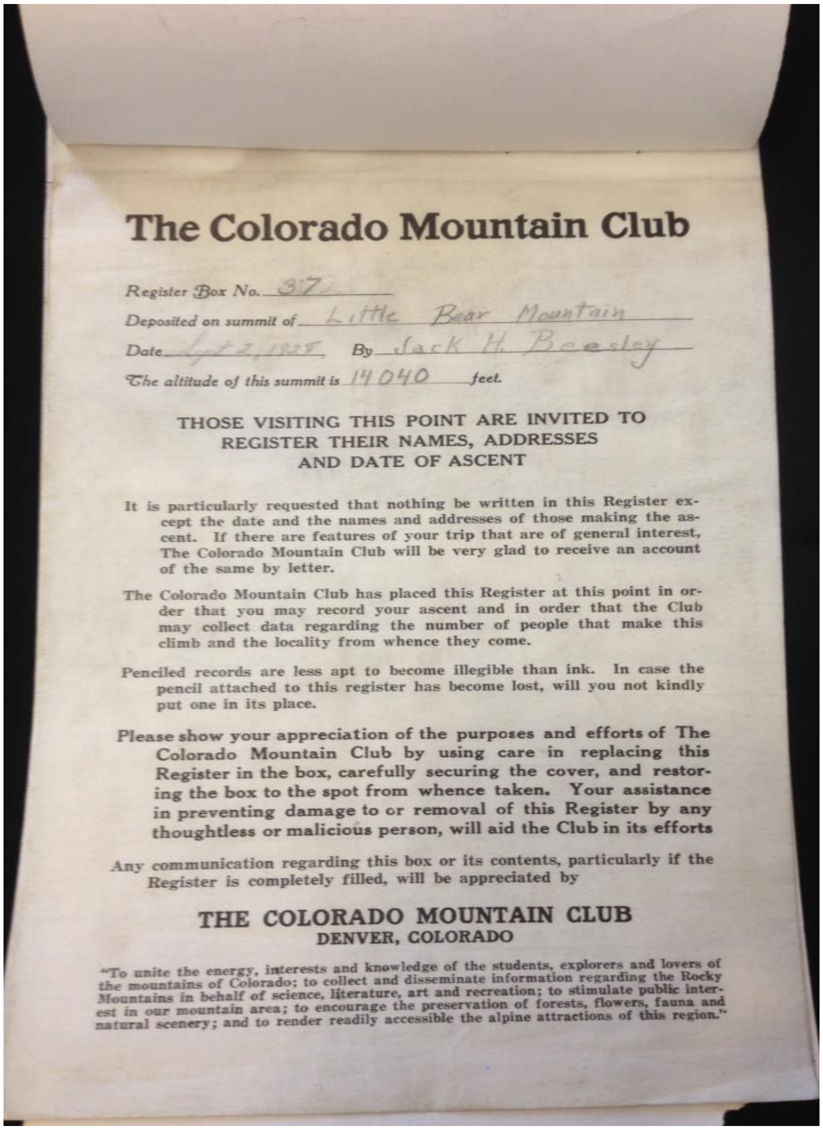
Figure 13. Despite clustering of Fourteeners in the Sangre de Cristos, standard route trailheads are located on opposite sides of the range. The southernmost peak, Culebra, is on private land and climbing is only permitted on summer weekends for a $100 fee.

Figure 14. Crestone conglomerate rock of the Sangre de Cristo Range with an old piton still inserted in a small crack.

American Mountaineering Center

The CMC, in partnership with the American Alpine Club (AAC), started the AMC in Golden, CO in 1993, which houses the most extensive mountaineering library west of the prime meridian (CMC 2015a). Included in that collection, is an archive of Fourteener summit registers dating back to the early part of the 20^{th} century (Figure 15).

All the archival trail usage reconstruction for this study was done using the summit registers at the AMC.



The Colorado Mountain Club

Register Box No. 37

Deposited on summit of Little Bear Mountain

Date Sept 2, 1928 By Jack H. Beesley

The altitude of this summit is 14040 feet.

THOSE VISITING THIS POINT ARE INVITED TO REGISTER THEIR NAMES, ADDRESSES AND DATE OF ASCENT

It is particularly requested that nothing be written in this Register except the date and the names and addresses of those making the ascent. If there are features of your trip that are of general interest, The Colorado Mountain Club will be very glad to receive an account of the same by letter.

The Colorado Mountain Club has placed this Register at this point in order that you may record your ascent and in order that the Club may collect data regarding the number of people that make this climb and the locality from whence they come.

Penciled records are less apt to become illegible than ink. In case the pencil attached to this register has become lost, will you not kindly put one in its place.

Please show your appreciation of the purposes and efforts of The Colorado Mountain Club by using care in replacing this Register in the box, carefully securing the cover, and restoring the box to the spot from whence taken. Your assistance in preventing damage to or removal of this Register by any thoughtless or malicious person, will aid the Club in its efforts

Any communication regarding this box or its contents, particularly if the Register is completely filled, will be appreciated by

THE COLORADO MOUNTAIN CLUB
DENVER, COLORADO

"To unite the energy, interests and knowledge of the students, explorers and lovers of the mountains of Colorado; to collect and disseminate information regarding the Rocky Mountains in behalf of science, literature, art and recreation; to stimulate public interest in our mountain area; to encourage the preservation of forests, flowers, fauna and natural scenery; and to render readily accessible the alpine attractions of this region."

Figure 15. CMC summit register for Little Bear dated September of 1928 found in the AMC archives.

Standard Routes

Regarding the field collection of impact indicator data, the standard routes were used to represent the overall physical shape of each peak (See Table 19 in the Appendix). Standard routes often times, but not always, coincide with the easiest path to the summit, but on virtually all peaks they receive the most usage. The standard route on any given peak may change for a variety of reasons, like restoration; however, the precise routes were defined from the latest version of the most widely used guidebook by Gerry Roach (2011).

Social and Technological Milieu

Another important component to the study area is the social and technological milieu, as monumental disruptions have occurred since this garden was last tended. Prior to current interconnectedness, peak-baggers were attracted by adventures in books and tales told at pubs, the signals of which could only travel so far. Now there are podcasts, RSS feeds, mobile applications, and social media bolstered by LTE and broadband networks, all of which can fit snugly into those seemingly useless shirtfront pockets. Websites and their corresponding mobile applications, like 14ers.com, give climbers access to route and peak descriptions, photographs, maps, weather reports, and a platform for users to create and share content like trip reports, current conditions, and personal checklists; even information on which summits have cell reception. Users struggling to find a climbing partner for a weekend adventure can use forum and direct messaging features to plan trips with strangers. The point is that access to information and people is eroding the fear of the unknown that once kept climbers at bay. Therefore, the issue of sustainability on Colorado Fourteeners must be refocused and the monitoring and management methods employed must be equally as nimble as the peak-baggers topping out and the smartphones that inform them.

CHAPTER IV

METHODOLOGY

Longitudinal Analyses

To thoroughly answer the first research question – How have the dynamics of trail usage and recreational impacts changed? – it must be parsed into four distinct pieces, each with its own sub-question. First, changes in trail usage were addressed by comparing data gathered in 2013 for the date range of 2005-2012 against those of Kedrowski (2006, 2009) gathered in 2005 for the date range of 1995-2004. Second, changes in the relationship between explanatory variables and trail usage were tested by updating both data sets and measuring the differences. Third, to measure changes in impact indicators, fresh field data were gathered and compared against those of Kedrowski (2006). Finally, the same methods were used to create both interim and composite indices with the updated data and compared against the previous values. The specific sub-questions were:

1. Has trail usage changed significantly?
2. How has the relationship between trail usage and explanatory variables changed?
3. How have impact indicators changed?
4. Have the interim and composite indices changed significantly?

Trail Usage

In an attempt to answer the first sub-question – Has trail usage changed significantly? – a two-pronged approach was employed. First, names on summit registers archived at the AMC were counted and classified into trail usage groups, and then statistically compared against Kedrowski's from 2005. Second, for a spatial view and quick reference by resource managers, the results were mapped.

To draw the longitudinal comparison, Kedrowski's (2006, 2009) original methodology was followed as closely as possible in terms of counting and collating the trail usage data, but the date range of eligible summit registers was shifted from 1995-2004 to 2005-2012 (See Figure 55 in the Appendix). The counts were organized by month and year, and then classified into a *Low*, *Moderate*, or *High* category according to several criteria (Table 3). Annual or monthly classifications were used depending upon the completeness of the data for each peak during the climbing season months of May through October. If a full year of data were available, the annual classification scheme was applied. Otherwise, the average of at least two complete climbing-season months of data was used for classification. Peaks ranked as *Low* had either 0-500 summiters per year or 0-50 per month. *Moderate* peaks had 501-1500 per year or 51-300 per month. *High* peaks had more than 1500 summiters per year or more than 300 per month.

Table 3

Fourteener trail usage classification criteria

Trail Usage Class	**Annual (# of summiters) n=18***	**Monthly (# of summiters) n=10***
Low	**0-500**	**0-50**
Moderate	**501-1500**	**51-300**
High	**>1500**	**>300**

*26 peaks originally ranked *High* were assumed to have not changed class, 3 peaks used the nearest neighbor rule, and 1 had no data (*N=58*).

Three out of the 4 peaks without sufficient register data were subsummits to higher peaks nearby, so they assumed the classification of their nearest neighboring peak. The nearest neighbor rule was used for *Cameron*, Challenger, and *North Eolus*. *Cameron* is most-often climbed en route to Lincoln, so it assumed the same classification. Similarly, Challenger is on the way to Kit Carson, and *North Eolus* is about a five-minute scramble from the connecting saddle to Eolus. The other peak for which no data could be found was La Plata, which is not a subsummit to a neighboring peak, but is 6.29 miles as the crow flies from Elbert. Instead of the nearest neighboring peak, the same *Moderate* trail usage classification from Kedrowski (2006, 2009) was assumed.

After classifying the data into ordinal groups according to the rules above, a matched-pairs (dependent-sample) test was performed to see whether the changes were statistically significant.

Explanatory Variables

To answer the second sub-question – How has the relationship between trail usage and explanatory variables changed? – another two-pronged approach was taken. First, the explanatory variable portion of Kedrowski's study (2006, 2009) was recreated using fresh field data gathered in the summer of 2013 along with the updated trail usage data, followed by a comparison of results. Second, to tease out and visualize nuances of change, the results were collated, tabulated and charted.

Recreating the explanatory variable portion of Kedrowski's study (2006, 2009) involved several steps. First, fresh field data for the five original variables found significant in explaining trail usage from 1995-2004 (i.e., DD, DPR, TL, Class, THE) were collected. The straight-line distance to Denver was measured between GPS waypoints collected from every summit and the Colorado State Capitol building. The summit waypoints were also used to measure the direct distance from each peak to the nearest paved road. The length of each standard route, and the elevation of the corresponding trailhead, was measured with a GPS. Lastly, technical route classifications were mined from the foremost guidebook by Roach (2011).

To determine whether the updated field variables still explained trail usage, the data were grouped by the new trail usage classes (*Low*, *Moderate*, *High*) and evaluated with ANOVA. Pearson-product correlation was then used to assess the strength and direction of the relationship between trail usage and significant explanatory variables. Finally, to gain a semblance of the degree to which the relationships have changed, all results were compared against those of Kedrowski (2006, 2009).

Impact Indicators

To answer the third sub-question of the longitudinal analysis – How have impact indicators changed? – fresh field data for the original nine absolute and potential impact indicators (i.e., TS, SB, SBN, FR, %DW, %4WD, *%ELNT*, *%TMNT*, *%RMNT*) on all 58 standard routes were gathered and compared against those from Kedrowski (2006), the results of which were then tabulated and charted.

Data collection was completed in the summer of 2013 using a standardized form (See Figures 56-57 in the Appendix), handheld tally counter, and GPS. To expound, every standard route was surveyed for the following variables as defined below.

1. Informal trails (IT): number of informal trails observed per mile – equivalent to original TS (Figure 16). Counted with handheld tally counter.

Figure 16. IT observed on the West Slopes route to the summit of Bierstadt in the Front Range. Note that neither tread is > 5 ft. wide so no %DW.

2. Switchbacks (SB): Ratio of switchbacks observed per mile (Figure 17). Totals were tallied directly on the field data form and then divided by TL.

Figure 17. SB on the Northwest Ridge route to the summit of La Plata in the Sawatch Range. The SB in the photo extend all the way to the alpine meadow below.

3. Switchbacks needed (SBN): Ratio of additional switchbacks recommended by the researcher per mile (Figure 18). Steep and eroded route segments were visualized with SB based on local topographic limitations, the number of which was tallied and divided by TL.

Figure 18. SBN observed on the Northeast Ridge route of *N. Maroon* in the Elk Range.

4. Campsites (CS): Ratio of campsites per mile – equivalent to original FR (Figure 19). Totals were tallied along the standard route and divided by TL.

Figure 19. CS observed near Lake Como en route to Little Bear, Blanca, and Ellingwood in the Sangre de Cristo Range.

5. Doublewide trail (%DW): Percentage of trail wider than 5 feet (Figure 20). DW route segments were measured between GPS mileages[5] noted on the field data form, which were then totaled and divided by TL.

Figure 20. DW trail segment observed on the East Slopes route to the summit of Quandary in the Tenmile/Mosquito Range. The tape measure in the photo was extended 5 ft.

[5] The resolution of the GPS mileage was to the 100th of a mile, or 52.8 feet.

6. Four-wheel drive trail (%4WD): Percentage of route (in miles) that is a four-wheel-drive road (Figure 21). 4WD route segments were also measured between GPS mileages noted on the field data form, totaled, and divided by TL.

Figure 21. The infamous 4WD Lake Como Road observed along the standard routes to Little Bear, Blanca, and Ellingwood in the Sangre de Cristo Range.

7. Elevation gain with no trail (*%ELNT*): Percentage of route elevation gain (in feet) with cairns or markers but no formal trail (Figures 22-23). *ELNT* route segments were measured between altitude readings, totaled, and divided by the overall route elevation gain.

Figure 22. *ELNT/TMNT* observed on the Maroon Bells in the Elk Range. There is no formally marked trail, but notice the cairn on the left-hand side of the foreground ridgeline. Pyramid is in the background.

8. Trail miles with no trail (*%TMNT*): Percentage of route miles with cairns/markers but no formal trail (Figures 22-23). *TMNT* segments were also measured between GPS mileages, totaled, and divided by TL.

Figure 23. *ELNT/TMNT* on the Keyhole route to the summit of Longs. Notice how the path of travel is delineated with markers as opposed to cairns.

9. Route miles with no trail or markers (*%RMNT*): Percentage of route miles with no cairns/markers or formal trail (Figure 24). *RMNT* were measured between GPS mileages, totaled, and divided by TL.

Figure 24. *RMNT* observed along the East Slopes route to the summit of Snowmass in the Elk Range. Notice that neither cairns nor markers delineate a path.

Post-collection, descriptive statistics were compared against those from 2005 (i.e., Kedrowski 2006).

Impact Indices

To answer the final sub-question of the longitudinal section – Have the interim and composite indices changed significantly? – the indices were recreated following the same methodology previously outlined (Equations 1-7) in the Literature Review section, but with updated trail usage, impact indicator, and explanatory variable data gathered in 2013. The index values were then compared against those from 2005, the results of which were tabulated, charted, and mapped for spatial reference and visualization. Finally, the differences were tested for statistical significance using a matched-pairs (dependent-sample) test between the iFEDI from 2005 and 2013, and the FEDI from 2005 and 2013.

CHAPTER V

RESULTS

Longitudinal Analyses

Trail Usage

According to the data, 30 peaks were classified as *High*, 18 *Moderate*, and 10 *Low*. Eight peaks graduated to a higher trail usage group while none demoted (Figure 25; See Table 20 in the Appendix). Crestone Needle, *North Eolus*, Mt. Wilson, and *El Diente* went from the *Low* to *Moderate* trail usage group; Sneffels, *Cameron*, Lincoln, and Shavano went from the *Moderate* to *High* group. Half of the peaks that changed classes are located in the San Juan Range, two are in the Tenmile/Mosquito, and both the Sawatch and Sangre de Cristo Ranges had a peak change class. The highest average class change by range was the Tenmile/Mosquito, followed by the San Juan, Sangre de Cristo, and Sawatch. None of the peaks in the Elk and Front ranges changed classes. Spatially, the changes suggest trail usage is migrating into the interior of Colorado.

The results of the Wilcoxon signed-ranks test (data were not normally distributed, and were downgraded from interval/ratio to ordinal) suggest the mean ranks of the old and new trail usage groups were not drawn from the same population, and the difference between them was statistically significant with 99.5% confidence ($Z=-2.83$, $p=0.005$). Simply put, trail usage on Colorado Fourteeners increased significantly between the windows of 1995-2004 and 2005-2012.

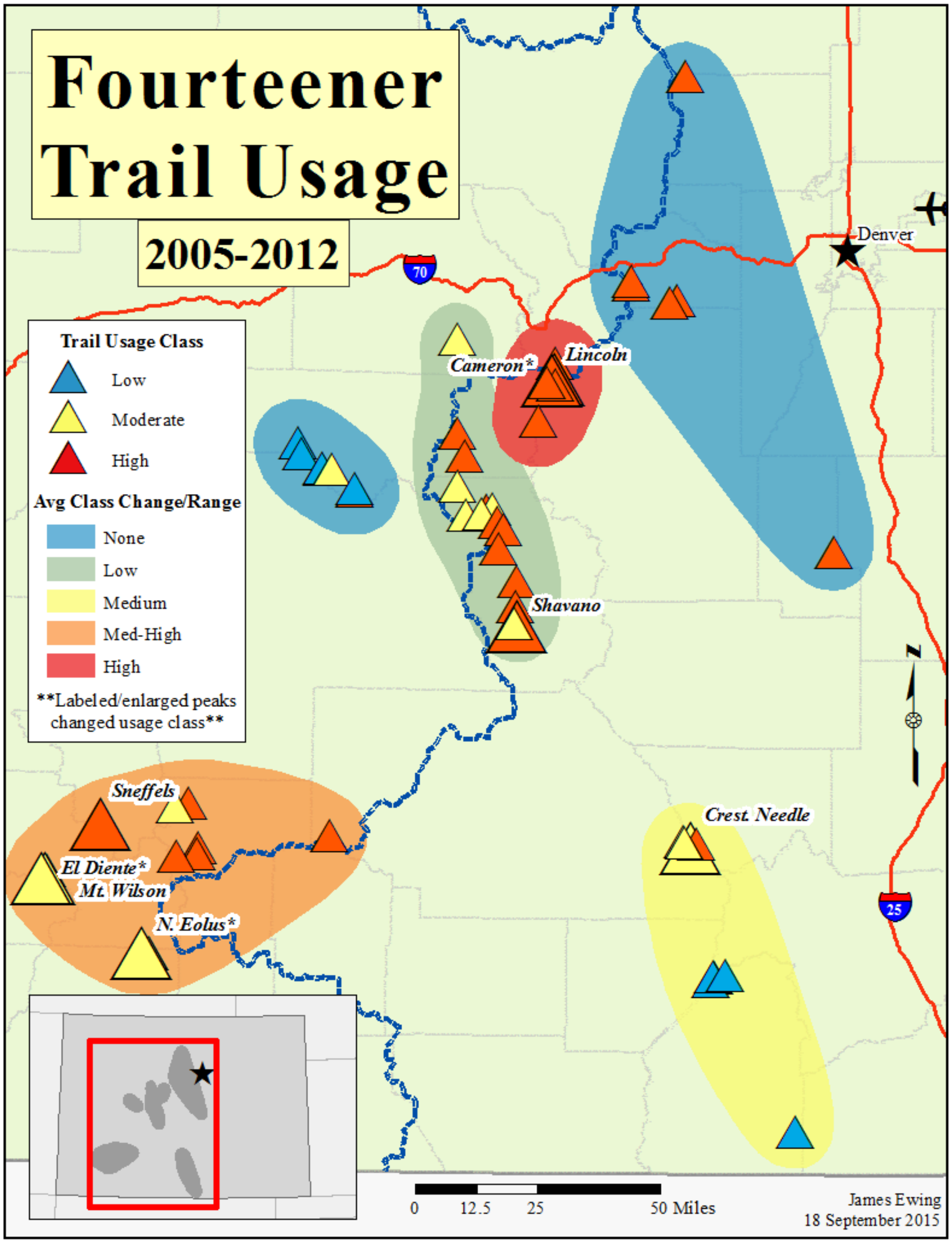


Figure 25. Distribution of trail usage classifications and average class change by range. Specific class-changing peaks labeled with enlarged symbols.

Explanatory Variables

Descriptively, the explanatory variables were similar to those of Kedrowski (2006, 2009), but with some interesting differences (Figure 26). The average direct distance to Denver was 120.66 miles; *El Diente* was furthest at 209.15 miles, and Evans was the closest at 36.62 miles (Table 4). The average direct distance to the nearest paved road was 5.04 miles; Windom was furthest at 9.80 miles, and Pikes was the closest at 0.04 miles. Notably, Evans was previously closest to a paved road, but Pikes is now 60% closer as the famous Pikes Peak Highway was paved to the summit in 2011 (Rappold 2011).

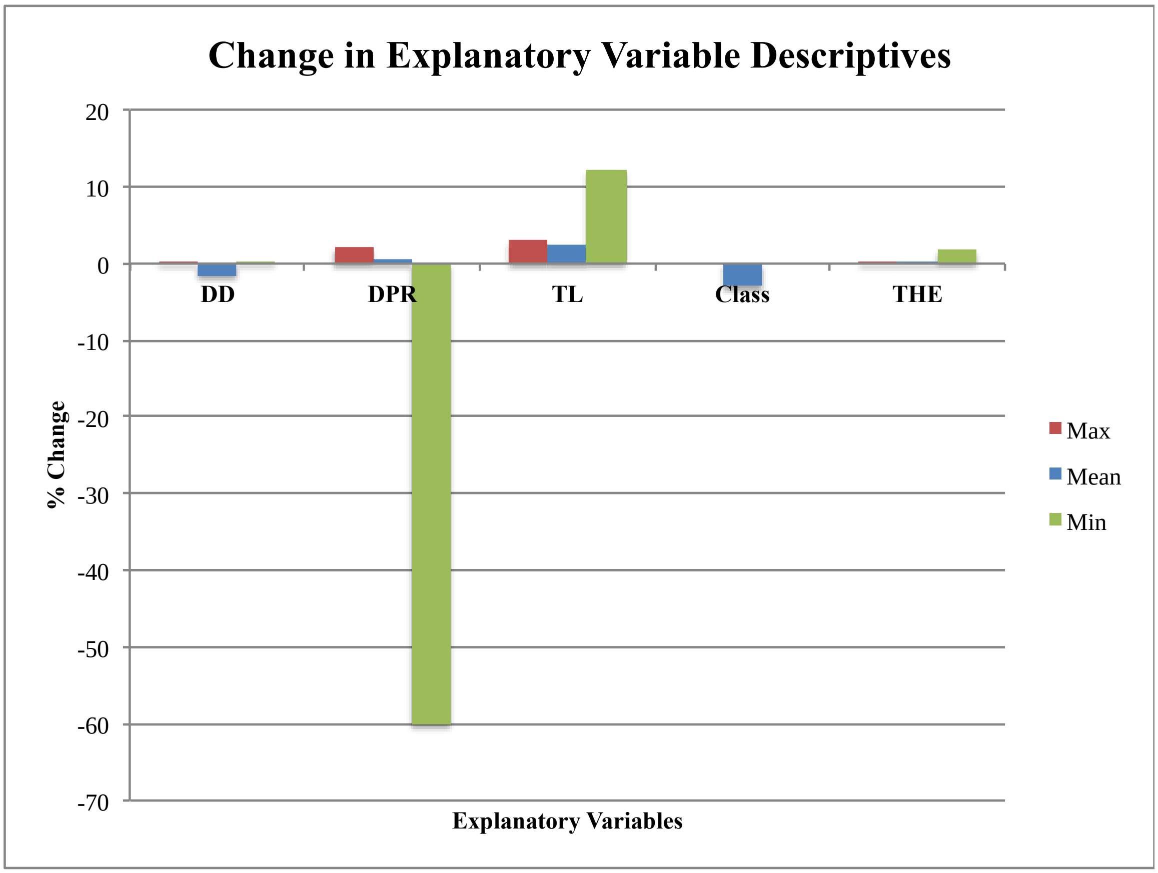


Figure 26. Change in descriptive statistics for explanatory variables.

Table 4

Descriptive statistics for variables that explain trail usage on Colorado Fourteeners (N=58) from 2005-2012.

Explanatory Variables	Mean	Standard Deviation	Max[1]	Min[2]
DD (miles)	**120.66**	**50.58**	**209.15**	**36.62**
DPR (miles)	**5.04**	**2.49**	**9.80**	**0.04**
TL (miles)	**5.49**	**2.01**	**10.50**	**1.75**
Class	**2.28**	**0.83**	**4.00**	**1.00**
THE (feet)	**10,026.24**	**1,109.30**	**12,076.00**	**8,139.00**

[1]Maximum; [2]Minimum

Standard route length was on average 5.49 miles, the longest of which was to the summit of Snowmass at 10.50 miles. The shortest route was to Bross at an interesting 12% longer distance of 1.75 miles. The Bross trail was re-routed in 2009 in response to public access issues, which is the likely explanation for the longer length (CFI 2015d). The true summit of Bross has been legally inaccessible since 2005 (Figure 27).

Figure 27. Posted no legal access sign en route to the summit of Bross. A bypass trail was constructed in 2008 (Table 8).

The average technical rating for the peaks was 2.28. Pyramid, *N. Maroon*, Capitol, Wilson, Sunlight, and Little Bear, were the most technically challenging with class 4 standard routes. Grays, Quandary, Elbert, Huron, Belford, Oxford, San Luis, and Handies were the least technically challenging with class 1 routes. Surprisingly, the average technical ratings were 3% lower than the previous study, the data source of which was an earlier edition of Roach's guidebook. Using the data provided by Kedrowski (2006), a total of 7 standard routes changed technical rating between the 2nd and 3rd edition of the guidebook.[6] Torreys went from class 2 to 1.5, Pikes from 1 to 2, Huron from 2 to 1, Belford from 2 to 1, Oxford from 2 to 1, *Conundrum* from 2.5 to 2, and Handies from class 2 to 1. With the exception of Pikes, these peaks were downgraded in technical rating.

The average trailhead elevation was 10,026 feet, the highest of which was the Kite Lake Trailhead for the Lincoln group[7] at 12,076 feet. The lowest was the Lake Como trailhead for Blanca, Little Bear, and Ellingwood at 8,139 feet. While slight variations for variables measured using a GPS/GIS should be expected, the means were within 2.6% of the original data.

Aggregated by trail usage group, the variable means reveal some interesting trends (Figure 28). Peaks classified as *High* (n=30) were further from Denver and paved roads, with slightly longer, less technical routes starting at higher elevations. The four peaks that went from *Moderate* to *High* (i.e., Lincoln, *Cameron*, Sneffels, and Shavano) were on average 106.88 miles from Denver, 3.80 miles from the nearest paved road, 3.05 miles long, technically rated at 2.1, with trailheads starting at 11,361 feet. While the average increase in distances to Denver and trailhead elevations for the *High* group were clearly driven by the usage-class-changing peaks, the longer distances to the nearest paved road, longer route lengths, and less technical route-ratings were not. The longer distances to paved roads are best explained by differences in data collection and

[6] Routes were identical for these peaks between studies
[7] i.e., Democrat, *Cameron*, Lincoln, Bross

calculation methods between studies as the un-paving of roads seems highly unlikely. Longer route lengths could be due to several factors: inherent GPS error, differing route segments, and/or variations in precise trailhead locations. Less technical routes, however, are due to 6 peaks being demoted in classification between the 2nd and 3rd edition of the guidebook from which the data were collected.

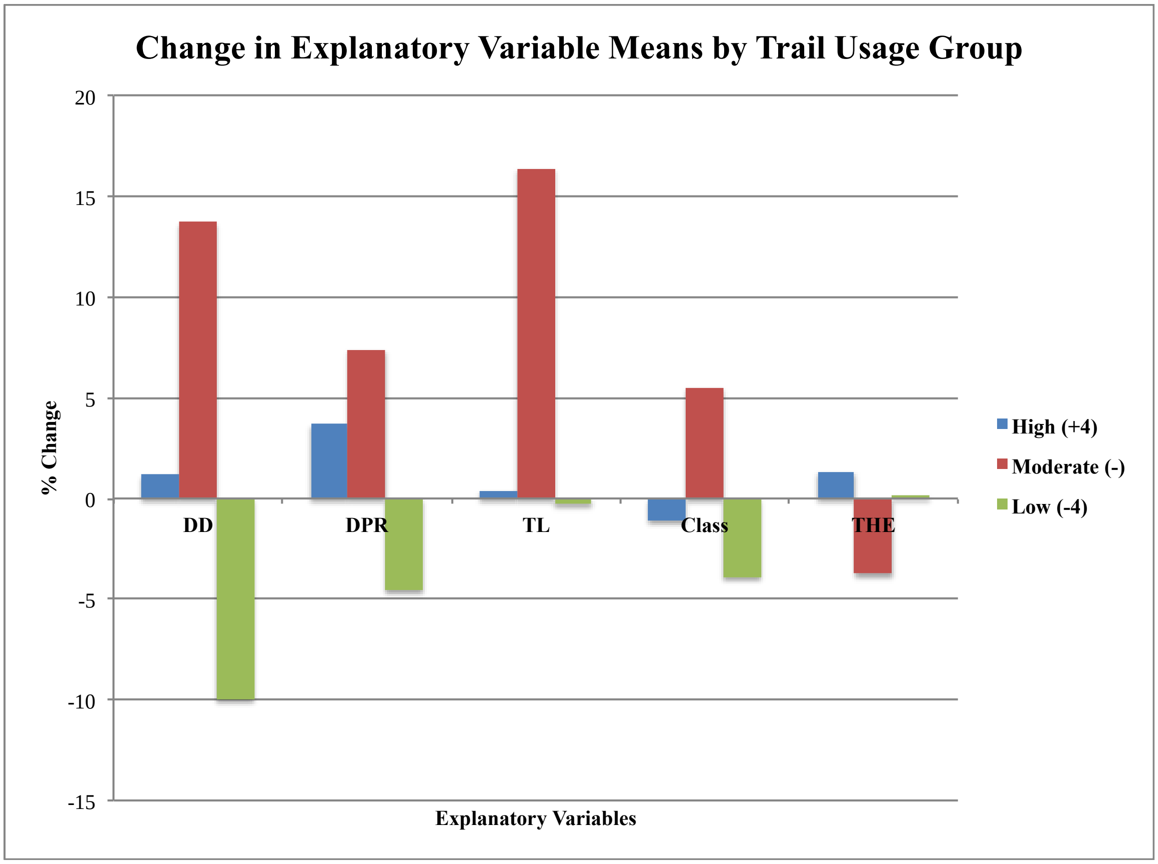


Figure 28. Mean change in explanatory variables aggregated by 2005-2012 trail usage groups.

The explanatory variable descriptive statistics for the *Moderate* group of peaks (n=18) were the most different. Prima facie, *Moderate* peaks were further from Denver and paved roads, with longer, more technically challenging standard routes starting at lower elevations. This group lost the four peaks noted above, and gained four from the *Low* group. The four peaks that went from *Low* to *Moderate* trail usage (i.e., Crestone

Needle, *N. Eolus*, Mt. Wilson, and *El Diente*) were an average of 187 miles from Denver, 5.57 miles from the nearest paved road, 7.16 miles long, technically rated at class 3.3, with trailheads at 9,464 feet. Average increases in distance to Denver, distance to the nearest paved road, route length, and technical rating, along with the average decrease in trailhead elevation, can be at least partially explained by usage-class-changing peaks. The *Moderate* group lost four peaks that were pulling averages in the opposite direction of the trends noted, and gained four peaks amongst those furthest from Denver with longer, more technically challenging routes starting at lower elevations. The longer average distance to paved roads are best explained by the loss of the peaks to the *High* group and study error; the four peaks upgraded to the *High* group were considerably closer to paved roads, and the four peaks that joined the *Moderate* group were on average just slightly below the overall group average, creating a net increase in distance.

The least climbed peaks (n=10) were on average closer to Denver and paved roads, with slightly shorter, less technically challenging standard routes starting at higher elevations, all of which runs counter to previous observations. Notably, the average distances to Denver and to the nearest paved road for the *Low* group are now less than those of the *Moderate* group (Table 5). If explanatory variables for the *Low* group are trending in the opposite direction of expectations, what are the underlying reasons for why so few people climb these peaks? While a full examination of this question is outside the scope of this paper, simply looking at these peaks reveals some interesting commonalities.

All *Low* usage peaks have some glaring difficulty and/or inconvenience guarding their summits. Half of them require backcountry camping,[8] or an extremely long and technically challenging day. For example, the standard route to Crestone Peak crosses Broken Hand Pass, which means the climber must ascend a Class 3 couloir and then descend the other side before re-ascending the Red Gully once the South Face has been reached. Crestone Needle, a closely neighboring summit, avoids the up and down of the Crestone Peak route by ascending directly from Broken Hand Pass. Despite their close proximity, Crestone Needle had *Moderate* trail usage, while Crestone Peak remained *Low*.

Further to the south, Lindsey has an isolated trailhead on the east side of the Sangre de Cristo Range, and is surrounded by Fourteener groups that offer more interesting routes and a chance to bag multiple summits in the same trip, so perhaps it gets overshadowed. The southernmost Fourteener in Colorado, Culebra, is guarded by isolation and private property. The Cielo Vista Ranch regulates the climbing of Culebra and was charging $100/climber for access in 2013. In the Elk range, the Maroon Bells (i.e., Maroon, *N. Maroon*) are two of the most difficult and dangerous Fourteeners in the state (Figure 29). The 2,800 ft. ascent up the East Slope of South Maroon is one of the most exhausting stretches on any Fourteener, and is followed by difficult route finding on extremely loose and exposed class 3 terrain. *North Maroon* has similar challenges, but on class 4 terrain. Finally, *Conundrum* is an inconveniently accessed unofficial

[8] i.e., Crestone Peak, Little Bear, Ellingwood Point, Capitol, and Snowmass

Fourteener that requires the average climber to trace and retrace the periphery of a cirque[9] while crossing over the summit of Castle Peak twice.

Figure 29. US Forest Service warning sign near the Maroon Lake Trailhead just south of Aspen.

[9] Bowl-shaped, steep-walled mountain basin.

The results of the ANOVA analyses suggest all five original variables had statistically significant variability somewhere between the trail usage groups, and were therefore drawn from different populations, meaning they “explained” trail usage (Table 5). According to post-hoc tests, the only significant difference for DD and DPR was between the *High* and *Moderate* trail usage groups. TL was significantly different between the *High* and *Low* trail usage groups only. Both Class and THE were different between the *High* and *Moderate*, and *High* and *Low* groups, but not between *Moderate* and *Low*. The anticipated linear increase in explanatory variable means as trail usage goes down (decrease for THE), as observed by Kedrowski (2006, 2009), no longer applies to DD and DPR. In fact, the *Moderate* usage group means were highest in both cases. Interestingly, the *Moderate* data points appear to be grouping closer to the *Low* trail usage group for TL, Class, and THE.

Table 5

Comparison of group means for explanatory variables on Colorado Fourteeners (3 groups, N = 58) from 2005-2012

Explanatory Variables	**2005-2012 Trail Usage Group Means**			**ANOVA**	
	n=30HI[1]	**n=18MOD[2]**	**n=10LO[3]**	**F-value**	**P-value**
DD (miles)	**99.57**	**148.10**	**134.53**	**6.78**	**0.002****
DPR (miles)	**4.21**	**6.09**	**5.64**	**3.94**	**0.025***
TL (miles)	**4.84**	**5.96**	**6.60**	**3.93**	**0.025***
Class	**1.83**	**2.67**	**2.95**	**13.72**	**0.000****
THE (feet)	**10,519.63**	**9,541.00**	**9,418.90**	**7.62**	**0.001****

[1]High; [2]Moderate; [3]Low; *p < 0.05; **p < 0.01

The results of the Pearson-product correlation analyses suggest all five variables were significantly correlated to the trail usage groups (*High*-1, *Moderate*-2, *Low*-3). The correlations are actually the opposite of what the signs indicate because the counterintuitive numbering schema. For example, longer distance to Denver was positively correlated to the trail usage group numbers, which corresponds to less usage (Table 6). Class had the strongest correlation to trail usage, followed by THE, DD, TL, and DPR (Table 6). There were, however, some interesting shifts in the strength of those relationships. DD, DPR, and Class had a weaker relationship to trail usage, while TL and THE were more strongly correlated (Figure 30).

Table 6

Pearson-product correlation results for original explanatory variables

Variables	Trail usage class (2005-2012)
Trail usage class (2005-2012)	**1**
	-
DD (miles)	**0.351**
	0.007
DPR (miles)	**0.286**
	0.029
TL (miles)	**0.350**
	0.007
Class	**0.558**
	0.000
THE (feet)	**-0.433**
	0.001

Correlations listed on top; p-values underlined below

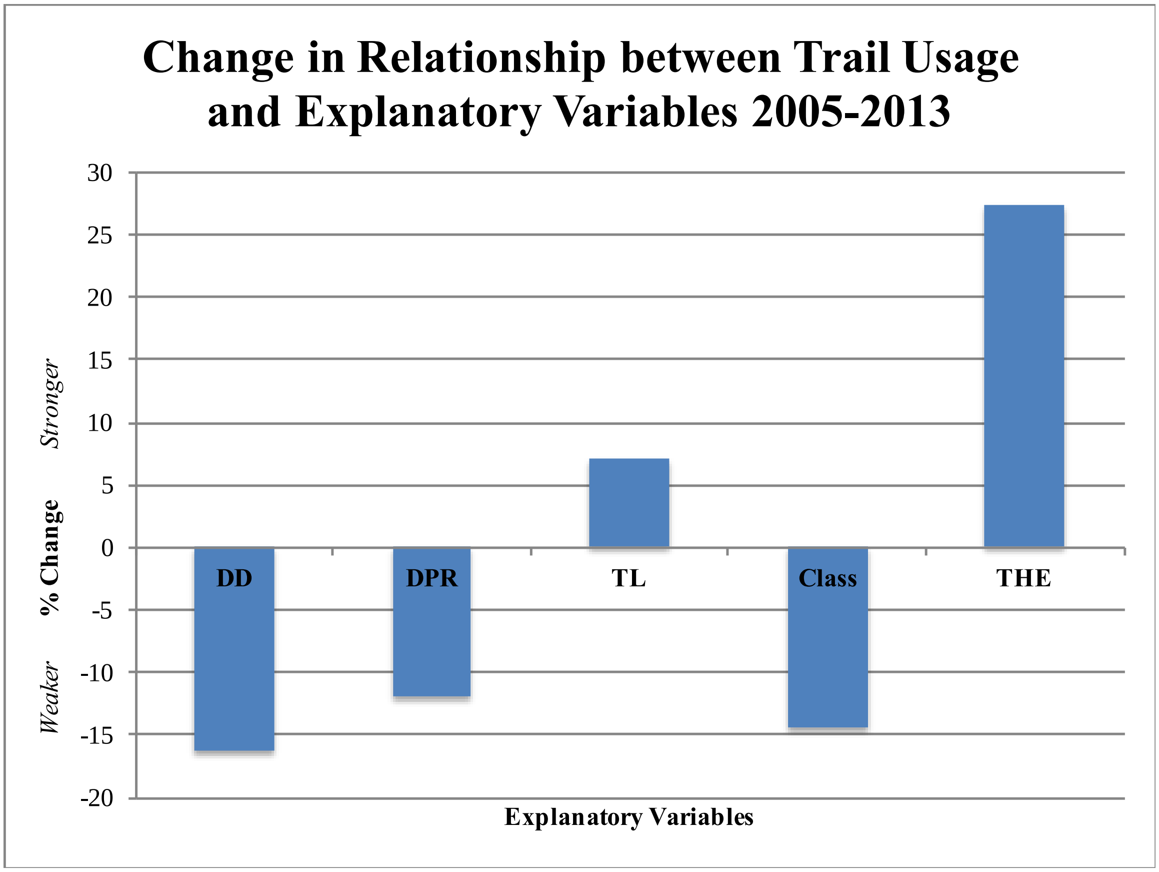


Figure 30. Change in correlation strength between trail usage and explanatory variables.

To summarize, the data suggest peak-baggers still most often climb peaks closer to Denver and paved roads, with shorter, less technical routes starting at higher elevations; however, relative to 2005, climbers are: venturing deeper into the mountains, less hindered by accessibility, more technically capable, and increasingly focused on shorter routes starting at higher elevations. In other words, the peak-bagging community is not only growing in size, but also progressing in its ability to access trailheads and reach summits guarded by technical routes. Pure physical fitness demands, represented by trail length and trailhead elevation, are the only explanatory variables more strongly correlated to the trail usage groups.

Impact Indicators

According to the data, there were an average of 26.32 IT/mile on every standard route (Table 7), which was 119% higher than in 2005 (Figure 31). Democrat had the most IT/mile with 58.06, and Culebra had the least with 3.19. Switchbacks were up nearly 9% with an average of 6.03/mile; Belford had the most with 31.09 SB/mile and Culebra the least with 0. Switchbacks needed were down 3% with an average of 0.58/mile. *Cameron* overtook S. Maroon with the highest SBN/mile at 3.67; 34 peaks did not need any switchbacks. Observed campsites were up 87% at 3.25/mile. Little Bear had the most CS/mile with 10.04, while six peaks had none. The average percentage of DW trail was down 78% to 10.95. Longs bumped Grays from the highest percentage of DW spot with 42.78, while Antero and Little Bear eclipsed Culebra with none. The average percentage of trail as 4WD road was 20.10, which was up 7% from 2005; 89.88% of Antero's standard route was 4WD, while 33 peaks had none. The average percentage of ELNT was down 5% at 11.55; Sneffels overtook Culebra as the standard route with the most elevation gain and no trail at 42.01%, and 17 peaks had a trail all the way to the summit. On average, 6.16% of routes were TMNT, which was down 18% from 2005. Sunshine superseded Culebra with the highest percentage of TMNT at 24.13, and again 17 peaks had a trail all the way to the summit. Finally, the average percentage of RMNT was down 57% to 1.9. Culebra had by far the highest %RMNT at 79.68, and 51 peaks had a trail or cairns marking the standard route all the way to the summit.

Table 7

Descriptive statistics for impact indicator data gathered in 2013

Impact Indicators (Totals)	Mean	Max[1]	Min[2]	Max Peak	Min Peak
IT/mi	**26.32 (133.24)**	**58.06 (370)**	**3.19 (8)**	**Democrat (Capitol)**	**Culebra**
SB/mi	**6.03 (30.47)**	**31.09 (122)**	**0**	**Belford (Oxford)**	**Culebra**
SBN/mi	**0.58 (2.71)**	**3.67 (12)**	**0**	***Cameron* (Lindsey)**	**34 Peaks**
CS/mi	**3.25 (19.43)**	**10.04 (75)**	**0**	**Little Bear (Ellingwood/Blanca)**	**6 Peaks**
%DW	**10.95**	**42.78**	**0**	**Longs**	**Antero and Little Bear**
%4WD	**20.10**	**89.88**	**0**	**Antero**	**33 Peaks**
%ELNT	**11.55**	**42.01**	**0**	**Sneffels**	**17 Peaks**
%TMNT	**6.16**	**24.13**	**0**	**Sunshine**	**17 Peaks**
%RMNT	**1.9**	**79.68**	**0**	**Culebra**	**51 Peaks**

[1]Maximum; [2]Minimum

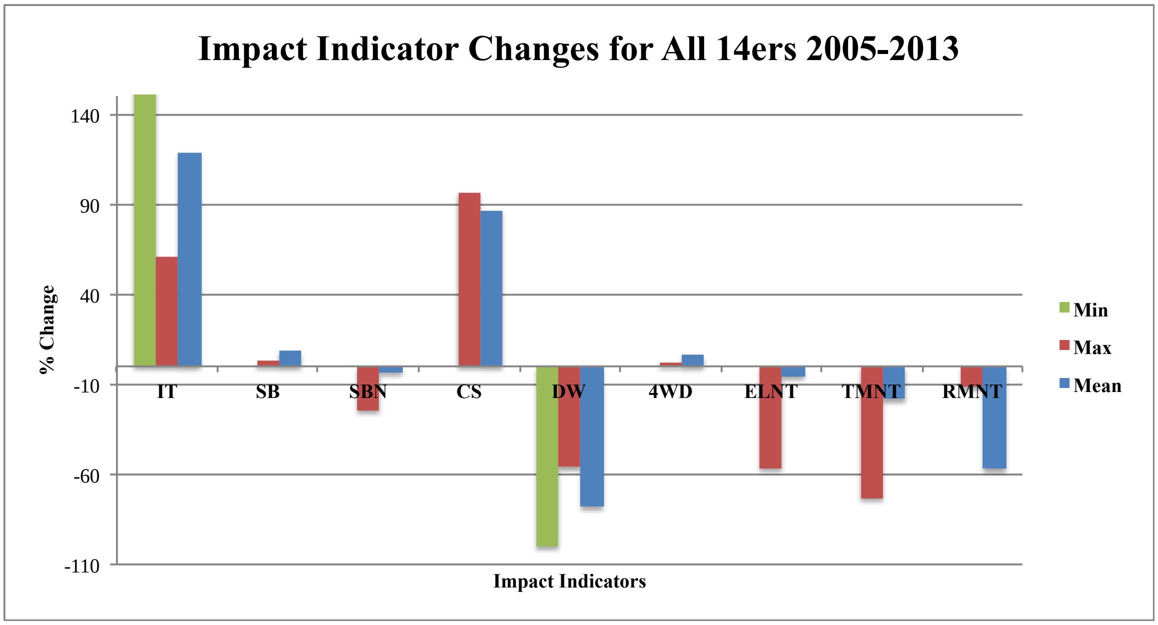


Figure 31. Change in descriptive statistics for impact indicators.

The major spike in IT is likely a function of significantly higher trail usage, and differences in variable definition and data collection (Figure 31). This study likely had a stricter definition of IT – any route segment with multiple tracks as evidenced by a central vegetation island, or any other indication of trail braiding or spurring. A stricter definition would lead to more tally counter clicks and higher overall numbers. However, the effects of significantly higher trail usage on IT must not be ignored.

The increase in SB is evidence that the CFI and other groups have completed reconstruction projects on several standard routes since 2005 (Figure 31; Table 8).

Table 8

Formal reconstruction projects completed since the inception of the CFI (2015e)

Peak	Project Years	Route	Range
La Plata	1995	Northwest Ridge	Sawatch
Belford	1995-1996	Missouri Gulch	Sawatch
Oxford	1995-1996	Missouri Gulch	Sawatch

Table 8 (continued).

Peak	Project Years	Route	Range
Humboldt	**1997-1998**	**South Colony Lakes***	**Sangre de Cristo**
Huron	**1998, 2002**	**Clear Creek**	**Sawatch**
Harvard	**1999-2002**	**North Hornfork Basic**	**Sawatch**
Bierstadt	**1999-2002, 2014-2015****	**Guanella Pass**	**Front**
Missouri	**2000-2001**	**Missouri Gulch**	**Sawatch**
Grays	**2000-2002**	**Stevens Gulch**	**Front**
Torreys	**2000-2002**	**Stevens Gulch**	**Front**
Quandary	**2001-2002**	**East Slopes**	**Tenmile/Mosquito**
Crestone Peak	**2001-2005**	**South Colony Lakes***	**Sangre de Cristo**
Crestone Needle	**2001-2005**	**South Colony Lakes***	**Sangre de Cristo**
Tabeguache	**2002**	**Jennings *Closed***	**Sawatch**
Capitol	**2002**	**Capitol Lake**	**Elk**
Sneffels	**2003-2004**	**Yankee Boy Basin**	**San Juan**
Massive	**2003-2005**	**North Halfmoon Creek**	**Sawatch**
Wetterhorn	**2004-2005**	**Matterhorn Creek**	**San Juan**
Evans	***2005-2006***	***Chicago & Summit Lake***	***Front***
Pyramid	***2005-2006***	***NE Ridge Approach***	***Elk***
Massive	***2006-2009***	***East Slopes***	***Sawatch***
Windom	***2007, 2009-2010***	***Chicago Basin***	***San Juan***
Sunlight	***2007-2009-2010***	***Chicago Basin***	***San Juan***
Bross	***2008***	***Bypass***	***Front***
Democrat	***2008***	***Kite Lake***	***Front***
Uncompahgre	***2008***	***Nellie Creek***	***San Juan***
Yale	***2008-2011***	***Denny Creek***	***Sawatch***
Blanca	***2011-2012***	***Lake Como****	***Sangre de Cristo***
Ellingwood	***2011-2012***	***Lake Como****	***Sangre de Cristo***
Holy Cross	***2011-2012***	***Halfmoon Pass***	***Sawatch***
N. Maroon	***2012***	***NE Ridge Approach***	***Elk***

Italicized projects were completed after the previous study; *Project completed by the Rocky Mountain Field Institute (RMFI);

**Project completed after field observations were made for this paper

As an extension of the observed 9% increase in SB/mile, likely resulting from reconstruction projects, SBN/mile should be down relative to 2005; however, determining where and how many switchbacks ought to be constructed for any given route segment was exceedingly subjective. The slope angle, aspect, and topography, for example, could factor into each researcher's prescribed number of SBN differently. For future research, a combination of trail miles and elevation gain could provide a better platform by which SBN can be prescribed in a more consistent, standardized way.

The alarming spike in observed CS/mile is most likely a function of increased trail usage and loose camping regulations (Figure 31). Very few campsites in Colorado require a permit, and even fewer carry a cost. What is more, stone fire rings along 4WD roads and backcountry trails are becoming a part of the Colorado landscape.

The major decrease in %DW is most likely due to a combination of trail reconstruction and differing variable definitions (Figure 31). Regarding the latter, the stricter definition of IT could have affected the resulting %DW because trail tracks running parallel but less than 5 feet in width were counted as IT. It remains unclear as to whether the same definitions guided the data collection of Kedrowski (2006) in 2005. Within the confines of this study, trail segments could be both IT and %DW if and only if there were multiple tracks with one or both being greater than 5 feet wide. Inconsistent data collection resulting from untidy variable definitions underscores the need for strict and standardized definitions used to inventory impact indicators.

The slight increase in %4WD is most likely the result of differing trailheads (Figure 31). As mentioned earlier, several standard routes begin in the midst of a 4WD road; however, there are not always signs indicating precise trailhead locations.

Moreover, the condition of mountain roads can change rapidly, so trailheads vary accordingly on as short as daily timescales. The sheer volume of climbers with access to 4WD vehicles is likely higher, which could result in minor extensions of %4WD; however, most rough mountain roads have existed for decades and are bookended with massive boulders or the road simply dries up. Thus, the slight uptick in %4WD most likely resulted from routes starting at lower points along 4WD roads.

A detail worth mentioning is that, within this study, 4WD segments were required to be active roads. Route segments that were inactive and inaccessible 4WD roads were counted as %DW. It remains unclear whether this definition is consistent with the previous study.

The cumulative decreases in %ELNT, %TMNT, and %RMNT make a lot of sense with the observed increase in trail usage and IT (Figure 31). Over time, trails get worn into places they did not previously exist, especially in fragile alpine tundra zones. Furthermore, route-finding on some of the more technically challenging peaks can be quite difficult, so climbers sometimes will create cairns to mark the route not only for future climbers, but so they can find their way back down. It would be shocking if several more years of increased trail usage did not result in decreases for %ELNT, %TMNT, and %RMNT as more and more clearly marked routes connect trailheads to summits.

Impact Indices

iFEDI

The bookends for the most and least impacted of the iFEDI calculated for 2013 were Longs (1.8661) and Little Bear (-1.4024), respectively (See Table 21 in the

Appendix). The top 10 highest scoring, or most impacted, peaks included 4 from the Front Range (Longs, Bierstadt, Pikes, and Evans), 2 from the Sawatch (Antero and Tabeguache), 2 from the Tenmile/Mosquito (*Cameron* and Democrat), and 2 from the San Juan (Sneffels and Sunshine). The top 10 lowest scoring, or least impacted, peaks included 5 from the Elk Range (*Conundrum*, *N. Maroon*, Snowmass, S. Maroon, and Capitol), and 5 from the Sangre de Cristo (Ellingwood, Lindsey, Crestone Peak, Culebra, and Little Bear). Classified by Jenks Natural Breaks, the peaks in the poorest shape were Sneffels, Sunshine, Bierstadt, and Longs (Figure 32). Of note, Culebra, which based on subjective intuition, ought to serve as a calibration peak on the low end of the scale, was just outside the top 5 lowest scoring peaks.

Aggregated by range, the Front had the highest average iFEDI score at 1.0173; Longs and Grays were the respective highest and lowest scoring peaks (Figure 32; Table 9). Interestingly, the San Juan had the second highest mean iFEDI score at 0.5185, bookended by Sneffels (highest) and San Luis (lowest), despite its position furthest from Denver. The Tenmile/Mosquito Range ranked third in mean iFEDI (0.5018), followed by the Sawatch (0.3040) and Sangre de Cristo (-0.1128) in fourth and fifth places, respectively.

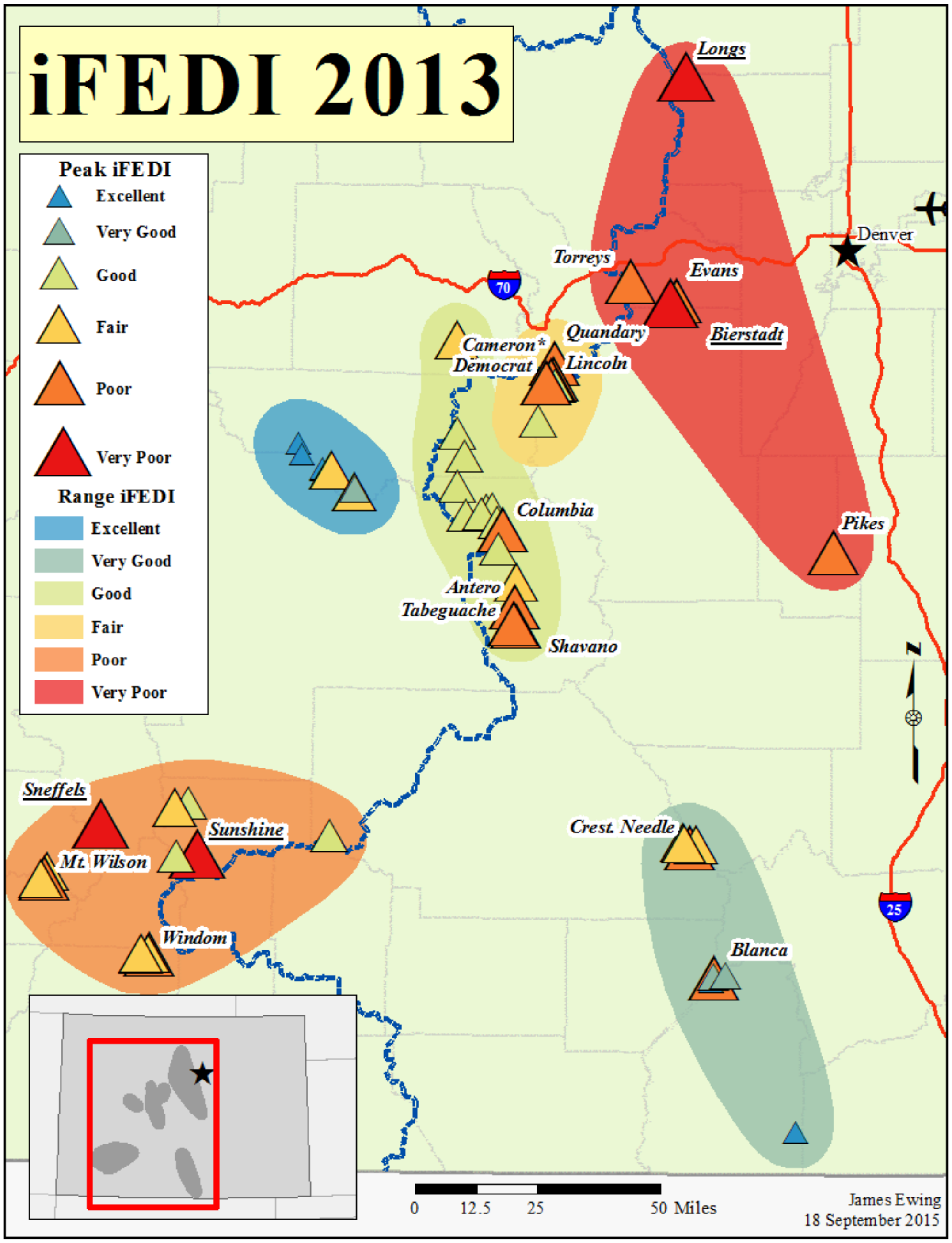


Figure 32. Peak and Range iFEDI from 2013. Labeled peaks classified as poor and very poor (natural breaks – Jenks). Very poor peaks are underlined.

Table 9

Descriptive statistics for the 2013 iFEDI by mountain range

Range (Count)	Mean iFEDI 2013	Max[1]	Min[2]
Front (6)	**1.0173**	**1.8661 (Longs)**	**0.1460 (Grays)**
Tenmile/Mosquito (6)	**0.5018**	**0.6977 (*Cameron*)**	**0.2115 (Bross)**
Sawatch (15)	**0.3040**	**0.9644 (Antero)**	**0.0464 (Oxford)**
Sangre de Cristo (10)	**-0.1128**	**0.6431 (Blanca)**	**-1.4024 (Little Bear)**
Elk (7)	**-0.5843**	**0.4967 (Castle)**	**-1.3365 (Capitol)**
San Juan (14)	**0.5185**	**1.8637 (Sneffels)**	**0.0003 (San Luis)**

[1]Maximum; [2]Minimum

The results of the longitudinal iFEDI comparison suggest the least impacted peaks of 2005 sustained the largest magnitude of change (Figure 33). Sunshine had the largest increase in iFEDI at 641%, and S. Maroon had the largest decrease at -1,025%. The signal of the formal reconstruction projects completed after 2005 (Table 8) is noticeable as ten of the thirteen peaks scored lower in 2013. Surprisingly, most of the measured change was improvement as the totaled index values for 2013 were more than 6% *lower* than in 2005 (Table 10). It is suspected, however, that this apparent improvement could just be a function of how outliers on the high end of the data range effect the normalized values combined to create the index.

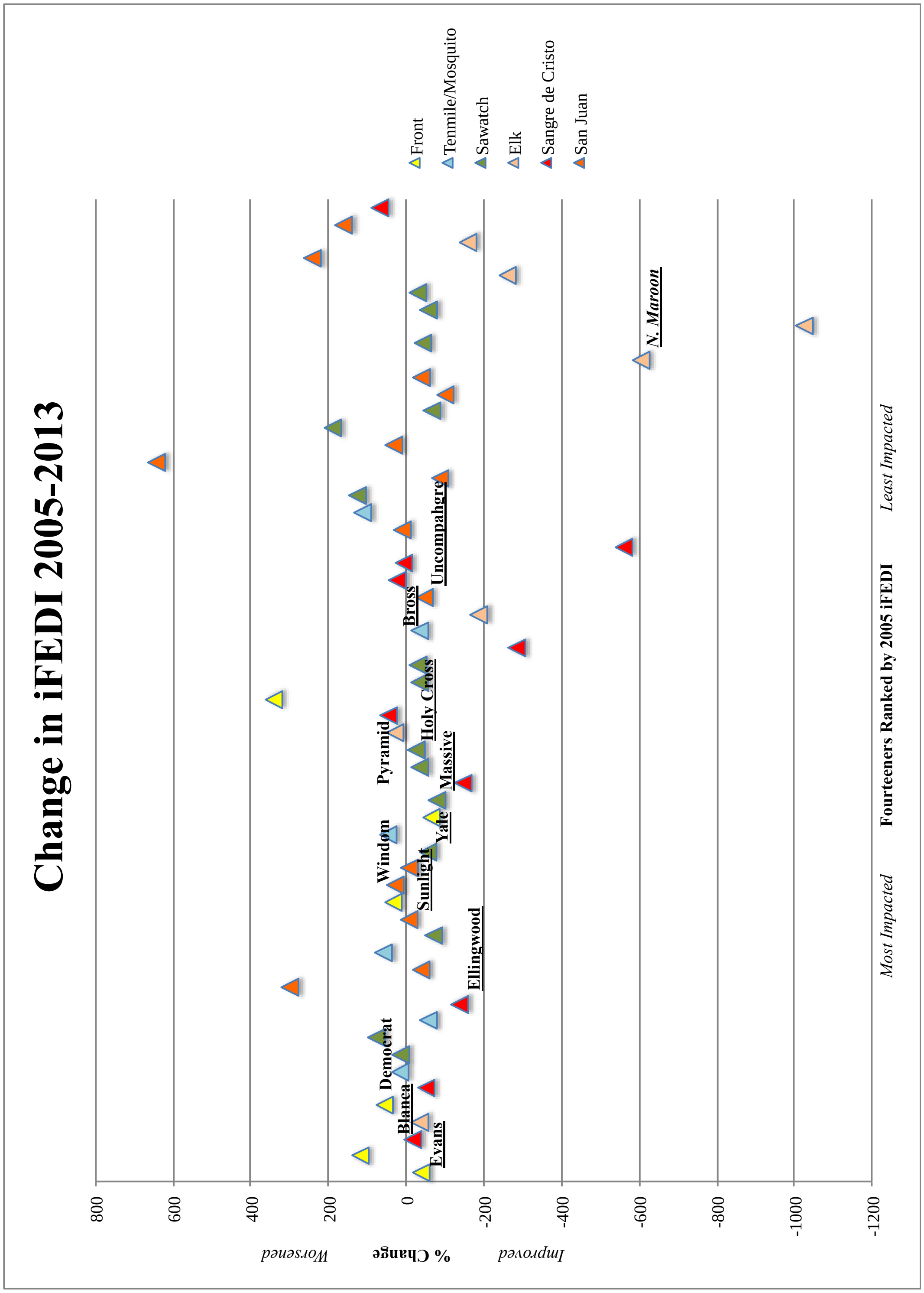


Figure 33. Percent change in iFEDI scores from 2005 to 2013 ordered by 2005 iFEDI. Labeled peaks had a reconstruction project completed after 2005. Underlined peaks had a lower iFEDI score in 2013 than in 2005.

Table 10

Comparison of iFEDI totals from 2005 to 2013

Index	2005 Total	2013 Total	Difference	% Change (Total*)
iFEDI	16.8047	15.7151	-1.0896	-6.48 (-1,771.64)

*Total percent change for individual peaks

Aggregated by range, the San Juan had the greatest increase in iFEDI/peak at 77%, followed by the Front (75%) and Tenmile/Mosquito (23%; Figures 34-35). The Elk had the greatest improvement with an average 321% decrease in iFEDI/peak, followed by the Sangre de Cristo (-106%) and Sawatch (-9%). Spatially, the greatest increases, located either very near or far from Denver (i.e., Front, Tenmile/Mosquito, San Juan), sandwich in the greatest decreases of the interior ranges (i.e., Elk, Sawatch; Figure 34).

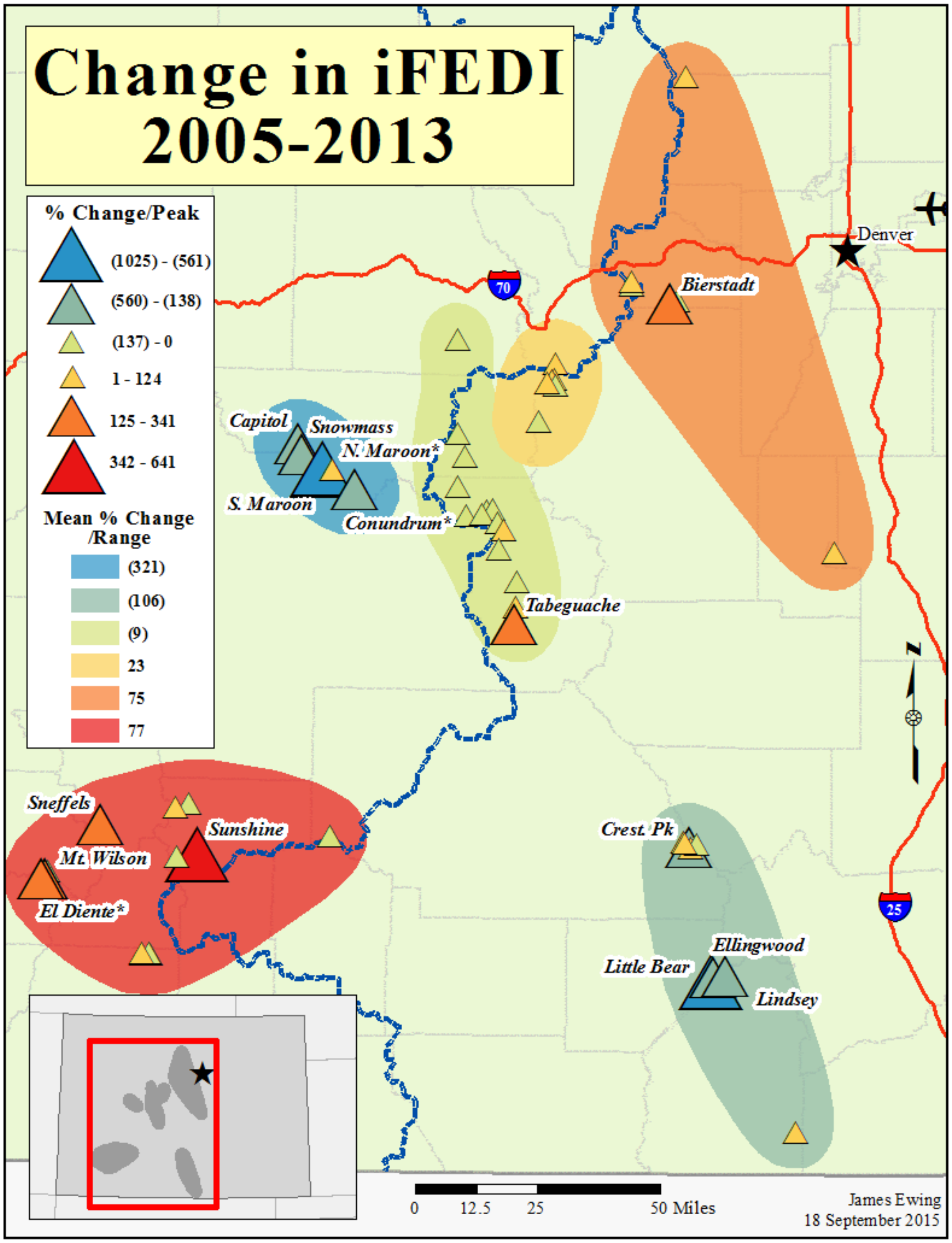


Figure 34. Percent change in iFEDI scores from 2005-2013. Labeled peaks are in top and bottom two classes (natural breaks – manual; only change was to shift middle class break to 0).

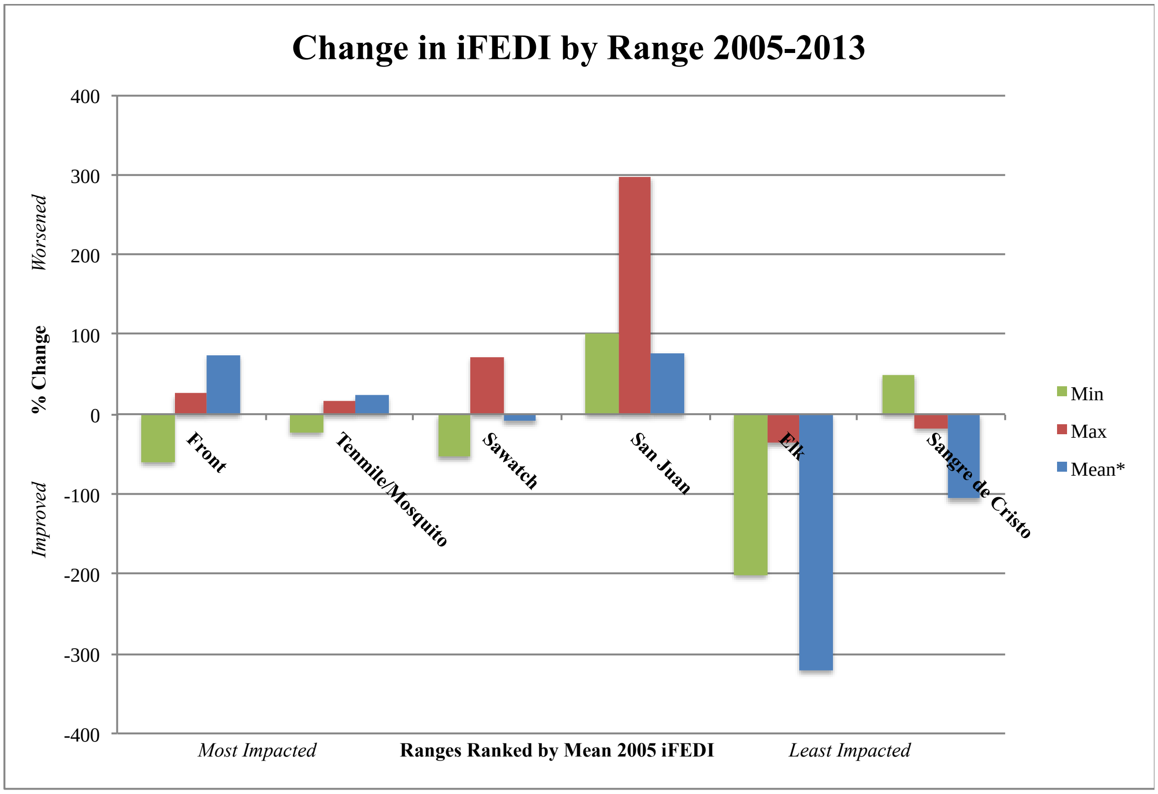


Figure 35. Change in iFEDI by Range 2005-2013. *Mean percent change/peak by range, not change in range mean.

However, the results of the Wilcoxon signed-ranks test (data not normally distributed) suggest no statistically significant difference exists between the 2005 and 2013 iFEDI datasets (Z=-.956, p=0.339). Thus, according to a combination of trail usage and absolute/potential impact indicators, Fourteener trails were in roughly the same shape in 2013 as they were in 2005.

FEDI

According to the 2013 FEDI, Sneffels and Capitol were on either ends of the high/low spectrum with scores of 4.6749 and -4.6552, respectively (See Table 22 in the Appendix). The top ten highest scoring peaks included 6 from the San Juan (Sneffels, Sunshine, Uncompahgre, San Luis, Handies, and Redcloud), 2 from the Front (Longs and Bierstadt), 1 from the Sawatch (Antero), and 1 from the Sangre de Cristo (Blanca). The lowest ten scoring peaks included 5 from the Elk (*Conundrum*, *N. Maroon*, S. Maroon, Snowmass, and Capitol), and 5 from the Sangre de Cristo (Ellingwood, Lindsey, Crestone Peak, Culebra, and Little Bear). Classified by Jenks Natural Breaks, the peaks in the poorest shape were Sneffels, Sunshine, and Longs (Figure 36). Culebra was the 4th lowest score.

Aggregated by range, the Front had the highest average FEDI score at 2.6293; again Longs and Grays were the highest and lowest (Figure 36; Table 11). The Tenmile/Mosquito had the second highest mean FEDI at 2.3336, bookended by *Cameron* and Quandary. The San Juan had the third highest mean FEDI at 2.1005, followed by the Sawatch (1.5708), Sangre de Cristo (-0.8739), and Elk (-2.0875). Interestingly, the San Juan had a higher mean FEDI than the Sawatch.

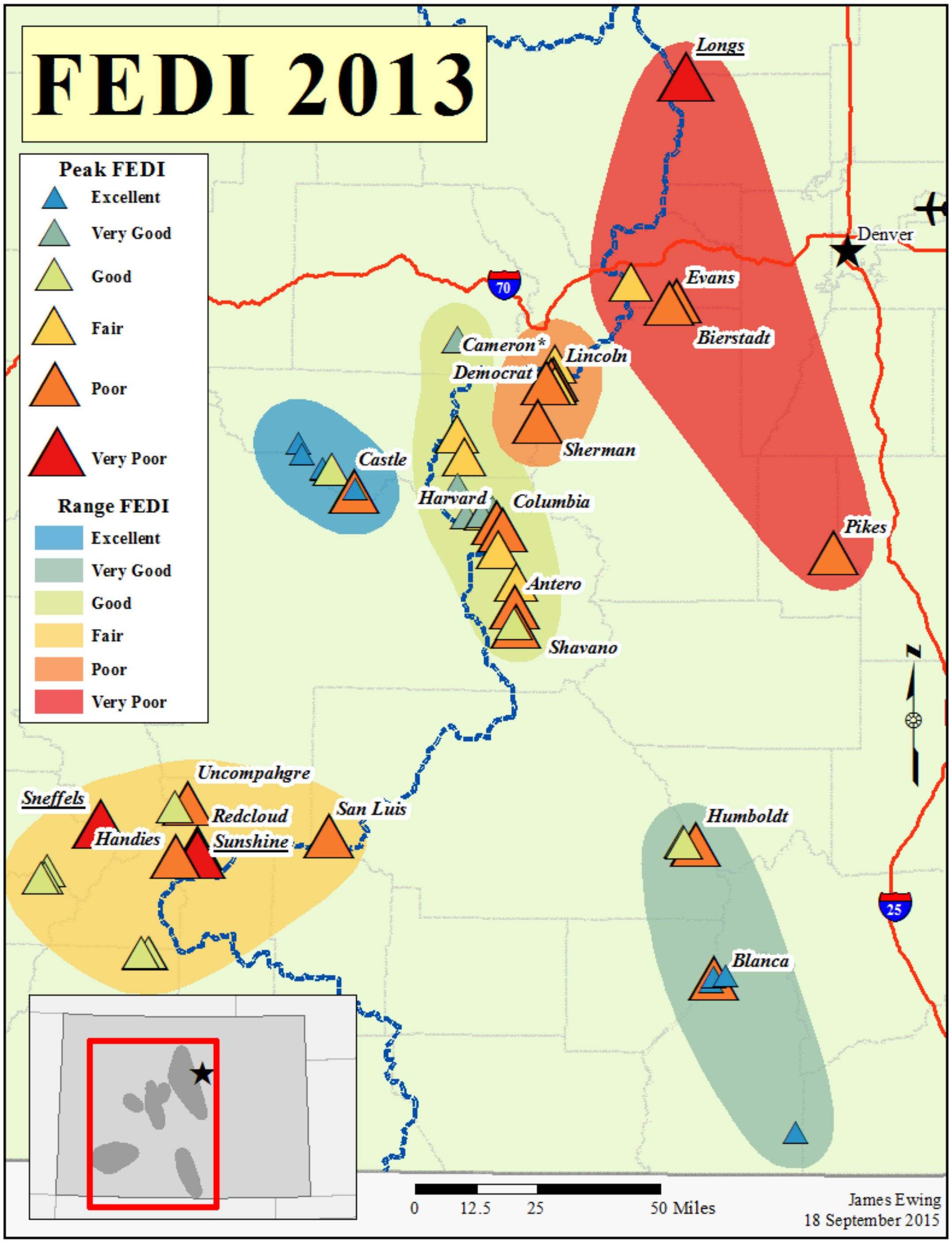


Figure 36. Peak and Range FEDI from 2013 (natural breaks – Jenks). Labeled peaks are poor and very poor. Underlined peaks are very poor.

Table 11

Descriptive statistics for the 2013 FEDI by mountain range

Range (Count)	Mean FEDI 2013	Max[1]	Min[2]
Front (6)	**2.6293**	**3.9030 (Longs)**	**1.4704 (Grays)**
Tenmile/Mosquito (6)	**2.3336**	**2.6014 (Cameron)**	**1.9082 (Quandary)**
Sawatch (15)	**1.5708**	**2.7939 (Antero)**	**0.3861 (Oxford)**
Sangre de Cristo (10)	**-0.8739**	**3.0241 (Blanca)**	**-4.2521 (Little Bear)**
Elk (7)	**-2.0875**	**2.4800 (Castle)**	**-4.6552 (Capitol)**
San Juan (14)	**2.1005**	**4.6749 (Sneffels)**	**0.9070 (Wilson Peak)**

[1]Maximum; [2]Minimum

The results of the longitudinal FEDI comparison also suggest the least impacted peaks from 2005 sustained the greatest changes; however, the majority of that change was worsening scores as the totaled index values were 190% higher in 2013 (Figure 37; Table 12). Again, part of this apparent worsening is due to how outliers effect the normalized values that contribute to the index. Sunshine had the greatest increase in FEDI score at 1,232%, and Little Bear had the greatest decrease at -4,293% (Figures 37-38). The signal of formal reconstruction projects completed after 2005 was dampened as only two of the thirteen peaks showed improvement (Figure 37).

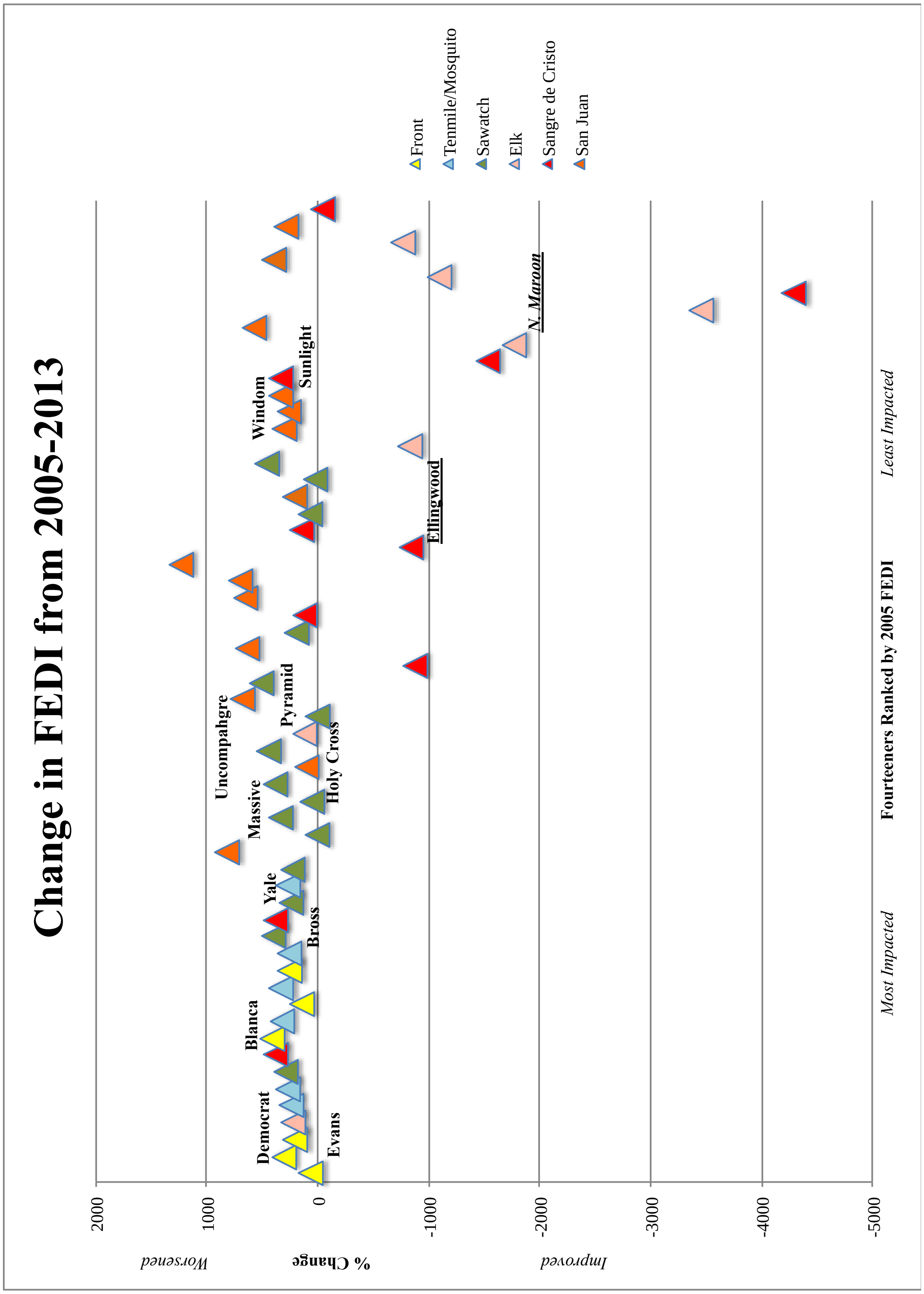


Figure 37. Change in FEDI from 2005-2012. Labeled peaks had a formal reconstruction project after 2005. Underlined peaks showed improvement.

Table 12

Comparison of FEDI totals from 2005-2013

Index	2005 Total	2013 Total	Difference	% Change (Total*)
FEDI	20.5119	59.3945	38.8826	189.56 (-62.57)

*Total percent change for individual peaks

Aggregated by range, the San Juan had the greatest increase in FEDI/peak at 510%, followed by the Tenmile/Mosquito (279%), Sawatch (241%), and Front (225%). The Elk had the greatest improvement with a mean 1,084% decrease in FEDI/peak, followed by the Sangre de Cristo (-626%; Figures 38-39). Spatially, the greatest increases were furthest from Denver (i.e., San Juan) and in the interior ranges (i.e., Tenmile/Mosquito, Sawatch; Figure 38).

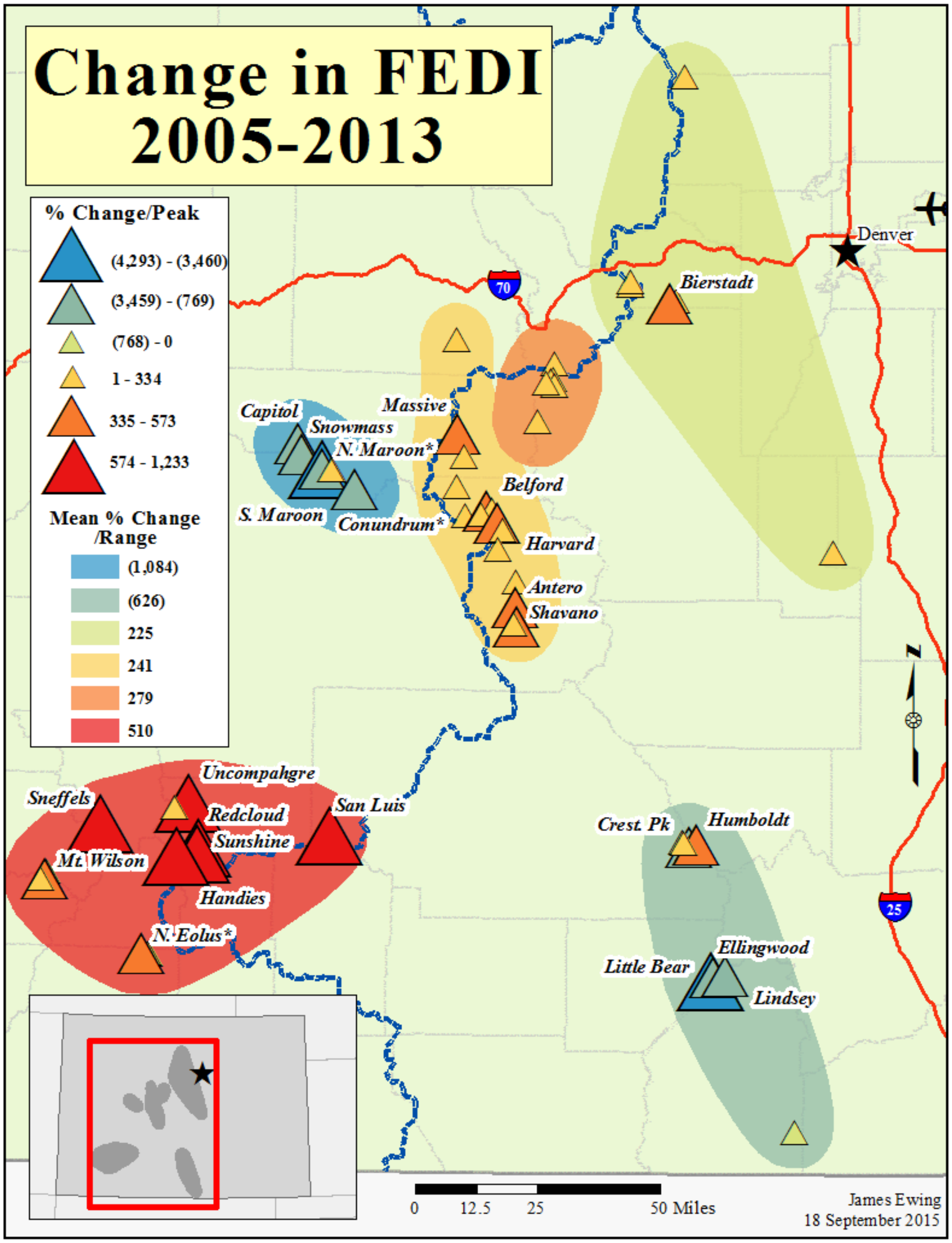


Figure 38. Change in FEDI scores from 2005-2013 (Natural Breaks – Manual; only change to Jenks was to shift middle class break to 0).

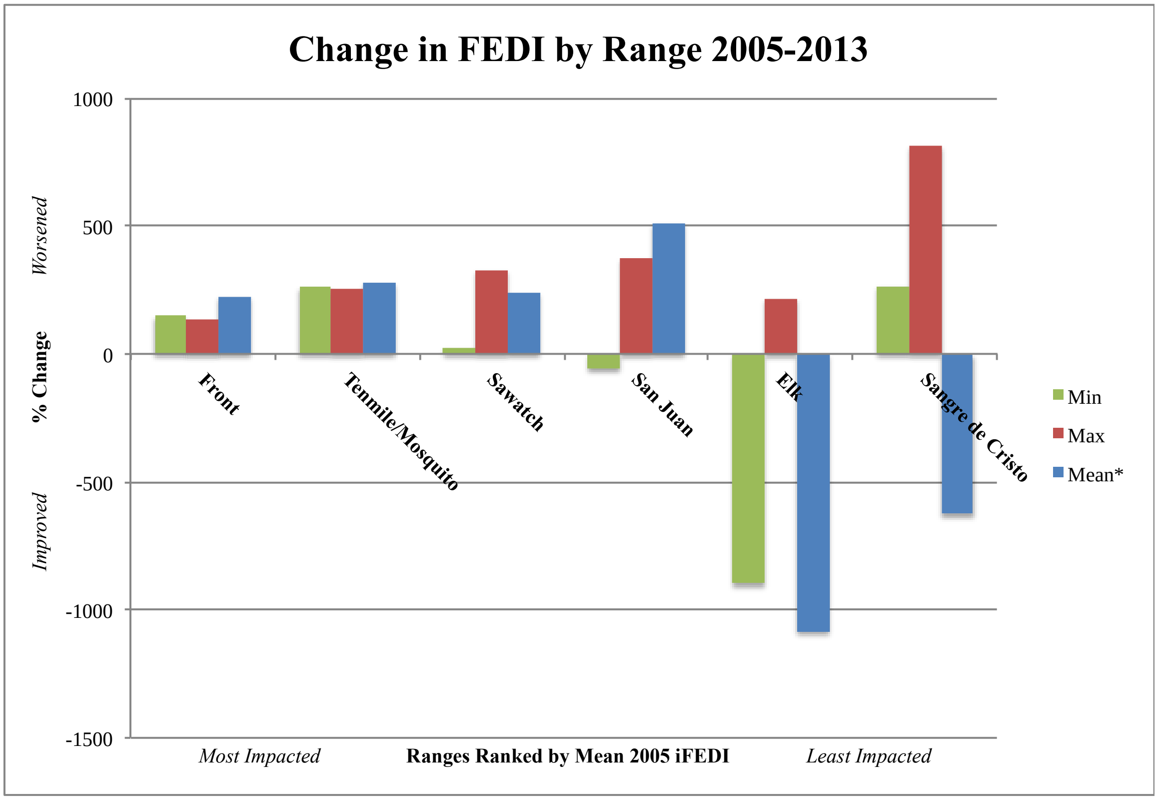


Figure 39. Change in FEDI by Range 2005-2013. *Mean percent change/peak by range, not change in range mean.

The results of the Wilcoxon signed-ranks test (data not normally distributed), suggest a significant difference exists between the 2005 and 2013 FEDI datasets (Z=-2.845, p=0.004). With the totaled FEDI values nearly tripling between 2005-2013 (Table 12), it can be assumed that Colorado Fourteeners were in significantly worse shape in 2013 according to the combination of trail usage, impact indicators, and explanatory variables.

Study Error and Limitations

There are several sources of error that must be discussed to properly paint the boundaries of the aforementioned results, and to form a basis by which improvements can be made. The largest springs of study error pertain to accuracy, validity, and reliability.

In what follows, those three error-fountains will be discussed as they apply to each segment of the longitudinal analyses.

Longitudinal Analyses

Trail Usage

The weakest aspects of the trail usage analysis relate to accuracy and reliability. In terms of accuracy, the same methods were used to count and collate the trail usage data; however, some important efficiency measures were implemented to complete the project within time constraints. The summit registers of interest at the AMC had not been archived, but were instead disheveled in dozens of boxes spread out on the racks in the archival basement. After days of tracking down and organizing registers by peak and range, it became evident that the archival data collection portion of this project needed to be prioritized in the event that it could not be thoroughly completed within a reasonable amount of time (Figure 40).

Figure 40. Summit registers from 2005-2012 sorted by peak (folders) and range (rows) from top to bottom: Front (2 rows + box), Tenmile/Mosquito, Sawatch, Elk, San Juan, and Sangre de Cristo. The thickness of the folders gives an interesting gleam of the volume and distribution of trail usage. Note how thick the Front and Tenmile/Mosquito folders are relative to the Elk Range, for example.

The focus of the project was the change in trail usage as it relates to the methodological construct set forth by Kedrowski (2006, 2009). More specifically, the goal was to determine which peaks, if any, originally ranked as *Low*, *Moderate*, or *High* had either graduated or demoted to a different class. After counting several of the 26 peaks originally classified as *High*, the unlikeliness of their demotion to a lower trail usage group became obvious. Moreover, there was no compelling reason why any of the *High* peaks would have incurred a substantive decrease in usage. If anything, additional classes on the high end of the spectrum would have been useful to show the degree to which trail usage has increased above the highest class, but that was outside the scope of the project. After uncovering this pattern, the assumption that trail usage on *High* peaks likely did not decrease was conceptualized, and the priority shifted to counting registers for the 28 peaks (i.e., 3 used the nearest neighbor, 1 had no data) originally classified as *Low* or *Moderate*, none of which were found to have demoted a trail usage class. Thus, the notion that peaks originally ranked *High* remained so crystallized into an underlying assumption of the project, which, coupled with a different person counting names relative to 2005, could be a source for system-wide bias in the measuring process.

Perhaps the most prominent issue with the trail usage data is unreliability. The original data from 2005 was already relatively unstable, and it only appears to have gotten worse. To sketch the conundrum, visualize the finite number of everyone that sets foot on a Fourteener in any given year. Immediately pare away a portion to account for those that never reach the summit. Continue whittling for those that do not sign the register despite a successful summit; reasons for not signing the register vary from personal to not having room to write initials on the paper provided and everything on and around that continuum – some resort to leaving gum wrappers, sticky notes, cigarettes, even pickle jars (Figure 41). Then chisel the number even further to factor in register data lost forever by deep snow, water damage, wind, and marmots that seem to have developed a palate for summit register contents. Trim further as register data must then be transported from the peaks to the archives at the AMC in Golden, CO. Once in the archives, the disheveled contents must be flattened, sorted, organized, and counted, a process during which data are invariably lost. Point being, there are compounding layers of data loss and unreliability along the supply chain, which seem to be getting worse.

Figure 41. Summit register along with a jar of pickles and Tupperware stashed on the summit of Capitol in the Elk Range.

The CMC historian estimated that half of the registers in years past made it back to the archives; however, more recently, that number is considerably lower; in fact, the CMC stopped distributing official registers in 2012 (Smith 2015). Unfortunately, there are no other legitimate trail usage data sources for all Colorado Fourteeners for the temporal range of interest. In other words, counting names on summit registers was not a very good game to begin with, but it was the only one in town. If the data from 2005 were a nominal percentage of actual trail usage, due to the compounding losses noted above, it is a relatively safe bet that the percentage of actual trail usage represented in the counts for this study is less. Perhaps a different way to look at the reliability issue is that the results are increasingly conservative.

Explanatory Variables

The most glaring issues with the explanatory variable portion concern accuracy and validity. While the original methodology was again followed as closely as possible, there were some notable differences. DD and DPR were calculated using a GIS instead of a Delorme atlas. The difference in calculation methods is an improvement, to be sure, but could have introduced a certain amount of error in the comparison. Moreover, identical methods were used to gather TL (GPS), Class (guidebook), and THE data (GPS), but there were some noteworthy changes in where data were collected for several peaks with shifting standard routes and trailheads.

As for routes, the standard on Castle is now the Northeast Ridge because the climb to the saddle of the Northwest Ridge route has been badly eroded (See Table 19 in the Appendix). Also, the South Slopes of Yale have been closed for environmental reasons so the Southwest Slopes route is now standard. Finally, the sustainable switchbacks of the Northwest Ridge trail have replaced the West Slopes route on Belford.

In terms of trailheads, the Denny Gulch trailhead for the old South Slopes route to Yale was closed and relocated to Denny Creek. Similarly, a portion of the Silver Pick Basin providing access to the Wilson Group was inaccessible, and replaced by the Rock of Ages trailhead. While many of the peaks had proper trailheads with parking lots and signs, there were several routes that essentially started when the road became “four-wheel drive”. In addition to the subjectivity of a four-wheel drive characterization, the quality of mountain roads is notoriously capricious on a seasonal cadence, so there could have been variability between precise locations of 4WD trailheads (Figure 42). These changes had some effect on the trail length and trailhead elevation data.

Figure 42. Mountain road washed out by recent storm. Under "normal" conditions, this road is passable in a 2WD car. Under the circumstances, this stretch may be impassable with a 4WD vehicle.

Impact Indicators

Perhaps the greatest begetter of error with the impact indicators section is the validity of the variables, specifically: IT, SBN, %4WD, %TMNT, %ELNT, and %RMNT. In retrospect, the consistency of the variables between studies was suspect because the interpretation of their operational definitions were likely stricter and more fleshed out in this study.

Beginning with the problematic absolute variables, IT were defined for this study as any trail spur or braiding observed with no length or width requirements, just clearly auxiliary to the formal trail (Figure 43). Route segments could be IT and %DW if treads fit both definitions. The subjectivity of SBN precludes its usefulness as an impact indicator. Local topographic factors combined with judgment calls could have researchers prescribing completely different SBN for the same route segment. The operational definition of %4WD breaks down unless signs mark the beginning and ending of these segments. Most often, 4WD roads were clearly marked; however, there were several instances where a trailhead began when the road became 4WD, a definition with plenty of space for interpretation and exposure to the caprice of mountain road conditions, as already mentioned (Figure 42). Moreover, some old 4WD mountain roads are no longer in use or have been blocked off. Should these have been counted as %DW if they were inactive?

Figure 43. Trail segments in the foreground were counted as IT because there are clearly multiple treads. It remains unclear whether this definition led to consistent accounting between studies. Capitol looms in the background.

As for the potential variables, all three suffered from loose definitions that made it difficult to define segment boundaries. The %TMNT and %ELNT indicators were essentially the same variable, just with distinct measuring sticks, so they were problematic for the same reasons. At what point does a formal trail end and %TMNT/%ELNT begin? Is it where the formal tread ends and cairns or markers begin? Where are the boundaries between %TMNT/%ELNT and %RMNT? Does the researcher stop measuring at the last cairn/marker observed? There are no signs or clear indications in the field, so there was an uncomfortable level of interpretation and judgment while delineating these segments. These validity issues extend into the impact indices that rely upon the impact indicators as input for Equations 1-7.

Impact Indices

In addition to the validity issues inherited by the input variables, the impact indices suffer from accuracy and reliability issues that are somewhat interrelated. Beginning with accuracy, there is a built-in bias stemming from the operational definitions of the impact indicators as well as the variables selected for inclusion in the study. Several variables are either related or not discretely defined. For example, SB and SBN are essentially two sides of the same coin. Reconstructed routes with sundry SB will necessarily have less potential for SBN; if one variable goes up the other goes down. Though they do not overlap perfectly, there is enough that the effect on the resulting indices is essentially an inadvertent 2X weight. Similarly, %TMNT and %ELNT are essentially the same variable, so including both as inputs inadvertently weights the resulting indices.

Additional shortcomings pertain to the usefulness of the variables. SB, %4WD, %TMNT, %ELNT, and %RMNT are rather uninformative from a resource management standpoint. Surveying signs of healthy, sustainable trails (e.g., SB) or areas that could potentially lead to impacts (i.e., %TMNT, %ELNT, %RMNT) does not seem particularly useful. The signals of sustainability will be presented in fewer observable negative impacts, and segments where no trail proves problematic will present symptoms captured by other, more discretely definable impact indicators, like IT and %DW. As for %4WD, not a whole lot can be done to curtail their use short of closing down the old mining roads that make up the majority of these segments. Also, the true impacts of %4WD will show up in other variables because its main contribution is to provide access to peaks for more people, which could eventually lead to trail-specific impacts like IT, %DW, and CS. In trying to create comparable index values, blending positive and negative, related and non-discrete variables introduce biases that are difficult to overcome.

Perhaps the greatest source of error for the impact indices stems from their exposure to unreliable data built into the architecture of the equations. The trail usage data influence the final index values on three separate occasions (Figure 44). Moreover, these data drive the mathematical equations, putting the index values on wildly different scales. For example, the iFEDI scoring scale for *High* trail usage peaks (Equation 2) is -0.17 to 3.83 because the average of the absolute variables gets added to potential variables (i.e., a point for each normalized input variable, one of which is negative). The same scoring scale for the *Moderate* trail usage peaks is -0.17 to 1.83, and -3.17 to 0.83 for *Low* trail usage (Equations 3-4). There is the potential for a 6-point swing based entirely on unreliable trail usage data. The exposure to these data is magnified in calculating the FEDI scores.

The FEDI scoring scales are: -0.17 to 8.83 for *High* trail usage, -0.17 to 2.83 for *Moderate*, and -8.17 to 0.83 for *Low* (Equations 5-7). Compounded with the potential point swing built into the iFEDI, there is a potential 16-point swing built into the FEDI all based on arbitrarily classified, unreliable trail usage data. Even assuming that the longitudinal comparison holds to a certain degree because both trail usage data sets (i.e., from 2005 and 2013) were equally unreliable raises all sorts of questions with regard to the accuracy of the results.

To summarize, all the accuracy, validity, and reliability issues within each study segment seems like plenty to sink the dinghy, the interesting comparisons notwithstanding. The ray of sunshine amongst all the darkness, however, is that identifying major issues precipitates their rectification.

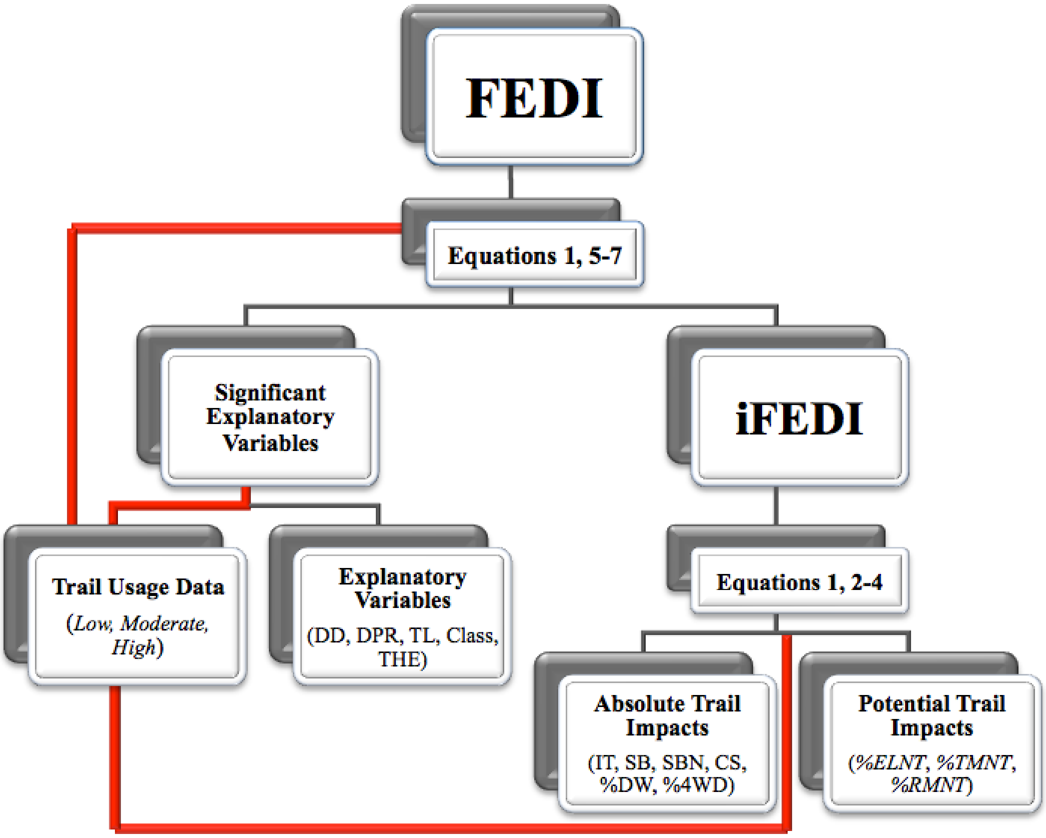


Figure 44. The original conceptual framework had trail usage data influencing the final FEDI on three separate occasions.

CHAPTER VI

EVALUATION ADJUSTMENTS

Improvement Opportunities

To thoroughly answer the second research question - How can the input parameters and methodologies for evaluating the dynamics of trail usage and recreational impacts be optimized to produce better results for resource managers? - the trail usage, explanatory variable, and impact indicators and indices dimensions were evaluated with a fine-toothed comb. The adjustments are detailed in the appropriate sections below. Please note that all were designed to increase the utility of results for resource managers.

Trail Usage

Perhaps the tallest flame in this entire study is the unreliability of the trail usage data, so a way to proceed is to calve off the trail usage and explanatory variable portion as distinct lines of inquiry relative to impact indicators and indices. The two should not be combined until reliable and complete trail usage data can be mustered. In an effort to advance the explanatory variables, however, the unreliable trail usage data was used with an asterisk, but not in building adjusted indices for reasons previously fleshed out. Thus, the improvement to the trail usage component of this study is in recognizing its weaknesses and removing it from places it does not belong.

Explanatory Variables

To provide context for improving upon the original explanatory variables, the details of what they were and why they explained trail usage must be revisited. Many of the relationships are fairly obvious. Peaks located further from Colorado's major population center (DD) are more costly to climb. Peaks tucked away from paved roads are less accessible (DPR), often times requiring specialized methods of transport[10] or additional time to hike the distance. Inaccessible peaks are also riskier in terms of accident-response, so skill-level is more important. Longer routes demand more time and a higher fitness level of the climber (TL). Technically challenging routes require more skill and experience (Class). Routes that begin at lower elevations require time and fitness to cover the vertical gain (THE). Cheaper Fourteeners[11] are more affordable and are therefore climbed with higher frequency.

While all five original variables explained the unreliable summit register data, four of them are glaringly tangential to the pragmatic inception of trail usage - the trip decision-making process of climbers. For example, climbers do not use Euclidean distance to Denver while evaluating travel costs, but instead think in terms of network costs[12] that often times circuitously navigate the mountains. The relationship between trail usage and network costs should be a more nuanced and accurate description of reality. The same is true while evaluating accessibility. Instead of direct distance from the summit to the nearest paved road, climbers use network costs between the end of paved road and the trailhead.

To evaluate the standard climbing route, concerns are primarily focused on difficulty, which dictates the necessary time, fitness, gear, and skill requirements. There are several metrics to evaluate route difficulty, like TL, Class, and THE. While Class will always be central to the evaluation process, round trip length and total elevation gain,

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[10] e.g., four-wheel drive vehicle, train, etc.
[11] e.g., short travel, accessible, easy route in terms of technical rating and fitness requirements, etc.
[12] e.g., distance, time, etc.

as opposed to one-way TL and THE, better reflect variables used pragmatically by trip decision-makers.

Another potential variable to explain trail usage is Roach's (2011) "*efferculty*" system, which suggests the effort required and difficulty of a route. The R Point (RP) values are based on elevation, route length in time and distance, elevation gain, and technical difficulty. The *efferculty* system was developed to give climbers a way to compare the toughness of climbs, and determine roughly how long the routes will take to complete. Climbing speeds vary as a function of technical and physical competency, but on average, climbers take an hour to complete 20-25 RP. As an example, the Keyhole Route on Longs is 348 RP, so it will likely take the average climber between 14-17 hours to complete. Over time, climbers can figure out their average RP/hour to better plan for trips.

To summarize, the degree to which the following pragmatically couched variables explain trail usage were tested using the same methods employed with the originals:

1. Network distance to Denver (NDD; quantitative, primary): Network distance (miles) from the summit to the intersection of I-75 and I-25.
2. Network distance to the nearest paved road (NDPR; quantitative, primary): Network distance (miles) from where the paved road ends to the standard route trailhead.
3. Round-trip length (RTL; quantitative, secondary): Network distance (miles) from the trailhead to the summit and back to the trailhead along the standard route.
4. *Efferculty* (RP; qualitative, secondary): Overall difficulty of the standard route as suggested by Roach (2011).

5. Total elevation gain (TEG; quantitative, secondary): Total elevation gain from the trailhead to the summit and back to the trailhead along the standard route.

NDD were calculated using a GIS and waypoints collected at the intersection of I-75/I-25 in Denver and the termini of paved roads leading to trailheads. NDPR were collected using a GPS. RTL, RP, and TEG data were gathered from Roach's latest guidebook (2011). While RTL and TEG were originally gathered as primary data, their secondary counterparts from Roach's guidebook (2011) were used instead because climbers typically rely on secondary information for trip decision-making.

Again, the same methodology was then used to determine if and how these variables explained trail usage. The data were grouped by the new trail usage classes (*Low*, *Moderate, High*) and evaluated with ANOVA, followed by Pearson-product correlation to assess the strength and direction of significant relationships.

Results

The average NDD was 172.17 miles (Table 13). The Windom Group[13] was furthest from Denver at 324.79 miles; Evans was the closest at 43.42 miles. The average NDPR was 6.18 miles. The San Luis trailhead was furthest from paved roads at 27.70 miles, and seven peaks had paved roads all the way to the trailhead.[14] The standard routes were on average 11.15 miles round-trip, had an *efferculty* of 280 RP, and a TEG of 4,543 feet. The longest route was on Snowmass at 21.80 miles round-trip, and the shortest was Bross at 2.80 miles. The most *effercult* peak was Crestone at 535 RP. The least *effercult* was Democrat at 113 RP. Crestone also had the highest total elevation gain

[13] i.e., Windom, Sunlight, Eolus, and *N. Eolus*
[14] i.e., Longs, Bierstadt, La Plata, Yale, Maroon, N. Maroon, and Pyramid

at 6,744 feet, and Democrat the lowest at 2,148 feet. Unsurprisingly, network distances and TEG were more variable than their legacy counterparts from the previous study as evidenced by the higher standard deviations (cf. Tables 4, 13).

Table 13

Descriptive statistics for adjusted variables that explain trail usage on Colorado Fourteeners (N=58) from 2005-2012

Adjusted Explanatory Variables	Mean	Standard Deviation	Max[1]	Min[2]
NDD (miles)	**172.17**	**81.95**	**324.79**	**43.42**
NDPR (miles)	**6.18**	**5.44**	**27.70**	**0.00**
RTL (miles)	**11.15**	**4.02**	**21.80**	**2.80**
RP	**279.93**	**105.71**	**535.00**	**113.00**
TEG (feet)	**4542.66**	**1164.02**	**6744.00**	**2148.00**

[1]Maximum; [2]Minimum

Aggregated by trail usage group, the adjusted explanatory variable means had some interesting characteristics (Table 14). The *Moderate* group again reflected the longest average NDD, and NDPR. Intuitively, one would think the *Low* group should have the longest network distances; however, in keeping with the changes in trail usage dynamics noted while using the original input variables, this was not the case. In fact, the *Low* group had the shortest average NDPR.

Table 14

Comparison of group means for adjusted explanatory variables on Colorado's Fourteeners (3 groups, N = 58)

Adjusted Explanatory Variables	2005-2012 Trail Usage Group Means			ANOVA	
	n = 30 HI[1]	n = 18 MOD[2]	n = 10 LO[3]	F-value	P-value
NDD (miles)	137.78	220.52	188.35	7.29	0.002*
NDPR (miles)	5.74	7.98	4.24	1.77	0.180
RTL (miles)	9.93	11.88	13.50	3.72	0.031*
RP	217.90	319.06	395.60	21.13	0.000**
TEG (feet)	3944.40	5174.67	5199.80	11.13	0.000**

[1]High; [2]Moderate; [3]Low; *$p < 0.05$; **$p < 0.01$

According to the results of the ANOVA analyses, all adjusted explanatory variables had enough between-trail-usage-group variability to suggest they were drawn from different populations, save NDPR, which did not meet the 95% confidence interval criterion (Table 14). Post-hoc analyses suggest NDD had a significant difference between the *High* and *Moderate* groups only. The RTL difference was between the *High* and *Low* trail usage groups. RP was the only explanatory variable to have a significant difference between all three trail usage groups, and TEG was significantly different between *High* and *Moderate*, and *High* and *Low*. Again, there is a pattern of the explanatory variable means not increasing linearly as trail usage goes down, which is somewhat unexpected. The group means for NDPR were nearly the exact opposite of expectations as the *Low* trail usage group had the shortest drive from the end of paved road to the trailhead, which explains why the variable was insignificant.

The four explanatory variables that passed the ANOVA analyses were positively correlated with the trail usage-numbering schema (i.e., *High*-1, *Moderate*-2, *Low*-3; Table 15). Remember the counterintuitive signs of the correlation results. Put simply, peaks with a longer NDD, longer RTL, higher RP, and higher TEG had less trail usage.

Table 15

Pearson-product correlation results for adjusted explanatory variables

Adjusted Variables	**Trail usage class (2005-2012)**
Trail usage class (2005-2012)	**1**
	-
NDD	**0.335**
	0.01*
RTL	**0.344**
	0.008**
RP	**0.657**
	0.000**
TEG	**0.485**
	0.000**

Correlations listed on top; P-values listed below; *p < 0.05; **p <0.01

The strongest correlation was between trail usage and RP (*efferculty*), followed by TEG, RTL, and NDD (Table 15). Recall that RP combines summit elevation, route length (time and distance), elevation gain, and technical difficulty. Unswervingly, RP was the most correlated to trail usage in part because it combines a form of several of the explanatory variables already on the table (i.e., route length, elevation gain, and technical classification). The redundancies of TEG and RTL could be excluded from future analyses for simplification; however, unpacking the constituents of RP affords a more nuanced view of how the individual variables influence pragmatic trip decision-making.

To summarize, routes with longer RTL, higher TEG, more RP, located further from Denver were climbed significantly less. Also of note, the eclectic RP has emerged as a variable offering an excellent standalone explanation of trail usage, followed by Class, TEG, RTL, and NDD. The NDPR was insignificant as an explanatory variable.

Impact Indicators

In an attempt to clean up the indices, the first order of business is to toss the problematic impact indicators into the ash can, including: SB, SBN, %4WD, *%ELNT*, *%TMNT*, and *%RMNT*. Removing 6 out of 9 impact indicators may seem outlandish; however, the remaining – IT, CS, and %DW – cover nearly the entire spectrum of observable impacts with discrete definitions and little redundancy. There is a variable, however, that will fill one of the few voids left by the remaining impact indicators: qualitative trail condition classes (Table 16).

Table 16

Qualitative trail condition classes developed by Sanjay K. Nepal (Marion et al. 2006)

Qualitative Trail Condition Class Descriptions
Class I – Lightly damaged trail. Either one or a combination of several impact features is present. Trail width is <5 ft; no more than three treads apparent; low to moderate potential for trail expansion; some muddy spots may be present; incision is <0.5 ft; some exposed and loose soil may be present on the trail surface. Overall, a trail under this classification is stable and does not require any maintenance as long as the conditions do not deteriorate further.
Class II – Moderately damaged trail. Trail segments clearly show deteriorating conditions. Either a single impact feature with significant damage, or a combination of more than two impact features is present: trail is wider than 5 ft; incision between 0.5 and 1.0 ft (incision of 1.5 ft in the absence of any other features will satisfy the condition itself); more than three treads are present; muddiness and running water on trail; trail is displaced; and soil is unconsolidated. The degree and magnitude of trail damage is significant enough to prescribe some management actions.

Table 16 (continued).

Qualitative Trail Condition Class Descriptions
Class III – Highly damaged trail. This is a potential hotspot, showing either one type of impact feature or a combination of several features. Both the magnitude and the extent of damage are significant. Basic impact features include trail width, multiple treads and incision. Usually these are present in combined forms, for example trail braiding leading to excessive width. In certain cases, trail width is less but several treads are present, some of which are deeply incised (> 1.5 ft). Frequently exposed bedrock and roots are present in addition to other impact features. A trail affected by landslides or localized slope failures also qualifies as a highly damaged trail.
Class IV – Severely damaged trail or "hotspot." Either a single criterion or a combination of several impact features qualifies this category. The basic parameters are trail width, multiple treads, and trail incision, and are significantly damaged in extent and magnitude compared with Class III. Other impact features being satisfactory, if the basic parameters show heavy damage, it is considered as severely damaged. A trail under this classification exhibits excessive width (> 10 ft), multiple treads (>5 ft), and incision > 1.5 ft. It may also exhibit signs of downhill sliding. Soil on the trail surface is unconsolidated, and no organic layer is present; exposed bedrock is frequent; trailside is highly eroded; root exposure is excessive; trail is very muddy requiring circumvention; trail outslope is > 10%. Overall, a trail under this classification requires urgent repair, without which land degradation is inevitable in the near future. Damage is likely to spread out both vertically (depth) as well as horizontally.

Condition-class systems have been used in the recreation ecology literature for monitoring impacts for some time, but have not been applied to Colorado Fourteeners. Although all the condition-classes listed in Table 16 were not used in this study, they provided the basis from which the final impact variable was created: Class IV segments (C4).

Within the confines of this study, C4 are defined as: any segment of trail >10 ft. in width and > 1.5 ft. in incision. The addition of this variable to IT, CS, and %DW provides the missing puzzle piece, incision, and also accentuates the worst of the worst trail segments in need of immediate restoration.

To summarize, a combination of the following discretely defined impact variables should provide a simple inventory much nearer the mark of what resource management will find useful:

1. Informal trails (IT): number of informal trail spurs or braiding observed per mile. Counted with handheld tally counter. IT have no length or width requirements, just need to clearly be auxiliary to the formal trail. Route segments can be IT and DW if treads fit both criteria.
2. Campsites (CS): Number of campsites per mile. Totals were counted along the standard route and divided by TL. IT leading to CS were counted accordingly, as were DW and C4.
3. Doublewide trail (%DW): Percentage of trail wider than 5 feet. DW route segments were measured between GPS mileages[15] noted on the field data form, which were then totaled and divided by TL. Again, an IT segment could also be DW if the tread(s) fit the criteria.
4. Class IV segments (C4): Number of trail segments wider than 10 feet and incised more than 1.5 feet per mile (Figure 45). C4 segments are generally short, so they were tallied on the field data sheet, which were then totaled and divided by TL.

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[15] The resolution of the GPS mileage was to the 100th of a mile, or 52.8 feet.

Figure 45. Class IV segment on the East Slopes route of Shavano in the Sawatch Range.

To provide a deeper look for resource managers, the remaining variables were descriptively analyzed, charted, and mapped.

Results

In an effort to avoid redundant reporting, IT, CS, and %DW will not be described here, but are included in Table 17 for reference. All remaining variables, however, will be charted and mapped to tease out spatial relationships. The average C4/mile across all the peaks was 1.87; Democrat had the most at 9.22 C4/mile, and 9 peaks had none (Table 17). Longs had the highest total C4 segments with 65.

Table 17

Descriptive statistics for remaining impact indicators

Remaining Impact Indicators (Totals)	Mean	Max[1]	Min[2]	Max Peak	Min Peak
IT/mi	**26.32 (133.24)**	**58.06 (370)**	**3.19 (8)**	**Democrat (Capitol)**	**Culebra**
CS/mi	**3.25 (19.43)**	**10.04 (75)**	**0**	**Little Bear (Ellingwood/Blanca)**	**6 Peaks**
%DW	**10.95**	**42.78**	**0**	**Longs**	**Antero and Little Bear**
C4/mi	**1.87 (8.31)**	**9.22 (65)**	**0**	**Democrat (Longs)**	**9 Peaks**

[1]Maximum; [2]Minimum

The Tenmile/Mosquito had the highest mean C4/mile by range with 5.56, followed by the Front (3.79), Sawatch (1.90), San Juan (1.11), Elk (0.59), and the Sangre de Cristo had the least (0.44; Figure 46). Lincoln, Longs, Cameron, and Democrat were the peaks with the highest density of C4, all of which are confined to the Tenmile/Mosquito and Front ranges. Every peak with the lowest C4/mile classification was located in the Elk, Sangre de Cristo, or San Juan Range.

Hearkening back to the previous explanatory variable adjustments, RP emerged as a frontrunner in terms of explanatory value despite the unreliability of the trail usage data. It would make sense that more challenging peaks, as measured by RP, would be climbed less and perhaps have fewer impacts. Interestingly, there is a positive trend between C4/mile and easier peaks (Figure 47).

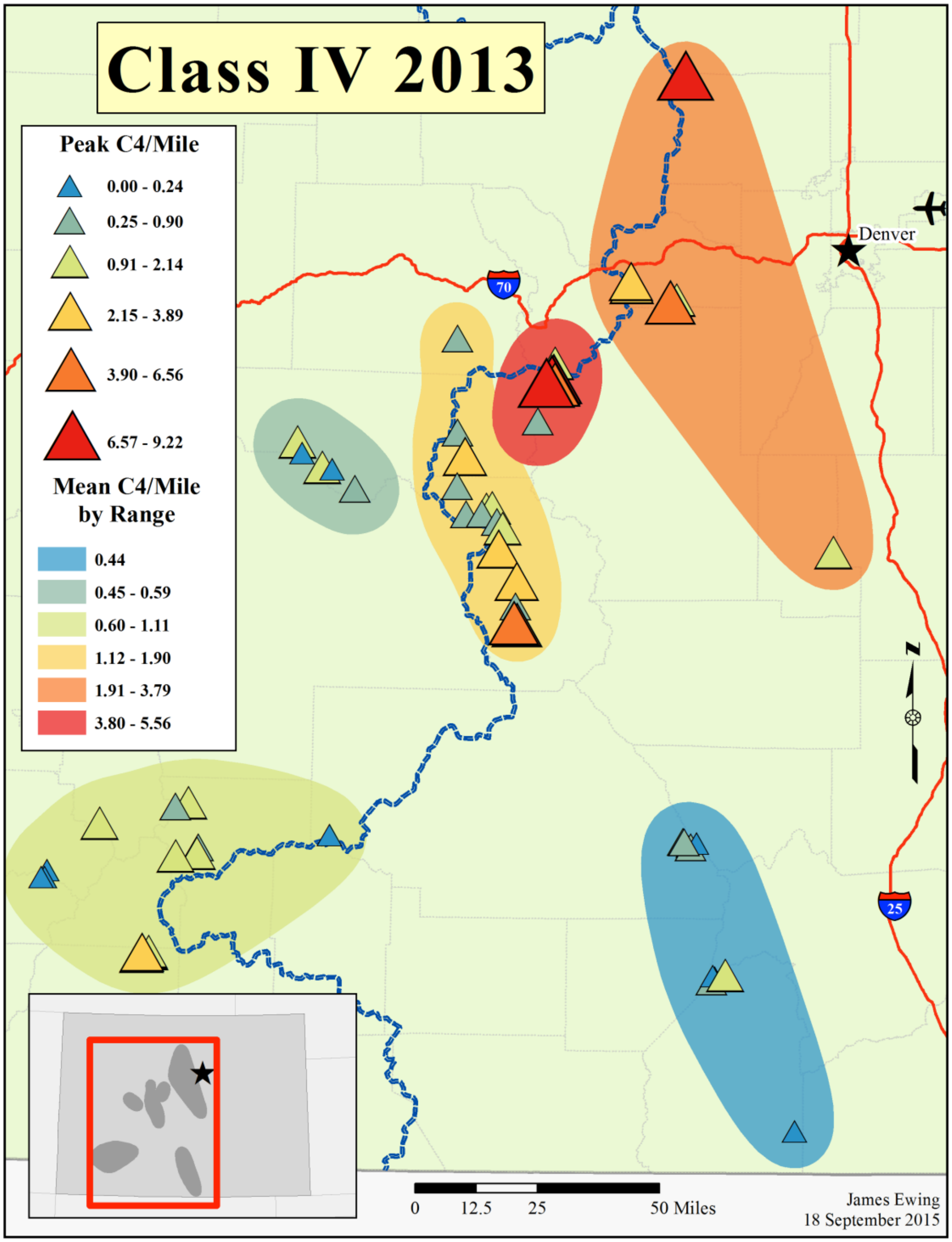

Figure 46. Spatial distribution of Class IV (C4) segments per trail mile by peak and range. Classifications based on Jenks Natural Breaks.

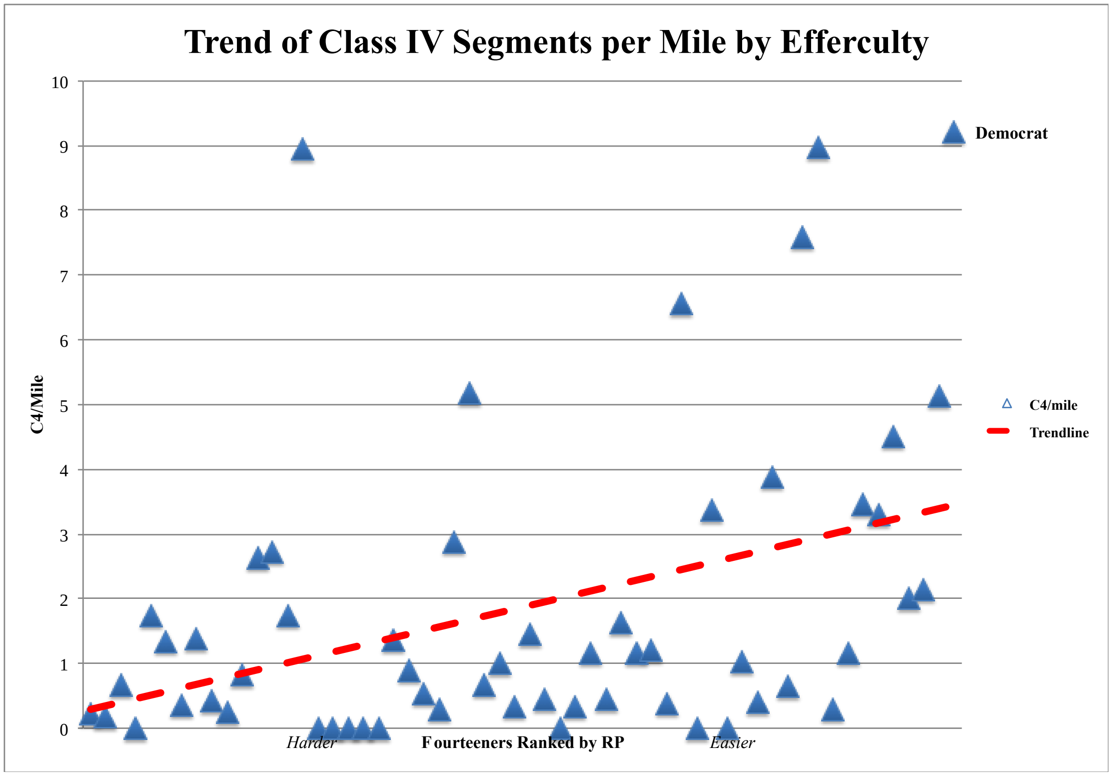

Figure 47. Positive trend visible between Class IV segments per mile and decreasing efferculty.

The Tenmile/Mosquito Range also had the highest mean IT/mile with 49.34, followed by the Sawatch (30.07), Elk (24.99), Front (22.11), Sangre de Cristo (21.72), and San Juan (18.20; Figure 48). Lincoln, Cameron, Democrat, and Bross had the highest density of IT. All of the peaks with the lowest IT/mile were confined to the Sangre de Cristo and San Juan ranges. There also appears to be a slightly positive trend between observed IT/mile and easier RP peaks, which makes sense because lower RP peaks typically have more people and more opportunity for them to wander off-trail (Figure 49).

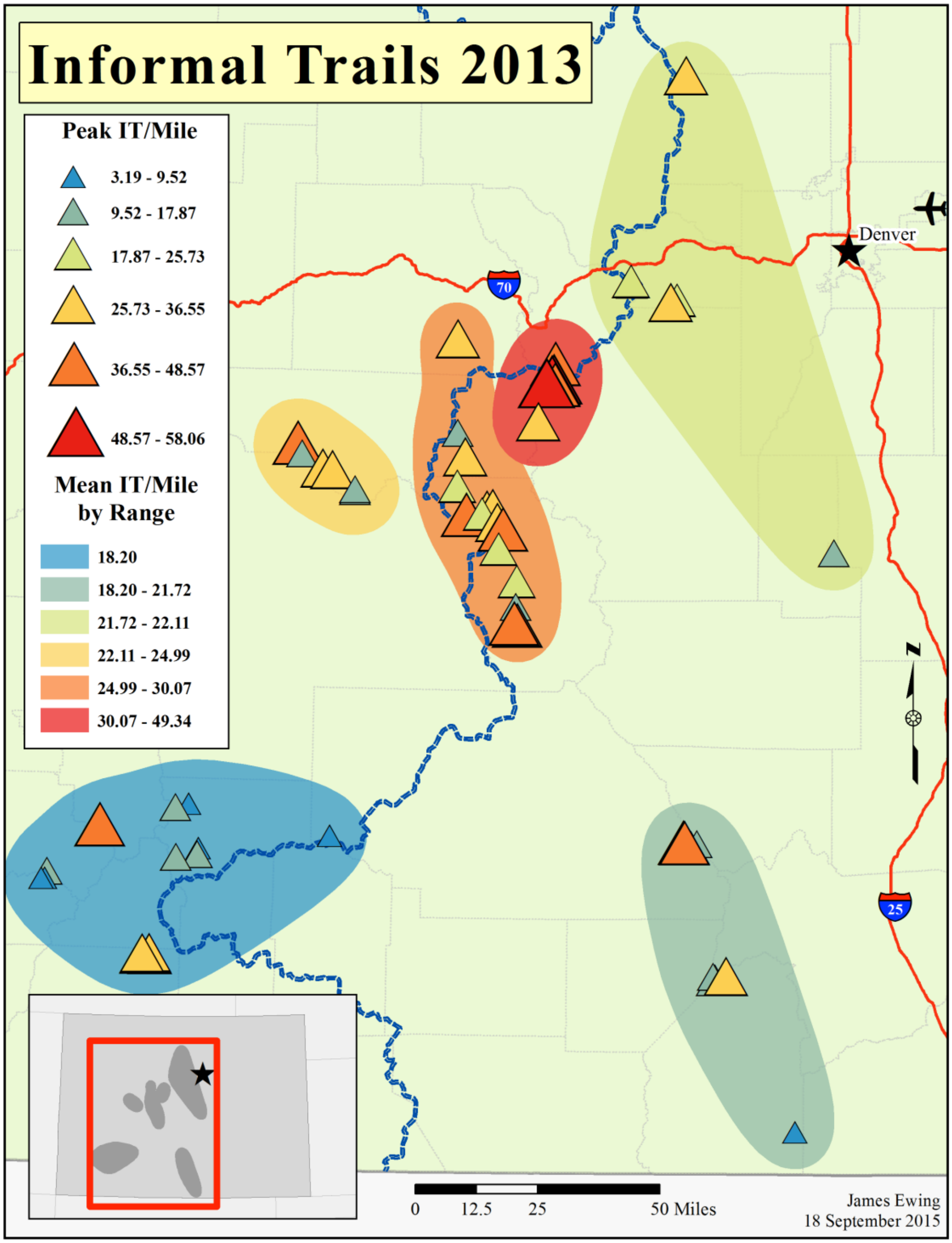

Figure 48. Spatial distribution of IT per trail mile by peak and range. Classifications based on Jenks Natural Breaks.

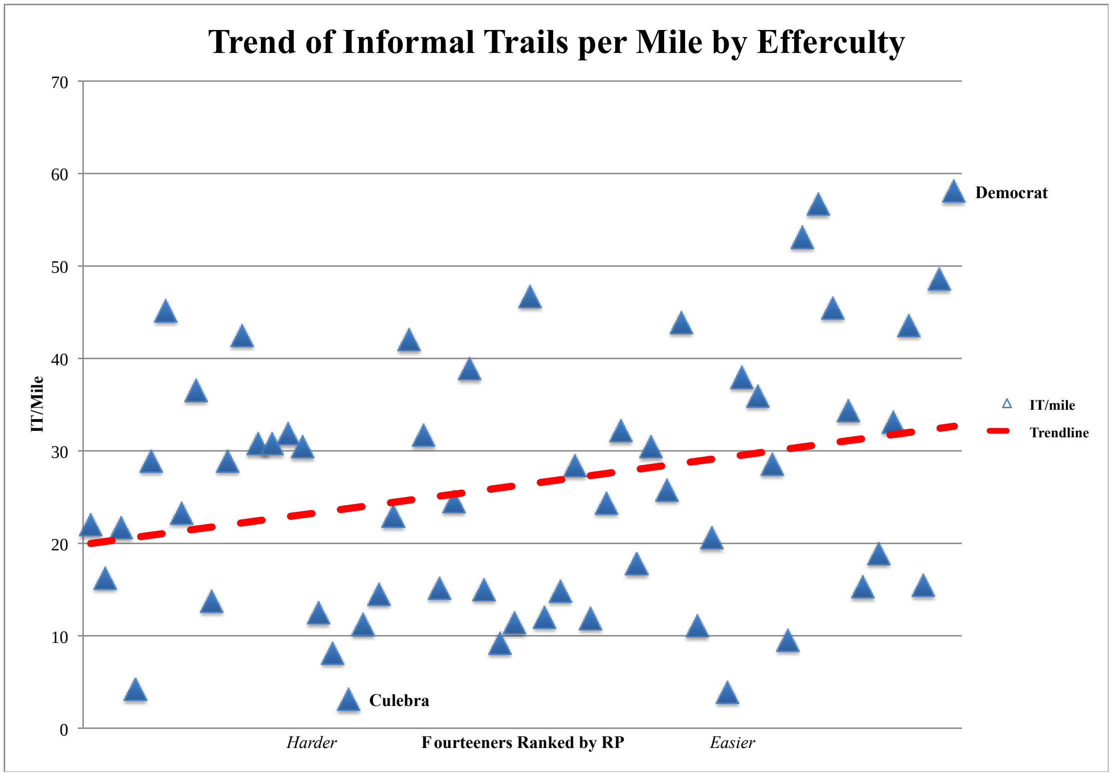

Figure 49. Positive trend visible between IT per mile and decreasing *efferculty*.

The Sangre de Cristo Range had the highest mean CS/mile with 5.04, followed by the Tenmile/Mosquito (4.12), Sawatch (3.70), San Juan (2.45), Elk (2.44), and Front (1.12; Figure 50). Evidently, not too many climbers camp in the Front Range, likely because most of the peaks are convenient day trips from Denver. Blanca, Ellingwood, Little Bear, and Columbia have the highest densities of CS on their standard routes. The trend between CS/mile and lower RP peaks is negative, which makes sense because easier peaks do not require overnight trips (Figure 51).

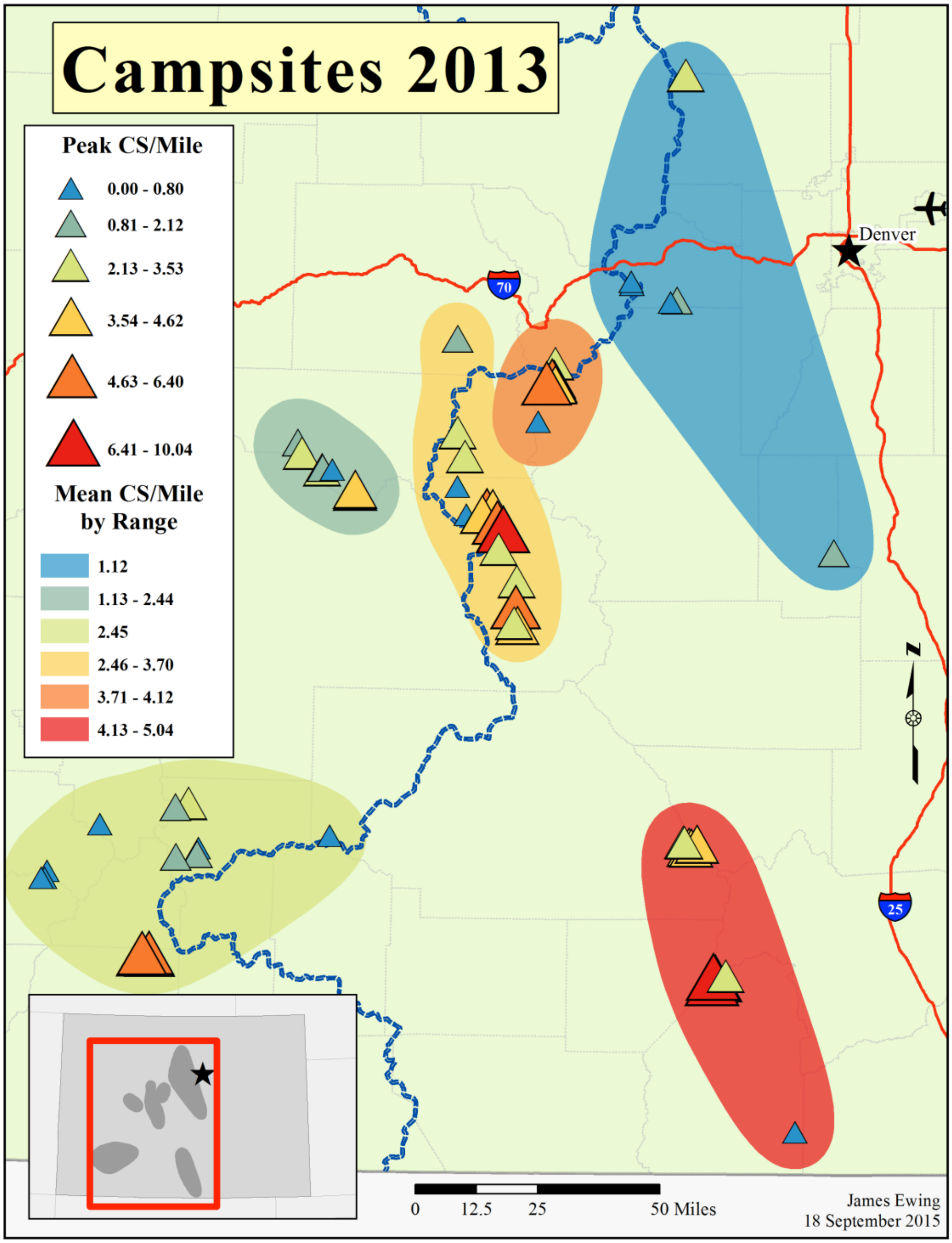

Figure 50. Spatial distribution of CS per trail mile by peak and range. Classifications based on Jenks Natural Breaks.

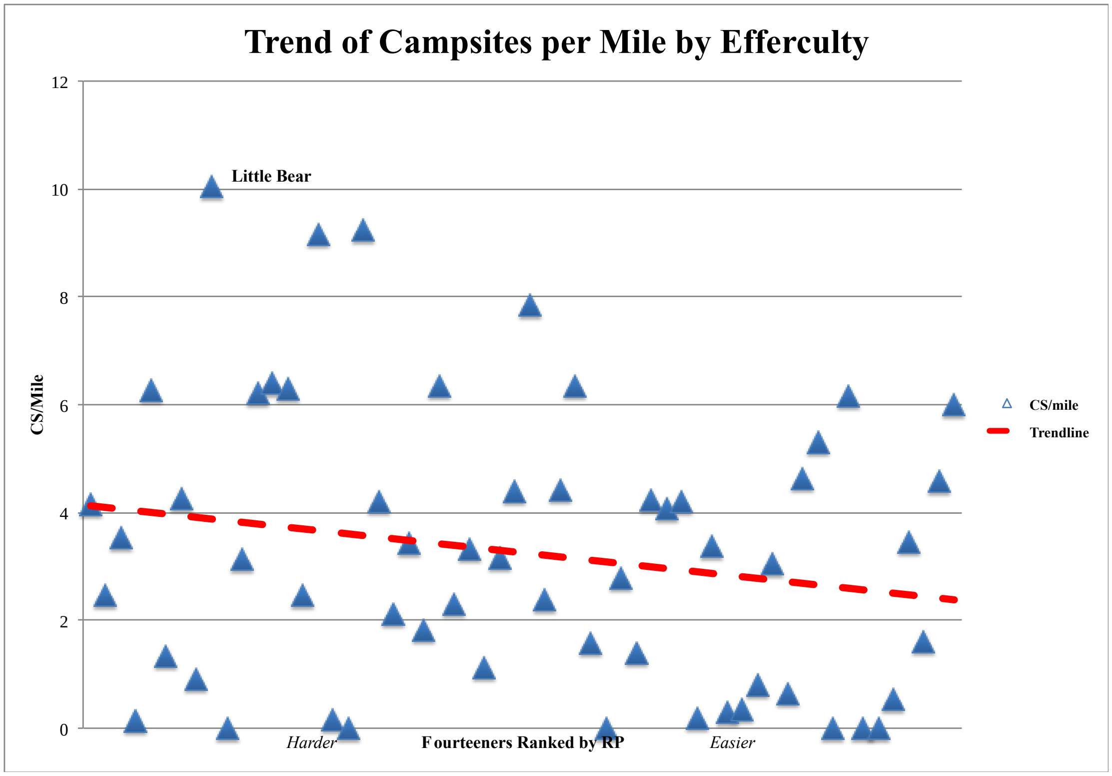

Figure 51. Negative trend visible between CS per mile and decreasing *efferculty*.

The Front has by far the highest mean %DW by range with 29.84%, followed by the Sawatch (12.83%), Tenmile/Mosquito (12.19%), San Juan (8.15%), Elk (5.21%), and Sangre de Cristo (3.97%; Figure 52). The peaks with highest %DW were Longs, Bierstadt, Yale, Grays, Torreys, and Elbert. Only two peaks had no DW, Antero and Little Bear, likely because their standard routes have long segments of 4WD roads. Similar to IT and C4, there is a positive trend between peaks with high %DW and lower RP, or easier peaks (Figure 53). Fewer people climbing through more difficult terrain tends to produce narrower travel corridors.

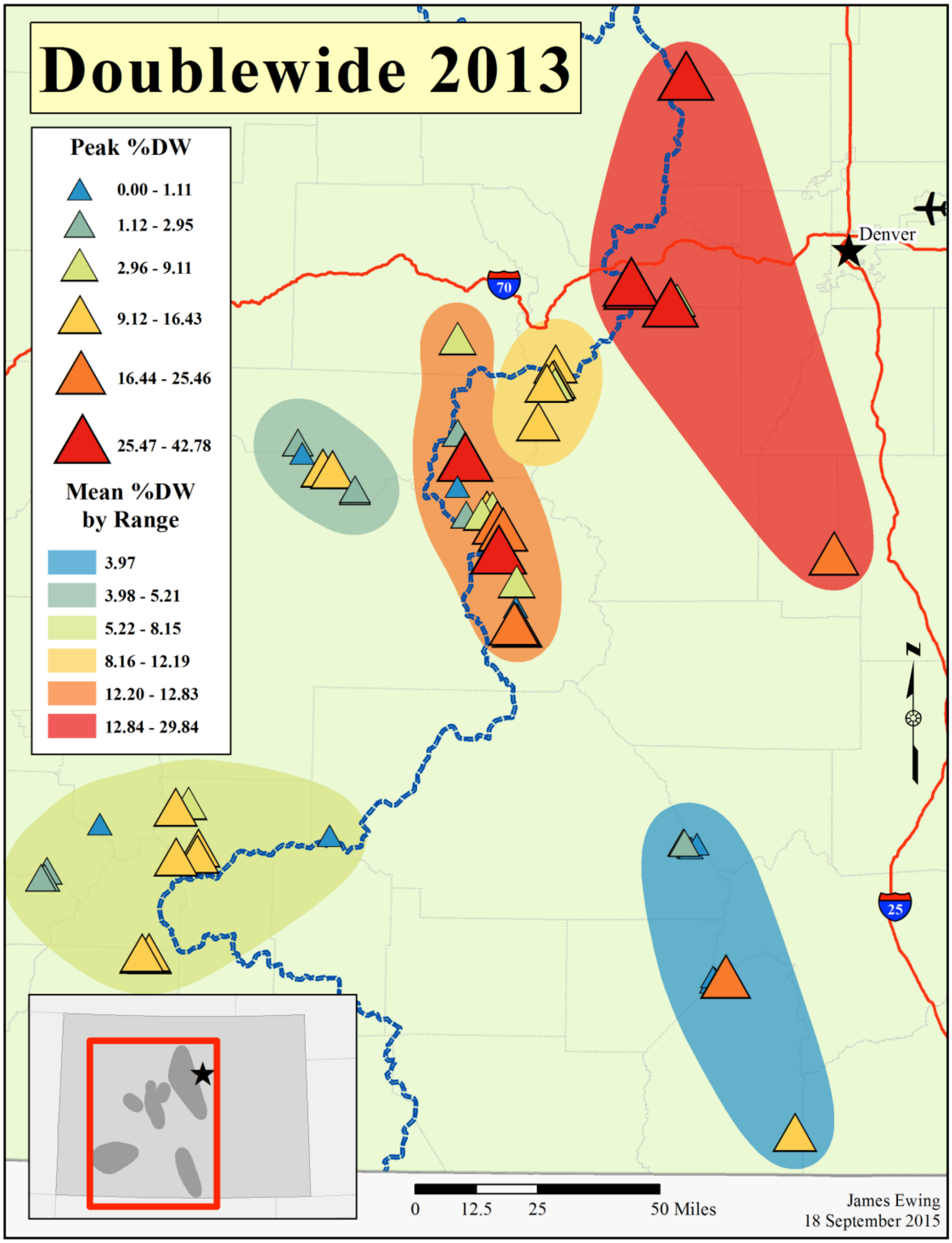

Figure 52. Spatial distribution of %DW by peak and range. Classifications based on Jenks Natural Breaks.

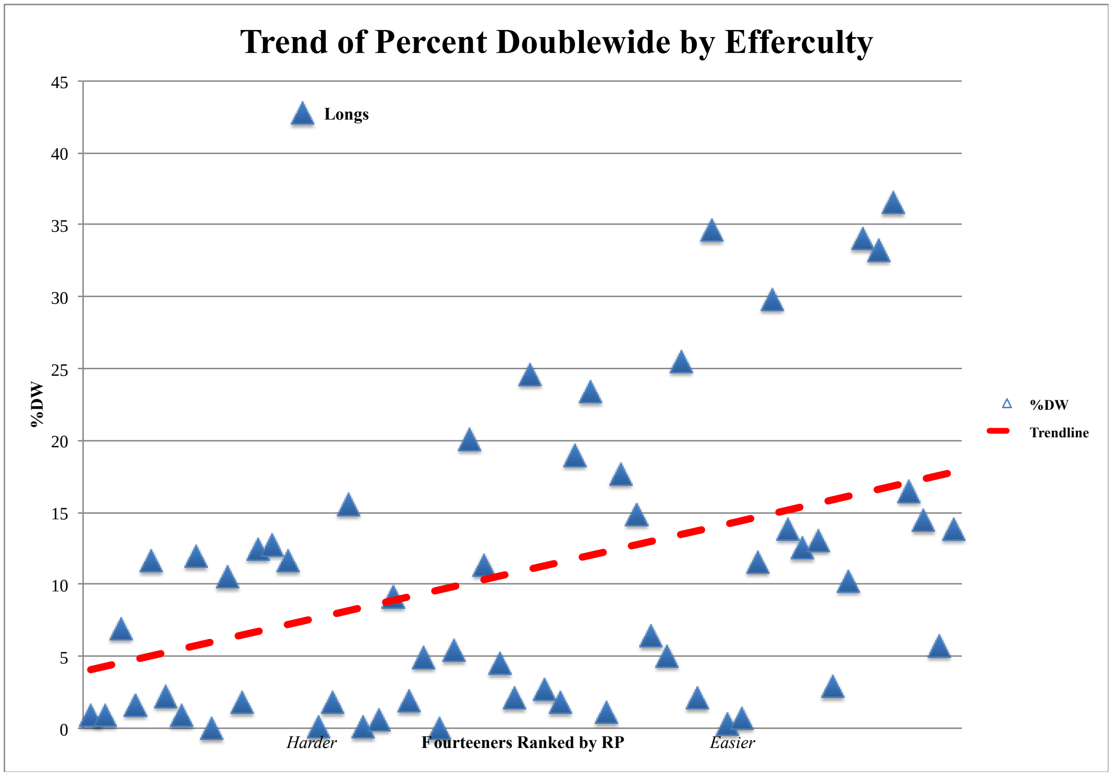

Figure 53. Positive trend between %DW and decreasing *efferculty*.

After establishing impact variables relatively immune to the errors associated with those jettisoned, the remaining concern is how to combine them in a simple way to create comparable and informative results.

Impact Indices

After discussing the unreliability of the trail usage data, calving off the explanatory variables portion, and culling problematic impact indicators, the mechanics of the index equations must be adjusted. Recall that perhaps the biggest source of error for the original indices was that the machinery of the original conceptual framework had the unreliable trail usage data influencing the final index values three times along the assembly line: in determining significant explanatory variables; in determining how the potential impact variables affect the iFEDI; and finally in determining how the significant explanatory variables affect the FEDI. Now that the spoiled ingredients have been identified and removed, the most palatable dish possible for resource managers has a simple elegance to it - take the freshest, most complementary ingredients, measure them out according to import, and combine them with a simple recipe to create the Fourteener Trail Impact Index (FTII; Equation 8).

$$FTII = \frac{[(3*IT)+(2*CS)+(1*\%DW)+(4*C4)]}{4}$$

Equation 8. Fourteener Trail Impact Index for all peaks.

The strengths of Equation 8 include: minimized exposure to unreliable data; discretely defined, validated impact indicators; a simple and accurate mathematical combination allowing for researchers to weight variables by importance to resource management. In this instance, C4 was determined to be of the highest importance because they are trail segments in the worst shape possible. IT were a close second, because they can lead to the trail incision, erosion, and widening that is extremely damaging in the alpine tundra zone. Although CS are almost always accompanied by negative impacts, they were rated third, because they can be constructed and used sustainably. Also, a portion of the damage created by CS is presented as IT, C4, and DW. Lastly, DW segments were determined to be the least important partially because their reconstruction is not always necessary, until they become problematic enough to be classified as C4.

To create a fresh synopsis of impacts, the FTII scores were calculated by running the remaining impact indicators (i.e., IT, CS, %DW, C4) through Equation 1 for normalization, and then Equation 8 to create the final values. For quick reference and visualization, the results were tabulated and mapped.

Results

The FTII was bookended by Democrat (2.1290) on the high end, and San Luis (0.0260) on the low end (See Table 23 in the Appendix). The top ten highest scoring peaks included 4 from the Tenmile/Mosquito Range (Democrat, *Cameron*, Lincoln, Bross), 2 from the Front (Longs, Bierstadt), and 4 from the Sawatch (Shavano, Tabeguache, Columbia, and Elbert). The top ten lowest scoring, or least impacted, peaks included 6 from the San Juan (San Luis, *El Diente*, Mt. Wilson, Wilson Peak, Redcloud, and Wetterhorn), 1 from the Sangre de Cristo (Culebra), 1 from the Elk (Snowmass), and 1 from the Sawatch (La Plata). Classified by Jenks Natural Breaks, the peaks in the poorest shape were Democrat, *Cameron*, Lincoln, Longs, and Shavano (Figure 54). The peaks in the best shape were San Luis, *El Diente*, Mt. Wilson, Culebra, and Wilson Peak.

Aggregated by range, the Tenmile/Mosquito had the highest FTII score at 1.5104; Democrat and Sherman were the respective highest and lowest scoring peaks within (Figure 54; Table 18). The Front Range had the second highest average FTII at 0.8995, followed by the Sawatch (0.8324), Sangre de Cristo (0.5746), Elk (0.5141), and San Juan (0.4951). Spatially, the FTII scores seem to roughly match the notion that impacts degrade with increasing distance to Denver.

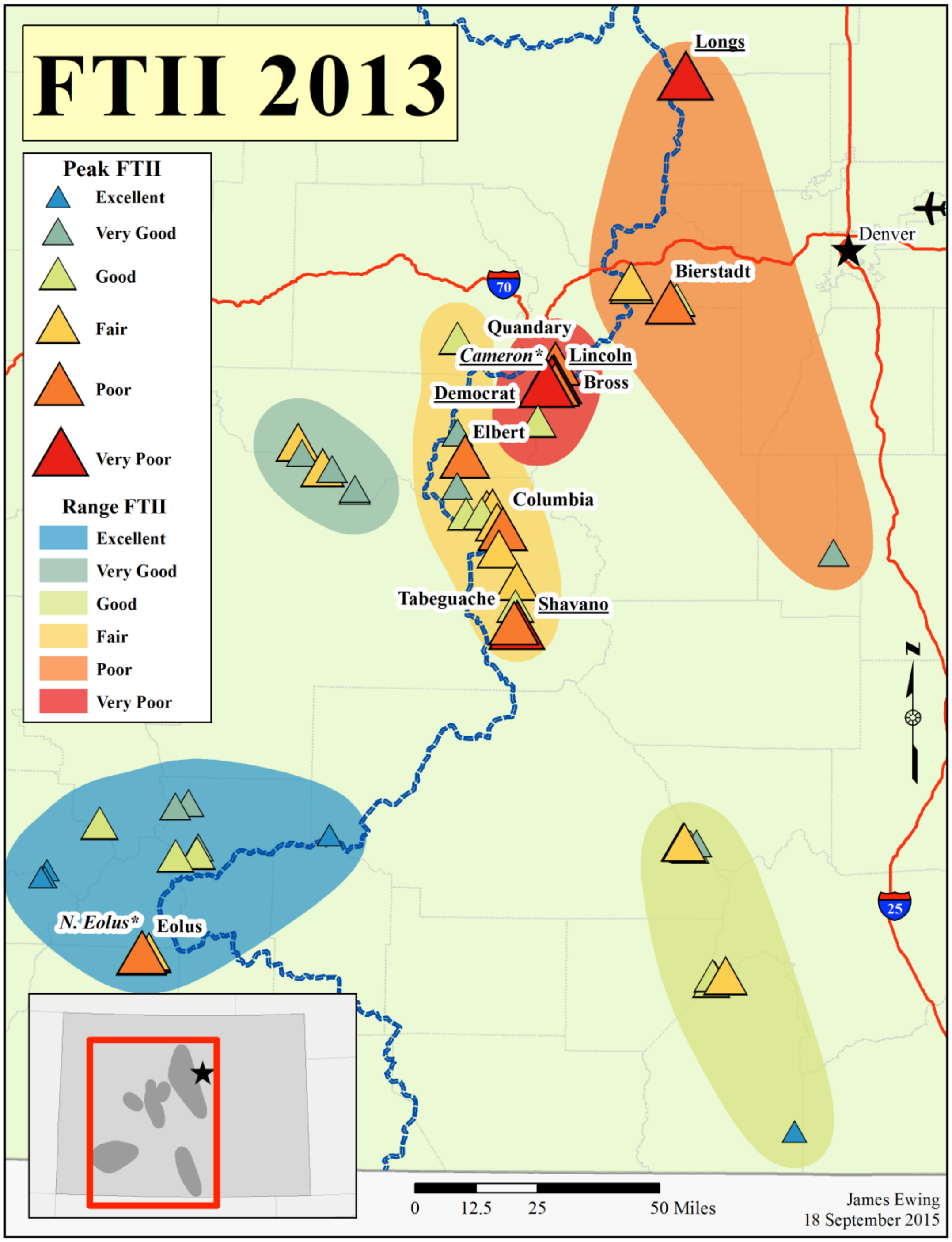

Figure 54. Spatial distribution of FTII 2013 by peak and range. Classifications based on Jenks Natural Breaks.

Table 18

Descriptive statistics for the FTII by mountain range

Range (Count)	Mean FTII	Max[1]	Min[2]
Front (6)	**0.8995**	**1.7171 (Longs)**	**0.4590 (Pikes)**
Tenmile/Mosquito (6)	**1.5104**	**2.1290 (Democrat)**	**0.5995 (Sherman)**
Sawatch (15)	**0.8324**	**1.6253 (Shavano)**	**0.3038 (Massive)**
Sangre de Cristo (10)	**0.5746**	**0.8159 (Lindsey)**	**0.0908 (Culebra)**
Elk (7)	**0.5141**	**0.7993 (Capitol)**	**0.3285 (Snowmass)**
San Juan (14)	**0.4951**	**1.0665 (*N. Eolus*)**	**0.0269 (San Luis)**

[1]Maximum; [2]Minimum

CHAPTER VII

DISCUSSION

Overview

The goals of this study were to provide the Colorado Fourteener community with an assessment of trail usage and recreational impact dynamics, and to refine evaluation methods to ultimately produce a cogent synopsis of where managers ought to focus resources. Between 2005 and 2012, trail usage increased significantly with eight peaks promoting to a higher group: Crestone Needle, *North Eolus*, Mt. Wilson, *El Diente*, Sneffels, *Cameron*, Lincoln, and Shavano (Figure 25). The Tenmile/Mosquito Range had the highest proportion of peaks change classes, followed in order by the San Juan, Sangre de Cristo, and Sawatch; the Elk and Front Range had no change (Figure 25).

The relationship between trail usage and the still significant explanatory variables - DD, DPR, TL, Class, THE - took some interesting turns between 2005 and 2013. Class remained the strongest explainer of the trail usage groups; however, the correlation weakened along with that of DD and DPR (Figure 30). Conversely, TL and THE were increasingly correlated to trail usage. The results suggest climbers are less hindered by accessibility and are perhaps more sophisticated in technical ability, but generally seek out peaks with lower pure fitness demands as measured by TL and THE.

The results of the trail usage and explanatory variable analyses seem to suggest that climbers are venturing deeper into the mountains, perhaps in response to overcrowding in the Front Range, and the addition of important social and informational components. Networking, trip reports, and route information have become more readily available, and climbers can more easily orchestrate group outings. The confluence of these systems has begun to erode the limitations of accessibility and anxiety that has kept many climbers away from peaks tucked deeper in the mountains with more technical and exposed routes. On the other hand, no amount of social media, carpooling, or confidence can prepare one physically for the demands of a 20-mile route with 6,000 ft. of elevation gain. There are no convenient shortcuts for physical preparation, so the burgeoning correlation between TL and THE to trail usage makes sense. Climbers are looking to avoid the crowds of the ranges close to Denver, and they are working through the natural progression of less physically demanding routes first.

In terms of impact indicators, IT and CS were considerably higher in 2013 than in 2005, the most likely explanation of which is increased trail usage and lean restrictions (Figure 31). The number of observed SB was higher, and correspondingly, SBN was lower, which both are evidence of reconstruction projects. The slight uptick in 4WD was most likely due to variability in the precise locations of trailheads as most Colorado 4WD roads have been there for decades. The impact variables with the greatest decrease were DW, ELNT, TMNT, and RMNT. The dip in DW, coupled with the spike in IT, underscored the importance of clean variable definitions to guide data collection. Although the CFI, and other groups, have completed tremendous reconstruction work on about a quarter of the peaks since 2005 (Table 8), the signals of which were perceptible in several of the impact indicators and indices, a -78% change in DW is at least partially a function of differing definitions between studies. The leading suspicion is that much of what was considered DW in 2005 was defined and counted as IT in this study, contributing to the 119% spike of the latter and 78% dip of the former. Of course, higher trail usage and reconstruction work accounts for some of the phenomena.

Turning back to ELNT, TMNT, and RMNT, the decreases make sense with higher trail usage and IT (Figure 31). Climbers marking routes with cairns and wearing trails into the landscape will constantly erode these variables. Although ELNT and TMNT will likely always have a stake on Colorado Fourteeners because the ubiquitous bands of talus that preclude a formal trail, it would not be surprising if RMNT disappears completely as all routes will eventually be marked by either organic treading or with formal cairns.

According to the 2013 iFEDI, the Front Range was in the worst shape, somewhat surprisingly followed by the San Juan, Tenmile/Mosquito, Sawatch, Sangre de Cristo, and Elk (Figure 32). Sneffels, Sunshine, Bierstadt, and Longs were in the worst individual shape. However, the differences between the iFEDI datasets were statistically insignificant, and the results suggest that on the whole, Colorado Fourteeners were actually in slightly *better* shape in 2013 than in 2005, which was surprising given the significant increase in trail usage, and spikes in IT and CS. Again, some of this signal is likely due to outliers and normalization, but perhaps the increase of reconstructed, sustainable routes has dampened the effects of recreational impacts caused by higher trail usage to a certain degree. The largest changes in iFEDI were strikingly concentrated toward the less-impacted portion of the 2005 scale, and much of the worsening impacts were heaped in the San Juan mountains, which are furthest from Denver (Figures 33-35).

According to the 2013 FEDI, the Front Range was in the worst shape on average, followed by the Tenmile/Mosquito, San Juan, Sawatch, Sangre de Cristo, and Elk (Figure 36). Sneffels, Sunshine, and Longs had the most impacts for individual peaks. In-step with expectations, the 2013 FEDI dataset was significantly different than that of 2005, and the results suggested Fourteeners were in considerably *worse* shape in 2013 than in 2005 as evidenced by the overall much higher totaled FEDI values (Table 12). Similar to the iFEDI results, there is a clear pattern in where the changes were concentrated: less-impacted peaks on the 2005 scale, and in the San Juans (Figures 37-39).

These observations are consistent in highlighting shifts in the way climbers are accessing peaks further from Denver. Climbing opportunities through social media, access to information, and the avoidance of crowds are potential drivers of the increased activity and impacts observed in ranges further from Denver.

After inventorying the accuracy, validity, and reliability issues with each component of the longitudinal analyses, several major improvement opportunities were docketed. The trail usage data were determined to be too unreliable to take part in the impact indices, but were still used to advance the explanatory variables as a separate line of inquiry.

Four of the five adjusted explanatory variables – NDD, RTL, RP, and TEG – were statistically significant in explaining trail usage, with the exception of NDPR. Lending credence to its accuracy, and perhaps widespread use, the RP system had the strongest correlation to trail usage, followed by TEG, RTL, and NDD. Surprisingly, NDD and RTL were slightly less correlated to trail usage relative to their original counterparts (i.e., DD and TL; cf. Tables 6, 15). The differences, however, were so negligible that they are essentially equivalent in explanatory value. Relative to THE, TEG was considerably more valuable as an explanatory variable, perhaps because it captures the subtleties of routes that ascend and descend in both directions, making them more time consuming and exhausting for climbers, a detail pixelated by mere THE.

Substantial validity, redundancy, and utility issues were uncovered for 6 of the 9 original impact indicators (i.e., SB, SBN, %4WD, %TMNT, %ELNT, %RMNT), ultimately leading to their removal from the study. Borrowing from the recreation ecology literature, C4 segments were added to the remaining IT, CS, and %DW to round out the suite of impact indicators appropriate for accurate index creation. A deeper dive into the magnitude and spatial distribution of these variables was taken to provide resource managers with a 2013 snapshot that could help prioritize reconstruction efforts.

The Tenmile/Mosquito Range had the highest mean C4/mile followed by the Front, Sawatch, San Juan, Elk, and Sangre de Cristo (Figure 46). Lincoln, Longs, *Cameron*, and Democrat were in the worst shape in terms of C4/mile. The Tenmile/Mosquito Range also had the highest mean IT/mile, followed in order by the Sawatch, Elk, Front, Sangre de Cristo, and San Juan (Figure 48). The Decalibron (i.e., Lincoln, *Cameron*, Democrat, and Bross) had the highest IT/mile. In terms of CS/mile, the Sangre de Cristo Range had the most, followed by the Tenmile/Mosquito, Sawatch, San Juan, Elk, and Front (Figure 50). Blanca, Ellingwood, Little Bear, and Columbia had the highest CS/mile for individual peaks. Notably, the Front Range had the fewest mean CS/mile. The Front Range had by far the highest %DW average, followed by the Sawatch, Tenmile/Mosquito, San Juan, Elk, and Sangre de Cristo (Figure 52). Longs, Bierstadt, Yale, Grays, Torreys, and Elbert had the highest %DW of all the peaks.

Finally, to rectify the reliability and accuracy issues with the input parameters and equations used to create the indices, the trail usage data and explanatory variables were withheld along with the variables nixed from the suite of impact indicators, and the FTII was conceptualized. It was determined that IT, CS, %DW, and C4 should be included and weighted based on reconstruction priority and reparability. Thus, C4 were weighted heaviest, followed by IT, CS, and %DW. According to the FTII, the Tenmile/Mosquito Range was in the worst shape in 2013, followed by the Front, Sawatch, Sangre de Cristo, Elk, and San Juan (Figure 54). Democrat, *Cameron*, Lincoln, Longs, and Shavano had the highest index scores, and were therefore the most impacted peaks.

In terms of a synopsis to fit the resource management framework, perhaps the most valuable results of this study are Tables 18 and 23, and Figure 54, because they provide specific ranks, scores, and the spatial distribution of impacts as of 2013 with minimal error. Spatially, most of the impacts are located in the Tenmile/Mosquito, Front, and Sawatch Ranges; however, more climbers with access to information, partners, and an apparent increasing desire to get away from overcrowded peaks could put the least impacted San Juan and Elk Ranges at high risk in the coming years. This begs the question of whether it is a better strategy to focus limited resources on severely impacted peaks, or to allocate them toward preserving peaks still in excellent shape. While there are many ancillary factors that go into prioritizing efforts (e.g., logistics, budget, human capital, access, location, etc.), the results of the FTII will at least arm resource managers with a population-wide survey of impacts to make data-informed decisions.

Future Directions

Future work should include implementing a more accurate and reliable way to capture trail usage data. The CMC launched a virtual summit register in the Fall of 2013, called mySummits, that enables users to input various attribute data for successful summit bids (CMC 2015b). However, capturing trail usage data is on the periphery of the CMC's dartboard, so the efficacy of mySummits, as it relates to producing useful data for resource managers, will ultimately be dictated by user adoption; as of the summer of 2015, the system had just north of 2,000 records, so there is still plenty of room for traction (Vermeal 2015). Perhaps more auspicious, the CFI has been collecting usage numbers utilizing infrared counters on various routes around the state, but a population-wide monitoring system has not yet been stood up, and perennial funding issues continue to represent a major hurdle (Hanus 2015). In this era of Big Data, there must be an elegant and reliable solution on the horizon. Hard trail usage counts would be a welcome addition to the impact surveys of this study, and would ultimately provide a more complete picture from which resource managers can make decisions. It would also open up, and legitimize, the explanatory variable line of inquiry that attempts to uncover why certain peaks are climbed more than others.

Future research specific to relating trail usage data to explanatory variables could improve upon this study by advancing well beyond network distance. There are many other network costs used by climbers during practical trip decision-making that can be modeled and tested. For example, network costs could be travel times and/or round trip fuel costs. Overnight lodging costs in close proximity to trailheads during the climbing season could be factored in – not everyone is willing to sleep in their car or "cowboy camp"[16] at the trailhead. These data, however, should probably be gathered in a way that best mimics how the majority of climbers do so in practice – secondary information from guidebooks, google maps, and/or websites.

Another attractive line of inquiry could be to better understand and strengthen Roach's (2011) *efferculty* system. While the 3rd edition of the guidebook unveils

[16] Lay down a sleeping pad and bag and sleep under the stars.

efferculty, it says nothing about how the ingredients were combined to create the R-point values. As the best explanation for trail usage, *efferculty* is certainly deserving of a closer look.

The "how many" and "where" of this study will always be central to resource management, but until ongoing hard trail usage counts are achieved, the "why" will remain relevant because it suggests the "where". Once a data collection system is put in place, researchers of similar focus can divest the explanatory variable portion, leaving it to the ecotourism/recreation psychology realm where it belongs.

The impact indicators used to create the FTII could be expanded upon. Ultimately, IT, CS, %DW, and C4 were incorporated in this study; however, there are many other possible variables. For example, SBN could be discretely defined based on topographic markers like slope, aspect, and width of the workable area. Until a well-crafted definition is articulated, however, the variable should remain on the too subjective to be useful shelf. Another attractive possibility could be to assign trail condition classes, based on tread width, count, incision, and soil conditions, (Table 16) to every segment of every standard route. These data would be highly valuable for resource management. Any additional impact features to be examined must be appropriately validated to maximize the consistency of results.

The FTII could be expanded upon to include new variables, and/or perhaps weight the variables differently. If a system for gathering legitimate data were put in place, trail usage could be reincorporated into the impact index. An unsustainable, highly used route, is at a much higher risk of being impacted, if it has not already been, than a comparable route with less usage. Perhaps the risk of impacts should be indexed separately from existing impacts, as each would provide a different kind of information. Also, the mathematical combination of the impact features can be easily fine-tuned to fit any application. The indices, however, are only as good as the underlying data so building high quality data sets for well-defined impact features is paramount.

Another future research opportunity applies to resource management more broadly. Fine-tuning methodologies for monitoring rates of change could provide an evaluation platform for resource management practices. Empirically verifying the efficacy of executed plans and strategies over time could contribute significantly to the advancement of resource management in general. There is still a lot of foundational work to be done before this is possible, but placing it on the roadmap will hopefully encourage future researchers to standardize impact features and methodologies with an eye toward making resource management evaluation a reality.

A final note – assuming the CFI and other Colorado Fourteener managers inform their decisions with research of some kind, it begs the question why this material is not openly available to the public. Transparency into their methods and processes could go a long way in expediting the development of a robust system for monitoring and managing the peaks. The opacity with which these groups perform research seems to contribute to an overarching lack of connective tissue between Fourteener-specific research and the more mature methodologies of disciplines like recreation ecology. Opening the blinds could allow managers to leverage increasing interest in the peaks as a resource to help mitigate the issues. With current capital constraints, the labor of the academy seems like it should be an attractive proposition.

CHAPTER VIII

CONCLUSIONS

This study was designed to help resource managers better understand how to assess important changes in variables that affect the areas they shepherd, and ultimately make well-informed decisions. The challenge of maintaining the integrity of fragile alpine environments with limited resources can be more effectively addressed with a clear picture of how many, where, and why people are climbing, along with a robust system for monitoring impacts. Such an understanding not only creates the possibility for proactive management, but also an opportunity to evaluate and improve upon management practices in general.

Moving forward, systems for gathering reliable trail usage data are critical for successful management. With these data in place, explanatory variables become an entirely separate, though interesting, topic of study. Also critical is the identification of specific impact features of interest accompanied by tightly fashioned operational definitions that ensure the consistency, accuracy and validity of future research. As the machinery of recreation ecology are used to reconstruct and protect various montane environments, place or region-specific impact features, along with recipes for how to combine them to create informative indices, will eventually be necessary as management teams address unique issues with varying depths of resources.

Seemingly an axiom for managers of mountain trails, undercapitalization necessitates the measure twice cut once approach campaigned for throughout the halls of this paper. Though this approach requires more heavy lifting up-front, the donations and tax dollars thrown at these issues can be stretched further, and the costs of measuring will decrease as the wrinkles in systems and methodologies get ironed out. Moreover, cultivating a transparent and open dialogue regarding the challenges, limits, and data needs of managers is perhaps the best way to knock the dust off the lever of academia, which is a major opportunity to decrease measuring costs.

This project should serve to refocus the issue of recreational impacts on Colorado Fourteeners and other regions, while providing methodologies that yield results applicable to those obliged to serve and protect the beauty and vitality that makes montane environments attractive destinations.

APPENDIX

Table 19

Information on Colorado Fourteeners and 2013 data collection

Peak	Range	Elevation*	Trailhead**	Route**	Class	Date Climbed
Longs	**Front**	**14261**	**Longs Peak**	**Keyhole**	**3.0**	**7/10/13**
Grays	**Front**	**14279**	**Grays Peak**	**North Slopes**	**1.0**	**6/20/13**
Torreys	**Front**	**14272**	**Grays Peak**	**South Slopes**	**1.5**	**6/20/13**
Evans	**Front**	**14270**	**Echo Lake**	**Chicago Creek**	**2.0**	**6/24/13**
Bierstadt	**Front**	**14065**	**Guanella Pass**	**West Slopes**	**2.0**	**6/19/13**
Pikes	**Front**	**14115**	**Crags Campground**	**Northwest Slopes**	**2.0**	**6/17/13**
Quandary	**Tenmile-Mosquito**	**14270**	**Quandary**	**East Slopes**	**1.0**	**7/1/13**
Lincoln	**Tenmile-Mosquito**	**14291**	**Kite Lake**	**West Ridge**	**2.0**	**7/2/13**
Cameron*	**Tenmile-Mosquito**	**14243**	**Kite Lake**	**West Ridge**	**2.0**	**7/2/13**
Bross	**Tenmile-Mosquito**	**14177**	**Kite Lake**	**West Slopes**	**2.0**	**7/2/13**
Democrat	**Tenmile-Mosquito**	**14152**	**Kite Lake**	**East Ridge**	**2.0**	**7/2/13**
Sherman	**Tenmile-Mosquito**	**14040**	**Fourmile Creek 4WD**	**Fourmile Creek**	**2.0**	**7/3/13**
Holy Cross	**Sawatch**	**14012**	**Half Moon**	**North Ridge**	**2.0**	**7/11/13**
Massive	**Sawatch**	**14428**	**Mount Massive**	**East Slopes**	**2.0**	**7/4/13**
Elbert	**Sawatch**	**14440**	**North Mt. Elbert**	**Northeast Ridge**	**1.0**	**7/6/13**
La Plata	**Sawatch**	**14343**	**Lake Creek**	**Northwest Ridge**	**2.0**	**7/5/13**
Huron	**Sawatch**	**14012**	**South Winfield 4WD**	**Northwest Slopes**	**1.0**	**7/13/13**
Belford	**Sawatch**	**14205**	**Missouri Gulch**	**Northwest Ridge**	**1.0**	**7/13/13**
Oxford	**Sawatch**	**14160**	**Missouri Gulch**	**West Ridge**	**1.0**	**7/13/13**
Missouri	**Sawatch**	**14073**	**Missouri Gulch**	**Northwest Ridge**	**2.0**	**7/13/13**
Harvard	**Sawatch**	**14427**	**North Cottonwood**	**South Slopes**	**2.0**	**7/16/13**
Columbia	**Sawatch**	**14079**	**North Cottonwood**	**West Slopes**	**2.0**	**7/16/13**
Yale	**Sawatch**	**14204**	**Denny Creek**	**Southwest Slopes**	**2.0**	**7/12/13**
Princeton	**Sawatch**	**14205**	**Mt Princeton Rd 4WD**	**East Slopes**	**2.0**	**7/15/13**
Antero	**Sawatch**	**14276**	**Baldwin Gulch**	**West Slopes**	**2.0**	**7/20/13**
Shavano	**Sawatch**	**14236**	**Blank Gulch**	**East Slopes**	**2.0**	**7/19/13**
Tabeguache	**Sawatch**	**14162**	**Blank Gulch**	**E Ridge - Shavano**	**2.0**	**7/19/13**
Crest. Pk	**Sangre de Cristo**	**14298**	**Lower South Colony**	**South Face**	**3.0**	**8/21-22/13**
Crest. Needle	**Sangre de Cristo**	**14201**	**Lower South Colony**	**South Face**	**3.0**	**8/21-22/13**

Table 19 (continued).

Peak	Range	Elevation*	Trailhead**	Route**	Class	Date Climbed
Humboldt	**Sangre de Cristo**	**14069**	**Lower South Colony**	**West Ridge**	**2.0**	**8/21/13**
Challenger	**Sangre de Cristo**	**14084**	**Willow and S Crestone**	**North Slopes**	**2.5**	**8/20/13**
Kit Carson	**Sangre de Cristo**	**14169**	**Willow and S Crestone**	**West Ridge**	**3.0**	**8/20/13**
Blanca	**Sangre de Cristo**	**14349**	**Lake Como**	**Northwest Face**	**2.0**	**8/24-25/13**
Little Bear	**Sangre de Cristo**	**14040**	**Lake Como**	**West Ridge**	**4.0**	**8/24+26/13**
Ellingwood	**Sangre de Cristo**	**14049**	**Lake Como**	**South Face**	**2.0**	**8/24-25/13**
Lindsey	**Sangre de Cristo**	**14047**	**Lily Lake**	**North Face**	**2.5**	**8/23/13**
Culebra	**Sangre de Cristo**	**14051**	**Culebra Ranch 4WD**	**Northwest Ridge**	**2.0**	**8/24/13**
Capitol	**Elk**	**14141**	**Cap Creek/Ditch Trail**	**Northeast Ridge**	**4.0**	**8/5-6/13**
Snowmass	**Elk**	**14096**	**Maroon-Snowmass**	**East Slopes**	**3.0**	**7/31/13**
S. Maroon	**Elk**	**14162**	**Maroon Lake**	**South Ridge**	**3.0**	**7/30/13**
N. Maroon*	**Elk**	**14019**	**Maroon Lake**	**Northeast Ridge**	**4.0**	**7/30/13**
Pyramid	**Elk**	**14023**	**Maroon Lake**	**Northeast Ridge**	**4.0**	**8/3/13**
Castle	**Elk**	**14269**	**Castle Creek**	**Northeast Ridge**	**2.0**	**7/21/13**
Conundrum*	**Elk**	**14064**	**Castle Creek**	**South Ridge**	**2.0**	**7/21/13**
San Luis	**San Juan**	**14019**	**Stewart Creek**	**East Slopes**	**1.0**	**8/17/13**
Uncompahgre	**San Juan**	**14314**	**Nellie Creek 4WD**	**East Slopes**	**2.0**	**8/14/13**
Wetterhorn	**San Juan**	**14020**	**Matterhorn Creek**	**Southeast Ridge**	**3.0**	**8/15/13**
Redcloud	**San Juan**	**14037**	**S Creek-Grizzly Gulch**	**Northeast Ridge**	**2.0**	**8/16/13**
Sunshine	**San Juan**	**14006**	**S Creek-Grizzly Gulch**	**North Slopes**	**2.0**	**8/16/13**
Handies	**San Juan**	**14053**	**American Basin**	**West Slopes**	**1.0**	**8/15/13**
Windom	**San Juan**	**14092**	**Needleton**	**West Ridge**	**2.5**	**8/11-12/13**
Sunlight	**San Juan**	**14064**	**Needleton**	**South Slopes**	**4.0**	**8/11-12/13**
Eolus	**San Juan**	**14089**	**Needleton**	**Northeast Ridge**	**3.0**	**8/11-12/13**
N. Eolus*	**San Juan**	**14044**	**Needleton**	**South Spine**	**3.0**	**8/11-12/13**
Sneffels	**San Juan**	**14155**	**YB Basin mid-4WD**	**South Slopes**	**2.5**	**8/8/13**
Wilson Pk	**San Juan**	**14024**	**Rock of Ages**	**West Ridge**	**3.0**	**8/9/13**
Mt. Wilson	**San Juan**	**14250**	**Rock of Ages**	**North Slopes**	**4.0**	**8/10/13**
El Diente*	**San Juan**	**14164**	**Rock of Ages**	**North Slopes**	**3.0**	**8/9/13**

*Based on North American Vertical Datum of 1988; **Trailheads and standard routes from Roach (2011); Underlined cells indicate differences from Kedrowski (2006).

Table 20

Fourteener trail usage class comparison between annual ranges of 1995-2004 (Old; Kedrowksi 2006, 2009) and 2005-2012 (New)

FEDI Rank	Pk.	Range	Old	New	FEDI Rank	Pk.	Range	Old	New
1	Evans	Front	HI (1)	HI (1)	30	Elbert	Sawatch	HI (1)	HI (1)
2	Longs	Front	HI (1)	HI (1)	31	Harvard	Sawatch	HI (1)	HI (1)
3	Blanca	Sangre de Cristo	HI (1)	HI (1)	32	Crest. Pk	Sangre de Cristo	LO (3)	LO (3)
4	Castle	Elk	HI (1)	HI (1)	33	Bross	Tenmile/Mosquito	HI (1)	HI (1)
5	Pikes	Front	HI (1)	HI (1)	34	*Conundrum**	Elk	LO (3)	LO (3)
6	Humboldt	Sangre de Cristo	HI (1)	HI (1)	35	Uncompahgre	San Juan	HI (1)	HI (1)
7	Democrat	Tenmile/Mosquito	HI (1)	HI (1)	36	Challenger	Sangre de Cristo	MOD (2)	MOD (2)
8	Columbia	Sawatch	HI (1)	HI (1)	37	Kit Carson	Sangre de Cristo	MOD (2)	MOD (2)
9	Antero	Sawatch	HI (1)	HI (1)	38	Little Bear	Sangre de Cristo	LO (3)	LO (3)
10	Sherman	Tenmile/Mosquito	HI (1)	HI (1)	39	*N. Eolus**	San Juan	LO (3)	MOD (2)
11	Ellingwood	Sangre de Cristo	LO (3)	LO (3)	40	Quandary	Tenmile/Mosquito	HI (1)	HI (1)
12	Sneffels	San Juan	MOD (2)	HI (1)	41	Shavano	Sawatch	MOD (2)	HI (1)
13	Wilson Pk	San Juan	MOD (2)	MOD (2)	42	Redcloud	San Juan	HI (1)	HI (1)
14	*Cameron**	Tenmile/Mosquito	MOD (2)	HI (1)	43	Sunshine	San Juan	HI (1)	HI (1)
15	Huron	Sawatch	MOD (2)	MOD (2)	44	Wetterhorn	San Juan	MOD (2)	MOD (2)
16	Sunlight	San Juan	MOD (2)	MOD (2)	45	Tabeguache	Sawatch	MOD (2)	MOD (2)
17	Torreys	Front	HI (1)	HI (1)	46	La Plata	Sawatch	MOD (2)	MOD (2)
18	Windom	San Juan	MOD (2)	MOD (2)	47	San Luis	San Juan	HI (1)	HI (1)
19	Eolus	San Juan	MOD (2)	MOD (2)	48	Handies	San Juan	HI (1)	HI (1)
20	Yale	Sawatch	HI (1)	HI (1)	49	*N. Maroon**	Elk	LO (3)	LO (3)
21	Lincoln	Tenmile/Mosquito	MOD (2)	HI (1)	50	Missouri	Sawatch	MOD (2)	MOD (2)
22	Grays	Front	HI (1)	HI (1)	51	S. Maroon	Elk	LO (3)	LO (3)
23	Massive	Sawatch	HI (1)	HI (1)	52	Oxford	Sawatch	MOD (2)	MOD (2)
24	Lindsey	Sangre de Cristo	LO (3)	LO (3)	53	Belford	Sawatch	HI (1)	HI (1)
25	Princeton	Sawatch	HI (1)	HI (1)	54	Capitol	Elk	LO (3)	LO (3)
26	Holy Cross	Sawatch	MOD (2)	MOD (2)	55	Mt. Wilson	San Juan	LO (3)	MOD (2)
27	Pyramid	Elk	MOD (2)	MOD (2)	56	Snowmass	Elk	LO (3)	LO (3)
28	Crest. Needle	Sangre de Cristo	LO (3)	MOD (2)	57	*El Diente**	San Juan	LO (3)	MOD (2)
29	Bierstadt	Front	HI (1)	HI (1)	58	Culebra	Sangre de Cristo	LO (3)	LO (3)

*Unofficial Fourteeners; Underlined peaks changed trail usage class

Archival Data

Peak Name:

Mountain Range:

I.S.	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999
5														
6														
7														
8														
9														
10														
Tot->														
O.S.														
11														
12														
1														
2														
3														
4														
Tot->														

I.S.	1998	1997	1996	1995	1994	1993	1992	1991	1990	1989	1988	1987	1986	1985
5														
6														
7														
8														
9														
10														
Tot->														
O.S.														
11														
12														
1														
2														
3														
4														
Tot->														

Figure 55. Archival data form used to capture trail usage data from 2005-2012.

Field Data

Peak Name:__________ Range:__________ Route:__________ Date of Climb:__________

PR_{coord}:__________ TH_{coord}:__________ TH_{elev}:__________ ND_{mi}:__________

$Route_{mi}$:__________ EG_{ft}:__________ $Summit_{coord}$:__________ $Summit_{elev}$:__________

IT: Informal Trails (spurs/braids) **Total:**______ **CS**: Campsites/FR | | | | | | **Total:**______

%4WD: Route Length as 4WD road **Total Length:**________

Instance #->	1	2	3	4	5	6	7	8	9	10	11	12
TM 1												
TM 2												

%DW: Overly wide trail (>5 feet; TM) **Total Length:**________

Instance #->	1	2	3	4	5	6	7	8	9	10	11	12
TM 1												
TM 2												
Instance #->	13	14	15	16	17	18	19	20	21	22	23	24
TM 1												
TM 2												

SB: Switchbacks | | | | | | | | | | **Total:**________

SBN: Switchbacks Needed (Elevation and TM) **Total:**________

Instance #->	1	2	3	4	5	6	7	8	9	10	11	12
Elevation 1												
Elevation 2												
Distance (ft)												
TM 1												
TM 2												
Length (mi)												

C4: Class IV Segments (**Photograph and Waypoint**) | | | | | | | **Total Count:**______

Notes:____

Figure 56. Field data collection form for absolute impact indicators and explanatory variables.

Field Data

Peak Name:__________ Range:__________

%TM/ELNT: Route Length w/no physical trail (Elevations and TM) **Total Distance:**______ **Total Length:**______

Instance #->	1	2	3	4	5	6	7	8	9	10	11	12
Elevation 1												
Elevation 2												
Distance (ft)												
TM 1												
TM 2												
Length (mi)												

%RMNT: Route Length w/no trail or markers/cairns (Elevations and TM) **Total Length:**______

Instance #->	1	2	3	4	5	6	7	8	9	10	11	12
TM 1												
TM 2												
Length (mi)												

Notes:__________

Figure 57. Field data collection form for potential impact indicators.

Table 21

Comparison of iFEDI scores from 2005 and 2013 for all 58 peaks

2005 Rank	Peak	Range	iFEDI 2005	iFEDI 2013	2005 Rank	Peak	Range	iFEDI 2005	iFEDI 2013
1	**Evans**	**Front**	**1.4871**	**0.9227**	30	**Elbert**	**Sawatch**	**0.3566**	**0.2324**
2	**Longs**	**Front**	**0.8532**	**1.8661**	31	**Harvard**	**Sawatch**	**0.3289**	**0.2274**
3	**Blanca**	**Sangre de Cristo**	**0.7771**	**0.6431**	32	**Crest. Pk**	**Sangre de Cristo**	**0.3268**	**-0.6052**
4	**Castle**	**Elk**	**0.7742**	**0.4967**	33	**Bross**	**Tenmile/Mosquito**	**0.3232**	**0.2115**
5	**Pikes**	**Front**	**0.6259**	**0.9793**	34	***_Conundrum*_***	**Elk**	**0.3212**	**-0.2850**
6	**Humboldt**	**Sangre de Cristo**	**0.6257**	**0.3082**	35	**Uncompahgre**	**San Juan**	**0.3212**	**0.1715**
7	**Democrat**	**Tenmile/Mosquito**	**0.5930**	**0.6892**	36	**Challenger**	**Sangre de Cristo**	**0.3124**	**0.3782**
8	**Columbia**	**Sawatch**	**0.5605**	**0.6411**	37	**Kit Carson**	**Sangre de Cristo**	**0.3074**	**0.3274**
9	**Antero**	**Sawatch**	**0.5516**	**0.9644**	38	**Little Bear**	**Sangre de Cristo**	**0.3045**	**-1.4024**
10	**Sherman**	**Tenmile/Mosquito**	**0.5409**	**0.2329**	39	***_N. Eolus*_***	**San Juan**	**0.2783**	**0.3064**
11	**Ellingwood**	**Sangre de Cristo**	**0.4750**	**-0.1826**	40	**Quandary**	**Tenmile/Mosquito**	**0.2738**	**0.5766**
12	**Sneffels**	**San Juan**	**0.4683**	**1.8637**	41	**Shavano**	**Sawatch**	**0.2620**	**0.5877**
13	**Wilson Pk**	**San Juan**	**0.4588**	**0.2840**	42	**Redcloud**	**San Juan**	**0.2547**	**0.0341**
14	***_Cameron*_***	**Tenmile/Mosquito**	**0.4456**	**0.6977**	43	**Sunshine**	**San Juan**	**0.2507**	**1.8586**
15	**Huron**	**Sawatch**	**0.4417**	**0.1260**	44	**Wetterhorn**	**San Juan**	**0.2419**	**0.3179**
16	**Sunlight**	**San Juan**	**0.4390**	**0.4074**	45	**Tabeguache**	**Sawatch**	**0.2398**	**0.6933**
17	**Torreys**	**Front**	**0.4291**	**0.5733**	46	**La Plata**	**Sawatch**	**0.2341**	**0.0746**
18	**Windom**	**San Juan**	**0.4242**	**0.5458**	47	**San Luis**	**San Juan**	**0.2318**	**0.0003**
19	**Eolus**	**San Juan**	**0.4207**	**0.3821**	48	**Handies**	**San Juan**	**0.2175**	**0.1306**
20	**Yale**	**Sawatch**	**0.4124**	**0.1824**	49	***_N. Maroon*_***	**Elk**	**0.2154**	**-1.0872**
21	**Lincoln**	**Tenmile/Mosquito**	**0.4099**	**0.6028**	50	**Missouri**	**Sawatch**	**0.1852**	**0.1067**
22	**Grays**	**Front**	**0.4057**	**0.1460**	51	**S. Maroon**	**Elk**	**0.1313**	**-1.2150**
23	**Massive**	**Sawatch**	**0.3993**	**0.0833**	52	**Oxford**	**Sawatch**	**0.1137**	**0.0464**
24	**Lindsey**	**Sangre de Cristo**	**0.3988**	**-0.1873**	53	**Belford**	**Sawatch**	**0.1000**	**0.0700**
25	**Princeton**	**Sawatch**	**0.3882**	**0.2453**	54	**Capitol**	**Elk**	**-0.3710**	**-1.3365**
26	**Holy Cross**	**Sawatch**	**0.3846**	**0.2782**	55	**Mt. Wilson**	**San Juan**	**-0.4424**	**0.6187**
27	**Pyramid**	**Elk**	**0.3766**	**0.4863**	56	**Snowmass**	**Elk**	**-0.4442**	**-1.1497**
28	**Crest. Needle**	**Sangre de Cristo**	**0.3694**	**0.5326**	57	***_El Diente*_***	**San Juan**	**-0.5702**	**0.3383**
29	**Bierstadt**	**Front**	**0.3661**	**1.6163**	58	**Culebra**	**Sangre de Cristo**	**-2.8025**	**-0.9395**

Underlined peaks changed trail usage class

Table 22

Comparison of FEDI scores from 2005 and 2013 for all 58 peaks

2005 Rank	Peak	Range	FEDI 2005	FEDI 2013	2005 Rank	Peak	Range	FEDI 2005	FEDI 2013
1	**Evans**	**Front**	**1.6669**	**2.6132**	30	**Shavano**	**Sawatch**	**0.4100**	**2.4878**
2	**Longs**	**Front**	**0.9657**	**3.9030**	31	**Lindsey**	**Sangre de Cristo**	**0.4074**	**-3.1673**
3	**Pikes**	**Front**	**0.8470**	**2.5281**	32	**Handies**	**San Juan**	**0.3864**	**2.8427**
4	**Castle**	**Elk**	**0.7801**	**2.4800**	33	**Tabeguache**	**Sawatch**	**0.3835**	**1.1043**
5	**Democrat**	**Tenmile/Mosquito**	**0.7399**	**2.5066**	34	**Challenger**	**Sangre de Cristo**	**0.3708**	**0.8080**
6	**Sherman**	**Tenmile/Mosquito**	**0.6643**	**2.4515**	35	**Redcloud**	**San Juan**	**0.3676**	**2.7670**
7	**Columbia**	**Sawatch**	**0.6504**	**2.5350**	36	**San Luis**	**San Juan**	**0.3565**	**2.8473**
8	**Blanca**	**Sangre de Cristo**	**0.6372**	**3.0241**	37	**Sunshine**	**San Juan**	**0.3458**	**4.6077**
9	**Bierstadt**	**Front**	**0.6334**	**3.2070**	38	**Ellingwood**	**Sangre de Cristo**	**0.3397**	**-2.5180**
10	***Cameron****	**Tenmile/Mosquito**	**0.6160**	**2.6014**	39	**Kit Carson**	**Sangre de Cristo**	**0.3395**	**0.8091**
11	**Grays**	**Front**	**0.6111**	**1.4704**	40	**Missouri**	**Sawatch**	**0.3342**	**0.5641**
12	**Lincoln**	**Tenmile/Mosquito**	**0.5955**	**2.5245**	41	**Wetterhorn**	**San Juan**	**0.3199**	**0.9665**
13	**Torreys**	**Front**	**0.5931**	**2.0542**	42	**Oxford**	**Sawatch**	**0.3137**	**0.3861**
14	**Bross**	**Tenmile/Mosquito**	**0.5621**	**2.0096**	43	**Belford**	**Sawatch**	**0.3102**	**1.7187**
15	**Antero**	**Sawatch**	**0.5583**	**2.7939**	44	***Conundrum****	**Elk**	**0.3095**	**-2.2626**
16	**Humboldt**	**Sangre de Cristo**	**0.5493**	**2.6244**	45	**Windom**	**San Juan**	**0.2987**	**1.1801**
17	**Yale**	**Sawatch**	**0.5405**	**1.8384**	46	**Eolus**	**San Juan**	**0.2864**	**1.0324**
18	**Quandary**	**Tenmile/Mosquito**	**0.5282**	**1.9082**	47	**Sunlight**	**San Juan**	**0.2645**	**1.1326**
19	**Elbert**	**Sawatch**	**0.5185**	**1.6980**	48	**Crest. Needle**	**Sangre de Cristo**	**0.2478**	**1.0517**
20	**Sneffels**	**San Juan**	**0.5116**	**4.6749**	49	**Crest. Pk**	**Sangre de Cristo**	**0.2246**	**-3.2154**
21	**Huron**	**Sawatch**	**0.4990**	**0.5248**	50	***N. Maroon****	**Elk**	**0.2114**	**-3.5270**
22	**Princeton**	**Sawatch**	**0.4773**	**2.0702**	51	***N. Eolus****	**San Juan**	**0.1410**	**0.9484**
23	**Holy Cross**	**Sawatch**	**0.4758**	**0.7167**	52	**S. Maroon**	**Elk**	**0.1052**	**-3.5350**
24	**Massive**	**Sawatch**	**0.4754**	**2.2914**	53	**Little Bear**	**Sangre de Cristo**	**0.1014**	**-4.2521**
25	**Wilson Pk**	**San Juan**	**0.4498**	**0.9070**	54	**Capitol**	**Elk**	**-0.3898**	**-4.6552**
26	**Harvard**	**Sawatch**	**0.4454**	**2.3962**	55	**Mt. Wilson**	**San Juan**	**-0.4489**	**1.3156**
27	**Pyramid**	**Elk**	**0.4311**	**0.9446**	56	**Snowmass**	**Elk**	**-0.4665**	**-4.0573**
28	**La Plata**	**Sawatch**	**0.4268**	**0.4356**	57	***El Diente****	**San Juan**	**-0.5471**	**0.9940**
29	**Uncompahgre**	**San Juan**	**0.4107**	**3.1912**	58	**Culebra**	**Sangre de Cristo**	**-2.6719**	**-3.9038**

Underlined peaks changed trail usage class

Table 23

FTII scores from 2013

Rank	Peak	Range	FTII	Rank	Peak	Range	FTII
1	**Democrat**	**Tenmile-Mosquito**	**2.1290**	30	**Sneffels**	**San Juan**	**0.6083**
2	***Cameron****	**Tenmile-Mosquito**	**2.0466**	31	**Sherman**	**Tenmile-Mosquito**	**0.5995**
3	**Lincoln**	**Tenmile-Mosquito**	**1.8096**	32	**Blanca**	**Sangre de Cristo**	**0.5840**
4	**Longs**	**Front**	**1.7171**	33	**Missouri**	**Sawatch**	**0.5816**
5	**Shavano**	**Sawatch**	**1.6253**	34	**Evans**	**Front**	**0.5783**
6	**Bross**	**Tenmile-Mosquito**	**1.4392**	35	**Holy Cross**	**Sawatch**	**0.5694**
7	**Tabeguache**	**Sawatch**	**1.3323**	36	**Ellingwood**	**Sangre de Cristo**	**0.5694**
8	**Columbia**	**Sawatch**	**1.2861**	37	**Handies**	**San Juan**	**0.5647**
9	**Bierstadt**	**Front**	**1.1360**	38	**S. Maroon**	**Elk**	**0.5417**
10	**Elbert**	**Sawatch**	**1.0965**	39	**Crest. Needle**	**Sangre de Cristo**	**0.5299**
11	***N. Eolus****	**San Juan**	**1.0665**	40	**Antero**	**Sawatch**	**0.5115**
12	**Eolus**	**San Juan**	**1.0469**	41	**Crest. Pk**	**Sangre de Cristo**	**0.4928**
13	**Quandary**	**Tenmile-Mosquito**	**1.0382**	42	**Sunshine**	**San Juan**	**0.4826**
14	**Yale**	**Sawatch**	**0.9748**	43	**Pikes**	**Front**	**0.4590**
15	**Windom**	**San Juan**	**0.9634**	44	**Pyramid**	**Elk**	**0.4395**
16	**Belford**	**Sawatch**	**0.9192**	45	**Castle**	**Elk**	**0.3898**
17	**Sunlight**	**San Juan**	**0.9192**	46	***Conundrum****	**Elk**	**0.3789**
18	**Lindsey**	**Sangre de Cristo**	**0.8159**	47	**Uncompahgre**	**San Juan**	**0.3763**
19	**Challenger**	**Sangre de Cristo**	**0.8111**	48	**Humboldt**	**Sangre de Cristo**	**0.3681**
20	**Harvard**	**Sawatch**	**0.8085**	49	**Wetterhorn**	**San Juan**	**0.3584**
21	**Capitol**	**Elk**	**0.7993**	50	**La Plata**	**Sawatch**	**0.3452**
22	**Kit Carson**	**Sangre de Cristo**	**0.7924**	51	**Snowmass**	**Elk**	**0.3285**
23	**Torreys**	**Front**	**0.7675**	52	**Massive**	**Sawatch**	**0.3038**
24	**Oxford**	**Sawatch**	**0.7539**	53	**Redcloud**	**San Juan**	**0.2703**
25	**Princeton**	**Sawatch**	**0.7507**	54	**Wilson Pk**	**San Juan**	**0.1305**
26	**Grays**	**Front**	**0.7391**	55	**Culebra**	**Sangre de Cristo**	**0.0908**
27	***N. Maroon****	**Elk**	**0.7213**	56	**Mt. Wilson**	**San Juan**	**0.0872**
28	**Little Bear**	**Sangre de Cristo**	**0.6914**	57	***El Diente****	**San Juan**	**0.0305**
29	**Huron**	**Sawatch**	**0.6265**	58	**San Luis**	**San Juan**	**0.0269**

Double underlined peaks had reconstruction project completed after 2005; Single underlined peaks pre-2005

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