Climate, Adventure, and Colorado: Analyzing the effects of climate change on adventure tourism in Colorado, with a case study on Rocky Mountain National Park

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Climate, Adventure, and Colorado:
Analyzing the effects of climate change on adventure tourism in Colorado, with a case study on Rocky Mountain National Park.

Defended November 2\textsuperscript{nd}, 2016

By
Aaron Charney
University of Colorado Boulder

A thesis to be submitted to the University of Colorado Boulder
In partial fulfillment
Of the requirements to receive Honors designation in Environmental Studies
2016

Thesis Advisors

\textit{Dale Miller, Committee Chair, Department of Environmental Studies}
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# Table of Contents

Abstract .......................................................................................................................... iii
Preface ............................................................................................................................ iv
Introduction ..................................................................................................................... 1
Background ...................................................................................................................... 4
  Defining Outdoor and Adventure Tourism ................................................................. 4
  Growth of Adventure and Outdoor Tourism ............................................................... 5
  Climate Change and Outdoor Tourism ...................................................................... 8
Literature Review ........................................................................................................... 11
Methodology .................................................................................................................. 14
Data and Results ........................................................................................................... 20
Analysis ......................................................................................................................... 32
Discussion ..................................................................................................................... 47
Further Research ......................................................................................................... 55
Conclusion .................................................................................................................... 57
Bibliography .................................................................................................................. 58
Abstract

This project looks at the relationship between climate and outdoor tourism in Colorado. In a time where rates of outdoor and adventure tourism are increasing, and the climate is also changing, the relationship between these two variables is important. Focusing on a case study of Rocky Mountain National Park (RMNP), this project looks at past trends of park visitation and climate, analyzing how these variables have fluctuated together. Visitation data was collected from the National Park Service Database. Climate data, represented as measurements of air temperature, snow depth, and precipitation increments, were collected from SNOTEL weather stations through the Natural Resources Conservation Service Report Generator. Multiple bivariate correlations and regressions were run to analyze the data. Visitation and climate data were compared with sales tax revenue data from surrounding counties through regression analysis. These analyses were done in order to analyze the influence of climate on economic measures through the intermediary relationship with tourism. A negative correlation was found between snow depth and visitation, a positive correlation between air temperature and visitation, and an insignificant relationship between precipitation and visitation. The final tests revealed a positive relationship between visitation and the economies of surrounding towns. Further impacts of climate change on RMNP are discussed, and the study is put into context with other research. The conclusions of this thesis finds that while climate change can have a significant relationship with outdoor tourism and related economies, the extent and direction of these relationships are determined by the specific type of activity and the ecosystem in which tourism takes place.
Preface

This thesis project is being submitted to the University of Colorado as part of the requirements to receive honors designation in the Undergraduate Environmental Studies Program. The idea for this thesis came to me as I was hiking the Inca Trail in Peru. In complete awe of my natural surroundings, I was struck by the possibility that climate change could potentially alter ecosystems in a way that could cause future generations to not be able to experience the world’s natural beauty in the same way that I am today. Upon returning from my trip in Peru, and being reminded of the splendor of my home state of Colorado, this idea resonated with me even further. I combined my love for Colorado and experiencing other natural wonders in the world, with my question of how climate could impact the abilities of tourists to experience the world, in order to come up with my research question.

I would like to extend gratitude to my advisors Dale Miller, Amanda Carrico, and Keith Stockton, for their relentless help throughout this process. I would also like to thank my family and friends for pushing me to challenge myself in pursuing this project, and for their support in making the completion of this thesis possible.
Introduction

In recent decades there has been a global increase in rates of international tourism. As technology continues to advance in the 21st century, it becomes increasingly possible for people to travel to far destinations and experience different parts of the world. Along with a greater ability to visit different places, societal changes have led to an increase in the desire to travel. These factors, among others, have led to the increase in global tourism. Within the tourism industry, there is a specific sector that revolves around outdoor destinations, and has a large emphasis on the environment. Outdoor and adventure tourism, including activities such as backpacking, skiing, hiking, rafting and many more, represent this specific sector of tourism that has experienced an especially significant rise in recent decades.

As tourism has increased, the world has been facing another significant transformation: climate change. Scientific research has empirically shown that since the industrial revolution, CO2 concentrations in the atmosphere have increased at a rate much faster than observed in previous periods. Higher concentrations of CO2 have caused a warming atmosphere, and a multitude of other consequences that cascade through ecosystems. These consequences of climate change have been found to alter ecosystems, and it has been predicted that these effects could lead to drastic alterations of the environment on many levels. Since outdoor tourism has its’ foundation in a relationship with the environment and natural world, these effects of climate change must in some way have an impact on the industry. Thus,
the research question that this thesis seeks to answer is: what are the effects of climate on outdoor tourism, and further, how does a changing climate affect the rates of tourism to different destinations.

In order to analyze the relationship between climate and outdoor tourism, this thesis looks at a case study of Rocky Mountain National Park. Mountain ecosystems represent a destination that is both increasingly popular for tourists, and extremely vulnerable to climate change. Therefore, by focusing on RMNP as a case study, the main objective of this thesis is to understand the relationship between recent climate and outdoor tourism trends.

In order to answer the research question, this thesis uses methods of statistical analysis to examine the relationships between the variables in question. Climate data, comprised of measurements of air temperature, snow depth, and precipitation, was collected for the years of 2001-2016. Rates of outdoor tourism in this project are measured by visitation data to RMNP ranging from 2001-2016 as well. These variables are compared individually through bivariate correlations, and then compared in a comprehensive model with multiple regressions. After establishing the relationship between climate and visitation, this project looks at how these changing variables are related to the economies of the counties surrounding RMNP.

Overall, this thesis project hopes to establish a framework by which the relationship between several environmental and social variables can be compared. While this project only provides results for the relationship of these variables for Rocky Mountain National Park, the hope is that the ideas expressed and the
methods used could be implemented in other cases to analyze these relationships on a global scale.
Background

Defining Outdoor and Adventure Tourism

When people travel the world, whether it is to some place an hour from home, or somewhere on the opposite side of the globe, they do so in order to engage with or experience something different. The vast array of different cultures, landscapes, and multitudes of different experiences that our world has to offer is one of the reasons why people travel and engage in the practice of tourism. Loosely defined, tourism is the result of the goods and services that take place and are offered somewhere that is set apart by distance from one’s usual home (Hudson; 2003). Tourism has recently been noted as one of the fastest growing economic sectors, and one of the largest economic activities in the world (World Tourism Organization, 2014; Hudson, 2003). With this in mind, it is important to break down tourism, and look at the different aspects of the industry, including the many different types of tourism.

There are a variety of forms of tourism that have been studied and are currently practiced. Among these, are mass tourism, adventure tourism, sustainable tourism, conservation tourism, community-based tourism, volunteer tourism, and ecotourism (World Tourism Organization, 2014). Amid the various types of tourism, an encompassing category can be assimilated from adventure, sport, and health tourism. These three types of tourism are related in that they have similar motivations behind them, and that they all incorporate values that can lead to improvement of the quality of one’s life, based on active participation in an outdoor environment (Hall, 1992). Although somewhat similar, an interesting sector of
tourism to look at, especially as it is growing quickly both in demand and supply, is that of adventure tourism, otherwise known as sport or outdoor tourism.

Adventure tourism has been defined as travel from one’s home with the intention to participate in sport or recreation, possibly for competition (Hudson, 2003). Through the 2014 Global Report on Adventure Tourism, the World Tourism Organization has differentiated adventure tourism from other types of tourism by establishing specific criteria. In working with the Adventure Travel and Trade Association (ATTA), the 2014 report states that in order to be considered adventure or outdoor tourism, a trip must include at least two of the following criterion: physical activity, a natural environment, and cultural immersion (World Tourism Organization, 2014). This definition makes clear how adventure tourism is distinct from other types of tourism, including mass tourism, which would include things like cruises, theme parks, and urban sight-seeing.

In furthering the definition and understanding of adventure tourism, there are other key aspects that differentiate it from other types of tourism. Four key distinctions have been proposed. Adventure tourism is resilient, it attracts high value customers, it supports local communities, and it adheres to principles that support sustainable practices (World Tourism Organization, 2014). It is these aspects of adventure and outdoor tourism, along with a variety of societal changes, which have led to the recent growth of this specific sector.

**Growth of Adventure and Outdoor Tourism**
Rates of tourism as a whole, and particularly outdoor and adventure tourism, have increased in recent decades. In a ten-year period, from 1989-1999, worldwide
revenue from tourism increased from $221 billion to $445 billion (Gartner, 2000; WTO, 1999). There are a variety of hypothesis as to why rates of tourism have so dramatically increased in the past few decades. Amongst these postulations, researchers have pointed to changes in a variety of societal norms and values. These societal changes that have possibly had an effect on tourism include, but are not limited to: increased flexibility in work schedules and holidays; a greater desire for travel, leisure, and physical activities in our daily lives; higher numbers of commercial sectors offering inexpensive services; increased marketing of outdoor places as a setting to have a good time; and a growth in the variety of equipment that can allow anyone to enjoy leisure pursuits (Gartner, 2000). While all of these factors could have a correlation with the increase in the tourism sector as a whole, there could be more specific reasons as to why there has been a rise in adventure and outdoor tourism specifically.

As societal norms and values change, it has been found that tourists are now seeking outdoor activities and places more than ever before (Curtis, 2011). Studies have found that while tourism as a whole has increased considerably, as seen in the over 100% increase in worldwide tourism revenue proposed in the aforementioned World Trade Organization (WTO) study, adventure tourism has grown even faster. In 2010, a study found that adventure travel accounted for $89 billion in tourism revenue. In 2012, the same study found that adventure tourism revenue had increased to $263 billion, making up nearly 40% of total travel (Adventure Travel Trade Association and George Washington University, 2013). Along with previously stated reasons for increasing global tourism, these increases in adventure tourism
have been attributed to an increase in departures to international destinations; an increase in the percent of travelers going on adventure trips; and an increase in disposable income and total spending (World Tourism Organization, 2014). Though these factors have all led to an increase in the desire for outdoor travel, there are changes that have made adventure travel much more accessible.

Much of adventure tourism and travel is based on the desire to push limits and explore the unknown. An increase in the accessibility of these risks and adventures has played a role in the rise of outdoor tourism. Increases in the amount of information about the previously unknown, along with new technologies that have helped mitigate the risk of adventures into this unknown, have worked towards making it so more people can engage in outdoor adventures. Drastic improvement in technology have increased the safety of travel itself (i.e. flying in an airplane), so people are now even further seeking to challenge the risks of outdoor and adventure activities (Kane and Tucker, 2004).

With people spending more time and money to travel in the outdoors and experience the environment, it is important to understand how outdoor tourism and the environment interact. There is research on the impacts that tourism and travel in general have on the environment. Research has shown that global tourism can have a variety of effects on various landscapes including alteration in land cover and use, increased energy usage, biotic exchange and extinction of certain species, the spread of diseases, and alteration in perceptions of the environment (Gossling, 2002). One of the most direct effects of tourism on the environment is caused by extensive energy use. A 2009 study on the impacts of tourism on the environment...
found that tourism caused 4.4% of global CO2 emissions (Peeters and Dubois, 2010). While these studies, and many others, show the impacts of tourism on the environment and their possible links to anthropogenic climate change, there is not as much research looking into the effects of this relationship in the opposite direction. In a time when people are increasingly engaging in outdoor and adventure tourism, which has the environment as its main attraction, and a time with observed climate change, it is also important to understand how climate change is affecting different places, and thus how it is affecting outdoor tourism to these places.

**Climate Change and Outdoor Tourism**

As people are increasingly traveling to destinations based on environment and outdoor qualities, it becomes increasingly important to understand how the climate and environment of these areas affects the desire of people to travel there. Tourists are increasingly taking into account factors such as wind, temperature, snow conditions, and humidity, along with other various weather and climate dynamics, when making their decision as to where to travel (Curtis et. al., 2011). As adventure tourism has its foundation in the environment, including specific landscapes and climates, as the climate changes, and thus landscapes start to change, it is possible that rates of outdoor tourism to certain areas will change as well.

There are a variety of climactic factors that could lead to a change in rates of outdoor tourism in different destinations and environments. On a global scale, it is predicted that with higher CO2 levels, the overall volume of tourism, the trends in
outdoor tourism, people’s satisfaction with their travel, and even the safety of some tourism will change (Smith, 1990). Researchers have made propositions as to how the climate will affect tourism, and how these effects should be analyzed. The major risk that faces tourism from climate change is the possibility that destination areas will change in a way that could make them less attractive to tourists. In assessing how these environments might change, it has been proposed that to see the effects on tourism, it is important to look at how tourist destinations’ attractiveness will change in relation to competing destinations (World Tourism Organization, 2014; Hamilton et. al., 2005).

The effects of climate change on tourism by alteration of destination environments, represents indirect effect. Examples of indirect effects are sea level rise and coastal erosion, decreased snowpack and shorter season length, reduction in air quality, and reduction in species diversity in ecosystems like coral reefs. Climate change is also predicted to have direct impacts on tourism by influencing tourists decisions as to what type of climate and environment they want to visit (Viner and Agnew, 1999). Due to climate change becoming ever more apparent, its’ effects on the environment and thus tourism, both directly and indirectly, will start to become more evident also. It has been stated that the continued success of tourism around the globe is closely related to the preservation and enhancement of the natural environment and climate (Viner and Agnew, 1999). It is now more important than ever to understand how climate change is affecting various ecosystems, in order to understand how it will affect tourism to these areas, and thus affect many more parts of society, including culturally and economically.
While these effects can be seen at a broad and global scale, the effects are more easily analyzed and observed on a small scale in particular ecosystems. There are many places around the world that are popular outdoor tourism destinations and also represent fragile ecosystems in which the effects of climate change have already been observed. Amongst these different ecosystems are plains ecosystems, coral reefs, mountain and alpine ecosystems, and rainforests, amongst many more. While many places with these various ecosystems could be used as case studies to research the direct and indirect effects of climate change on tourism, one place that has a diverse array of ecosystems that are seen to be affected by climate change, and also a booming outdoor and adventure tourism industry, is Colorado.
Literature Review

While much of this study focuses on the relationship between climate change and visitation, it is important to understand previous research that points to evidence of recent climate change. A multitude of climate models have hypothesized many different outcomes based on varying climate scenarios. Though the various scenarios are based on varying estimates of CO2 emissions and other environmental factors, for the purposes of this study, it is important to comprehensively understand what is causing climate change, and what the expected effects are.

While the global environment naturally goes through warming and cooling cycles, recent warming has been so extreme, that scientists have pointed to causes other than natural processes. Since the industrial revolution, greenhouse gas (GHG) concentrations have increased at a rate that is unprecedented in recent geologic history (Pachauri et. al., 2015). The aforementioned increase in GHG concentrations can be partially attributed to an increase in anthropogenic emissions since the industrial revolution.

Anthropogenic climate change has greatly been caused through emissions of particular chemicals that cause a “greenhouse effect” on the global climate. Though from varying industries and sources, the main chemicals causing recent warming are carbon dioxide (CO2), methane, (CH4), and nitrous oxide (N2O). Anthropogenic emissions have been so large that since 1750, atmospheric concentrations of carbon dioxide have increased by 40%, methane has increased by 150%, and nitrous oxide has increased by 20%. As concentrations of these chemicals increase, they decrease
the ability of heat to escape earth’s atmosphere, causing the ‘greenhouse effect’ that is a major driver of climate change (Pachauri et al., 2015).

Increased GHG concentrations and a warming atmosphere can have a multitude of effects that can cascade through ecosystems. Though climate warming is a global problem, the effects are spatially heterogeneous and vary with diverse ecological responses (Walther et al., 2002). Amongst the observed impacts of climate change, some of the most noticeable have been atmospheric and oceanic warming. A compilation of data sets and models found that air and ocean temperatures globally have increased on average .78 degrees Celsius since 1880 (Pachauri et al., 2015). With changes in sea and air temperatures, come changes in chemical and biological processes in ecosystems across the world.

Recent upsurges in seawater temperatures have caused chemical changes in the ocean that can lead to the death of many organisms. 1998 experienced one of the worst global coral bleaching events, with complete loss of live coral in many parts of the world. This was caused by just a slight increase (1-2 degrees Celsius) in water temperatures (Hoegh-Guldberg, 1999). Further impacts of climate change include the risk of loss of entire ecosystems, a decrease in biodiversity, shifts in ecological communities and the phenology of various organisms, and much more. Climate change could also have direct impacts on human society, with increased risk of food and water insecurity, and risks associated with extreme weather events (Walther et al., 2002; Pachauri et al., 2015).

The potential impacts of global warming span from those discussed above, to many more effects on both natural ecosystems and human societies. As
environmental consequences of global warming have already been observed and recorded in many places across the globe, it is now important to see how this is affecting human society and culture. This project analyzes these impacts by looking at the relationship between observed climate change and human activities.
Methodology

To look at the relationship between climate and outdoor tourism in Colorado, the methods for this thesis involve running multiple statistical tests, including bivariate correlations and multiple regressions, between meteorological, park visitation, and economic data. Meteorological data includes monthly measurements of snow depth, precipitation increments, and air temperature, from various locations in and around Rocky Mountain National Park. Park visitation data was obtained from the National Park Service database, and includes total monthly recreational visits to the park. The economic data used in this study includes sales tax revenue data from counties surrounding the park. All data used in this project range from August 2001 through May of 2016.

Meteorological data was collected using historical data from various SNOTEL station locations. This study uses data from 15 stations located inside, and in close proximity to the national park. These stations, with varying altitudes, latitudes, and longitudes, were chosen based on the criteria of either being in the national park, or with in close proximity, in order to gain a greater perspective of the regional
climate.

Figure 1: Map of Rocky Mountain National Park and locations of the 15 SNOTEL stations used for data collection in this study.
<table>
<thead>
<tr>
<th>Station Name and ID</th>
<th>Elevation (ft.)</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copeland Lake: ID 412</td>
<td>8,600</td>
<td>40.21</td>
<td>-105.57</td>
</tr>
<tr>
<td>Wild Basin: ID 1042</td>
<td>9,560</td>
<td>40.2</td>
<td>-105.6</td>
</tr>
<tr>
<td>Bear Lake: ID 322</td>
<td>9,500</td>
<td>40.31</td>
<td>-105.64</td>
</tr>
<tr>
<td>Phantom Valley: ID 688</td>
<td>9,030</td>
<td>40.4</td>
<td>-105.85</td>
</tr>
<tr>
<td>Never Summer: ID 1031</td>
<td>10,280</td>
<td>40.4</td>
<td>-105.96</td>
</tr>
<tr>
<td>Lake Irene: ID 565</td>
<td>10,700</td>
<td>40.41</td>
<td>-105.82</td>
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<tr>
<td>Willow Park: ID 870</td>
<td>10,700</td>
<td>40.43</td>
<td>-105.73</td>
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<tr>
<td>Joe Wright: ID 551</td>
<td>10,120</td>
<td>40.53</td>
<td>-105.89</td>
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<td>Hourglass Lake: ID 1122</td>
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<td>-105.63</td>
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<td>High Lonesome: ID 1187</td>
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<td>Long Draw Reservoir: ID 1123</td>
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<td>University Camp: ID 838</td>
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<td>Niwot: ID 663</td>
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<td>Stillwater Creek: ID 793</td>
<td>8,720</td>
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<td>Willow Creek Pass: ID 869</td>
<td>9,540</td>
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<td>-106.09</td>
</tr>
</tbody>
</table>

Table 1: Location information and station name of SNOTEL stations used in this study.

From these various stations, monthly snow depth, precipitation increment, and air temperature data was collected. Data was collected through the United States Department of Agriculture National Water and Climate Center Natural Resource Conservation Service Report Generator. For snow depth, three monthly data points were collected from each station. Snow measurements made on the first day, the median day, and the last day, of each month were collected. These were then aggregated and averaged to get a monthly average snow depth for each station. Once monthly averages were created for snow depth at each station, these were averaged together to create a monthly average snow depth for Rocky Mountain National Park. Monthly precipitation increments and air temperature were aggregated in a similar way. It is important to note that snow depth and precipitation increment are mutually exclusive, and measured separately. Average
monthly data for both of these meteorological variables was collected from SNOTEL reports. Once data for all 15 stations was collected, it was again averaged together in order to have average monthly measurements for RMNP from August 2001 through May of 2016.

Visitation data was collected from the National Park Service database. Monthly visitation data represents the total amount of recreational visits to the park per month. Data was given in monthly totals, so no averaging was necessary. The economic data used in this study is compiled of sales tax revenue from counties surrounding Rocky Mountain National Park. The towns of Estes Park and Granby are two of the largest towns that serve as ‘entrances’ to Rocky Mountain National Park, and are in Larimer and Grand County respectively. The economic measurements used in this study are thus sales tax revenue data from Larimer and Grand County. As with meteorological data, visitation and tax revenue data are monthly measurements ranging from August 2001 through May 2016.

Once all data was collected and aggregated, statistical tests were used to interpret relationships between the variables. All statistical tests were run using statistical analysis software SPSS. First, meteorological predictor variables (snow depth, precipitation, and air temperature) and visitation data were independently graphed to visualize trends and patterns through the past 15 years. Secondly, bivariate correlations were run between all three meteorological variables. This test was run in order to analyze how the changing climactic factors are related to one another. Correlation coefficients from this test are used to explain how these changing factors are related to each other, and to what degree they vary together.
Next, a multitude of bivariate correlations were run between the predictor variables and park visitation. The correlation coefficients and significance found from these tests are used to discuss the relationships between visitation and the meteorological variables independently. Next, three more bivariate correlations were run between the three predictor variables and visitation as the dependent variable. However, for this correlation, the test was controlled to only look at the correlation for summer months (May through August). This test was run to analyze if the predictor variables have a different correlation with visitation during the summer months, which tend to be months of highest visitation to Rocky Mountain National Park.

Using the same data, with visitation as the dependent variable and the three weather factors as independent predictor variables, a multiple linear regression was run. The results from this test are used to analyze the variation in visitation that is explained by the predictor variables both altogether and independently. This analysis will be conducted by looking at the $R^2$, Beta, and significance values.

Controlling for only summer months, and using the same variables, another multiple linear regression was run. Next, another regression using all three predictor variables was run, but this time, controlling to only look at the non-summer months. Both of these regressions are analyzed using correlation coefficients, beta values, and p-values for significance, and will be compared to each other in order to analyze if the predictor variables have a stronger influence on visitation during different periods of the year.
Finally, statistical tests were run incorporating economic data. Using sales tax revenue data from Grand and Larimer County, bivariate correlations were run comparing monthly visitation and sales tax data from Larimer and Grand County independently, and the tax data from the two counties combined. Through analysis of the correlation coefficients from these tests, the relationship between park visitation and the economies of surrounding counties is discussed. Next, a multiple regression was run with snow depth, precipitation, and air temperature as independent variables, and the sum of tax revenue data from the two counties as the dependent variable. From this test, the $R^2$ value, significance, and beta values are used to analyze the relationship between climate and economic measurements. The final statistical test ran for this project is a multiple regression with meteorological and visitation data as independent variables, and summed tax revenue data as the dependent variable. These results are used in comparison with the results from the previous regression, in order to analyze the correlation between climate and economic data directly, in contrast to the relationship of climate to economic data through visitation to Rocky Mountain National Park.
Data and Results

In order to fully understand the correlation between climate and visitation to Rocky Mountain National Park, it is important to understand recent climate and visitation trends independently. The three meteorological variables used in this study were looked at and graphed separately to analyze recent climate trends.

Figure 2: Average Monthly snow depth for Rocky Mountain National Park. Graph shows an aggregated average for the park from all 15 stations used.

Figure one shows the average monthly snow depth for the park (as aggregated from the used SNOTEL stations) through the past 15 years. As is apparent in the figure, although seasonal fluctuations in snow depth have remained
relatively constant, the trend-line shows that overall, average snow depth has declined in Rocky Mountain National Park.

![Average Monthly Precipitation for RMNP](image)

Figure 3: Average monthly precipitation increment in inches for Rocky Mountain National Park. Averages calculated from aggregated precipitation data from 15 SNOTEL stations.

Figure 2 shows the monthly precipitation increment averaged for Rocky Mountain National Park as a whole. This graph shows that although there have been monthly and seasonal fluctuations in precipitation since 2001, average monthly precipitation has increased throughout the period of this study. Although average precipitation has increased, it is apparent from this figure that monthly
precipitation has been much more variable than average monthly snow depth and air temperature as seen in Figures 2 and 4.

![Average Monthly Air Temperature for RMNP](image)

**Figure 4:** Average monthly air temperature for Rocky Mountain National Park as aggregated from monthly averages from 15 SNOTEL stations.

By looking at figure 3, it is apparent that there are consistent seasonal trends in air temperature in RMNP. Although seasonal fluctuations appear to have remained relatively constant, the trend line shows that within the past 15 years, average air temperature has increased. In addition to understanding climate data,
for purposes of this project, it is also important to understand recent trends of visitation to RMNP.

Figure 5: Monthly Visitation to Rocky Mountain National Park obtained from the National Park Service Database.

Figure 4 shows the increase in total visitation to Rocky Mountain National Park since August 2001. Analyzing this graph shows the seasonal trends of visitation; high tourism numbers during summer months (over 600,000 during peak months every year), and tourism drops to under 100,000 during winter months.
every year. While these seasonal trends appear to be relatively constant, a trend line of monthly visitation shows that since 2001, average visitation to Rocky Mountain National Park has increased.

After looking at the individual trends of climate variables and visitation in RMNP, this thesis looks at the relationships between these variables. In order to do this, bivariate correlations were run between the three observed climate variables.

<table>
<thead>
<tr>
<th></th>
<th>Snow Depth</th>
<th>Precipitation</th>
<th>Air Temperature</th>
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<td><strong>Snow Depth</strong></td>
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<td><strong>Precipitation</strong></td>
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<td>1</td>
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<tr>
<td></td>
<td>Significance (2-tailed)</td>
<td></td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Air Temperature</strong></td>
<td>Pearson Coefficient</td>
<td>-0.641</td>
<td>-0.265</td>
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<tr>
<td></td>
<td>Significance (2-tailed)</td>
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</tbody>
</table>

Table 2: Bivariate Correlations between meteorological predictor variables used in this study. Correlation significant at p-value <0.05.

This study found significant correlations between all observed meteorological variables (p-value <0.05) Snow depth and precipitation have a moderate positive correlation (Coefficient=.438). There is a strong negative correlation between snow depth and air temperature (Coefficient=-.641). This test found a weak negative correlation between air temperature and precipitation (Coefficient=-.265).

The next tests ran for this study were multiple bivariate correlations between park visitation and the measured climate variables.
This study found a strong negative correlation between snow depth and park visitation (Coefficient=-.693). There is a moderate negative correlation between precipitation and visitation (Coefficient=-.330). Lastly, there is a strong positive correlation between air temperature and park visitation (Coefficient=.905) All correlations represented in Table 3 are statistically significant (p-value <.05).

Next, a correlation similar to the previous one was ran, however controlling for only summer months (May-August), in order to analyze the relationships between climate and visitation during peak tourist season.

<table>
<thead>
<tr>
<th></th>
<th>Snow Depth</th>
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<th>Visitation</th>
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<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Precipitation</strong></td>
<td>Pearson Correlation</td>
<td>0.467</td>
<td>1</td>
<td>-0.376</td>
</tr>
<tr>
<td></td>
<td>Significance (2-tailed)</td>
<td>0.000</td>
<td>0.004</td>
<td>0.014</td>
</tr>
<tr>
<td><strong>Air Temperature</strong></td>
<td>Pearson Correlation</td>
<td>-0.772</td>
<td>-0.376</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Significance (2-tailed)</td>
<td>0.000</td>
<td>0.004</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Visitation</strong></td>
<td>Pearson Correlation</td>
<td>-0.81</td>
<td>-0.321</td>
<td>0.866</td>
</tr>
<tr>
<td></td>
<td>Significance (2-tailed)</td>
<td>0.000</td>
<td>0.014</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Table 4: Bivariate Correlations between climate variables and visitation as dependent variable, tested over only summer months (May-August). Significant at P-value <.05.
All climate relationships are significant when controlling for just summer months (p-value < .05). During only summer months, snow and precipitation have a moderate positive correlation (Coefficient=.467). Snow depth and air temperature have a strong negative correlation (Coefficient=-.772). Precipitation and air temperature have a moderate negative correlation (Coefficient=-.376) during summer months.

Controlling for just summer months, snow depth has a significant negative correlation with visitation (p-value < .05; Coefficient=-.81). Precipitation and visitation have a statistically significant negative correlation (p-value < .05; Coefficient=-.321). Finally, during the summer season, this study found air temperature to have a significant (p-value < .05) strong positive correlation with park visitation (Coefficient=.866).

The next step in this study was to run a multiple regression with climate factors as independent variables, and park visitation as the dependent variable.

<table>
<thead>
<tr>
<th></th>
<th>Dependent Variable: Park Visitation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beta</td>
</tr>
<tr>
<td>Snow Depth</td>
<td>-0.18</td>
</tr>
<tr>
<td>Precipitation</td>
<td>-0.046</td>
</tr>
<tr>
<td>Air Temperature</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.777</td>
</tr>
<tr>
<td>Model Statistics</td>
<td>Adj. R^2=.841</td>
</tr>
</tbody>
</table>

Table 5: Standardized Coefficients (Beta) and significance of correlations between predictor variables and the dependent variable: park visitation. Relationships significant at Sig. Value < .05.
Snow depth has a significant weak negative relationship with park visitation (p-value <.05; Beta=-.18). Precipitation has a weak negative correlation with park visitation (Beta=-.046). However, the influence of precipitation on visitation was statistically insignificant (p-value >.05). Lastly, statistical analysis found air temperature to have a significant strong positive influence on park visitation (p-value <.05; Beta=.777). The model as a whole is statistically significant (p-value <.05), with the combined influence of climate variables having a strong influence on the variation in park visitation ($R^2=.841$).

Next, a regression was run between the three predictor variables and park visitation, but controlling the model to only look at summer months.

<table>
<thead>
<tr>
<th>Dependent Variable: Park Visitation</th>
<th>Beta</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snow Depth</td>
<td>-0.373</td>
<td>0.009</td>
</tr>
<tr>
<td>Precipitation</td>
<td>0.128</td>
<td>0.308</td>
</tr>
<tr>
<td>Air Temperature</td>
<td>0.354</td>
<td>0.013</td>
</tr>
<tr>
<td>Model Statistics</td>
<td>Adj. $R^2=.363$</td>
<td>Sig.=.000</td>
</tr>
</tbody>
</table>

Table 6: Results from multiple regression between climate predictor variables and park visitation. Analysis was run only for summer months (May-August) during the period of the study. Relationships significant at p-value <.05.

During only summer months, snow depth has a statistically significant (p-value <.05) moderate negative correlation with park visitation (Beta=-.373). During these months, precipitation has a weak positive influence on park visitation (Beta=0.128). However, the influence of precipitation on visitation is again statistically insignificant (p-value >.05). The relationship between air temperature and visitation during summer months is represented a statistically significant (p-value <.05) moderate positive relationship (Beta=.354). The model was as a whole
significantly predicts a moderate amount of the variation in park visitation during summer months (p-value <.05; $R^2=.363$).

Next, another regression was ran with all climate variables as independent variables and visitation as the dependent factor. However, for this regression, the relationships between the variables were looked at controlling for only non-summer months (September-April).

<table>
<thead>
<tr>
<th>Dependent Variable: Park Visitation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Beta</td>
<td></td>
</tr>
<tr>
<td>Snow Depth</td>
<td>-0.253</td>
</tr>
<tr>
<td>Precipitation</td>
<td>-0.060</td>
</tr>
<tr>
<td>Air Temperature</td>
<td>0.691</td>
</tr>
<tr>
<td>Model Statistics</td>
<td>$R^2=.710$</td>
</tr>
</tbody>
</table>

Table 7: Results from multiple-regression between park visitation and climate during non-summer months (September-April). Relationships significant at significance value <.05.

During non-summer months, there is a statistically significant (p-value <.05) weak negative influence of snow depth on park visitation (Beta=-0.253). Precipitation has a weak negative correlation with park visitation (Beta=-0.060). This test found that the influence of precipitation on park visitation during non-summer months is statistically insignificant (p-value >.05) Controlling for the same months, air temperature has a significant (p-value <.05) strong positive correlation with park visitation (Beta=0.691). This model is statistically significant (model p-value <.05), with the climate variables explaining 71% of the variance in park visitation ($R^2=.710$).

The final statistical tests run for this thesis look at the relationships between climate, visitation, and tax data. The first test includes bivariate correlations.
between park visitation and tax revenue data from Grand and Larimer County independently, and then between visitation and the sum of tax revenue from both counties. The results of these correlations are shown below.

<table>
<thead>
<tr>
<th></th>
<th>Visitation</th>
<th>G. County Tax</th>
<th>L. County Tax</th>
<th>Tax Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visitation</td>
<td>1</td>
<td>0.298</td>
<td>0.404</td>
<td>0.414</td>
</tr>
<tr>
<td>Significance (2-tailed)</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Grand County Tax Revenue</td>
<td>0.298</td>
<td>1</td>
<td>0.426</td>
<td>0.499</td>
</tr>
<tr>
<td>Significance (2-tailed)</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Larimer County Tax Revenue</td>
<td>0.404</td>
<td>0.426</td>
<td>1</td>
<td>0.997</td>
</tr>
<tr>
<td>Significance (2-tailed)</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Sum of Tax Revenue</td>
<td>0.414</td>
<td>0.499</td>
<td>0.997</td>
<td>1</td>
</tr>
<tr>
<td>Significance (2-tailed)</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Table 8: Results of Bivariate Correlations between park visitation and tax revenue data from counties surrounding Rocky Mountain National Park. **Significance at P-value <0.05.

All relationships found in this tests are statistically significant (p-value <.05).

Visitation has a weak positive correlation with tax revenue from Grand County (Coefficient=.298), and a moderate positive correlation with tax revenue from Larimer County (Coefficient=.404). When tax data was summed together, visitation has a moderate correlation with this economic measurement as a whole (Coefficient=.414).
Next, a regression was run using the sum of tax revenue from both counties as the dependent variable and climate variables as independent variables. This regression was run in order to assess the direct effect that each climate variable has on the economy of both Grand and Larimer County. Results of this multiple regression are shown below.

<table>
<thead>
<tr>
<th>Dep. Variable: Tax Revenue</th>
<th>Beta</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snow Depth</td>
<td>-0.249</td>
<td>0.013</td>
</tr>
<tr>
<td>Precipitation</td>
<td>0.060</td>
<td>0.443</td>
</tr>
<tr>
<td>Air Temperature</td>
<td>0.196</td>
<td>0.036</td>
</tr>
</tbody>
</table>

Model Statistics: Adj. $R^2 = .133$

Table 9: Results from multiple regression with sum of tax revenue from Larimer and Grand County as dependent variable. Relationships significant at p-value < 0.05.

Snow depth has a statistically significant (p-value < 0.05) weak negative correlation with tax revenue from Grand and Larimer County (Beta=-0.249). While precipitation has weak positive correlation with tax revenue (Beta=0.060), this relationship is insignificant (p-value >.05). Air temperature has a significant weak negative correlation with tax revenue from both counties (p-value <.05; Beta=.196). This multiple regression shows that the observed climate variables significantly explain 13.3% of the variance in the dependent variable (Model p-value <.05; $R^2 = .133$).

The final statistical test in this study is a multiple regression with the sum of tax revenue from Grand and Larimer County as the dependent variable. However, in this test, along with climate variables as independent variables, park visitation is also an independent variable, to help understand how much of the relationship
between climate and the economy is direct, and how much of it is explained through
the effect of climactic factors on park visitation.

<table>
<thead>
<tr>
<th>Dep. Variable: Tax Revenue Sum</th>
<th>Beta</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snow Depth</td>
<td>-0.147</td>
<td>0.149</td>
</tr>
<tr>
<td>Precipitation</td>
<td>0.088</td>
<td>0.256</td>
</tr>
<tr>
<td>Air Temperature</td>
<td>-0.246</td>
<td>0.134</td>
</tr>
<tr>
<td>Visitation</td>
<td>0.569</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Table 10: Results from multiple regressions with the sum of tax revenue from Grand
and Larimer Counties as dependent variable. Relationships significant at p-value
<0.05.

When climate variables and visitation are used to explain tax revenue, snow
depth has a weak negative influence on tax revenue (Beta=-0.147); precipitation has
a weak positive influence on tax revenue (Beta=0.088); and air temperature has a
weak negative correlation with tax revenue (Beta=-0.246). However, with visitation
as an additional independent variable in the model, the relationships between all of
the climate variables and tax revenue are statistically insignificant (p-value >.05).
Park visitation has a significant (p-value <.05) moderately strong influence on tax
revenue (Beta=.569). This regression found that climate variables and park
visitation together, significantly explain 17.9% of the variance in sales tax revenue
of Grand and Larimer County together (Model p-value <.05; R^2=.179).
Analysis

In analyzing the results of this study, it is imperative to understand recent climate trends in Rocky Mountain National Park, and how they relate to each other.

**Monthly Average Air Temperature by Year**

![Monthly Average Air Temperature by Year](image)

Figure 6: Monthly average air temperature by year in Rocky Mountain National Park as aggregated from the SNOTEL weather stations used in this study.

The trend-line drawn from the results in figure 5 shows that within Rocky Mountain National Park, the average air temperature has been increasing throughout the period of this study. As air temperatures have risen in RMNP, the other climactic variables measured for this study have been observed to be changing as well.
Figure 7: Average annual snow depth and monthly precipitation increment as aggregated from the SNOTEL weather stations used in this study. Graph depicts data from 2002-2015 as the range of years in this study in which monthly data for every month was available.

While it is not apparent from the graphs themselves what recent climate patterns have been, the trend-lines shown for both variables exhibit recent patterns in both snowfall and precipitation in RMNP. The trend-line for average snow depth shows that throughout the period of this study, the average annual snow depth has been decreasing. The graph represented for precipitation in Figure 7 depicts annual averages of monthly precipitation increments in the area studied in this project. The trend-line for this graph illustrates the increasing trend in monthly
precipitation from 2002-2015. In analyzing Figures 6 and 7 together, it is apparent that as air temperature increases, average snow depth has decreased, and average precipitation increments have increased.

Other similar research has analyzed the relationships between the climactic variables analyzed in this study. In the realm of climate models and climate change, much research suggests that with higher CO2 levels in the atmosphere, air temperatures will increase. The Intergovernmental Panel in Climate Change indicated in its Fourth Assessment Report that global land-surface air temperatures have increased throughout the period on record (Hartmann et. al., 2013). Following expectations of warming air temperatures, research has looked at the relationship between climate warming and other meteorological factors such as snow fall and precipitation. It has been predicted that with a warming climate, the Northern Hemisphere will see decreasing snowpack, and further, higher amounts of precipitation will fall as rain, and equally less will fall as snow (Pachauri and Mayer, 2015; Beniston, 2003; Clow, 2009). This study found results that are congruent with prior research.

Looking at the changing rates of precipitation and snow-depth in Rocky Mountain National Park, it is possible to compare these in order to put them into context with previously stated expectations of how they are correlated. The trendlines in Figure 7 for average precipitation increment and snow depth have equations of $y=0.032x+2.4294$ and $y=-0.473x+25.023$ respectively. Calculating for the total change in the average measures of these variables, it can be found that from 2002-2015, the annual average monthly precipitation increment increased by 17.12%,
and average snow depth has decreased by 24.57%. While these numbers are not
totally equal, they are relatively similar, and point to congruency between this study
and the aforementioned expectation that as air temperature increases, more
precipitation will fall as rain and equally less will fall as snow.

In this study, the relationships between air temperature, snow depth, and
precipitation are represented with statistical analysis in Table 2 in the results
section. A bivariate correlation between air temperature and snow depth indicate a
strong negative correlation (Coefficient=-.641). This suggests that as temperatures
continue to increase, there should be a decrease in snow depth across the region
measured in this study. The results of this test show that the hypothesis of
decreasing snowpack as a result of climate warming is found to be true in RMNP
through the period of this study. A weak negative relationship between air
temperature and precipitation shown in Table 2 (Coefficient =-.265) suggests that
through the period of this study, as air temperature increases, monthly precipitation
has decreased at a low rate. This result is different from previous suggestions that a
warming climate will experience increasing amounts of rainfall (Beniston, 2003).
The inconsistency of this finding could be attributed to the fact that through the
period of this study, snow depth has decreased at a greater rate (-24.57%) than
precipitation increment has increased (17.12%). These findings suggest total
precipitation has decreased, due to a greater decrease in snow than increase in
precipitation, but by referring back to the trend-line in Figure 7 for monthly
precipitation increment, it is apparent that precipitation (exclusive from snow fall)
has increased throughout the period of this study. It is important to note that while
the correlations are statistically significant (p-value < 0.05), the correlations themselves do not prove causation.

By analyzing recent climate trends in Rocky Mountain National Park, this study has shown that the region is experiencing the predicted effects of climate warming. In understanding that the RMNP region is experiencing climate change, it is next important to analyze how these climate trends are related to visitation to Rocky Mountain National Park.

To analyze how visitation to Rocky Mountain National Park has changed in relation to climactic variables, first it is important to visualize and understand visitation patterns to the park on their own throughout the period of the study.

![Average Monthly Visitation by Year](image)

Figure 8: Average monthly visitation to Rocky Mountain National Park by year. Obtained from the National Park Service Database.
While not on a consistent basis, the trend-line depicted in Figure 8 shows that from the years of 2002-2015, average monthly visitation to Rocky Mountain National Park has increased. While there are many possible factors that could have contributed to this tourism trend, this thesis looks at to what degree climate trends during the same period have had an influence on the increase in visitation.

There exists much other prior research into the relationship between climate and tourism that is multifaceted and points to relationships going in multiple directions. Within this, research has suggested that climate plays a role in tourism by shaping tourists’ decisions as to where to travel. The same research indicates that in order for tourism to continue being an important industry, it must have a close link to the preservation of the environment and climate (Viner and Agnew, 1999). More specifically than this, research has suggested that various climactic factors, including but not limited to temperature, humidity, snowfall, and water temperature effect visitors’ decisions and satisfaction in regards to tourist destinations (Curtis et. al., 2011). This thesis expands on prior research by looking at effects of air temperature, snow depth, and precipitation on tourism specifically in Rocky Mountain National Park.

To analyze these relationships, this project first ran bivariate correlations between park visitation and the three climate variables independently, results of which are expressed in Table 3. Visitation has a strong negative correlation with snow depth (coefficient=-.693), a moderate negative correlation with precipitation (coefficient=-.330), and a strong positive correlation with air temperature (coefficient=.905). These correlations suggest that as air temperatures rise, it is
expected for visitation to rise with it, but if snow depth and precipitation increase, there would be a correlational decrease in park visitation. It is important to note that although there is a correlation between all predictor variables and visitation, the coefficient for air temperature is much stronger than those for snow depth and precipitation. Thus, this study found that air temperature has a much stronger influence on park visitation than the other measured climactic variables. While these relationships were found to be significant (p-value <0.05), they remain simple correlations and do not imply any causation of climate on visitation trends.

In order to further analyze the relationship, and the degree to which each climactic factor effects visitation, a multiple regression was run with climate factors as predictor variables and park visitation as the dependent variable. By running a multiple regression, it is possible to analyze the strength of the relationship of each predictor variable on park visitation while controlling for the other predictor variables. The results of this first regression are represented in Table 5.

The first relationship analyzed is that between snow depth and visitation. With a Beta coefficient of -0.18 and a p-value <0.05, there is a significant weak negative influence of snow on park visitation. In relation to the coefficient found from a bivariate correlation between these two variables, the results from the multiple regression suggest a much weaker relationship. This comparison can be analyzed to suggest that while snow depth does have a statistically significant influence on visitation to Rocky Mountain National Park, when other climactic factors are controlled for, snow depth predicts less of the variation in visitation on its own. The regression found a Beta coefficient of -.046 between precipitation and
park visitation. However, this relationship is insignificant (p-value >.05). The insignificance of this relationship can be interpreted to mean that when other climactic factors are controlled for, precipitation does not have a meaningful influence on visitation to the park. The final relationship analyzed in this regression is that between air temperature and visitation. With a statistically significant (p-value <.05) beta value of .777, it is shown that air temperature can be used to predict a moderate amount of variation in the dependent variable (park visitation).

The multiple regression denoted in Table 5 also had whole model statistic outputs, which are important in the analysis of the effects of climate on tourism in Rocky Mountain National Park. The model in its entirety represented a statistically significant relationship (p-value <.05) with an adjusted $R^2$ value of .841. These values suggest that when the influence of all three-predictor variables are combined, climate as a whole explains roughly 84.1% of the variation in visitation to RMNP. This suggests a strong relationship between climate and visitation, but there are other factors that could explain the remaining variance in park visitation. Amongst these other possible factors that could explain variance in visitation is the time of year, or seasonality. Thus, this project then compares the relationship of climate variables to visitation in different periods of the year.

In order to look at the relationship between climate and visitation with regards to seasonality, this thesis analyzed the relationships controlling for three time frames: 1) Looking at data annually for all months (discussed above), 2) controlling for only summer months (May-August), and 3) controlling for only non-summer months (September-April). Note that summer months are defined as
months of ‘peak tourist season’ in Rocky Mountain National Park, having the highest visitation numbers. The comparisons of statistical results for each time frame are shown in the table below.

<table>
<thead>
<tr>
<th></th>
<th>Full Year</th>
<th>Summer (May-August)</th>
<th>Non-Summer (September-April)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beta</td>
<td>Sig.</td>
<td>Beta</td>
</tr>
<tr>
<td>Snow Depth</td>
<td>-0.18</td>
<td>0.000</td>
<td>-0.373</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-0.253</td>
</tr>
<tr>
<td>Precipitation</td>
<td>-0.046</td>
<td>0.171</td>
<td>0.128</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-0.06</td>
</tr>
<tr>
<td>Air Temperature</td>
<td>0.777</td>
<td>0.000</td>
<td>0.354</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.691</td>
</tr>
<tr>
<td>Model Stats</td>
<td>R^2</td>
<td>Sig.</td>
<td>R^2</td>
</tr>
<tr>
<td></td>
<td>0.841</td>
<td>0.000</td>
<td>0.363</td>
</tr>
<tr>
<td></td>
<td>0.71</td>
<td>0.000</td>
<td></td>
</tr>
</tbody>
</table>

Table 11: Results from multiple regressions ran between climate variables as predictor variables and visitation as the dependent variable. Table shows comparison of results when controlling for different periods of the year.

The results depicted in Table 11 show how the relationship between climate and tourism to Rocky Mountain National Park vary depending on season and time of year. The results for the regressions when ran for all months throughout the period of the study have been discussed above. It is next important to analyze the relationships between climate and visitation when controlling for only summer (peak tourism) months, and non-summer months, and then compare these to the results for the entire year.

In regards to the relationship between snow depth and visitation, when looking at a time frame of the entire year, snow has a weak negative influence on visitation (Beta=-0.18). When controlling to look at this relationship only during summer months, snow depth has a moderate predictive negative influence on visitation (Beta=-0.373). When looking at this relationship during only non-summer
months, snow depth is again found to have a moderate weak negative relationship with park visitation (Beta=-0.253). The relationship between snow depth and visitation is significant during all time frames (p-value <0.05). While all of the relationships were found to be weak to moderate negative relationships, it is interesting to compare the strengths of these relationships across time frames.

Snow depth has the strongest influence on visitation during summer months only, and the weakest influence on visitation when looking at the entire year. In comparing the strength of the relationship between snow depth and visitation in summer months versus non-summer months, many possible conclusions can be drawn. During winter months, there is already the expectation of snow, when compared to summer months, there is generally much less snow and warmer air temperatures. Due to this, it is possible that in summer months, when it is expected for there to be less snow, snow could have a greater influence on the decision making process of visitors, and thus a greater influence on park visitation numbers.

In regards to the relationship between precipitation and park visitation, when controlling for the full year and non-summer months, precipitation has a weak negative influence on visitation, and during summer months, precipitation has a weak positive influence on visitation. While the contrast of these relationships is interesting (positive relationship during summer, and negative during non-summer), it is important to keep in mind that for the year as a whole, precipitation has a negative influence on visitation, indicating that with more rain, as is expected with a warming climate, we would expect to see less visitation over all (Burakowski et. al., 2012). Although these relationships are interesting, the model found the
relationship between precipitation and visitation during all three time frames to be statistically insignificant (p-value >.05). Though the distinction between the relationships of these variables through different time frames is thought provoking, the insignificance suggests that the influence of precipitation on the variation of visitation hinders no further discussion.

The final relationship shown across time frames in Table 11 is that between air temperature and visitation. As discussed above, when looking at the entire year, the relationship between these two variables is described with a Beta value of 0.777. When controlling for only summer months air temperature has a moderate positive predictive influence on visitation (Beta=0.354), and when looking at non-summer months air temperature has a strong positive relationship with park visitation (Beta=.691). The relationships between air temperature and visitation when controlling for all time frames is statistically significant (p-value <0.05).

As was the case with snow depth, it is important to compare the strength of the relationship between air temperature and visitation across summer months and non-summer months. Table 11 shows during non-summer months, air temperature can predict a much larger amount of the variation in visitation than it can during summer months. While both relationships are positive, indicating that year round higher air temperatures will lead to more visitation, the fact that the relationship is significantly stronger during the winter months can lead to some interesting conclusions. It is possible that since summer months are already peak tourism months, visitation numbers will be high regardless of air temperature, but during winter months when visitation is generally lower, even slightly warmer air
temperatures will have a greater influence on people’s decision to visit the park. Restated, the results shown in table 11 could mean that since summers are already warmer than winters, marginally warmer temperatures have a greater influence on visitation during non-summer months than during the summer.

Another interesting result shown by comparing the relationships of climate to visitation across various time frames is that in all observed periods, air temperature has a stronger relationship with visitation than either of the other climactic dynamics. This is important in that while snow depth and precipitation have an influence on visitation (precipitation found to be insignificant so is not as important to this discussion), through all time frames, changes in air temperature will predict a much greater proportion of the variation in visitation than other climate factors.

The last results to analyze from Table 11 are the results from the three models as a whole. The $R^2$ value of 0.841 for the entire year has already been discussed, but it is again interesting to look at the difference of this value between summer and non-summer months. In all time frames the predictive value of the model as a whole on park visitation is statistically significant (p-value <.05). For summer months, the model has a moderate positive influence on visitation (Adjusted $R^2$=0.363), and for non-summer months the climate model as a whole has a strong positive relationship with visitation (Adj. $R^2$=0.71). This suggests that overall climate factors have a much stronger influence on visitation to Rocky Mountain National Park during non-summer (which is also low tourist season) months when compared to summer months. This could again suggest that since
visitation numbers are already higher during the summer, marginal changes in climate conditions have a greater influence on park visitation during the winter, than during the summer.

In analyzing the relationship between visitation to Rocky Mountain National Park and economic data, this project first looked at the correlations between visitation and sales tax revenue data from Grand and Larimer County. The full results of this test are represented in Table 8, but are additionally summarized briefly in the table below.

<table>
<thead>
<tr>
<th></th>
<th>G. County</th>
<th>L. County</th>
<th>Tax Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visitation</td>
<td>Coefficient</td>
<td>0.298</td>
<td>0.404</td>
</tr>
<tr>
<td></td>
<td>Significance</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Table 12: Bivariate Correlations between park visitation and sales tax revenue data from Grand and Larimer County individually, and the sum of tax revenue data from both counties.

The results shown in the table above suggest that park visitation has a moderate positive correlation with sales tax revenue in both Grand and Larimer County. A coefficient of 0.404 for the relationship of visitation and tax data from Larimer county suggests that visitation has a stronger relationship with the economy of Larimer County than it does with that of Grand County (coefficient=0.298). After seeing that there is some sort of positive correlation between visitation and economic measurements of counties surrounding Rocky Mountain National Park, this project then analyzed the relationship between climate variables and tax revenue through a multiple regression analysis.

The results of this analysis are represented in Table 9. Snow depth has a weak negative influence on the variation of summed tax data from the two counties.
(Beta=-0.249). Both precipitation and air temperature have weak positive influences on tax revenue with Beta values of 0.060 and 0.196 respectively. However, as was the case with park visitation, the influence of precipitation on the dependent variable is statistically insignificant (p-value >0.05). The relationships between snow depth and air temperature to tax revenue are statistically significant (p-value <0.05). While these relationships are weak, the results can be interpreted to show that climate, as measured through snow depth and air temperature, does have an impact on the economies of surrounding counties.

The model statistics for this multiple regressions showed a significant (p-value <0.05) weak predictive influence of climate on tax revenue with and $R^2$ value of .133. This indicates that climate variables account for around 13.3% of the variation in sales tax revenue for Larimer and Grand County combined. This small of a $R^2$ value suggests that there are many other factors that contribute to variation in tax revenue data. Due to this, visitation was added to this model as another predictor variable in order to assess what portion of the influence of climate on tax revenue data is through climate’s influence on park visitation.

The results of this model are indicated in Table 10. Visitation has a statistically significant (p-value <0.05) moderately strong relationship with tax revenue data (Beta=0.569). However, when visitation was added to the model as an independent variable, the relationships between all climate factors and tax revenue became insignificant (p-value >0.05). This finding suggests that all of the significant variation of tax revenue explained by climate factors is due to climactic influence on visitation, which is then shown to have a strong relationship with tax revenue.
This result, that the predictive influence of climate on tax revenue of Grand and Larimer County is through its’ influence on visitation, is represented again in the model statistics for this regression (Adjusted $R^2=.179$). This value, which is higher than the predictive value of just climate on tax revenue ($R^2=.133$), indicates in another way that the influence of climate on economic measurements is mostly through, its influence on visitation as a predictor variable. It is important to note that while this models predictive value is statistically significant (p-value <0.05), it only suggests that climate and visitation explain 17.9% of the variation in tax revenue data, suggesting that there are many other variables that contribute to and could explain other variations in the observed economic measurement of the counties surrounding Rocky Mountain National Park.
Discussion

While this thesis focused solely on past trends of the relationship between climate and visitation in Rocky Mountain National Park, the implications of the project, regarding how climate and tourism are related, could become relevant in a much larger context. Understanding the results of this project can start to illuminate how climate, and climate change in the future, will impact various social structures such as tourism. However, this project only looked at the relationship between three climactic factors and visitation, when there are far more variables that can play a role in these relationships.

Prior research on the relationship between climate and tourism has suggested that in order to understand the correlation between the two, it is important to understand how the ‘attractiveness’ of a destination is changing, especially in relation to its competitors (Hamilton et al., 2005). The ‘attractiveness’ of a destination could change through a variety of potential effects ranging from direct effects, including changes to environmental conditions that are drivers of tourism, to indirect effects, including changes to mountain landscapes and changes to the market demand for varying destinations or activities (Beniston, 2003). With this in mind, in order to more fully understand how climate change could impact visitation to RMNP, it is important to look at how other variables that could alter the ‘attractiveness’ of the park are changing, in addition to the variables looked at in this study.

In addition to air temperature, snow depth, and precipitation (the three climactic variables researched in this study), there are many other factors that could
influence tourists decision to visit the park, that are also being affected by climate change. Amongst these ecological factors is that of natural processes and disturbances. One natural disturbance process that is common in mountain ecosystems is wildfires. Climate change has already had a correlation with wildfire rates, as research has shown that increasing temperatures and lower snowpack in the Western United States have been linked with an increase in the frequency and severity of wildfires (Westerling et. al., 2006; Byrne et. al., 2015). In addition to increasing frequency of fires, it is predicted that warming air temperatures could lead to longer fire and drought seasons, which could cause fire prone areas to become continued hazards (Flannigan et. al., 2006; Beniston, 2003). An increase in wildfires in an ecosystem like that of Rocky Mountain National Park could have effects that that cascade through many levels of the ecosystem, possibly altering the ‘attractiveness’ of the place as a tourist destination.

Along with wildfires, other ecological processes and disturbances have been altered by recent climate change. Amongst these is an effect that has already been observed in many areas in Colorado: the presence of pine beetle outbreaks. With a warming climate comes warmer winters and fewer extreme cold events, which allow pine beetles to spread and reproduce at a much faster rate, which is partially what led to a 13-year outbreak in the Western US that killed between 2 and 3.3 million hectares of pine forests (Byrne et. al., 2015). A warmer atmosphere effects pine beetle populations directly by limiting the amount of extreme cold events, allowing the populations to avoid cold-induced mortality. Pine beetle larvae have a minimum temperature threshold for survival, so during normal years, there are
many cold-events that reach below this threshold and can serve as controls on the over-wintering populations. However, with warming winters, there are less of these extreme cold events, so the over-wintering populations can flourish, leading to larger outbreaks. Indirect effects of a warming climate on insect population outbreaks include the possibility of the warming environments effect on host trees. A warmer environment could possibly lead to longer periods of drought, which puts stress on trees and lowers their ability to defend against insect infestations, leading to an increase in insect populations. (Byrne et. al., 2015; Creeden et. al., 2014).

Through increased disturbances such as pine beetle outbreaks and wildfires, which are correlated with a warming environment, climate change could affect the appearance of ecosystems, thus affecting people’s decisions to visit certain places.

Another way in which climate change could affect the ‘attractiveness’ of RMNP, which happens directly through warming, and indirectly through mechanisms such as the disturbances discussed above, is the affect on vegetation patterns (Byrne et. al., 2015; Bentz et. al., 2009). The dependence of plant communities on various hydrological systems provides a link through which climate change affects vegetation. Since many alpine plants depend on snow for protection during the winter, and on snowmelt for water supply in the spring, it is possible that in areas with decreasing snow fall (as this study found is the case in RMNP), plants could become vulnerable to summer desiccation (Beniston, 2003). Other research suggests that the impacts of climate change on vegetation patterns could be so significant that by the end of this century, nearly 48% of ecosystems in the western United States could change to the point where they would have no analog to current
vegetation patterns (Bentz et. al., 2010). Along with effects on vegetation, there are many possible effects of climate change on animal life within Rocky Mountain National Park.

A study by the National Park Service that focuses specifically on the effects of climate change within Rocky Mountain National Park makes many predictions as to how various aspects of the ecosystem will be affected. The report suggests that birds could be exposed to new diseases that would flourish in warmer temperatures, along with species moving their ecological niches to higher latitudes and elevations. It is also expected that mammals in the park, both large and small, will move their habitats to higher elevations or latitudes in order to compensate for increasing temperatures (Brown et. al., 2007).

While this study itself focused on climactic factors that could affect the decision making process of visitors, the research discussed above shows how climate change could alter ecosystems in a way that could change the proposed ‘attractiveness’ of a place as a tourist destination. It is important to note that while this research points to the idea that climate change will have an effect on tourist destinations, and thus possibly an effect on tourism numbers, most research has not indicated whether this effect will be seen as an increase or decrease in tourism. To look at whether or not these effects on tourism will be positive or negative on a larger scale, it is then interesting to compare the results of this study to predictions of how climate change will affect tourism in other areas.

In looking to relate this thesis to the effects of climate change on other tourist activities, it is interesting to compare the results to a sector of tourism that utilizes a
very similar ecosystem to that of Rocky Mountain National Park: the ski industry. The ski industry is an interesting sector of tourism to look at, especially with regards to the impacts of climate change due to the industries heavy dependency on natural snow and cold temperatures (Dawson et. al., 2009). It is also important to look at the ski industry as it contributes greatly to the economies of involved communities. It is estimated that in the 2009-2010 season winter sport activities added over $12 billion to the U.S. economy, and that specifically in Colorado, the ski industry generates a $4.8 billion annual economic impact (Burakowski and Magnusson, 2012; Colorado Ski County USA, 2016). As the ski industry and visitation to RMNP are both examples of outdoor tourism in Colorado that have an impact on local economies (the impact of visitation to RMNP was found in this study and represented in Tables 8-10), they provide a good comparison to look at how climate change could affect different types of outdoor tourism.

In regards to outdoor tourism in the ski industry, research shows that in nearly all states with ski industries, low snowfall years are correlated with lower ski visits, and in Colorado specifically, the change in skier visits between high and low snowfall years is -7.7% (Burakowski and Magnusson, 2012). While this study statistically shows how climate change could affect outdoor tourism in areas like Colorado, other research has looked into more possible indirect effects. Amongst these effects, numerous organizations have predicted that a warming climate leading to less favorable climactic conditions could cause business to want to shorten seasons, raise prices, or change to other outdoor activities. Expected effects also include a negative influence on tourists desire to go camping, hiking, or engage
in other outdoor activities (Alvord, et. al., 2008). This proposition, that with decreasing levels of snow, the industry experiences decreasing levels of skier visits, suggests a positive correlation between snow fall and outdoor tourism in regards to skiing. The research discussed above also indicates that warming temperatures could lead to ‘less favorable climate conditions,’ and thus less skiing, implies a negative correlation between air temperature and outdoor tourism in the ski industry.

These correlations suggested through research about climate change and ski tourism indicate relationships between climate and outdoor tourism that are different than the results of this study. While research on ski tourism suggests a positive relationship with snow fall a negative correlation with air temperature, this study found a negative correlation with snowfall and a positive correlation with air temperature in regards to visitation to RMNP. While skiing in Colorado and visitation to RMNP take place in similar ecosystems, the effects of climate and climate change on these distinct types of outdoor tourism are shown to have opposite correlations.

There are many possible explanations as to why climate seems to have a different effect on varying types of outdoor tourism, regardless of if they take place in similar ecosystems. The one major distinction that can be drawn from this example is the difference in seasonality of tourist activities. Visitation to Rocky Mountain National Park is much higher during summer months, while peak ski tourism numbers are during the winter season. This difference in seasonality of tourist activities suggests that the different tourist activities are dependent on
different climates. This suggestion is supported by the correlations between climate and the different activities noted above.

A negative correlation between ski visits and air temperature and a positive correlation with snow would indicate that there should be higher numbers of ski tourism during months where temperatures are lower and there are higher amounts of snow: during the winter. A positive correlation between RMNP visitation and air temperature and negative correlation with snow indicates that it would be expected that visitation would be higher when air temperatures are high and snow fall is low: during the summer.

The proposition that climate and climate change have differing impacts on outdoor tourism depending on the location and activity can be further developed by looking at other research. A study by David Viner and Maureen Agnew looks at a variety of global destinations and suggests possible consequences of climate change on tourism to these places.

The Maldives is a popular tourist destination because of the archipelagos’ pristine beaches and coral reefs. Recent climate change has threatened this destination through means of ocean acidification, coral bleaching, and sea level rise. 40% of tourists to the Maldives visit with intentions of scuba diving and seeing coral reefs. Climate change could have a direct effect on this as coral reefs have been observed to be dying due to ocean acidification and increasing water temperatures. As the Maldives are comprised of many low-elevation islands, sea level rise poses a threat as it could potentially wash away portions of the archipelago (Viner and Agnew, 1999).
Many regions of East and South Africa have large tourism industries with a great focus on national parks and wildlife reserves. Climate change poses a threat to vegetation, wildlife, and ecological patterns through many of these parks. A change in the environment that currently attracts tourists, could pose a threat to the tourism industry in many parts of Africa. As increasing ocean temperatures and ocean acidification continue to cause mass coral bleaching events, much of the tourism industry in Australia is under threat of climate change as well (Viner and Agnew, 1999).

The conclusion that can be drawn from these comparisons is important in putting this thesis into context, and using this information to look into the future. The effects of climate, and the potential effects of climate change, on outdoor tourism, can vary drastically. While general predictions could be made about how increasing temperatures and other changing climactic variables will affect outdoor tourism, the specifics of these relationships, depend on the location of the destination, the seasonality of the activity, and the different environmental and climactic conditions that the activity rely on. While this thesis has portrayed the relationship between climate and outdoor tourism to Rocky Mountain National Park, in order to understand the relationship in other locations and for other sectors of outdoor tourism, further case studies would have to be undertaken.
Further Research

As this study focused very narrowly on a case study of Rocky Mountain National Park, there are still many questions of interest in regards to the relationship between climate and tourism. Firstly, it would be interesting to look at the relationships between other climate variables and visitation in Rocky Mountain National Park. This study focused on only three climate variables; air temperature, snow, and monthly precipitation increment. However, as discussed above, there are many other climactic factors within RMNP that have been, and could continue to be affected by climate change. In order to entirely comprehend the effects of climate change on tourism to the national park, further case studies and research would be necessary in order to understand how these other variables affect the decision making processes of tourists, and thus how they could affect visitation.

This paper briefly discusses how climate change impacts other types of outdoor tourism and other tourist destinations. As is mentioned, these relationships between climate and tourism can vary greatly. To gain a more comprehensive understanding of the correlations between climate change and tourism on a global scale, more case studies similar to this could be conducted for different locations and tourist activities.

Lastly, while the results of this study suggest a positive relationship between park visitation and economic measures of surrounding communities, the results also suggest that there are many other variables that play a role in the variation of economic measurements. Further research could suggest how climate and tourism interact with these other variables that impact the economy in order to more
understand these relationships. Further case studies could also suggest how climate and tourism relate to economic measures in regards to other tourist destinations and activities.
Conclusion

Overall, this study achieved its goal of analyzing how climate and tourism to Rocky Mountain National Park are related. Statistical analysis through bivariate correlations and multiple regressions found that in the case of RMNP, current climate trends have been correlated with an increase in park visitation. Visitation has a significant positive correlation with air temperature, a significant negative correlation with snow, and an insignificant negative correlation with precipitation. This study also found that the aforementioned increase in park visitation has a positive correlation with the economic well being of adjacent communities. While these results are important in understanding the future of tourism to RMNP, the finding that the relationships between climate and tourism vary greatly with different tourist activities and destinations is extremely important.

The hope is that more case studies such as this will be conducted for various locations and activities. In gaining a greater understanding of how climate drives tourism and thus the economies of related areas, it could be possible to better form strategies and plans that could be useful in the continued success of the global tourism industry, and thus the ability for people to experience other parts of the world.
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