CLIMATE CHANGE AND RECREATION: IMPACTS OF CLIMATE CHANGE ON LANDSCAPE SERVICES ASSOCIATED WITH TOURISM IN BIG BEND NATIONAL PARK

A Dissertation

by

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ABSTRACT

Big Bend National Park has some of the most diverse ecosystems and landscapes in the country. Tourists are drawn to the park's unique biological diversity provided by the park's natural resources each year. The potential impacts of climate change and the effects it will have on the tourism industry are a concern. The goal of this research was to identify the relationship between climate and visitation and estimate the potential impact climate change would have on that relationship. The objectives are divided between two essays.

The first essay focuses on identifying the link between climate and tourism and predicting how climate change could influence recreational visitation. A monthly and a seasonal model were developed that identified the relationships between age, population, income, gas price, precipitation and mean, minimum and maximum temperature. The results indicate that mean temperature, precipitation and gas price influence visitation seasonally. Under representative concentration pathway (RCP) 4.5 and 8.5 climate change scenarios, annual visitation was projected to be 319,083 and 322,385, respectively, with more visits occurring in cooler temperatures. The RCP 4.5 scenario had a projected increase of 8.83% in overall visitation. However, under the more severe conditions of the RCP 8.5, scenario visitation was projected to increase by 9.96% overall.

The second essay focuses on using variations of a zonal travel cost model to estimate visitor willingness to pay to visit the park, which can be viewed as a proxy for

the value of the natural resources within the park. An alternative model factored average zonal income into the calculation of total travel cost. The traditional zonal travel cost model estimated the park's total value at US$1,301,446,000. However, the value predicted by the alternate model was slightly higher at US$1,422,244,000. Taking into consideration the projected effect of climate change on visitation, the value of the natural resources that contribute to tourism at the park will increase. Under the RCP 4.5 scenario, the value predicted by the traditional and alternate models increased to US$1,416,363,682 and US$1,547,828,145, respectively. Under the RCP 8.5 scenario, the value predicted by the traditional and alternate models increased to US$1,431,070,022 and US$1,563,899,502, respectively. Overall, the results of this study suggest that the tourism industry in and around Big Bend National Park might not be as susceptible to the negative impacts predicted to occur elsewhere because of climate change.

DEDICATION

To my family, whose love and support have made this possible. It goes without saying that I would not have been able to accomplish this without you all...thanks.

And to Pops- I am who I am because of who you were.

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Dr. Scott Shafer provided the visitor survey analyzed in the second essay. I completed all other work for the dissertation independently.

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1. INTRODUCTION

Big Bend National Park has some of the most diverse landscapes and ecosystems in the country and is the largest protected area of Chihuahuan Desert. Three natural divisions typically characterize the park; the Rio Grande River, the Chihuahuan desert and a chain of old volcanic mountains called the Chisos. The sharp contrast in elevation lends itself to dramatic climatic variation within the park. It is this variation that leads to the diversity of plant and animal species. The park is home to 1,200 plant species, 11 species of amphibians, 56 species of reptiles, 40 species of fish, 75 species of mammals, 450 species of birds and 3,600 species of insects some of which are found nowhere else on Earth. In 1979 the park was designated an International Biosphere Reserve.

Tourists are drawn each year to the unique landscape and biological diversity provided by the park's natural resources. Annual recreational park visitation has grown from 1,409 visitors in 1944 to 314,102 visitors in 2014 (*National Park Service* n.d.). Popular activities include hiking, bird watching, photography and off-roading. The increased tourism provides a major source of jobs and income to the surrounding communities.

Recently, however, there has been increased concern over the potential impacts of climate change and its potential effects on the park's tourism industry. The majority of current research agrees on three broad key changes:

- An overall decrease in precipitation particularly in semi-arid and arid landscapes, which will increase desertification.

- An increase in extreme weather events- more frequent and/or prolonged droughts and/or flooding.
- An overall warming of the Earth's temperature.

The latest report from the Intergovernmental Panel on Climate Change (IPCC) suggests that the Earth's average temperature could rise by as much as 0.2-5.5ºC by 2100 (Climate Change 2001). Decreased precipitation, prolonged droughts and higher temperatures would alter the distinct climatic regions of the park, causing them to become more uniform. This could potentially cause a shift in vegetation dynamics, habitat and biodiversity loss. Tourism to the park could be negatively impacted because of these changes.

The purpose of this dissertation is to identify the relationship between climate and tourism and estimate the potential impact of climate change on that relationship in Big Bend National Park. The first essay focuses on how climate change could affect the relationship between climatic variables and recreational visitation. Essay two focuses on estimating the monetary value of the natural resources associated with tourism. The objectives are to:

- Develop a monthly model that identifies the relationship between defined climatic and socioeconomic variables and visitation.
- Develop a seasonal model that identifies the relationship between defined climatic and socioeconomic variables and visitation.

- Utilize a Global Climate Model (GCM) to predict how climate change might impact visitation at the monthly and seasonal scale.
- Estimate visitors' "willingness to pay" via a zonal travel cost (ZTC) model for the natural resources that contribute to tourism under current climate conditions and estimate based on the previous objectives how this value might be impacted by climate change.

In the first essay I develop the monthly and seasonal climate-visitation model that identifies the link between variables and park recreational visitation. Also, I discuss the importance of scale and how it affects climate change modeling. During preliminary analysis the correlations between different climatic and socioeconomic variables and visitation at different time scales was examined. I then used the models I developed in conjunction with a GCM to estimate visitation under scenarios of climate change. Many of the currently available GCM's lack accuracy at finer scales; in order to negate the issue a method of forecasting is commonly used to down scale the models to finer resolutions. I used a current suite of CIMP5 models downscaled by the United States Geologic Service (*NCCV* n.d.).

The second essay examines the use of a zonal travel cost model and responses from a visitor survey conducted in 2010-2011 to estimate by proxy the value of the natural resources associated with tourism. ZTC's utilize consumer surplus estimates as a reflection of the consumer's "willingness to pay" for a specific good or service. The percent change in visitation under scenarios of climate change discussed in the first essay can be applied to the monetary value generated from the ZTC to estimate the monetary gain or loss in tourism from climate change.

The dissertation is organized into four sections. The first section gives a overall introduction to the topic. The second section contains the first essay that covers the development of the monthly and seasonal climate-visitation models. Previous work defining and analyzing climate change are discussed. Visitation estimates under climate change are discussed. Also, the issue of scale is introduced and I discussed how it affects modeling. Lastly, the limitations and results are presented. The third section contains the second essay that deals with the visitor survey and the ZTC to estimate willingness to pay as a by proxy for the value of natural resources associated with tourism. These results along with the estimated effect of climate change are presented here. Also, I will discuss how applying valuation principles to ecosystem services demonstrated the need for more of a cross-disciplinary approach to physical and social sciences, which has led to researchers calling for the field of landscape ecology to serve as link between the two. I define landscape services and explain how they are the primary drivers of tourism for the park. In the fourth section I explained how the potential impacts of climate change could impact the various aspects of the park (the smaller individual scales or processes) that in turn could alter the landscape services and impact tourism. I also summarize the results and provide suggestions for further research.

2. ESTIMATING MONTHLY/SEASONAL CLIMATE-VISITATION MODELS AND PREDICTING VISITATION UNDER CLIMATE CHANGE

2.1 Introduction

Big Bend National Park located in west Texas is one of the largest national parks in the U.S. Since its creation visitation has increased annually and today the park sees an average of 350,000 visitors a year. Tourism, especially nature-based tourism, can sometimes be victim of or a contributor to climate change. Nature-based tourism is any tourism that directly relies on experiences derived from or related to natural attractions. Tourism is one of the world's biggest and most profitable industries; in 1999 travel and tourism employed an estimated 663 million people globally and generated over $530 billion in tourist receipts (Diaz 2002). In some areas it is also the primary source of income. Many of the small communities around Big Bend depend on tourism as a major source of revenue. However, the relationship between climate and tourism, as well as, the potential impacts climate change could have is not well understood.

This essay focuses on identifying the relationship between climate and recreational tourism and assessing how climate change might impact visitor numbers. The objectives were to:

- Develop a monthly model that identifies the relationship between defined climatic and socioeconomic variables and visitation.
- Develop a seasonal model that identifies the relationship between defined climatic and socioeconomic variables and visitation; and

- Utilize a Global Climate Model developed by USGS in conjunction with the models developed under the previous two objectives to assess how climate change could impact visitation at the monthly and seasonal scales.

This essay is organized as follows: the problem and objectives are outlined in the introduction. A brief literature review follows that details background work that leads to current research to understand the relationship climate and tourism have with one another. The methods section contains detailed information about the study area, individual models and predictive analysis. The results section contains the analysis results. Finally, the conclusion synthesizes the findings and management implications.

2.2 Literature Review

Researchers have noticed climate change since the 1960's and the topic has become an issue for debate among scientists and politicians today. Welch notes that even back in the 60's scientists argued "the rate of change of greenhouse gas concentration and radioactive forcing has been and will continue to increase more rapidly than seen previously in the geologic history" (Welch 2008). Climate change is causing a change in climate patterns but it is only one aspect of the changing climate. Based on research by Cox and Broecker, the climate naturally cycles between warmer and cooler periods but man has influenced the rate and possibly the extent at which this cycling occurs (Cox et al. 2000) (Broecker 1975). The issues we face are determining the extent to which we influence climate change via global warming, figuring out how effects of climate change (including global warming) will impact our resources and daily activities and how or if slowing the progression of global warming would allow us enough time to adapt or mitigate natural climate change so that our resources and daily activities are unaffected. Until recently, the roles and impacts that climate/weather had on tourism and vice versa were not really considered and even today there is conflicting research findings as to how they interact and impact one another (Loomis and Crespi 1999, Pickering 2011).

Much of the recent research evaluating the links between climate and tourism has been conducted in Canada, Europe or Asia; very little of this research has taken place inside the U.S. Most of the recent research focuses on direct market industries, industries where related goods are essential for the production of the profitable consumer service, such as skiing. Several studies have examined the areas in and around the Canadian Rocky Mt. (Jones and Scott 2006, Scott et al. 2007). The research had mixed results, with one study finding that global warming had a minimal impact on visitation except under severe warming scenarios while the other indicated that park visitation would benefit from global warming due to a longer and improved tourist season (Agnew and Paluikof 2002). Loomis and Crespi found that while temperature has the most direct effect on where someone participates in an activity global climate change affects the availability of recreational resources (Loomis and Crespi 1999). Research conducted in other locations also identified that the effects of global warming which are often perceived by the main stream media to be negative might be positive or cause no net loss rather just shifting the market for that particular activity latitudinally (Gössling and Hall

2006, Pickering 2011, Amelung and Nicholls 2014). Agnew summarized the findings of several papers and at suggests that temperature has the strongest relationship with visitation (Agnew and Paluikof 2002). However, there were a few studies that looked at either precipitation or the combined effects of temperature and precipitation. Myer found that visitors are more sensitive to summer rainfall or the combined effects of temperature and precipitation (Myer and Dewer 1999). Pongkijvorisan looked at a park in Thailand that seems to have similar attributes to Big Bend, and they found that visitation corresponded to seasonality but for the country and southeast Asia as a whole tourism is expected to decrease in response to climate changes (Pongkijvorasin and Chotiyaputta 2013).

There were a few studies that focused on U.S. sites. Buckley and Foushee found that peak visitation to U.S. national parks has shifted to earlier in the year by 4 days since 1979 in response to climate change (Buckley and Foushee 2012), while a study by Scott and McBoyle found that the climate-visitor relationship was denoted by seasonality in southern cities (Scott and McBoyle 2001). Hodges *et al*. conducted an analysis of recreational sites in TN. They found that climate change will have a varied impact on recreational activities and that certain activities not related to direct market industries like skiing will likely benefit from climate change due to longer tourist seasons but seasonal summer activities will be negatively impacted due to increased temperatures (Hodges et al. n.d.). This could be similar to Big Bend due to the different microclimates within the park where different types of recreation occur might shift, and summer visitation will decline due to an even hotter desert climate but visitation in other seasons will increase or remain the same.

Jones and Scott used monthly estimates of climatic variables and visitation to observe the empirical relationship between climate and visitation in the Canadian National Park system (Jones and Scott 2006). Initially, multivariate linear models were used to narrow down the significant variables to derive 1-variable linear models. These results indicated that extreme temperature had the most influence on visitation in half of the parks they sampled. In a couple of cases precipitation was determined to be the most significant. The linear models were limited in that they continued to project an increase in visitation as temperatures rose. This is not realistic because at some point temperatures would become uncomfortable for most visitors, as suggested by the tourism-climate index (Scott and McBoyle 2002). However, Jones and Scott determined that the relationship between climate and visitation was non-linear and seasonal patterns were observed (Jones and Scott 2006).

Scale is a major issue that needs to be addressed in terms of identifying tourism activities and their underlying resources but also the spatial and temporal extent at which climatic variables can be accurately assessed. The scale at which they are analyzed affects the accuracy of climate models and all variables involved in the analysis. Thus, varying the scale can alter the results of climate data or climate change scenarios. Stehr and Storch looked at the different time scales involved in modeling climate change. They noted that extreme weather events that are often mistaken for signs of climate change get the greatest response from society (Stehr and Storch 1994). However, climate change occurs over a long slow time scale and we don't yet understand how or even if the fast short term time frame relates to it (Stehr and Storch 1994). Hobbs and Norton argued that the scale should match the problem, that is, the context you examine an issue needs to be at the same level as the issue (Hobbs and Norton 1996). For instance, if budgetary reform is being considered for a state park the factors that go into the decision process need to be addressed from the level of the stakeholders that utilize the park's resources (often local or state levels). While the majority of the literature surveyed advocates looking at smaller, more localized scales, because this level is primarily where policy decisions and management objectives are set and where these decisions have the greatest impact. Dramstad argued that the issue of scale needs to be examined from a broader perspective because the localized level contributes to unsustainable land use due to individual stakeholders own self-interest (Dramstad and Fjellstad 2012).

The majority of current literature to date focuses on an individual ecosystem or specific land cover/ land use type. Matzarakis and de Freitas went even further saying that the direct effects of climate on tourism occur on the micro scale and that effects at this scale are the most important to understand (undefined author 2002, *Proceedings of the First International Workshop on Climate, Tourism and Recreation, edited by A. Matzarakis and CR de Freitas, Porto Carras, Neos Marmaras, Halkidiki, Greece* n.d.). However, Wu makes an interesting observation that local ecosystem studies are too small in spatial extent to consider human/environmental interactions while global scales are too big because we don't know information about interactions, trade off or impacts at this level but the landscape level that consists of multiple ecosystems are ideal because it is at this level that we have the most impact and interaction (Wu 2013). In 2011 Avils noted that land cover change resulting from climate model forecasting will alter climate on regional scale due to changes in the terrestrial ecology and water balance (Avila et al. 2012).

A recent question in the literature is how to address the "mismatch" between the scale that occurs because services are usually produced in a different location from where consumption or decisions regarding management occurs. Furthermore, many processes and functions that lead to final ecosystem service production occur over multiple scales and the rate of interaction is hard to determine (Costanza et al. 1997). In order to address the issue of scale Haines-Young & Potschin developed a framework that allows information to transition between different classification schemes and connects different fields of study (Haines-Young et al. 2010, Potschin and Haines-Young 2012).

A variety of issues compounded by climate change are threatening tourism activities associated with the park. These issues include degradation of the natural ecosystems, invasion of exotic species, protection of endangered species, air quality and water quality and quantity concerns (*National Park Service* n.d.). In order to provide long-term management projections for the park climate change and its potential effects have to be taken into consideration. Therefore, we need to understand the relationship between visitation and climatic variables. Further, we need to know how the combination of climatic predictors and social predicators affect visitation.

2.3 Methods

The methodology for this study is adapted from two papers by Jones and Scott (2006) and Scott et al. (2007). In their research they used multiple regression to determine the statistic relationship between monthly visitation, temperature and precipitation.

2.3.1 Study Area

Early Native Americans inhabited Big Bend National Park at least 10,000 years ago. During the 16th and 17th century Spanish explorers crossed the Rio Grande River into the area looking for gold and silver but deemed the area uninhabitable. The Apaches and later the Comanche moved in before being pushed out by Mexican settlers and the United States military during the California gold rush. Exploration of the river and surrounding canyons began in the mid 1800's. In 1933 the state of Texas established Texas Canyons State Park using 15 school sections gained by the state. That same year land forfeited for non-payment of taxes was added and the name changed to Big Bend. By Oct. 27, 1933 the park was comprised of 160,000 acres. On June 20, 1935 Franklin D. Roosevelt signed a bill that designated the park as a national park. A deed of 100,000 acres was presented to President Roosevelt on June 6, 1944 and the park was officially established as Big Bend National Park on June 12, 1944. The park was designated an International Biosphere Reserve in 1979.

Big Bend National Park is located primarily in Brewster County and covers approximately 801,163 acres. The Rio Grande River serves as a portion of the park boundary line, 118 of the 1,000-mile international boundary that separates the U. S. from

Mexico falls under park jurisdiction. The park is open year round, 24 hours a day/ 7 days a week. Park visitation averages 350,000 or less per year with the majority of those visits occurring in March or on holiday weekends. Recreational activities range from hiking, camping and birding to photography and cultural and art exhibits.

The park has some of the most diverse landscapes and ecosystems in the country and is the largest protected area of Chihuahuan Desert. The park has a vast geologic history; the oldest activity is related to the Paleozoic Marathon orogeny. Many of the formations are composed of sedimentary material such as limestone that was deposited during the Cretaceous period when oceans covered much of the area. Three natural divisions typically characterize the park: the river, the desert and a chain of old volcanic mountains called the Chisos. The sharp contrast in elevation lends itself to dramatic climatic variation within the park. It's this variation that leads to the diversity of plant and animal species. The park is home to 1,200 plant species, 11 species of amphibians, 56 species of reptiles, 40 species of fish, 75 species of mammals, 450 species of birds and 3,600 species of insects some of which are found nowhere else on Earth (*National Park Service* n.d.).

2.3.2 Data

In order to analyze what impacts future climate change will have on tourism at Big Bend the "links" or relationships that exist between recreation and different climatic and socioeconomic variables must be defined. While we understand what drives people to participate in outdoor recreation we know less about the impacts and consequences that human-accelerated climate change will have on tourism, the environments in which activities take place or how the interactions of these factors will influence one another

Jones and Scott had enough data to establish a climatically average year (30-year period), whereas Big Bend's monthly visitation records do not go back far enough, so I wasn't able to establish this as a baseline (Jones and Scott 2006). However, using historical monthly climate summary data from the National Climate Data Center (1980-2010) and historical monthly visitation data from Big Bend I show the linkages between different climate variables and park recreational visitation via regression analysis (*NCDC* n.d.,, *Park Reports n.d..).* The climatic variables are monthly total precipitation (TPCP), monthly minimum temperature (MMNT), monthly maximum temperature (MMXT), and mean monthly temperatures (MNT). Climate readings were collected from various locations within and directly around the park.

The following socioeconomic variables were also used in conjunction with the climatic variables to see what effect they have on visitation. The variables are mean age, county population, annual household income, and monthly gas price. Data for Brewster County, TX was obtained from the Social Explorer database via Texas A&M University Libraries and is a compilation of the U.S. Census survey from 1980-2010 (*Social Explorer* n.d.). Due to changes in census format only certain variables proved suitable population, age and annual household income. Since census data estimates are in five-year increments the average was obtained and applied on a monthly scale in order to correspond to the climatic predictors. Historical monthly gas prices (Jan. 1980- Dec. 2010) were obtained from the U.S. Bureau of Transportation Statistics (*United States*

Department of Transportation n.d.). Finally, historical population estimates were obtained for Brewster County, TX from 1980-2010 from the U.S. Census Bureau website (*United States Census Bureau* n.d.). Since only yearly estimates are available the same value was assumed consistent over the entire year.

Climate Models (GCM's) under climate change scenarios were obtained from USGS's national climate change viewer (NCCV) system (*NCCV* n.d.). The data is a compilation of predictions from worldwide climate modeling centers that are participating in the 5th Climate Model Intercomparison Program (CMIP5) which provides feedback for the ongoing 5th Assessment Report published by the Intergovernmental Panel on Climate Change (IPCC); NASA downscaled the maximum, minimum temperature and precipitation estimates from the outputs of 30 models to an 800 meter scale in order to obtain estimates on a regional scale. (CMIP5) models have been shown to provide more accurate estimates at finer scales than previous iterations of the program. It also provides the most current estimates of regional climate under the future climate change scenarios.

2.3.3 Preliminary Analysis

I organized the data in Excel by year; within each year I organized the data by sampling station and month. In order to get monthly readings I averaged the individual station readings together. It is important to note that data was not consistently taken from the same weather stations over the course of the study; the stations used and their frequency of use varied month-to-month and year-to-year. The most commonly used stations included: Panther Junction, Chisos Basin, Boquillias, Persuido and Persimmon

Gap. Also, stations were sometimes missing individual monthly readings for example (precipitation missing for July and March) were included in the averages but other stations that had only 1-3 months' worth of data for the year were omitted from analysis. The weakness of the data impacted the significance of the correlation between climate and visitation. The relationship appears to be significant but weak. This means that when combined with other factors the correlations can become overshadowed or loose statistical significance. The weakness of the relationship also impacted model fit, some months or combination of months that went into the models did not fit as well as the others, which is likely due to this issue. Model fit was determined by plotted residual values.

A variety of statistical analyses were run on the entire dataset in order to discover any possible trends or correlations within the data. During this preliminary phase significant correlations was found for all variables in relation to visitation based on either a 0.10 or 0.05 level (Pearson's 2-tailed test). The correlations can be found in Table A-1 of the Appendix. The majority of predictors demonstrate statistical significance at the 0.10 level however, these correlations were isolated and should and did change when combined into various models. Over time the number of visitors to the park has increased (Figure A-1) while overall mean temperature doesn't seem to increase very much, if at all (Figure A-2). Overall, trends in the individual predictor variables can be observed over time as well. MMNT appears to be similar to MNT in that there is only a slight increase if any over time, see (Figure A-3). MMXT displays no significant change over time (Figure A-4). There does not appear to be any significant change in total precipitation over time (Figure A-5). Population and income display an increase over time. This is to be expected as tourism in the area and economic growth is consistent with the rest of the state (see Figures A-6 and A-7 respectively). Mean age increases slightly over time Figure A-8. Gas price is unique among the variables in that a quadratic trend over time is observed consistent with the flux in oil/gas market prices over the years, Figure A-9.

Trends can be seen in how the predictor variables related to recorded visits overall as well. Visitation appears to decrease as total precipitation increases (Figure A-10). The trend for the mean, maximum and minimum temperature predictors are non-linear (Figures A-11, A-12 and A-13). The gas prices also negatively affect visitation a slight decrease in visitation is noticeable as the price of gas increases; the ideal gas price for visitation appears to be between $1.50-$3.50 (Figure A-14). Visitation is positively affected by increases in population and mean income (Figure A-15, and A-16). There does not appear to be any significant affect due to age. These results mirror the same increasing trend over time that the predictors showed over time in earlier graphs. So to summarize as far as significant predictors of visitation are concerned it appears that temperature, precipitation and gas price could have a nonlinear correlation to visitation, possibly quadratic. After examining how the predictor variables related to each other and to visitation overall I started to develop the monthly and seasonal models.

2.3.4 Models

2.3.4.1 Monthly Visitation Model

First descriptive statistics and correlations (maximum, minimum, and mean) were generated for each month in the dataset in an effort to see how smaller scales impacted overall relationships. I thought some type of monthly-adjusted model would be best instead of removing outliers but I discover that removing the effects of month also removes a lot of the effects of temperature. I ran a basic linear regression model with all the predictors against recorded visits in order to identify and remove obvious outliers. Outliers were identified using a Cook's Distance cutoff equal to 4/n where n is the number of observations in the sample; any value above this number was excluded. In order to try and correct for an extrapolation of the year trend in which model predictions were lower than the visitation rate which I noticed with an earlier model that used just the climate data, I combined and transformed the population and year predictors into a single variable that accounts for the yearly change in population. Once this was done I began to define the actual model.

I began by putting together an individual monthly model. I started by regressing recorded visits on all the predictor variables for each month. Then, pulling out just the predictors that identified as significant and running the model one more time with just the significant predictors. I took into account model fit, determined by residual plot and tried different transformations in order to get the best fit. However, once I looked at the results I noticed that some months just did not fit well within a model no matter what I did. This leads me to believe that for certain individual months other factors than the seven I've examined affect visitation.

I decided to combine all twelve months into a single monthly model. In order to do this I created 11 dummy variables, one for each month and I omitted the month of April to avoid the dummy variable loop. This allowed me to isolate monthly patterns from the effects of climate or social predictors. Then I ran the model with the 11 new variables and the climatic and social predictors. From this result I pulled out the significant predictors based on correlation value and ran the model a second time with only the significant predictors. I tried different predictor variable transformations and I looked at the R^2 value to derive the best possible model. The value of R^2 ranges from 0 to 1. The closer the R^2 value is to 1 the better fit the model. From these results I was able to derive the final monthly model.

The basic format for the regression model can be expressed as

Equation 1: $v= B_0+B_1x_1+B_2x_2+B_3x_3+B_4x_4+B_5x_5+B_6x_6+B_7x_7+B_8x_8+\in,$

where v is equal to the number of visits and B_0 denotes the intercept, B_1 through B_8 symbolize the slope of the line and indicates how much the dependent variable changes for each 1-unit change in the associated independent variable. The variables x_1 through x_8 are the significant predictors (independent variables) for the monthly model, and $\in$ denotes the undefined error term.

B_o denotes the intercept or constant, which defines the value of the dependent variable if the values of all the independent variables were equal to 0. The dependent variable is visitation, which will be linked to a combination of independent variables.

The independent variables are: MMNT, MMXT, MNT, TPCP, monthly gas price, average household income, mean age and year/county population. The independent variables were chosen based on available data and the significant relationships found in previous studies, see section 2.2. I chose to include only the variables that demonstrated a significant relationship to visitation in the final model. The 0.05 significance level was used as the benchmark for significance. Residual values were generated in order to estimate the model. The observed values were compared to the expected values in order to validate the model and observe model fit.

2.3.4.2 Seasonal Visitation Model

In order to address the variability in the data caused by peak tourism seasons Scott et al looked at identifying the seasonal relationship between climate and visitation. Previous research by Jones and Scott found visitation patterns similar to Big Bend in that peak visitation corresponded to typical vacation times when the weather is favorable in Canada’s National Parks. The authors also found the relationship between climate and visitation to be non-linear (Jones and Scott 2006). As previously mentioned and as evident in Figure 1 recreational tourism in Big Bend appears to have a strong seasonal relationship

I followed the same preliminary procedure for the seasonal model as I ran for the monthly model. I ran regressions in order to identify outliers via Cook's distance equal to 4/n where n is the sample size. Then I regressed all of the climatic and socioeconomic variables as predictors for visitation and ran the basic regression again in order to identify which variables had the strongest relationship.

Based on Figure A-2 in the Appendix it appears either a transformed quadratic or a pair of linear models would have fit the data best. However, a quadratic seemed better suited for the monthly model while a pair of split linear models seemed better suited for the seasonal model. After looking at the monthly correlations and preliminary models it was apparent that again out of the three temperature related predictors MNT and MMNT had the most impact on visitation, so I decided to test out two model variations with each of predictor to see what worked best. The first model I tested was a split linear model that contained both the temperature predictor as well as the transformed temperature predictor along with the other predictors. The second model I tested was a variation of the first model that contained the temperature predictor only along with the other variables.

I chose to use the split linear model\that contained the temperature predictor and the other significant predictors only. I chose the model for a couple of reasons. First, the model is simpler and the inclusion of only the significant predictors eliminates non-pertinent information. Second, the simplified linear model preformed slightly better overall. I followed the same initial procedure that I followed for the monthly model Once this was done I began to define the actual model.

The inconsistency in the relationships between the variables discussed earlier eliminated the possibility of using traditional seasons for the model. I looked at all the data and identified the temperatures that were associated with the greatest number of visitors. Then I combined and averaged the temperatures. I was able to identify that the temperature at which maximum visitation occurred over the time span was 17.94ºC so I decided to split the data into two "seasons". The warm or above peak season consisted of months where the temperature was above 17.94ºC, while the cool or below peak season consisted of months where the temperature was below 17.94ºC.

I started out by regressing recorded visits by all the predictor variables for each month. Then, pulling out just the predictors that identified as significant and running the model again with just the significant predictors. I took into account model fit and tried different transformations in order to get the best fit. The basic format of the model is shown below and is similar to the monthly model except that it is divided into two seasons.

Equation 2: $v_a = Ɓ_o + Ɓ_1 x_1 + Ɓ_2 x_2 + Ɓ_3 x_3 + Ɓ_4 x_4 + Ɓ_5 x_5 + Ɓ_6 x_6 + Ɓ_7 x_7 + Ɓ_8 x_8 + \in.$

Equation 3: $v_b = Ɓ_o + Ɓ_1 x_1 + Ɓ_2 x_2 + Ɓ_3 x_3 + Ɓ_4 x_4 + Ɓ_5 x_5 + Ɓ_6 x_6 + Ɓ_7 x_7 + Ɓ_8 x_8 + \in.$

Here v_a is equal to the number of visits above 17.94ºC while v_b denotes the number of visits below 17.94ºC. $Ɓ_1$ through $Ɓ_8$ symbolize the slope of the line and indicates how much the dependent variable changes for each 1-unit change in the associated independent variable. The variables x_1 through x_8 are the significant predictors (MNT, MMXT, MMNT, TPCP, year, population, mean age and income, respectively) for the monthly model. $\in$ denotes an undefined error term. $Ɓ_o$ denotes the intercept or constant, which defines the value of the dependent variable if the value of the independent variables were equal to 0. The dependent variable was visitation, which was split into the two “seasons”. It was linked to a combination of independent variables. The independent variables were: MMNT, MMXT, MNT, TPCP, monthly gas price, average household income, mean age and year/county population. The independent variables were chosen based on available data and significant findings from other studies, see section 2.2. I chose to include only the variables that demonstrated a significant relationship to visitation in the final model. Significance was denoted from the p-value at a 0.05 level. Residual values were generated in order to estimate the model. The observed values were compared to the expected values in order to validate the model and observe model fit.

The final models in conjunction with the GCM provided by USGS are used to predict visitation under two different climate change scenarios. Monthly temperature and precipitation estimates provided by the GCM are applied to the final model. Then, I combined and averaged the monthly variables that formed the two seasons. Next I was able to insert the averages into the model with the corresponding variables and the result was a seasonal prediction of visitation under different climate change scenarios.

2.3.4.3 Projected Visitation Under Climate Change

The NCCV contains historical and future predictions from 30 of the downscaled models including the commonly cited Hadley model. I chose to average the results of all 30 available models in order to hopefully get the most robust estimate of change prediction. Two emission scenarios are available, RCP 4.5 and 8.5. RCP 4.5 is a moderate prediction scenario in which CO^2 equivalent won't exceed 650 ppm after 2100, but RCP 8.5 is the more aggressive scenario in which greenhouse gases rise unchecked though 2100 leading to CO^2 equivalents above 1,370 ppm. I chose to compare the results generated by both scenarios. However, based on Gosling and Hall's survey in which tourists stating that temperatures would need to increase drastically before tourism would be impacted I expected the RCP 8.5 scenario to predict fewer visitors (Gössling and Hall 2006). The model allows you to choose estimates from 4-time periods: 1950-2005, 2025-2049, 2050-2074, and 2075-2099. For the purposes of this analysis I chose to use the latest time period 2075-2099 in order to hopefully capture the most significant impacts of climate change on visitation. Maximum and minimum temperatures and total precipitation predictions were obtained from the climate model. In order to estimate mean temperature maximum and minimum temperature were averaged.

I chose to assume that the year would be a constant value. Since I decided to use the time period of 2075-2099, I chose the median value of 2087 to represent the yearly predictor value in the model. Future predictions of gas price are hard to estimate because of the constant fluctuations in the market due to crude oil cost, political confrontations, resource shortages or other similar issues. For the purpose of predicting visitation values I decided to carry over the gas prices that I obtained in the original data set from the Bureau of Transportation. I decided to use the prices for the year 2010 as it was within the timeframe analyzed by this research and it was the most recent estimate that I had.

In order to predict visitation under climate change I took the models then I input the data mentioned above into the different models. To identify the warm versus the cool seasons I looked at the averaged MNT value for each month under each scenario. The months that had an MNT value above 17.94ºC were grouped together and those months that had an MNT value less than 17.94ºC were grouped separately. I averaged the months that corresponded to each season together in order to get a single value for each predictor variable in each season. I did this twice so that I had a set of variables for the RCP 4.5 and 8.5 scenarios. The variables for each season were then applied to the model to obtain predicted visitation estimates under climate change.

2.4 Results

2.4.1 Monthly Visitation Model

As expected the climatic variables appear to be correlated to one another while visitation appears to be correlated to year and thus population. Total precipitation appears to be more dependent upon extremes (maximum or minimum temperature) depending on the month. However, there were a few noted exceptions, in Jan. and Feb. visitation is positively correlated to year (0.10 level), MMNT (0.10) and MNT (0.10 level). Next, the combined dataset was broken down by month.   Average age and income as well as gas price and a yearly variable that accounts for population change were then assessed as predictors of visitation along with the climatic variables. Gas price does appear to have a significant influence on visitation.

By identifying any monthly trends or relationships and by looking at how the variable correlations varied from month to month and/or differed from the overall correlations discussed in the preliminary analysis I discovered that specific months have a definite impact on the relationships between predictor variables and visitation. However, the majority of these trends are weak and not statistically significant.   For example, minimum temperature positively affects visitation in Jan., Feb., Oct., and May but has a negative effect in July and Aug.. However, the correlation indicates no significant effect in Mar., Apr., Jun., Sept. and Dec.. The relationship between maximum temperature and visitation differs by month as well. A positive relationship is indicated for Jan., Feb., Apr. and Oct. but visitation is negatively impacted in Apr., Jul., Mar. and Sept. No significant correlation between MMXT and visitation is detected for Dec., Nov., May or Jun. Mean temperature has a positive monthly relationship with visitation in Feb., Jan., Jun., Nov. and Oct. but is negatively correlated in Aug., Dec. and Jul. MNT seems to have no effect on visitation in Apr., Mar., May or Sept. Precipitation seems to have a positive effect on visitation in Apr., Feb., Jul. and May and a negative effect in Dec., Jan., Jun., Mar. and Oct.. However, April, Nov. and Sept display no correlation between precipitation and visitation.

Out of the socio economic predictors gas price seems to have the strongest relationship with visitation by month. Population appears to be mostly neutral- a positive relationship is displayed in Jul., Jun and Oct, while Aug., Jan and Mar. displayed a negative correlation. No effect was shown for the rest of the months. Gas price displays a primarily negative correlation; Aug. is the only month that displays a slightly positive trend while Sept. is the only month where gas price doesn't have much of an influence. It should also be noted that out of all the socio economic predictors' gas price was the only one that displayed any statistically significant correlations to visitation. Average income had no negative monthly correlations. April, Feb., Jan., Nov. and Oct. displayed slightly positive correlations while income had no effect on visitation in the remaining months. Mean age correlations by month were split fairly evenly although not significant positive correlation with visitation occurred in Apr., Aug., Jan and Nov while negative correlation was displayed in Dec., Jun., Mar., Oct. and Sept. In the months of Feb., Jul. and May, average age has no effect on visitation.

MMNT and MMXT proved to be somewhat significant for some of the months, for example MMXT was more significant in August while MMNT was significant in April but for most of the individual months none of the climatic predictors were significant. MNT seemed to have the most consistency across all the models I tested. Also, using MNT seems to "highlight" or allow the significance of gas price to be clearer.

While looking at the monthly correlations between the individual predictors I noticed that MMNT is less statistically stable than MNT. There were more multivariate outliers in the model that used MMNT than in the model with MNT. This caused the sample size value (N) and the degrees of freedom (df) to be significantly smaller in the model with MMNT. Having a smaller sample size and lower degrees of freedom affects the strength and accuracy of a model and can lead to incorrect results. Figure A-16 illustrate how inconsistent MMNT is across months and show that MNT being more consistent is thus more stable. Further, based on the overall correlations discussed in the preliminary analysis section and reported in Table A-1 MMNT seems to be more related to TPCP which isn't acceptable given it's significance to visitation. Figure A-18 illustrates the relationships between TPCP, MMNT and MNT. Based on this reasoning I decided to use MNT as the temperature predictor in the models.

The significant predictors were year and gas price. Both of these predictors displayed a significance value of .000. All of the other months demonstrated significance from the visitation of the reference month April. The final model is

Equation 4: v= -1054546.436+551.340(year)-2020.624(gas price) + ∈

The R^2 value for the model was 0.730. Table 1 provides the ANOVA test results for the model.

Table 1: ANOVA Results of the Monthly Model

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	35184302378.004	15	2345620158.534	63.942	.000[b]
	Residual	13022668676.729	355	36683573.737		
	Total	48206971054.733	370			

a. Dependent Variable: Recorded Visits

b. Predictors: (Constant), Sep, Year, GasPrice, Oct, Nov, Mar, Aug, Jul, Feb, May, Jan, Total Precipitation, Dec, Jun, Average Monthly Temperature

These results show that the overall model is significant based on a significance level of 0.05. Table 2 identifies which coefficients are significant within the model.

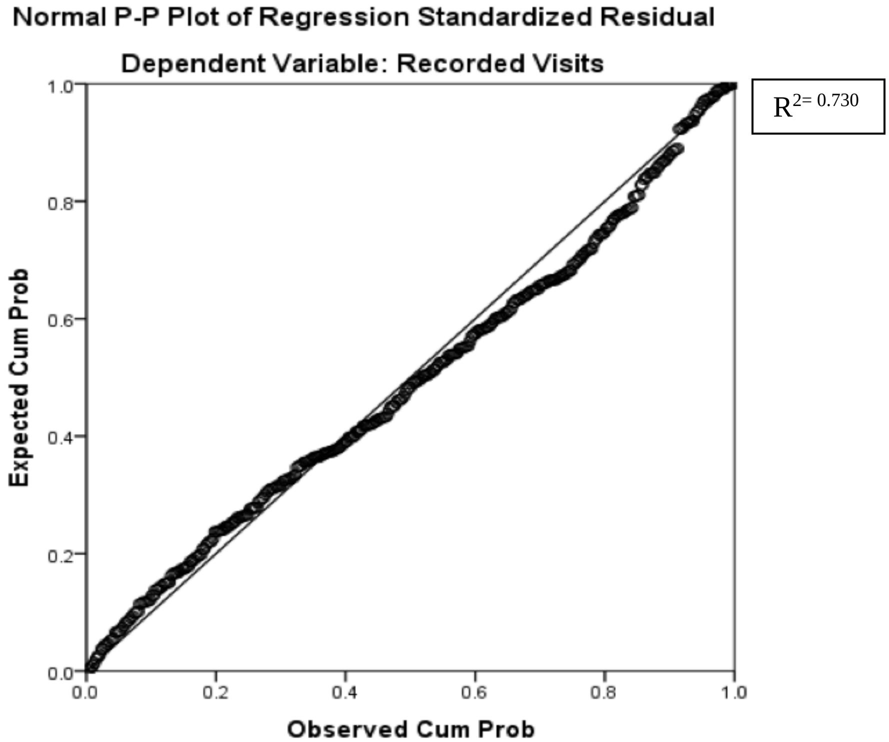
Table 2: Regression Results of the Monthly Model

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-1054546.436	70346.710		-14.991	.000
	Year	551.340	35.404	.432	15.573	.000
	Total Precipitation	-5.510	14.370	-.014	-.383	.702
	Average Monthly Temperature	-119.359	245.379	-.073	-.486	.627
	GasPrice	-2020.624	482.633	-.117	-4.187	.000
	Aug	-21448.557	2520.888	-.521	-8.508	.000
	Dec	-19545.963	3026.684	-.474	-6.458	.000
	Feb	-15622.652	2577.839	-.379	-6.060	.000
	Jan	-19284.036	3088.592	-.468	-6.244	.000
	Jul	-21815.217	2633.674	-.530	-8.283	.000
	Jun	-17109.668	2596.000	-.415	-6.591	.000
	Mar	3985.570	1945.932	.095	2.048	.041
	May	-13479.460	2008.758	-.327	-6.710	.000
	Nov	-12874.627	2163.147	-.313	-5.952	.000
	Oct	-17841.973	1560.788	-.433	-11.431	.000
	Sep	-21914.247	1966.084	-.532	-11.146	.000

a. Dependent Variable: Recorded Visits

Monthly visitation proved to be statistically significant from April visitation. Interestingly, average monthly temperature and visitation are not significant in the monthly model. -1054546.436 is the y-intercept, which is a constant. It is equal to the value of visitation if the value of all of the predictors (independent) were 0. It indicates where the fitted line crosses the y-axis. Since it is highly improbable that all of the independent variables to equal 0 no significant information about the relationship between climate and visitation is gained from this variable. 551.340 and -2020.624

indicate the slope of the regression line for the independent variables of year and gas price respectively. Slope identifies how much visitation changes in response to changes in year or gas price. For this model for every one unit change in in year or gas price visitation increases by 551.340 in response to year or decreases by -2020.624 in response to gas price. In general visitation to Big Bend will continue to increase over time but increases in the cost of gas over the same time period will cause visitation to decrease. Figure 1 depicts model fit by illustrating the correlation between the expected and the observed cumulative probability. The model appears to be close to the line and only varies slightly as the value increases. For the most part the model appears to be normally distributed.



: **Figure 1: Depiction of Monthly Model Fit- Expected vs. Observed Cumulative Probability**

2.4.1.1 Monthly Model Limitations

One of the major shortcomings of the model is that I had to average the data over the entire park. The diverse climatic variation of Big Bend would lend itself to each region being analyzed independently of the others but there is not any information on how visitors utilize the individual climatic zones of the park. Potentially, this could mean that I have missed some underlying trend that could help predict future visitation. Further, as mentioned in the Data and Preliminary Analysis section the number of and location individual station readings were not consistently reported over time and thus don’t represent each climatic zone equally over the time. Another possible limitation is that I considered only polynomial representation of the relationships between climatic variables and visitation based on initial analysis but it could be possible given the preceding limitations that a more complex function might yield better results. Based on research incorporating the Human Climate Index there is a range of temperatures where people can be comfortable where at or below a certain temperature visitation could rise or fall rapidly. During preliminary analysis I did notice some autocorrelation between visitation and consecutive months.

2.4.2 Seasonal Visitation Model

I discovered that the months of March and April were causing a significant degree of skewness to the data set. March and April correspond to holidays like Spring Break and the start of the warmer tourist season all of the other months have similar visitation numbers, Figure A-2 in the Appendix. The busiest time of year for the park is spring while the holiday season (Thanksgiving through Christmas) can be busy as well. There is a peak in the spring and a lesser but noticeable increase during the winter holiday season. This caused false results, such as visitation continuing to rise as maximum and minimum temperature increased.

While Jones and Scott were able to avoid this by analyzing the data by seasons, the nature of the Big Bend data wouldn’t allow me to do so, in part because the relationship between climate and visitation is so weak at times due to the temporal scale of the data (daily records would have provided better results) (Jones and Scott 2006). This caused the relationship to be inconsistent within the season for instance in Fall there is a strong significant relationship between temperature and visitation in Oct. but no for Sept. or Nov. (if I were to analyze the data according to season would negate the existing relationship in Oct.).

The R^2 and the root mean square error (RMSE) values for the different models can be seen in Table A-2. Based on this table it appears that MMNT out performs MNT in most of the models based on the larger R^2 value and the smaller RMSE values. However, I noticed that MNT does outperform MMNT in one of the above peak linear models but is slightly less powerful in the corresponding below peak model. But as I discussed in the earlier section I chose to go with MNT for better stability and because MMNT is strongly related to TPCP. I chose the linear model that contained only the significant predictors. The only other significant predictors besides temperature were TPCP, gas price and year. The above and below peak models are defined below in equations 5 and 6.

In the above peak model -603478.968 is the y-intercept, which is a constant. It is equal to the value of visitation if the value of all of the predictors (independent) were 0. The y-intercept indicates where the fitted line crosses the y-axis. Since it is highly improbable that all of the independent variables to equal 0 no significant information about the relationship between climate and visitation is gained from this variable. -1110.448 is the slope associated with mean temperature, for every one-unit increase in temperature visitation will decrease by 1110.448 people. Once again year has a positive impact on visitation. For every one unit increase in year visitation will increase by 330.325 people. Precipitation and gas price negatively impact visitation indicated by their signs. For every one-unit change in TPCP and gas price visitation will decrease by 67.544 and 1980.304 visitors respectively.

In the below peak model -1296891.463 is the y-intercept, which is a constant. It is equal to the value of visitation if the value of all of the predictors (independent) were 0.   The y-intercept indicates where the fitted line crosses the y-axis. Since it is highly improbable that all of the independent variables to equal 0 no significant information about the relationship between climate and visitation is gained from this variable. 2049.708 is the slope associated with mean temperature, for every one-unit increase in temperature visitation will increase by 2049.708 people. Similarly, to the previous models year has a positive impact on visitation. For every one-unit increase in year visitation will increase by 651.913 people. In the cooler (below peak) season precipitation has no significant impact on visitation. Gas price negatively impact visitation indicated by its sign. For every one-unit change in gas price visitation will decrease by 1785.307 visitors.

In general warmer drought-like conditions are shown to negatively impact visitation. However, cooler temperatures have a positive influence on visitation. Similarly to the monthly model visitation increases as time passes but increases in the price of gas causes visitation to decrease.

Equation 5   Va = -603478.968-1110.448(MNT)+330.325(year)-67.544(TPCP)-1980.304(gas price)

Equation 6   Vb =-1296891.463+2049.708(MNT)+651.913(year)-1785.307(gas price)

The standardized residuals appear to be fairly normally distributed. Based on histogram analysis the model might be slightly positively skewed but it doesn't appear to be significant. The ANOVA results for the above peak and below peak seasonal model are shown in Tables 3 and 4, respectively. Based on these results both models appear to be significant at the 0.05 level. The coefficients that contribute to the above peak model are shown in Table 5, while Table 6 contains the coefficients that contribute to the below peak model. The significance of predictors was evaluated at the 0.05 level.

Table 3: ANOVA Results of the Above Peak Seasonal Model

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	6424206408.259	4	1606051602.065	38.641	.000[c]
	Residual	8354153559.203	201	41562953.031		
	Total	14778359967.461	205			

a. AbovePeak = 1.00

b. Dependent Variable: Recorded Visits

c. Predictors: (Constant), GasPrice, Average Monthly Temperature , Year, Total Precipitation

Table 4: ANOVA Results of the Below Peak Seasonal Model

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	9859192658.660	3	3286397552.878	71.038	.000[b]
	Residual	6476787400.340	140	46262767.145		
	Total	16335980059.000	143			

a. Dependent Variable: Recorded Visits

b. Predictors: (Constant), GasPrice, Average Monthly Temperature , Year

Table 5: Regression Results of the Above Peak Seasonal Model

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-1060579.602	410533.990		-2.583	.011
	Average Monthly Temperature	-1070.742	136.235	-.424	-7.860	.000
	Year	595.140	225.639	.612	2.638	.009
	Total Precipitation	-68.564	14.232	-.262	-4.818	.000
	Population	-3.844	2.676	-.203	-1.436	.152
	GasPrice	-2115.126	900.206	-.166	-2.350	.020
	MeanIncome	.530	.508	.287	1.043	.298
	MeanAge	-1707.369	1450.447	-.373	-1.177	.241

a. AbovePeak = 1.00

b. Dependent Variable: Recorded Visits

Table 6: Regression Results of the Below Peak Seasonal Model

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-1373134.311	493691.392		-2.781	.006
	Average Monthly Temperature	2007.633	208.567	.520	9.626	.000
	Year	724.610	272.754	.598	2.657	.009
	Total Precipitation	1.629	40.905	.002	.040	.968
	Population	-4.818	3.315	-.207	-1.454	.148
	GasPrice	-2467.767	1290.544	-.141	-1.912	.058
	MeanIncome	1.011	.644	.439	1.571	.119
	MeanAge	-1886.146	1914.603	-.328	-.985	.326

a. Dependent Variable: Recorded Visits

Figure 2 depicts model fit of the above peak model by illustrating the correlation between the expected and the observed cumulative probability. The model appears to be close to the line and only varies slightly in the middle ranges. Figure 3 depicts model fit of the below peak model by illustrating the correlation between the expected and the observed cumulative probability. Again, the model appears close to the line indicating a good fit.

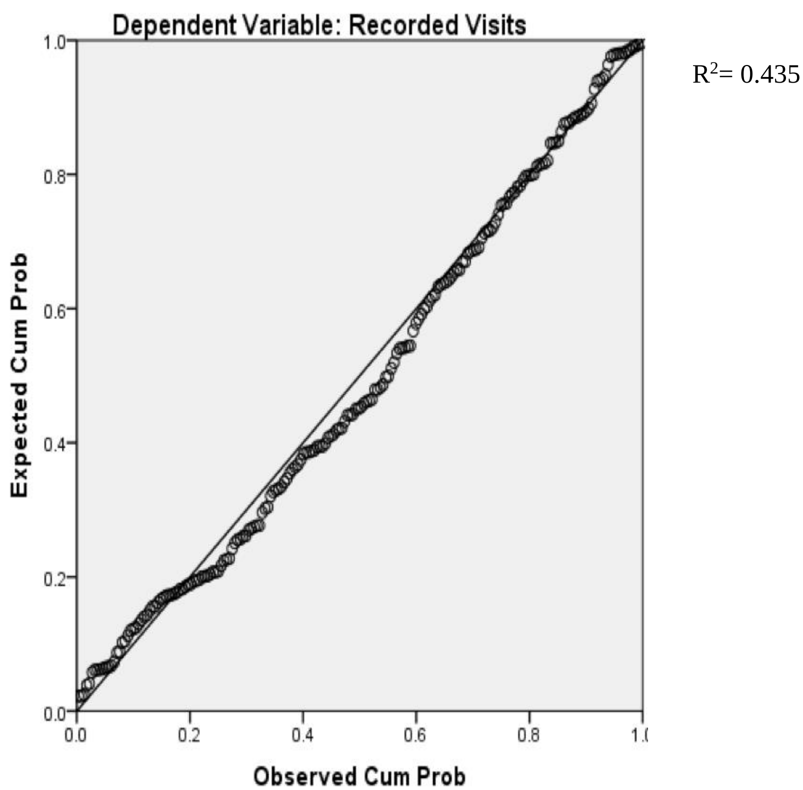
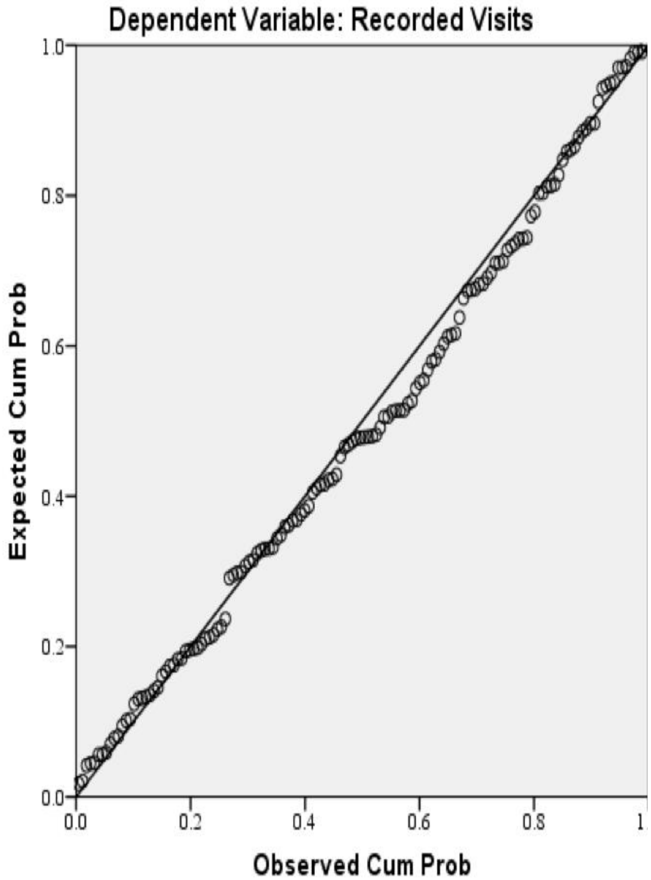


Figure 2: Depiction of Above Peak Seasonal Model Fit- Expected vs. Observed Cumulative Probability



R^2= 0.608

Figure 3: Depiction of Below Peak Seasonal Model Fit- Expected vs. Observed Cumulative Probability

2.4.2.1 Seasonal Model Limitations

The limitations of the seasonal model are similar to those of the monthly model given that they are derived from the same dataset. More data or data on a finer scale might have made analysis using traditional seasons more of a possibility. I think that having the opportunity to analyze the data in this manner would have provided more clear results.

Also, the model I chose might not have statistically been the strongest choice based solely on the numbers. Recall that minimum temperature outperformed average temperature on the majority of the models tested but given the stability and correlation issues associated with MMNT I chose to use MNT in the model

2.4.3 Projected Visitation Results

The models predicted weather variation at a monthly scale. Interestingly, there wasn’t much of a difference in precipitation variation between the RCP 4.5 and the 8.5 scenarios at this time scale. The estimates varied by only tenths of a millimeter between the two. I assumed that precipitation would be significantly less with the RCP 8.5 scenario given that most of the current research suggests precipitation will significantly decrease and drought conditions worsen under climate change in this area of Texas. On average there is a 2ºC increase in temperature, across all temperature variables, between the RCP 4.5 and 8.5 models. This was expected and corresponds to current literature, in their latest report IPCC suggests that the average temperature of the Earth could rise by as much as 5.5ºC by 2100 (Climate Change 2001). Simulation models created by Herbert suggest that the park will see up to a 4ºC increase in temperature by the end of the century. He also suggests that more warming will occur in the fall and/or at lower elevations and less in the summer and/or at higher elevations (Herbert 2004). However, the USGS model for Brewster County estimates the temperature variation to be fairly consistent month to month within both scenarios. The most significant temperature increase occurs in August. An example of the predicted MMXT for Aug. under the RCP 8.5 scenario is shown in Figure A-21 in the Appendix.

There is a month's difference between the seasons when comparing the RCP 4.5 to the 8.5 scenario. The cool season lasted from Nov.-March in the RCP 4.5 scenario while the cool season lasted from Nov.-Feb. only in the RCP 8.5 scenario. The warm season for the RCP 4.5 scenario extends from April through Oct. but in the RCP 8.5 scenario the warm season goes from March-Oct.. This finding shows that in the more severe scenario the cool season is getting shorter and the area will see warmer temperatures more quickly and for a longer period of time.

I used the coefficients from tables 5 and 6 to formulate the above peak and below peak model equations. Surprisingly, the more severe scenario, RCP 8.5, predicted slightly more visitors overall than the 4.5 scenario. The combined number of predicted visitors for the 4.5 scenario was 319,083 visitors versus 322,385 visitors for the RCP 8.5 scenario. Seasonally, visitation was predicted to be higher in the below peak or cool season than the above peak or warm season for both scenarios. The results can be seen in Figure 4, the predicted visitation under the RCP 4.5 scenario was 145,759 during the warm season and 173,323 visitors during the cool season. Predicted visitation during the warm season under the 8.5 scenario was 144,494 but during the cool season visitation increases to 177,891.

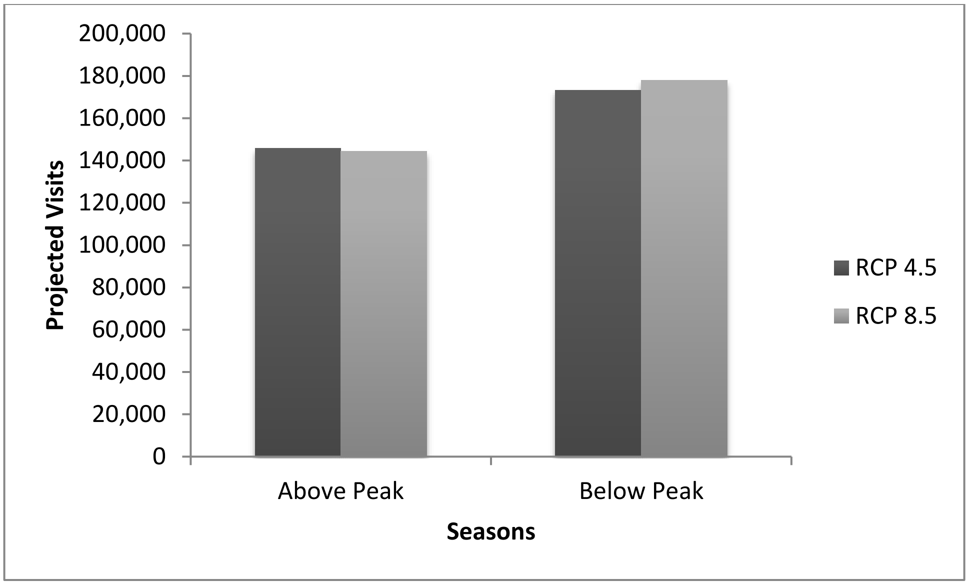


Figure 4: Comparison of Seasonal Projected Visits Under Climate Change Scenario[1][2][3]

The difference between RCP 4.5 and 8.5 indicates that it will get warmer creating less variation between seasonal temperatures. Also, the projected visitation patterns is similar for both scenarios, under the RCP 4.5 scenario there were slightly less visits overall. The warm season expands by 1 month under RCP 8.5. The RCP 8.5 scenario projected more visits overall. Projected visitation under both scenarios was consistent under both visitation seasons.

I wanted to see how these results compared to actual recorded visitation within the park, so I took the monthly 30-year (1980-2010) average of recorded recreational

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[1] Year span covered (2075-2099) for both models, used a median value of 2085

[2] Gas Price estimate was assumed constant and carried over from data

[3] MNT was derived from the average of MMXT and MMNT so it is susceptible to the variation between the two variables, the USGS model doesn't project MNT

visitation and organized it based on month into the same above and below peak "seasons" which I then averaged to get an estimate for each season, Figure 5. The predicted visits are similar in each season under the each scenario. However, recorded visits seem to be inverses of each other. In the warm season the 8.5 scenario has more visits versus fewer in the cool season but I believe this is simply due to the number of months included, recall that the cool season under the 8.5 scenario only occurred from Nov.-Feb. The RCP 4.5 scenario had a projected increase of 8.83% in overall annual visitation. However, under the more severe conditions of the RCP 8.5 scenario visitation was projected to increase by 9.96% overall. The predictive variability of the model appears to be minimal.

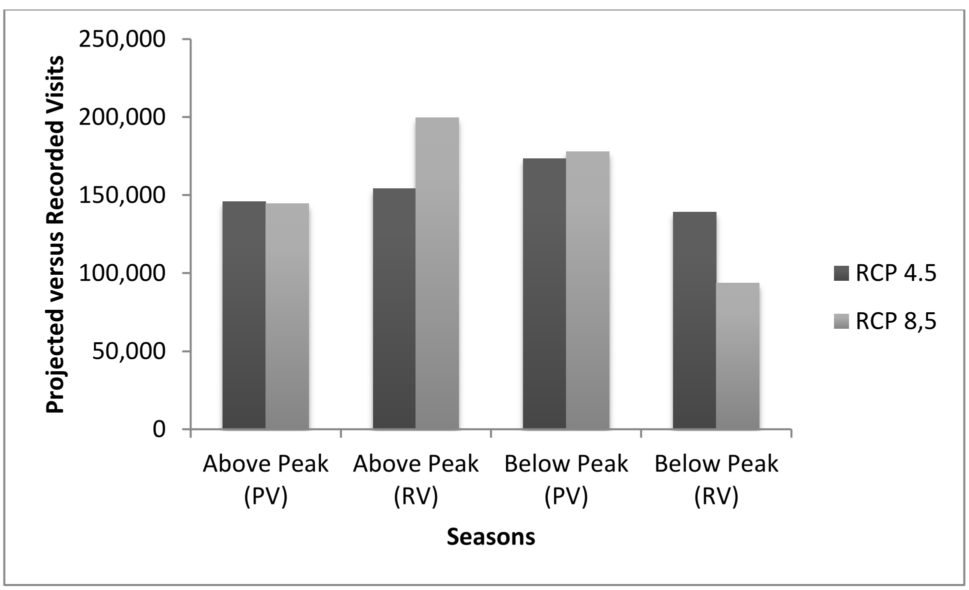

Figure 5: Comparison of Projected versus Recorded Visitation[4][5]

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[4] PV-Projected Visitation
[5] Recorded Visitation was estimated as the 30-year monthly average categorized by season

2.4.3.1 Projection Limitations

Once again data limitations as well as the analysis techniques used here affect the outcome of the model. I feel like a more robust data set could have provided the opportunity to model the traditional seasons within the park, which I feel would have provided a better sense of visitation change. For instance, I know that visitation decreases significantly in the months of July and Aug. but the model is unable to distinguish the smaller scale patterns due to the low predictive variability. Model fit wasn't precise and using say MMNT might have yielded slightly different results I chose MNT in part because it seemed the most logical that would impact average visitors. Given the variety of elevation in the park, the significance of the predictors would likely change somewhat depending on where you were in terms of elevation. This could affect visitation patterns but there was no way for the model to consider this.

2.5 Conclusion

Temperature and precipitation aren't significant within the monthly model due to the large amount of variation in attendance that was caused by the vast difference in weather between the months. Residual values were generated in order to predict visitation based on the model. The mean visitation value was 23,419.5067. The R^2 value combined with the normalcy of the graphs indicates that this is a statistically valid model for observing the monthly relationship between socioeconomic factors. However, my overall goal of this research is to illustrate the potential effect of climate change on park tourism. Therefore, I do not believe this model will work well for predictions under scenarios of climate change because at the monthly scale climatic predictors don't seem to be a factor that affects tourism. Other factors that might have affected the monthly model are inconsistencies in data as well as correlation between the variables. As I mentioned before in the literature review scale is a very important topic when discussing ecosystem/landscape services, climate change and natural resource management. At the monthly scale I believe that the variance between climatic predictors and visitation in affect is overshadowed and canceled out by the other predictors that have stronger relationships.

Overall, I believe based on the data that the seasonal model preforms better and is more statistically robust than the presented monthly model. I think that based on the visitation patterns it makes more sense to examine the data on a "seasonal" scale rather than a monthly one.   Data at a finer scale might improve the accuracy of the models or impact the results. I would also like to point out that although other researchers had success developing seasonal models based on an areas weather patterns, I believe that the nature of the tourism industry at Big Bend won't allow this because it's not so much based on the Human Climate Index (HCI), when climatic factors are favorable inducing tourism but rather is more relatable to holidays or when individuals have large blocks of time which enables them to travel and stay in various places for extended amounts of time. The remoteness of the park lends itself to this type of relationship, which I think makes typical seasonal analysis infeasible.

I think the model does a decent job of predicting actual visitation numbers. The predicted visitation estimates produced are fairly similar to the recorded visits. Also, records show that since 2010 park visitation has continued to increase so the increased numbers under both scenarios continue this trend. However, I don't believe that this method should be used to try and accurately predict visitation, it should be regarded as an estimate. It is interesting that visitation is predicted to be higher for the cool season under both scenarios. I think that this suggests a definite seasonality related to visitation and that visitors prefer an "ideal temperature range". This could suggest that as the climate changes visitors could become more influenced by the seasonal climatic conditions and an industry more defined by the HCI. However, overall visitation increased under the hotter/ drier 8.5 scenario. This suggests that while visitation in the respective seasons may vary overall park visitation won't be affected much by climate change. I do believe that the model is able to depict what the area will likely face under the increasing threat/severity of climate change.

When considered all together I believe that my results depict the general effect of climate change on visitation to Big Bend. Similarly to a study conducted by Bigano the link between climate and visitation is generally a weak one, so results aren't as precise as other studies(Bigano et al. 2006). Butler notes in his paper that seasonality is one of the most distinctive and typical characteristics of tourism on a global scale but that the industry considers it a problem because it creates what they define as a temporal imbalance (Butler n.d.). Essentially, this refers to issues with scale that can be expressed as elements like the number of visitors, visitor expense or traffic. I have discussed the importance of scale both in the data itself and the models. Jones and Scott found that regressions based on peak and non-peak visitation seasons demonstrated the most significant relationship between climate and visitation. They were able to identify minimum temperature that had the greatest impact on visitation (Jones and Scott 2006). However, Bigano states that he focused on temperature because other climatic variables are tied to temperature anyhow(Bigano et al. 2006). While minimum temperature did appear to have some impact on visitation I chose to use the mean temperature as it performed better overall with my dataset. Root et al looked at several case studies that found that certain plants and animals were already exhibiting a response to climate change, most notably changes in temperature (Root et al. 2003).

Precipitation was shown to negatively impact visitation on a seasonal scale. Brief extreme events like droughts can have lasting effects on ecosystems and can exceed threshold limits shifting biological communities, which can carry over to the landscape scale (Burkett et al. 2005). Given that diversity of species that the park supports and that bird watching and other similar activities are popular this could cause visitation to decrease or increase depending on the activity. If the basic idea of my model is correct visitation will shift seasonally depending on among other things temperature. The rise in temperature would not only impact species diversity but it might make certain seasons associated with an activity or species intolerable. Loomis and Crespi note that even gradual changes over prolonged periods of time may cause visitors to loose interest in recreational activities as the quality of the activity diminishes as a result of climate change (Loomis and Crespi 1999).

It's important to note that climate is not the only (or even the most important factor) that influences tourism. Perry as well as Gossling and Hall argue that tourists make travel plans irrespective of the climate (Gössling and Hall 2006, Perry 2006). My results suggest that other socio economic factors like gas price might be more significant than temperature or precipitation. But as Bigano notes these variables are hard to predict and can shift easily (Bigano et al. 2006). Buckley and Foushee suggest that these variables act on interannual timescales and influence the magnitude of visitation (Buckley and Foushee 2012). In summary, warmer, drought-like conditions that are predicted to occur in Big Bend as the effects of climate change become more severe will most likely shift the plant and animal community composition of the individual ecosystem that contribute to landscape level recreational activates. These shifts could cause visitation numbers to shift to a different season. However, other non-climatic variables are likely to have equal or greater influence on visitors. In other cases, recreational activities shift along latitudes to more suitable climates and/or the activities move indoors or are replaced by new ventures (Amelung and Nicholls 2014).

3. WHAT DO WE PAY TO PLAY? VALUATION OF THE NATURAL RESOURCES ASSOCIATED WITH TOURISM IN BIG BEND NATIONAL PARK

3.1 Introduction

Until recently, the discipline of economic valuation of ecosystems has been mostly theory. Case studies examined by Dixon and Sherman for parks in Africa and Thailand broke down the benefits and costs associated with each area based on eight categories however, exact dollar amounts for valuation of ecosystems was not given (Dixon and Sherman n.d.). Different authors approach ecosystem service valuation in different ways and as such the classification scheme used to categorize valuation techniques also varies. In general there are four categories of valuation techniques- direct market, revealed preference, stated preference and benefit-transfer. Within each of these categories there are a number of alternatives to choose from. Market-based techniques use the actual price of direct market goods like timber or utilize related market prices as a proxy for the value of that ecosystem good or service. The Economics of Ecosystems and Biodiversity (TEEB) breaks down market based approaches into three separate categories; market-price based, cost-based and techniques related to the costs of goods and services that go into the production of final and intermediate goods and services (*The Economics of Ecosystems and Biodiveristy* n.d.).

Revealed preference techniques rely on notion that the choices stakeholders make within the market (purchases) reveal their preference for or in what regard they hold ecosystem goods and services. The TEEB considers the alternative techniques within this category to be the travel cost method and the hedonic pricing method, although other studies have categorized these as market based approaches. Stated preference techniques use stakeholder surveys or hypothetical policy decisions to elicit "willingness to pay" or "willingness to accept" for ecosystem goods and services that don't have existing market value. Contingent valuation, group valuation and choice models are the three alternative approaches to this method. The benefit-transfer technique uses the market value of appropriate substitutes for related ecosystem goods and services as a proxy for goods and services that aren't well studied.

This essay focused on estimating the implied fiscal value of ecosystem services associated with tourism in Big Bend National Park. The objectives were to:

- Use Arc GIS in conjunction with visitor survey data to identify visitor points of origin and define zones.
- Use the Opportunity Distance Cost Matrix tool within Arc to estimate travel time and distance between the park and points of origin.
- Use a traditional zonal travel cost (ZTC) approach to estimate consumer surplus. This value can be interpreted as a visitors "willingness to pay" to enjoy the ecosystem/landscape level services associated with tourism. Thus, the implied value of the services is estimated from consumer surplus.
- Use a modified zonal travel cost (ZTC) approach to estimate consumer surplus. This value can be interpreted as another visitors "willingness to pay" to enjoy the ecosystem/landscape level services associated with

tourism. Thus, the implied value of the services is estimated from consumer surplus as well.

This essay is organized as follows: the problem and objectives are outlined in the introduction. A brief literature review follows that details background work that leads to current research being conducted today to understand the different valuation methods. The methods section contains detailed information about current park revenue and the ZTC model. The results section contains the analysis results and the conclusion synthesizes the findings and management implications.

3.2 Literature Review

The concept of ecosystem services was first mentioned in the early 1980's and grew out of an interest to have a scientific-based management approach in order to enhance human well-being (Coulson and Tchakerian n.d.). However, it was not until the 1990's that researchers started trying to define what they were (Costanza et al. 1997)**.**

To date the most comprehensive definition of ecosystem services has been provided by Mace (Mace et al. 2012). His definition classifies ecosystem services into three categories- goods, final and intermediate services. Goods are defined as the things people value, including all market and non-market services derived from ecosystems that people value. Final ecosystem services occur when the specific service is combined with other inputs to generate a specific good. Final ecosystem services also include direct end products of nature like timber. Intermediate ecosystem services are the ecosystem functions and processes that are needed to produce final ecosystem services and goods (Mace et al. 2012).

From this point researchers realized that in order for the concept to be valuable to future research and policy decisions problems with scale and double counting would need to be overcome. Discrepancies in scale lead to double counting because of the interrelated often-dependent relationships between ecosystem services, functions and processes. Most agree that the issue of scale is crucial to successful application and interpretation of the ecosystem services concept in real world analysis and that the services in question would need to be defined in spatial as well as temporal scale (Termorshuizen and Opdam 2009, Martin-López et al. 2009, Lindenmayer and Cunningham 2012, Cumming et al. 2012, Dramstad and Fjellstad 2012, Brandt et al. 2012, Wiens 2012, Dale et al. 2012). Recall that to avoid double counting dummy variables were used for the seasonal model in essay 1.

There has much discussion in the literature regarding the need for a means of incorporating and sharing information across various physical and social science disciplines in order to "accurately" estimate the economic value of natural resources (Boyd and Banzhaf 2007, Termorshuizen and Opdam 2009, Dramstad and Fjellstad 2012, Verburg et al. 2012, Zurlini et al. 2012, Ahern 2012, Musacchio 2013). Termorshuizean and Haines-Young proposed that the science of landscape ecology can act vehicle for cross-discipline collaboration needed for valuation (Termorshuizen and Opdam 2009, Haines-Young et al. 2010). Due in part to the broad definitions of landscape ecology and ecology along with the many aspects that define a landscape I believe that they are right, landscape ecology should be taken into account when contemplating natural resource valuation. Here's why: first consider the definition and factors that comprise a landscape; a landscape is a spatially explicit area comprised of recognizable and characteristic ecosystems (Coulson and Tchakerian n.d.). Furthermore, there are a number of attributes that can be used to define or describe a landscape-heterogeneity, geomorphology, patterns and the ecological processes that produce them, mosaic composition, scale and landscape function (Coulson and Tchakerian n.d.). As previously noted scale is a central theme that needs to be resolved for ecosystem service valuation because landscapes are defined first by their spatial and temporal scale this could help define the scope of the valuation process. The variety of attributes that define a landscape can also contribute or tie into aspects of another discipline for instance, urban planning, landscape design, resource management and eco. tourism. Next, the definition of ecology should be considered. Ecology is the study of how biotic and abiotic organisms interact with the environment in which they live. A lot of ecology studies focus on organism response and adaptation to changes in the environment (Coulson and Tchakerian n.d.). Organisms along with people and natural processes are drivers of ecological change. These changes impact the flow of resources and energy among individual ecosystems and the overall landscape, which in turn impacts the production of goods and services that stakeholder's value. The impacts can affect the quality or quantity of goods and services produced which will affect the value of the services and functions involved in the production process. It is essential that we gain a better understanding of how energy and materials flow within individual ecosystems and outward toward the larger landscape scale if there is to be any collaboration between disciplines. Zurlini points to combining aspects of sociology, economics and environmental science to create what he calls "socially ecological landscapes or (SEL's) (Zurlini et al. 2012). These are complex, adaptive, physical land units that are spatially and functionally defined consisting of social actors and institutions that interact on a regular basis linked by the flow of energy and materials between them. Within the system the social actors and institutions (stakeholder actions, political systems) act as drivers of change.

Work by Lindenmayer classifies ecosystem and environmental services within landscape services, which they define as the connection between physical systems and human services (Lindenmayer and Cunningham 2012). However, I would like to suggest that many of the non-use goods, resources and services that are enjoyed, used or manipulated by people which historically have been attributed to processes associated with individual ecosystems are actually more akin to landscape-level services. Drawing upon the classification of ecosystem services by Mace I propose that landscape services be defined as spatially explicit, "goods derived as a result of the interactions of multiple individual ecosystems interacting upon the landscape (Mace et al. 2012). Final and intermediate ecosystem services contribute to the production of the landscape service as a whole. Landscape functions can contribute to multiple landscape services but stakeholders define services whereas functions exist on their own (Termorshuizen and Opdam 2009). Usually these types of services consist of recreational opportunities, ecotourism ventures or aspects of the natural environment that an individual doesn't necessarily need for survival but it is something they enjoy so much so that they are willing to pay to conserve it such as aesthetic vistas.

The call for a means to link physical sciences such as landscape ecology to social parameters like spending or recreational habits as well as stakeholders' attitude towards environmental and natural resource concerns is noted by Musacchio and has been discussed in the previous section in conjunction with the traditional view of ecosystem services (Musacchio 2013). Termorshuizean argues that in order to bridge the gap the value of the landscape must be able to be related to intended changes in the structure and function of the physical landscape (landscape design and use) and we must decentralize landscape planning policy meaning looking at small local scales (Termorshuizen and Opdam 2009). I disagree with the latter part of this statement I believe that scale should be defined by the problems, goals and objectives of concern; in some instances it is both practical and necessary to use a broad scale approach. For example Hobbs-Newton note that some large-scale projects such as restoration efforts that impact large areas of land should be conducted and viewed from a landscape scale perspective and that this viewpoint also plays into the value of the resources, goods and services within the landscape (Hobbs and Norton 1996). Termorshuizean calls for landscape services to connect the science of landscape ecology to the notion of sustainable development but what is sustainability in itself other than the new "it phrase" in the literature (Termorshuizen and Opdam 2009, Wiens 2012).

While sustainability is considered paramount by many including Wu I'd like to point out that the notion of sustainability is not without fault (Wu 2013). First, what is considered sustainable is dependent upon the stakeholders in question, and another question to consider is the time scale over which sustainability is measured. The generally accepted benchmark is two human generations however, environmental timeframes move at a much slower rate than human generations so it is not an accurate indicator. Termorshuizean defines landscapes as "spatial-human ecological systems" that deliver a wide range of functions that are or can be valued by stakeholders because of economic, sociocultural or ecological reasons (Termorshuizen and Opdam 2009). Since the functions can be valued they can connect natural systems to human values and the issue with the present scientific view is that this value is not considered. Ecology studies only consider stakeholders to be drivers of landscape change while development studies consider stakeholders as organisms within the landscape and the resulting changes might or might not be beneficial to people.

Current research is beginning to consider the importance of the landscape itself instead of just concentrating on individual ecosystems within the landscape. A study conducted by Willeman found that the value of all landscape functions would increase by 2015. They argue that management and policy decisions should be spatially explicit because the effects of these decisions on the provisioning of landscape services will be location specific (Willemen et al. 2010). When dealing with public areas and activities such as tourism and recreation Willeman suggests that the value of recreational areas is not only tied to the site itself but the surrounding area contributes to the sites overall value therefore, in order derive the economic value of landscape services information about the specific site needs to be linked to the functionality of the whole landscape

(Willemen et al. 2010). In terms of policy and management decisions knowing the value of specific landscape services can help managers decide where improvements need to be made and when faced with loss of services can help decide which services need to be restored or conserved (Hobbs and Norton 1996).

There are different types of valuation techniques. Market-price approaches are normally used to value provisioning goods and services because the final products of production are directly traded on commercial markets. The market price method uses standard economic practices and principles to measure the total economic benefits gained from goods and services. Arrow explains that the notion that economic growth is good for the environment is based on the claim of a relationship between income and environmental quality (Arrow et al. 1995). The relationship states that as economic growth increases environmental degradation also increases up to a point when consumers begin to place priority on environmental improvements instead of increased yields and low production costs (factors of economic growth). Market-price approaches can provide information about the quantity and quality of goods or services and how changes in the quality or quantity of a particular good/service impact consumer behavior and the relationship between quantity and quality. Usually consumers will pay more for a higher quality good (up to a point) but they cost more to produce so producers want to produce slightly lower quality goods to control production cost. Therefore, in order to maximize economic benefit the ideal situation is to maximize consumer and producer surplus. This method is most often applied when the product in question is either an ecosystem good or a final ecosystem service that is a direct end product of nature with commercial value like timber, fish, or game wildlife.

There are several advantages to this method, it's based on accepted practices and principles, data needed is readily available and there is little doubt about the reliability of stakeholder's expressed values because the choices are based on their actual purchases. However, there are also a number of disadvantages to this method, the data available may not provide a complete picture of the value of an ecosystem good or service due to limited market value or imperfections associated with market fluctuations, confined to localized scales and has a tendency to overestimate value because it cannot account for intermediate services, functions or processes related to production of final goods and services.

Cost based techniques rely on the estimated cost of having to artificially simulate or recreate ecosystem goods and services in the face of a decline in quality or quality that affects well-being. "The Economics of Ecosystems and Biodiversity" (TEEB) lists alternative approaches within this category as avoid cost, replacement cost and restoration cost methods. The damage cost avoided method estimates the value of the loss incurred from the loss or depletion of ecosystem goods and services. The replacement and restoration methods infer ecosystem goods and services value from circumstantial evidence related to the cost of replacing or finding a substitute for a lost ecosystem service or mitigating the damage incurred on the larger scale when a particular good or service is lost or depleted, respectively (*The Economics of Ecosystems* *and Biodiveristy* n.d.). It is not a direct measure of stakeholder choice. This method is used in remediation and mitigation programs.

For instance, if a wetland gets destroyed in the process of building a new power plant even though the value of the goods and services of the wetland may not have been directly realized by the surrounding communities the value it provides is assumed to be equal at least to the cost the company will incur from the mitigation process that requires them to replicate it elsewhere. One drawback of this technique is that it does not lead to a "consistent distinction" between the quantity and the price because there is no reason for the distinction (Boyd and Banzhaf 2007).

The productivity method attempts to estimate the value of final/ intermediate ecosystem services or goods and functions and/or processes that go into the production of market-based goods and services. For example, the value of improving water quality can be estimated as the revenue gained from increased production/use of those goods and services that benefit from it such as commercial fishing or the profit losses associated with having to deal with the consequences of poor water quality such as wetland remediation. The relationship between price, quantity and quality of goods and services is particularly important to this method. Fluctuations in quality of goods and services involved in production can affect the quality or quantity of the final product, which impacts consumer demand and market price. This method works best when the intermediate good or service is a perfect substitute for another good/service involved in the production process or when producers see the only benefit from changes in quality or quantity of the final product.

The advantages of this method are that it can be inexpensive when the require data is readily available and implementation is not complicated. Drawbacks to the productivity method are that it can only be applied to those ecosystem service/goods that are needed to produce a final market-based good or service, market data may not exist, implementation can become complicated if changes to the particular good or service affect the final product which will impact the consumer and at larger scales it can lead to an underestimation of total value. Based on the literature there aren't many studies that apply this method directly,

The hedonic price method is one of the more widely used valuation techniques, it estimates the value of those goods and services that have a direct impact on commercial markets. The idea is that the market price can be viewed as a direct indicator of the value of the ecosystem goods or services that an area provides. The higher the market values the more valuable or desirable the ecosystem goods/service. It is commonly applied to urban areas that use housing costs to estimate the value of environmental factor or in rural areas to agricultural land to determine the benefits of continued agricultural production.

There are several advantages to this method. It is versatile enough to consider several factors at once as well as combinations of factors and determine how changes in ecosystem services or goods impact value. Also, there is usually an extensive amount of data available that is easy to obtain, current and detailed. It is also because you are essential looking at consumer purchasing history the assumed willingness to pay and thus ecosystem service value is based directly on stakeholder choices. Hedonic pricing does have several disadvantages- there are limitations related to what ecosystem goods and services can be assessed because they must be related to the housing market, this method can be expensive and complicated to apply because of the amount of knowledge and data required.   Also, because other factors usually impact why someone choses a particular property like affordability or lower taxes the house price may not be a complete representation of stakeholder wants or "free choice" furthermore, lack of stakeholder knowledge about the importance of ecosystem goods and services and how seemingly unrelated goods or services can affect their property can cause discrepancies in how the ecosystem value gets reflected in the market value.

The concept of travel cost models (TCM) was developed by Hotelling and later developed into empirical models by Clawson (Clawson and Knetsch 1956). It is a non-market approach based on the idea that the value people receive from a area and what they are willing to pay in order to conserve or protect the area must at least be equal to the cost incurred to visit the area, this includes travel costs and opportunity costs. If consumer surplus is significant enough it can override the opportunity cost of development (Boontho 2013). Flemming states that this method cannot determine non-use value but a study by Baerenklau combined it with a view shed analysis to determine the value of different recreational activities within a park (Fleming and Cook 2008, Baerenklau et al. 2010). TCM is best suited for studies that have a small sampling (count) size and is regarded by in many studies for its robust theory that is well suited for the transfer of values (Zandersen and Tol 2009). This method works best for ecosystems or areas that are unique or have unique non-use values like wildlife reserves, national parks when considering recreational benefits.

There are two variations of the travel cost method- individual and zonal approaches. Individual approaches use detailed stakeholder survey information to derive estimated value. Often times this method incorporates questions to act as a secondary filter for the breakdown of ecosystem service valuation for instance the survey will include questions about education level or annual household income. A study of a preserve in China found that the recreational benefit from the preserve resulted in a consumer surplus of $167,619 and that when all factors are considered the preserve had a positive benefit to cost ratio (Badola et al. 2010). Zonaal TCM does't rely so much on surveys of individuals but looks at the population within different zones often denoted by geographic or city centers in relation to their distances from the area of interest. Zonal studies work well for assessing use and non-use values associated with recreation.

The results provided by this method are beneficial for policy decision making and determining the best way to use funding and manage resources in order to achieve the most benefit. This technique can be combined with aspects of random utility models via more complex visitor data and complex statistical analysis to yield very detailed profiles describing how different types of stakeholders utilize ecosystem goods and services. The basic travel cost alternative is also less expensive than other methods. The drawbacks of this approach are that there is no way to incorporate multiple site visits for the same trip, it can be difficult to account for the time spent at each site and different visitation patterns and characteristics such as international visitors or multiple visitors to a site that pursue different activities can cause over or under estimates of overall value. Both Clawson and Knetsch state that dealing with time is a major issue that has to be addressed with this approach but Freeman argues that time should be included as a variable in studies because failing to do so increases the price elasticity of demand which reduces the overall estimate of the benefit value (Clawson and Knetsch 1956, Knetsch 1963, Freeman et al. 2014). Knetsch states that the length of time a visitor stays in a area is difficult to quantify because of the number of factors that can affect this decision but that such data is needed to conduct an individual travel cost assessment (Knetsch 1963).

Currently, much of the work that has been done focuses on using a contingent valuation approach that involves surveying a group of stakeholders to gage their "willingness to pay" for services based on how they answer specific questions. Several of the studies look at wildlife or address the value of agricultural cropland. In theory they can be applied to any good that generates value within a individual's utility function however, caution is advised when you consider where a person has the correct information or knowledge to make a choice reflective of their true opinions (Balmford et al. 2010). However, this method has been noted to have several flaws most notably bias associated with survey methods. Other issues with contingent valuation are the low response rate and whether the level of knowledge that the subject has about the issues can generate informed responses as noted by (Barkmann et al. 2008).

Choice models try to model an individual's decision process when they are faced with different alternative choices and their related outcomes. Choice models are usually combined with other techniques or included as part of a contingent valuation survey. Random Utility Models (RUM's) are an example of choice models. They are useful when trying to explain the reasoning behind why a stakeholder made a particular choice when given similar alternatives for a specified event (Phaneuf and Smith 2005).

Group valuation is relatively new and is sort of a means of combining aspects of stated preference techniques with other scientific data or random utility models as a way to capture additional values that may not be accounted for in traditional surveys. Usually it involves the more complex benefits of ecosystems or non-use benefits. This gives the ability to consider consumers direct choice and expressed choice (WTP) together. These models have the ability to consider multiple variables at once and could provide a solution for the double counting issues associated with assessing the value of ecosystem services associated with recreational demand.

The main advantage of stated preference techniques is that they can sometimes revel conflict among stakeholders or preference for a particular management strategy over others. They are beneficial for valuing non-use goods or services and can allow the interviewer to gain insight into the level of understanding the stakeholder has about the subject and related goals and consequences of management decisions. Recently, the accuracy of this method has come under scrutiny for it's inability to test if stakeholder surveyed response would mirror actual behavior if faced with the "real life" choice. Furthermore, researchers have found a stakeholders "willingness to accept" (WTA) certain choices and/or consequences rates higher than their "willingness to pay" (WTP) in theory these two factors should be similar however, when you think about it in context people are more willing to accept less ideal choices and face the consequences rather than pay a higher price. Price and cost are immediately gratifying and increased costs are noticed immediately, this is one of the main reasons I advocate ecosystem valuation in spite of the faults.

The benefit-transfer method involves the transfer of known economic benefit from one source to a similar source. If the dollar value for a particular good is known then the same good from a similar source usually in the same area is assumed to have the same value. This method can be employed when there is not enough funding to conduct new studies or if the goods and production resources come from the same region. However, a drawback to this method is that the existing values can be incorrect, from outdated studies or may not mirror the ecological process that deliver the final good which could create bias that two related ecosystems were similar when in fact they could be different. The USDA currently uses this method to estimate the average “unit day value” for different recreational activities on public drawing upon past studies when new data is unavailable (Baerenklau et al. 2010).

Increasingly, researchers have begun to use GIS based approaches to help determine value. Applications like SOLVES and view shed analysis techniques have been used to discern the value of recreational activities. Usually, zonal studies have a GIS component. While this method has its advantages it can also have disadvantages in that it only examines the direct benefits that one gets from the area in question, spatial scale can have an effect on the results as well as study design factors like multiple counting.

In order to address how landscape services relate to Big Bend National Park and nature tourism you must first acknowledge the benefits people receive from these types of activities. Musacchio dictates that direct access to nature improves human well-being and provides therapeutic opportunities (Musacchio 2013). Furthermore, Chen notes that sustainable tourism requires an understanding of how stakeholders use and perceive the resource in question (Chen et al. 2009). Dixon notes that the private benefits of protected areas are purely social benefits and increases in financial returns stem from tourism (Dixon and Sherman n.d.). Although they assessed ecosystem services a study of the Corbett Tiger Reserve in India by Badola noted that the valuation can be beneficial when arguing the case for classifying and protecting public lands and/or resources since a large part of their contribution to human well-being is mostly through public goods (Badola et al. 2010). It was also noted in the study that valuation of resources can aid managers when trying to figure out potential sources of revenue such as entrance fees because certain methods can pinpoint consumers "willingness to pay" for goods and services.

However, Panayotou argues that the value generated from natural resources doesn't reflect the true social costs and/or benefits obtained from their use (quoted in (Badola et al. 2010). This leads to management practices and policy decisions that are based on misleading information. Schenk goes further and says that motivation out of concern for the environment imparts lasting views in favor of conservation more so than economic incentives (quoted in (Dramstad and Fjellstad 2012). While I agree that any monetary estimate of value is inconclusive and usually undervalued as well as most short term returns on investment on natural systems are significantly less compared to the projected profit margins associated with commercial development of the same area valuation provides a starting point for further evaluation and a easily interoperated metric to present to stakeholders. I agree with Badola that the costs of conservation need to be assessed giving the stakeholders a clearing understanding of what they give up and get in return in order for conservation initiatives to be effective (Badola et al. 2010).

Valuation can also aid managers tasked with making daily decisions associated with operation of the park. Badola and others argue that valuation can help justify the need for certain areas to be protected and safeguard against potential changes, capture unseen value or benefits and can show whether the goods and services provided by said areas are fairly priced (Badola et al. 2010). Multiple studies have noted the usefulness of valuation for the implementation of management techniques as well as contributing setting up future planning objectives. Knetsch points out that few studies have been done that illustrate the demand relationships for recreation that are important when deciding how to allocate resources. They go on to suggest that better evaluation of economic costs and benefits associated with recreation would allow for a positive approach to questions about quantity, kinds, and location of resources as well as the timing of acquisition and development (Knetsch 1963). It is important to keep in mind that valuation can also show the impact and importance of the contribution biodiversity makes to protected areas by phrasing it in terms that stakeholders can easily understand. The ZTC portion of this study will attempt to determine the total overall value of the park as a whole by looking at visitor's willingness to pay as a proxy for value. During the course of the survey visitors to the park participated in a number of activities such as hiking, wildlife viewing, camping, off-roading, boating, hunting, site seeing (historical/cultural) horseback riding and other activities. The landscape services associated with these activities are important for determining their value.

3.3 Methodology

Clawson suggests that the travel cost approach is the most useful valuation method to assess recreational sites (Clawson and Knetsch 1956). I chose the zonal travel cost method of analysis for a couple of reasons. First and foremost it gives an overall assessment of the park as a whole, which is beneficial for planners and developers in the surrounding areas to be able to see revenue generated. Second due to data limitations this option was necessary because it requires less detailed data and is cost effective.

3.3.1 Study Area

According to the visitor survey conducted by Dr. Shafer et al in 2011-2012 40% of the park's visitors were visiting for the first time while 60% of those surveyed had been before. Popular activities included hiking and general sightseeing. The number of individuals who participated in activities such as, birding, wildlife watching and plant identification had decreased from previous surveys. Low water levels prevented many people from pursuing activities on the river. The biggest complaint visitors had about the park was the remote location (distance to access) and 1 out of 10 people said they didn't like the weather (Shafer n.d.). The majority that complained about the weather said that it was too hot (they came during the summer season but only a few indicated it was too cold (they referenced nighttime temperatures or activities like rafting). Several people that came during the summer also indicated that they noticed the negative impacts of drought and that low water conditions had impaired activities like rafting. Given that climate change is projected to increase the air temperature those visitors might find the conditions less favorable during the summer, so the peak season might shift to the cooler months (Jan., Feb., Nov. or Dec.).

Entrance fees for the park ranged from $0 (for educational groups) to $40 (for an annual pass). The average vehicle pass was $25 and was good for a week. Campsites range from $6 for a backcountry site for a pass holder to $14 for a developed campsite (*National Park Service* n.d.). There are several other lodging options in the areas surrounding the park such as RV parks, hotels and motels. The prices for theses vary according to location, season and the number of people. There are various dining options in the area surrounding the park; prices range from $7-$15 for meals. Guided outdoor excursions range from $150/3 hours to $550/8 hours. Guide and souvenir books can be purchased for about $2. The survey showed that the majority of visitors were older adults many of had some graduate school experience, that were either retired or had upper level jobs with high incomes. Most people reported that they spent between US$500-1,000 on their visit to the park (Shafer n.d.).

3.3.2 Data

Data for this study was provided by a follow-up survey of visitors to Big Bend National Park that participated in an on-site survey that was conducted by the Department of Tourism, Parks and Recreation Science at Texas A&M University on behalf of the Brewster County Tourism Council and park officials by Dr. Scott Shafer and colleagues. Mailers and email questionnaires were made available a week after the initial visit. The first survey was conducted on six different occasions from November 2011-October 2012 primarily within the park at the Panther Junction Visitors Center. Based on data collected from three previous studies that have been conducted since 2004 this small subset represents the typical distribution and concentration of visitor points of origin. Of the 495 total follow up responses 343 were included in the analysis. Some responders lived outside the United States or their zip code couldn't be matched. This data was then sorted and organized by zip code and their respective visitor data into an EXCEL spreadsheet that was later converted to a dBASE table before being loaded into ArcGIS.

GIS layers consisting of a boundary shapefile of the park, a shape file depicting the state boundaries for the entire U.S. and zip code data for the U.S. were uploaded and projected into a geodatabase. The shapefile of the park was obtained from park staff (Sirotnak n.d.). The file containing zip codes for U.S. cities and post offices as well as the U.S. state boundary shapefile were provided by ESRI via public access data (*ESRI Data & Maps* 2014). The zip code dataset also contained population data for each zip code based on the 2010 census. In order to run the OD-Cost Matrix tool a network analyst dataset that contained detailed information about U.S. roadways was obtained from the GIS and Mapping Services Department of Texas A&M University Library ("Texas A&M University Libraries" 2006)

General statistics related to the average cost of gasoline, airfare, speed limits and miles per gallon highway were accessed through the Bureau of Transportation. AAA provided an estimate of the cost per mile to operate a standard vehicle (Stepp n.d.). The average American minimum wage was provided by the U.S. Department of Labor (*BLS* 2011).

3.3.3 Preliminary Analysis

I started off by creating a geodatabase in ArcGIS. Then I uploaded the U.S. shapefile, park boundary file and the zip code file into the geodatabase. I projected all files into Albers equal area conic projection. Then I overlaid the .shp boundary file of the park onto the U.S. states boundary file. I imported the visitor survey data as a table into my geodatabase. Next, I related then joined the visitor data to the zip code layer using the zip code itself as the common field and choosing to keep the matching points. This produced an image that showed where visitors had traveled from in relation to the park Figure 6. This image shows that visitors are widely distributed but the majority are concentrated within the state of TX.

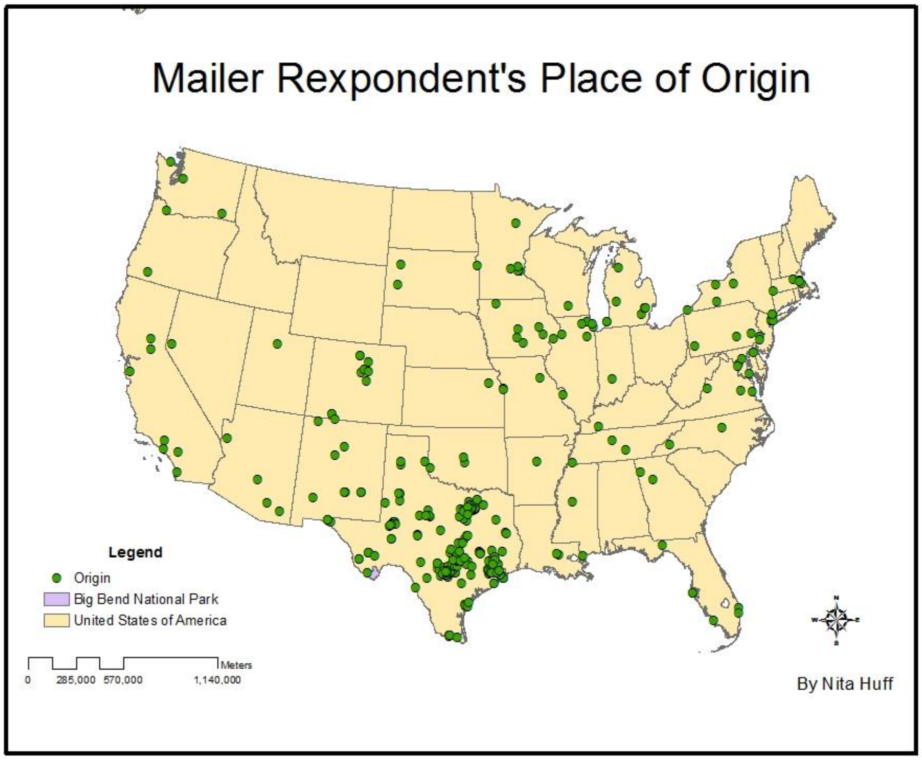


Figure 6: Departure Points of Big Bend Visitors

A multiple ring buffer was drawn to represent the different "zones" based on distance from the park. I chose to create 16 different zones at: 150, 300, 450, 600, 750, 900, 1,050, 1,200, 1,350, 1,500, 1,650, 1,800, 1,950, 2,100, 2,250 and 2,400 miles from the outside of the park shapefile in order to span the U.S. See Figure 7 for an illustration of zonal coverage.

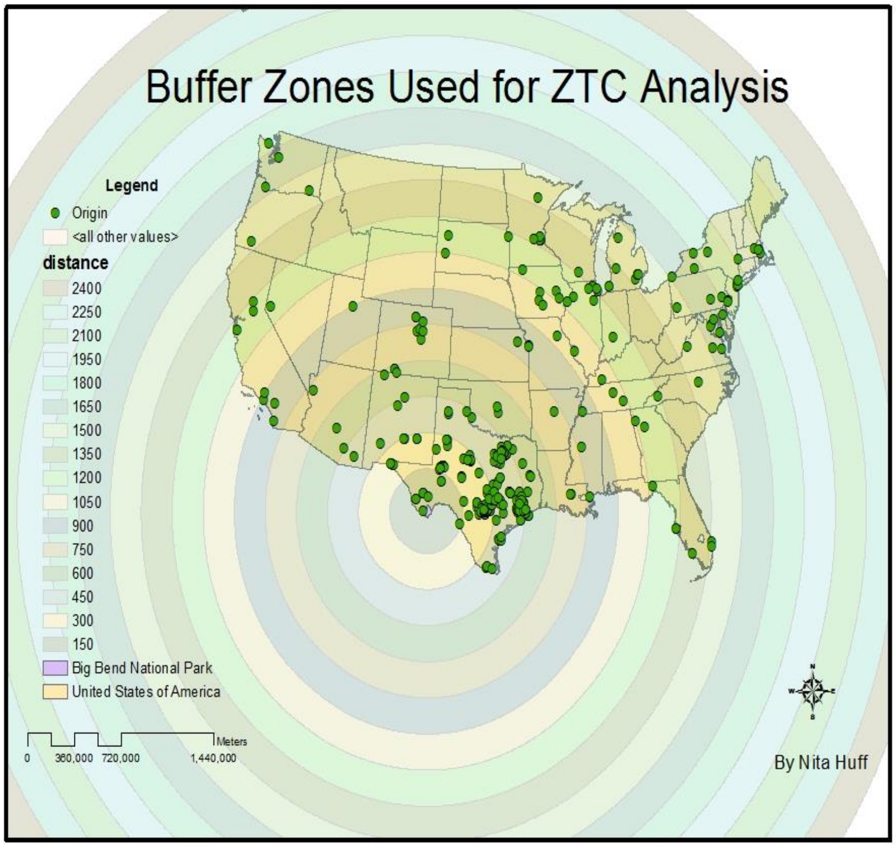


Figure 7: Zonal Coverage

In order to address double counting of visitors which is a known problem with ZTC studies discussed by Fleming I chose to have the program use a nearest-neighbor approach when zip code points were on a boundary of two zones (Fleming and Cook 2008). The point was assigned to the zone based on its cell value and the value of the cells adjacent to it. I then joined Figure 6 to Figure 7 using Figure 7 as the target. Using spatial mathematics within GIS the total population and total number of visitors was calculated for each zone. I was also able to average the other expenses that visitors reported for each zone: food, lodging, entertainment and camping. This data was used to run a network analyst simulation.

ESRI's Network Analyst tool is a spatial analyst tool that is commonly used in the transportation, marketing or municipal services sectors. It can preform tasks such as mapping deliveries, determining routes, identifying the closest facility, determining service areas or the optimum location for businesses. Although it is not commonly utilized in the natural sciences I wanted to see if it could help overcome past issues with determining travel time and distance discussed by Freeman (Freeman et al. 2014). In order to use this toolset I converted the park's boundary shapefile to a centroid point because the tool doesn't have the ability to run between points and polygons. I also had to import the U.S. transportation dataset that served as the 'path' that the tool traveled along. I decided that the opportunity-cost distance matrix tool within the analyst toolbox was well suited for this research.

The Opportunity Distance-Cost Matrix (OD-Cost matrix) tool finds and measures the least cost paths along the network from multiple origins to multiple destinations based on the shortest-distance algorithm by Dijkstra. Using the tool you can either solve for the shortest distance (miles) between your origin and destination while the tool estimates the accumulated time (minutes) it takes to travel along that route or the tool will solve for the fastest time to travel between an origin and destination while it estimates the corresponding distance. Based on previous research noted in Clawson (Clawson and Knetsch 1956)) that showed that when asked why a specific route was chosen over another travelers said they chose the route that resulted in the shortest distance between their origin and destination I chose to have the OD-Cost matrix solve for the shortest distance and estimate the corresponding travel time between each of the zip codes and the park.

3.3.4 Models

The basic approach for each variation of the zonal travel cost model is the same. The first step in identifying the ZTC model is to define the zones radiating out from the area of interest. In my case of Big Bend, I defined the 16 zones ranging from 150-2,400 miles, discussed in the previous section. The 300 and the 450-mile buffer zones had the highest number of visitors. Figure A-20 in the appendix illustrates the number of visitors that originated from each zone. No visitors traveled farther than 1,950 miles. Next, using the outcome of the spatial math preformed in GIS I was able to calculate the visitation rate per 1,000 residents in the population for each zone. I assumed that each visitor made only one round-trip visit to the park each year; therefore I divided the total number of visitors by the estimated zonal population in 1,000.

Then I had to determine travel distance and travel time for each zone. One-way travel distance and travel time were generated from the OD-Cost Matrix analysis discussed in the previous section. In order to get the approximate value for each zone I averaged the generated individual (point-to-point) distance and time together, respectively. I assumed that the return trips would be the same as the one-way trips, so I just doubled the average travel distance and time in order to get a round trip estimate. Using the round trip estimates of travel distance and time I was able to calculate the distance cost per mile and opportunity cost of trips from each zone. Finally, the total cost of the trip was calculated by adding together the distance cost per mile and the opportunity cost of the trip.

The next step was to use regression analysis to relate the visitation rate to the total travel cost and other potential predictors. The basic formula for the model is shown below in equation 7. I chose to use a semi-log transformation for a couple of reasons. I ran several different model combinations to determine the model that fit the data best. Based on similar research I conducted this model seemed to perform the best and second semi-log transformation restricts the demand to be non-negative, which resolves issues with double counting (Baerenklau et al. 2010).

Equation 7: $\ln y = B_o + B_1 C + B_2 x_2 + B_3 x_3 + B_4 x_4 + B_5 x_5 + B_6 x_6 + B_7 x_7 + \epsilon$

Y denotes the visitation rate, while B_o denotes the intercept or constant, which defines the value of the dependent variable if the values of all the independent variables were equal to 0. Since it is unlikely that all independent variables will ever equal 0 it doesn't provide much information. The dependent variable is the natural logarithm of visitation rate, which will be linked to a combination of independent variables. C is equal to the total travel cost of the trip. B_1 through B_7 symbolize the slope of the line and indicates how much the dependent variable changes for each 1-unit change in the associated independent variable. The variables x_1 through x_7 are the significant predictors (independent variables) for the model, and $\in$ denotes an undefined error term. The other independent variables are average zonal household income, mean age, the dollar amount spent on lodging, food, entrainment and camping. The independent variables were chosen based on available data and the literature review presented previously. A study at the University of Colorado suggests that income is an important factor for park tourism ("Chapter 15. Travel Cost Method of Valuing Environmental Amenities" 2006). While a study conducted by Uysal *et al.* that age was also important (Uysal et al. 1994).

The 0.05 significance level was used as the benchmark for statistical significance. Residual values were generated in order to estimate the model. The observed values were compared to the expected values in order to validate the model and observe model fit.

Next, using the results of the regression analysis I constructed a demand function (demand curve) for visits to the park. The first point on the curve is total number of visitors, over all the zones, if the additional costs were 0 based on just the costs associated with the model. The other points along the demand curve are found by estimating the total number of visitors as the cost to visit the park increases. It is customary to assume that this increase in price is attributed to an entrance fee. As I stated in the previous section the entrance fee for the park ranges from $0 (educational group) to $40 (annual park pass in 2010, the price has since went up to $50) however, according to the survey the majority of visitors traveled by car in which case the entrance fee is $25. I assumed that the first point was indicative of fee for educational groups and to derive successive points I increased the fee in increments from there. The original average total trip cost combined with the hypothetical entrance fee then was used to rerun the regression analysis in order to calculate the log of “y”. Then the total population of each zone multiplied the exponent of the natural ln of “y” in order to calculate the number of visits in each zone at that particular price. For each zone I increased the fee in increments until I reached what Fleming reefer’s to as the “choke price” which is the point at which the price to visit the site becomes too expensive and the number of visits falls to 0. However, due to the nature of logarithmic function and the quadratic transformation of the travel cost variable it is not possible for the choke price to reach 0. For these models visitation decreases to a certain point and then begins to increase again because of the quadratic transformation. It does not make sense visitation would increase as price increased so I used the price point at which visitation began to increase as my theoretical 0. At each new price point I added the number of visits in each zone together in order to determine the total number of visitors to the park as price increased.

The final step is to calculate the consumer surplus or the area under the demand curve. This value was interpreted as the visitors “willingness to pay” (WTP) for the overall use and value of the opportunities that Big Bend offers including all natural resources, ecosystem and landscape services that provide those opportunities. It was calculated by multiplying the total number of visits over the combined zones found in the previous step by the additional cost that was added to the original average total travel cost.

3.3.4.1 Traditional Zonal Travel Cost Model

The difference between the two model variations is how the travel cost is calculated. For this model the distance cost per mile was calculated by assuming that the average cost per mile for operating a standard sedan type vehicle in 2010 was 59.6₵ per mile (United States Department of Transportation n.d.). This value was multiplied by the round trip travel distance for each zone in order to estimate distance cost per mile. The total travel cost per minute also known, as the opportunity cost per trip is somewhat harder to distinguish. Common practice is to either use minimum wage or 1/2 to 1/3 of the yearly income (Fleming and Cook 2008), for this model I used the average minimum wage in 2010 as reported by the Bureau of Labor Statistics of $7.25 per hour. During an 8-hour day at this rate an individual makes 12₵ per minute. I used the round trip travel time generated from the OD-Cost Matrix analysis then I multiplied the round trip travel time by 0.12 in order to estimate the opportunity cost per minute of visiting from each zone. Once I had the opportunity cost per trip and the distance cost per mile I was able to add them together to determine the average total travel cost per trip for each of the zones. Table A-4 in the appendix shows the results, as expected the total travel cost per trip increases as the distance from the park increases.

3.3.4.2 Alternate Zonal Travel Cost Model

For the alternate ZTC model calculation of the total travel cost took into consideration visitor response from the survey. In order to calculate the distance cost per mile I assumed that in 2010 an average vehicle gets 27.5 miles per gallon going an average speed of 65 miles per hour, while the average price of gas was $2.66 per gallon based on the bureau of transportation statistics (*United States Department of Transportation* n.d.). Then I took the total round trip travel distance in each zone and divided it by the vehicle gas mileage in order to estimate the amount of gas used on the trip. I then multiplied this value by the average price of a gallon of gas to estimate the average amount spent on round trip travel from each zone. I interpreted this value as an estimate of the distance cost per mile.

I based the estimate of visitor's opportunity cost off of the visitors survey response, similar to an individual travel cost method, similar to ("Chapter 15. Travel Cost Method of Valuing Environmental Amenities" 2006). First, I converted the estimate of the round trip travel time calculated from network analyst from minutes to hours by dividing the estimated minutes by 60. Then in order to estimate the average zonal household income I took the mode of the visitors responses in each zone and since income choices were a range of values like $25,000-50,000 I averaged the high and low value to generate a single value. Next, I needed to calculate the value of time per hour (in dollars), I took the single value estimate of income and divided it by 3,400, which is average number of hours a 2 person household works in a year. Finally I took the estimated time value per hour and multiplied it by the converted travel time to calculate the time cost of travel, which I used as a proxy for the opportunity cost of the trip. Lastly, in order to estimate the average total travel cost of trips from each zone via the alternate model I added together the estimates of the distance cost per mile and the time cost of travel for each zone. Table A-5 in the appendix gives the results.

3.4 Results

3.4.1 Traditional Zonal Travel Cost Model

I ran basic correlations to examine overall relationships between the variables before any models were applied. Based on these correlations it appeared that visitor proportion is only correlated to buffer distance and travel cost. Age is related to lodging, entertainment, food and camping. Income does not seem to be correlated to any other variables. All of the expenditure variables are related to each other and to age. After trying several different models to improve model fit I noted that collinearity was an issue because of the small sample size and because of the nature of some of the data. Therefore, I decided to remove the age variable from the final model because it was highly correlated to the expenditure variables and added a quadratic transformation to the travel cost variable in order to fit the data better.

The final traditional ZTC model can be seen below in equation 8. Travel cost alone had a significance value of .000 while the squared term had a significance value of .001 both of which are significant at the 0.05 level.

Equation 8 $\ln(vp) = -0.800 - 0.005(\text{travel cost}) + 1.123E(-6)(\text{travel cost})^2 - 2.001E(-6)(\text{income}) + 0.000(\text{entertainment})$

The R^2 value for the model was 0.988. The model without the quadratic term had a R^2 change value of 0.717 with an F change value of 27.902. When the quadratic transformation was added to the model the R^2 change value decreased to 0.271, so about 3% of the variability with the dependent (ln(vp)) variable is accounted for by the addition of the non-linear effect. The F change value (non-linear effect only) decreased to 19.394 but the combined model had an F value of 60.600. This demonstrated that the quadratic variable addition is significant at the 0.05 level with a significance of F change value of 0.003 while the combined overall model has a significance value of .000. Table 7 provides the ANOVA test results for the model.

Table 7: ANOVA Results of the Traditional Model

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	32.576	1	32.576	27.902	.000[b]
	Residual	12.843	11	1.168		
	Total	45.419	12			
2	Regression	44.890	7	6.413	60.600	.000[c]
	Residual	.529	5	.106		
	Total	45.419	12			

a. Dependent Variable: ln(vp)

b. Predictors: (Constant), Travel_Cost

c. Predictors: (Constant), Travel_Cost, Income, Camping, Entertainment, Food, Lodging, TC_squared

The combined model is statistically significant at the 0.05 level based on the ANOVA F value of 60.600 with a significance of .000. Table 8 identifies which coefficients are significant within the model; model 2 is the combined model.

Table 8: Regression Results of the Traditional Model

Model[a]		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	-2.849	.639		-4.456	.001	-4.256	-1.442		
	Travel_Cost	-.002	.000	-.847	-5.282	.000	-.002	-.001	1.000	1.000
2	(Constant)	-.800	.436		-1.835	.126	-1.921	.321		
	Travel_Cost	-.005	.001	-2.738	-10.479	.000	-.007	-.004	.034	29.293
	TC_squared	1.123E-6	.000	2.035	7.864	.001	.000	.000	.035	28.729
	Income	-2.001E-6	.000	-.057	-.848	.435	.000	.000	.515	1.942
	Lodging	5.558E-5	.000	.415	1.785	.134	.000	.000	.043	23.183
	Entertainment	.000	.000	-.333	-2.145	.085	.000	.000	.097	10.362
	Food	-3.042E-5	.000	-.131	-1.189	.288	.000	.000	.193	5.193
	Camping	.000	.000	.243	1.929	.112	.000	.001	.147	6.817

a. Dependent Variable: ln(vp)

-0.800 is the y-intercept, which is a constant. It is equal to the value of visitation if the value of all of the predictors (independent) were 0. It indicates where the fitted line crosses the y-axis. Since it is highly improbable that all of the independent variables to equal 0 no significant information about the relationship between travel cost and visitation is gained from this variable. -0.005 and 0.000001123 indicate the slope of the regression line for the independent variables of travel cost and travel cost squared respectively. Slope identifies how much visitation changes in response to changes in travel cost or travel cost squared. For this model for every one-unit change in travel cost or travel cost squared the natural logarithm of visitation proportion decreases by 0.005 in response to travel cost or increases by 0.000001123 in response to travel cost squared. Even though they were not statistically significant at the 0.05 level I chose to include income with a slope of 2.001E(-6) based on previous research by Gossling *et al.* (Gössling and Hall 2006). I included the entrainment variable because it is the closest to being significant at 0.85 with a slope of 0. In general the natural log of visitation proportions to Big Bend will continue to increase over time but at some point the expenses become to great and will cause visitation to decrease. Figure 8 depicts model fit by illustrating the correlation between the expected and the observed cumulative probability. The model appears to be close to the line and only varies slightly as the value increases. For the most part the model appears to be normally distributed.

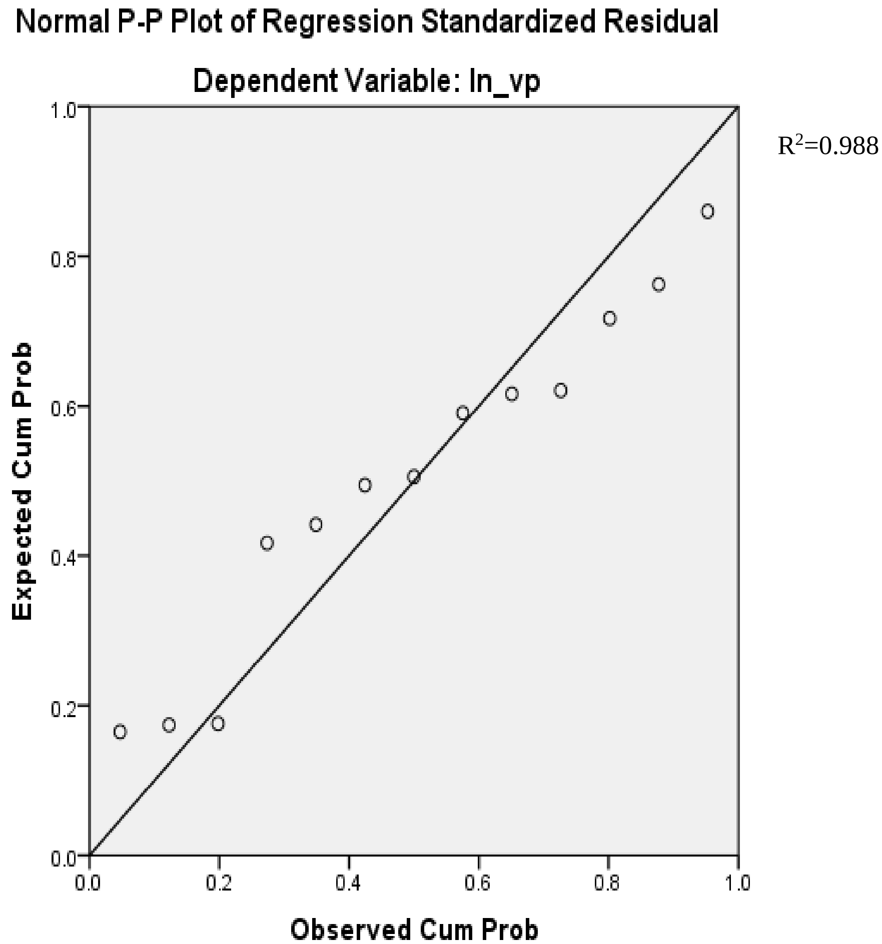


Figure 8: Depiction of Traditional Model Fit-Expected vs. Observed Cumulative Probability

3.4.1.1 Traditional Model Limitations

One of the drawbacks of this model was the small amount of data; even though a few hundred individual data points were initially analyzed organizing the data into zones for the final model resulted in significantly few data points. I believe that this lead to issues with collinearity, which lead to low tolerance levels. Also, the availability and initial processing of the data in ArcGIS affected the outcome. Zip code data for the

United States is very expensive, so I had to assume that the public data file provided by ESRI is accurate however I know that there were some errors. For example, zip codes are arbitrary points assigned by the postal service, they have no connection to census data so for instance the 2010 census information that was linked to the zip codes might have a value of 1 (often based on the location of a post office) instead of the correct data. Also, some zip codes for whatever reason were either missing or not picked up by GIS causing the final number of points analyzed to be significantly less. I also chose to eliminate visitors from outside the continental United States.

Travel cost models assume people travel for the sole purpose of visiting one site which can cause the overall value of the site to be overestimated if say someone visited multiple sites on a road trip. However, given the remoteness of Big Bend and that I analyzed only visits conducted within the continental United States I hope the potential for overestimation was minimized. How to define the opportunity cost of time is debatable particularly with traditional ZTC approaches because it assumes a common value for everyone. The population and number of visitors from major cities can manipulate the value expressed in different zones depending on how they are defined.

3.4.2 Alternate Zonal Travel Cost Model

My goal with the alternate model was to attempt to calculate opportunity cost in a way that was more reflective of the visitors from each zone. Once again I began by running basic correlations to examine the overall relationships between the variables before any models were applied. Based on these correlations it appeared that buffers were once again correlated to visitation proportion and travel cost. Further, age is once again related to lodging, entertainment, food and camping. However, due to the way that the opportunity cost of travel time was calculated for this model a significant correlation is identified between income and travel cost and the log of travel cost. I chose to use the same model format for the alternate ZTC that I used for the traditional because I wanted to be able to compare the results of the models and based on the different models I tried it seemed to fit well compared to other models that that I considered.

The final alternate ZTC model can be seen below in equation 9. Travel cost alone had a significance value of .001 while the squared term had a significance value of .002 both of which are significant at the 0.05 level.

Equation 9 $\ln(vp) = -3.344 - 0.006(\text{travel cost}) + 0.000001069(\text{travel cost})^2 + 3.023E(-5)(\text{income}) + 0.00(\text{camping})$

The R^2 value for the model was 0.963. The model without the quadratic term had a R^2 change value of 0.294 with an F change value of 4.587. The linear effect alone did not appear to be significant with a value of 0.055. When the quadratic transformation was added to the model the R^2 change value increased to 0.669, so about 7% of the variability with the dependent (ln(vp)) variable is accounted for by the addition of the non-linear effect. The F change value (non-linear effect only) increased to 15.223 however the non-linear effect does appear to be significant with a value of 0.004. Table 9 provides the ANOVA test results for the model.

Table 9: ANOVA Results for the Alternate Model

Model[a]		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	13.366	1	13.366	4.587	.055[b]
	Residual	32.053	11	2.914		
	Total	45.419	12			
2	Regression	43.755	7	6.251	18.788	.003[c]
	Residual	1.664	5	.333		
	Total	45.419	12			

a. Dependent Variable: ln(vp)

b. Predictors: (Constant), Travel_Cost

c. Predictors: (Constant), Travel_Cost, Food, Entertainment, Income, Camping, Lodging, TC_squared

The combined model is statistically significant at the 0.05 level based on the ANOVA F value of 18.788 with a significance of .003. Table 10 identifies which coefficients are significant within the model; model 2 is the combined model.

Table 10: Regression Results of the Alternate Model

Model[a]	Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Collinearity Statistics	
	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Tolerance	VIF
1 (Constant)	-4.311	.853		-5.052	.000	-6.189	-2.433		
Travel_Cost	-.001	.000	-.542	-2.142	.055	-.002	.000	1.000	1.000
2 (Constant)	-3.344	.598		-5.594	.003	-4.881	-1.807		
Travel_Cost	-.006	.001	-4.032	-7.180	.001	-.009	-.004	.023	43.051
TC_squared	1.069E-6	.000	3.115	6.011	.002	.000	.000	.027	36.663
Income	3.023E-5	.000	.862	4.588	.006	.000	.000	.207	4.820
Lodging	1.699E-5	.000	.127	.301	.776	.000	.000	.041	24.264
Entertainment	.000	.000	-.261	-.943	.389	.000	.000	.095	10.484
Food	-1.875E-5	.000	-.081	-.418	.693	.000	.000	.197	5.086
Camping	.000	.000	.328	1.449	.207	.000	.001	.143	7.012

a. Dependent Variable: ln(vp)

The y-intercept is -3.344, which is a constant. It is equal to the value of the log of visitation rate if the value of all of the predictors (independent) were 0. It indicates where the fitted line crosses the y-axis. Since it is highly improbable that all of the independent variables to equal 0 no significant information about the relationship between travel cost and visitation is gained from this variable. -0.006 and 0.00000169 indicate the slope of the regression line for the independent variables of travel cost and travel cost squared respectively. Slope identifies how much visitation changes in response to changes in travel cost or travel cost squared. For this model for every one-unit change in travel cost or travel cost squared the log of the visitation rate decreases by 0.006 in response to travel cost or increase by 0.00000169 in response to travel cost squared. For the alternate model I chose to include income and camping along with the travel cost variables. Again I included income based on previous research but it was almost significant at 0.06 and had a slope of 3.023E(-5). I chose camping over entertainment for this model because it was significant at 0.207 with a slope of 0. In general the log of the visitation rate to Big Bend will continue to a point increase but increases in the cost of travel over time will cause visitation to decrease. Figure 9 depicts model fit by illustrating the correlation between the expected and the observed cumulative probability. The model appears to be close to the line and only varies slightly as the value increases. The model appears slightly positively skewed but otherwise appears to be normally distributed.

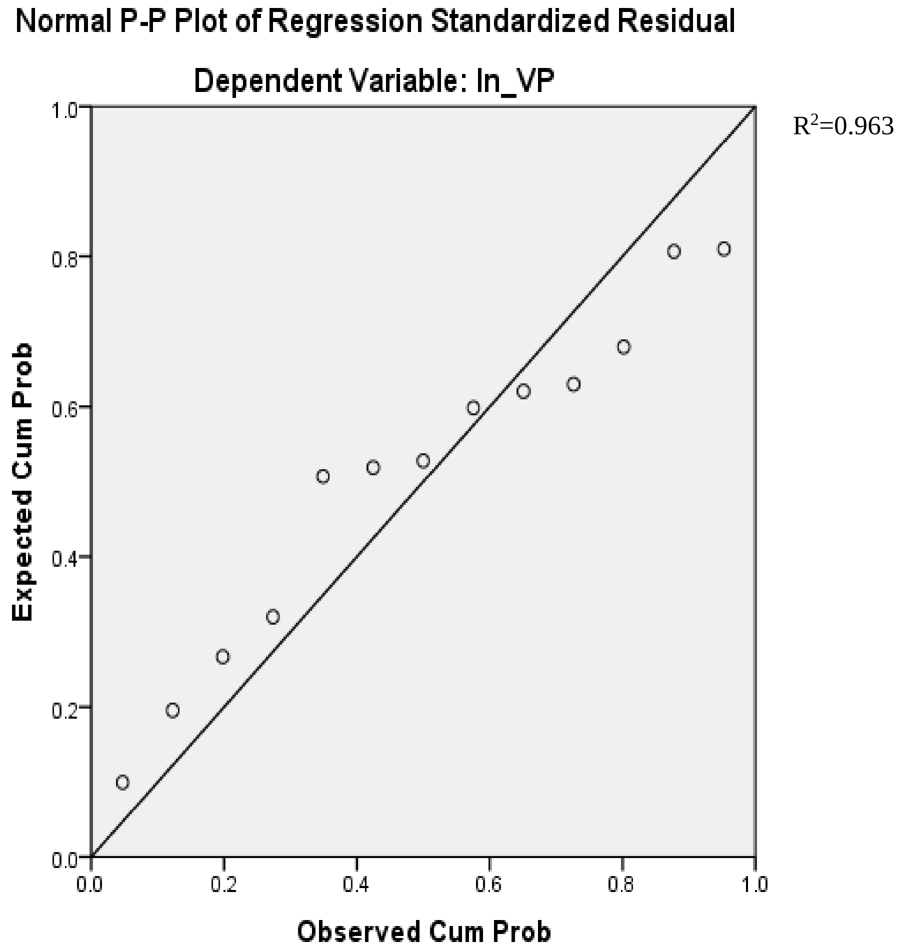


Figure 9: Depiction of Alternate Model Fit-Expected vs. Observed Cumulative Probability

3.4.2.1 Alternate Model Limitations

The model shortcomings are the same as those discussed for the traditional model in regards to data size and processing. My goal with this model was to attempt a more realistic approach to calculating opportunity cost, which was an issue with standard zonal travel cost models. As I mentioned in the methodology section the total cost for each trip is broken down by distance cost and opportunity cost in Table 2 of Appendix unlike the traditional model where total cost steadily increases as you get farther from the park with the alternate model cost fluctuates depending on zone due to fluctuating opportunity cost. The survey categorized income in ranges so I had to take the average of the upper and lower limit for analysis; this causes some discrepancy because I did not know exact values for all the respondents. In theory more detailed information about the visitors would help improve the accuracy of the model. The alternate model gives a more accurate depiction of park value and if more accurate income information were available the alternate model would provide more detailed results about how visitors value their time, which would give a better representation of value. However, since travel cost is the only significant predictor I do not believe this is possible with the model as it is.

3.4.3 Valuation Predictions

Both forms of the zonal travel cost model utilized theoretical additional cost added to a calculated total cost for visits made from each zone in conjunction with a predicted number of visits that was projected based on the addition of increasing costs to determine how much visitors were "willing to pay" as cost rose. Then the total amount visitors were willing to pay was estimated by adding together the value at each point along the demand curve. This final estimate was viewed as a proxy for how much visitors were willing to pay for the ecosystem and landscape services that contributed to the activities they participated in within the park; thus I used this as an estimate for the monetary value of those services.

3.4.3.1 Traditional Model

Based on previous research I did with a small subset of the initial in park survey data I expected the increased additional cost tolerated by visitors to decrease as distance to the park increased, meaning that the farther visitors had to travel they would be willing to incurred less additional cost because the initial travel expense is much higher- see appendix A-4. However, based on Figure 10 it appears that the response to additional cost was more varied and that visitors having to travel from farther away are willing to incur a greater amount of additional cost in order to visit the park. At a zonal distance of 150 miles, the price at which visitation no longer declines, is around $2,500 from here the choke price fluctuated between $2,300-$2,400. Around the 1500 mile zone the choke price begins to increase fairly consistently until the final 1950-mile zone.

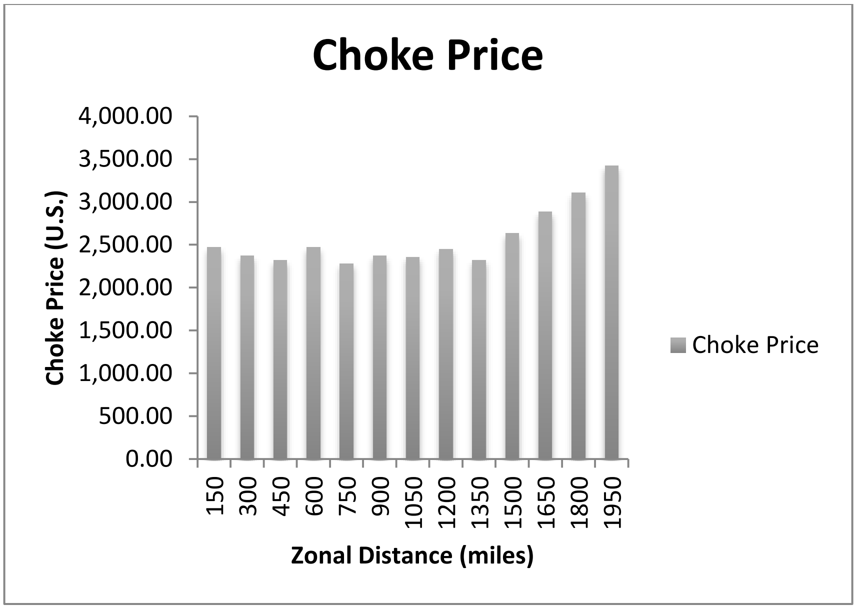


Figure 10: Traditional Model Choke Price

The demand curve generated for the traditional model can be seen in Figure 11. Initially, with no added additional cost the projected number of visits was 1,371,172 but since they did not have to contend with any additional cost in addition to their initial travel cost their willingness to pay for natural services was estimated at $0. With every increase in additional cost the projected number of visits decreases significantly per increase up until the additional cost becomes too much and the projected visits falls to 0. The curve has a very steep negative slope in relation to additional cost less than or equal to $500. The estimate of visitor willingness to pay fluctuates depending on the additional cost and the projected number of visitors. Even though the projected number of visitors decreases the calculated willingness to pay is offset by increasing additional cost. For instance, the estimated WTP at an additional cost of $126.40 with a projected number of visits of 826,887 is $104,518,576.40 but an increased additional cost of

$400.00, which decreases projected visits to 266,054, raised the estimated WTP to $106,421,692.61. An additional cost of $500 has 228,768 projected visitors but an estimated willingness to pay valued at $114,383,773.29. The WTP estimated at this price point was the highest of all the increments evaluated.

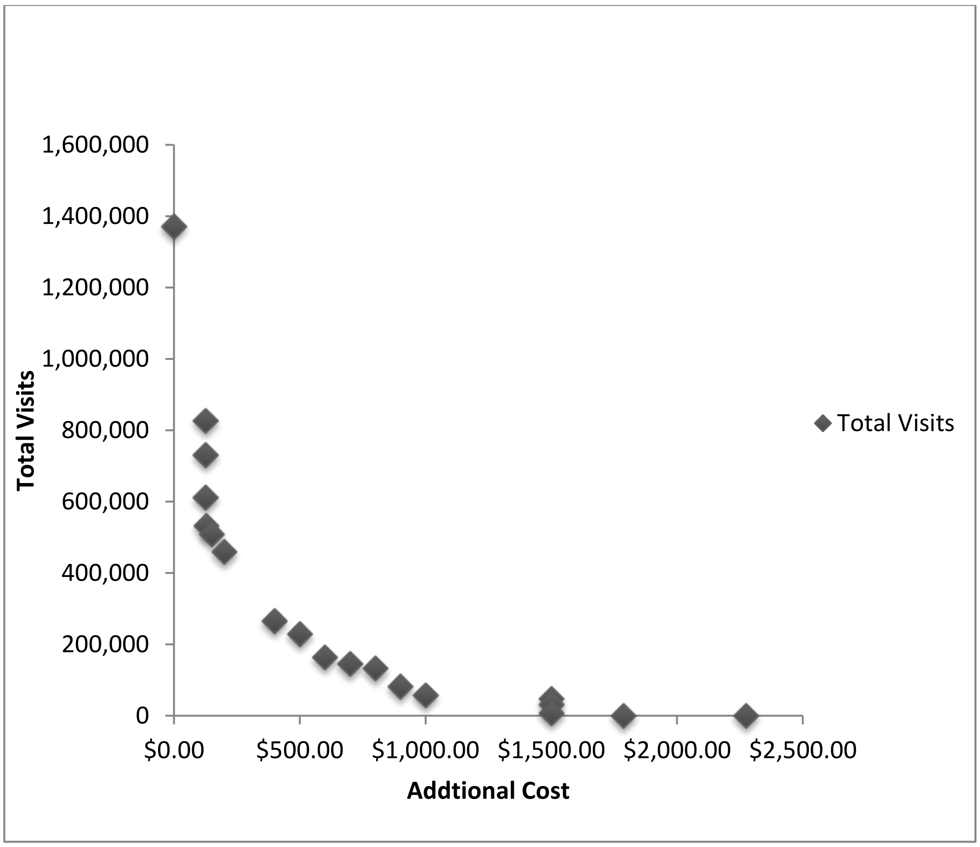


Figure 11: Traditional Model Demand Curve

Additional costs greater than $500 seem to level out the demand curve. After this point the projected number of visits still decreases but the rate of decrease isn't as steep as before. However, the derived WTP still fluctuates as before but does not seem to be as variable. Below $500 the decreasing number of visits was offset by increased additional cost, which meant that the estimated value of WTP could still be significant, above $500 the WTP estimates are generally smaller. An added cost of $800 projected visitation at 132,820 and produced an estimated WTP of $106,256,339.48. This was the highest estimate of WTP found above the $500 price point. After that the projected number of visits and the estimated WTP decreased until the additional cost reached a value of $2,274.00 at this point the projected number of visits and WTP fell to 0. Therefore, I conclude that any additional costs greater than $2,274.00 makes visits to the park to costly for visitors. The total estimated WTP for the landscape and ecosystem services related to tourism for Big Bend using a traditional ZTC model was $1,301,446,000.00.

3.4.3.2 Alternate Model

Initially, I expected the results of the alternate model to have more variation than I assumed the traditional model would have had before I ran the model based on how the total travel cost was calculated. I assumed that because the travel cost took into account the average zonal income that the estimated choke price and willingness to pay would fluctuate. Figure 12 illustrates the choke price of each zonal distance. The coke price for each zone based on this model is more variable with certain zones tolerating significantly higher additional costs. The 150-mile zone incurs the most additional cost with a choke price of $2,980; this means that visitors living closer to the park are willing to incur increased additional cost possibly because their total travel cost to get to the park is not as expensive. The choke prices decrease as expected the further from the park you travel until the 1,050-mile zone; here the choke price jumps up to $2,200. The choke price for the 1,200 and 1,350-mile zones decrease significantly from the 1,050-mile zone with the 1,350-mile zone having a slightly higher price than the 1,200 mile zone. The last significant increase in choke price occurred at the 1,500-mile zone her the choke price increased to just under $2,000. The sudden increases in choke price for the specific zones is caused by the income variable, the average income for these areas was lower than the other zones. The 1,050 and 1,500-mile zone each had an average income of $39,999, while the average income for the 150-mile zone was slightly higher at $59,999.

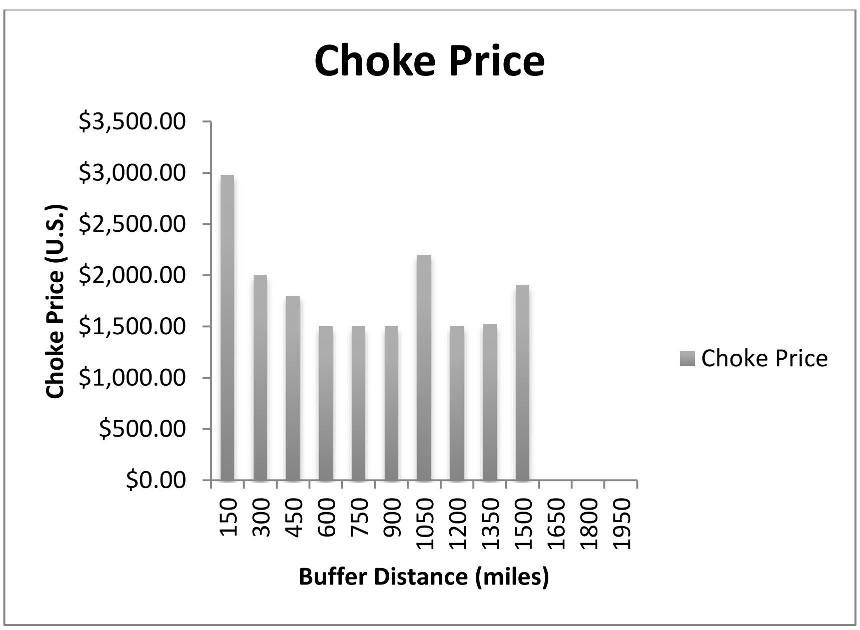


Figure 12: Alternate Model Choke Price

The demand curve for the alternate model can be seen in Figure 8. Similarly to the other model, with no added additional cost the projected number of visits was 1,312,621 but since they didn't have to contend with any additional cost in addition to their initial travel cost their willingness to pay for natural services was estimated at $0. $500 seems to be significant to this model as well, again the curve has a very steep negative slope for additional cost less than $500 but the curve seems to flatten and level out with increased additional cost above $500. The projected number of visits decreased with increased additional cost over the entire model. The willingness to pay does not seem to fluctuate as much for this model. From no additional cost added to $1,500 in additional cost the WTP increases with increasing additional cost. At an additional cost of $1,500 the projected number of visits is 124,855 but the estimated WTP is $187,283,077.00 which is the most WTP generated at a single additional cost price point for the model.

Additional costs greater than $1,500 the estimated amount of WTP predominately decreases as cost increases. There are only slight increases at additional cost of $1,510 and $1,530 where the estimated WTP increases from the previous value by less than 100,000 before continuing to decrease. With an additional cost of $2,980 the projected number of visits and the estimated willingness to pay fell to 0. Therefore, additional costs exceeding this amount make the trip and visit to costly for visitors. The combined total willingness to pay for the park visit as proxy for the value of landscape and ecosystem services related to tourism is $1,422,244,000.00.

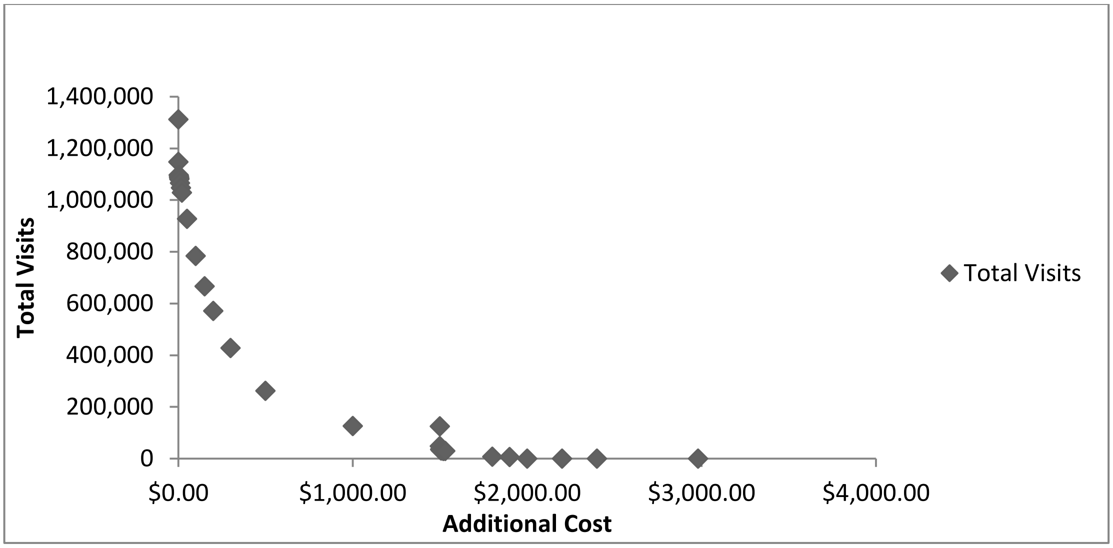


Figure 13: Demand Curve for the Alternate Model

3.5 Conclusions

Travel cost models are less controversial because they are based on standard techniques for measuring value. They have the ability to analyze actual behavior rather than hypothetical scenarios. Also, zonal travel cost models in particular require less data and are cheaper to produce than other valuation methods.

The models are similar differing only in how the total travel cost of trips form each zone is calculated therefore; they produced similar results. This is one factor that indicates that the models are robust in nature. The traditional model predicted an overall value of $1,301,446,000.00 for ecosystem and landscape services, while the estimated value predicted by the alternate model was slightly higher at $1,422,244,000.00. The slight increase in value depicted under the alternate model is due to the difference in the calculation of total trip cost per zone. The traditional model used the average minimum wage rate and an average vehicle operating cost to calculate distance cost and opportunity cost which contributed to total trip cost. The only values that were zone specific for this model were the travel time and travel distance. However, the alternate model was more complex and varied somewhat because zone specific information was used to calculate total trip cost. Instead of using minimum wage the alternate model used the average zonal income to calculate opportunity cost. Also, the average price of gas and miles per gallon were used to calculate the distance cost per mile. These minor differences caused the estimated total trip cost to fluctuate based on the zone. I believe that the variation in the choke price was a little more significant in the alternate model but the overall the pattern of the effect of increasing zonal distance on choke price is similar between the two models. The demand curves for the two models are almost identical.

The steep negative cost associated with additional cost below $500 for both models implies that visitation is highly sensitive to increasing cost for travelers spending less than this amount. The demand curves appear to flatten out with increasing additional cost exceeding $500. I am assuming that travelers that spend more than $500 dollars in additional cost for things like entertainment and lodging aren't as sensitive to price and for these individuals some other factor or additional cost besides those considered in this study are more important, justifying the economic loss. There are various possibilities of what these factors or additional cost could be, most of which are not measureable within the models and are thus beyond the scope of this research.

The usefulness of this type of study is if you want to find out if there was a benefit to spend money to implement programs to protect or improve a site. Zonal travel cost studies estimate the value of an areas recreational resources or use. They can be used to help monitor visitor satisfaction with the quality of resources at the park. Comparisons can be made between different sites within a park or between different parks to indicate where improvements to areas could be made to improve the quality of the resources. Over the long-term having an indication of an area recreational value can help in setting long-term goals and objectives. Tourism over the years in Big Bend has generally increased which is usually considered a positive but increased tourism also places more strain and wear on the recreational use of the area, having the ability to look at the change in value over the years would assist park officials in determining if the parks resources are able to sustain the increases in visitation or if steps need to be taken to insure the protection of said resources

4. OVERALL SUMMARY AND CONCLUSIONS

The purpose of this study was to identify the relationship between climate and tourism and estimate the potential impact of climate change on that relationship in Big Bend National Park. The relationship between climate and visitation and the potential impact that increasing severity of climate change will have on recreational visitation is evaluated in the first essay. The first major finding suggests that time scales are important to understanding the relationship between climate and recreational visitation within the park; it appears that climate and visitation interact on a seasonal scale. A second major finding indicates that visitation will actually increase as the effects of climate change become more severe. The potential increase in visitation affirms my belief that the relationship between climatic factors and park visitation is weak and that when deciding whether or not to visit Big Bend other factors like travel distance and cost weigh more in the decision making process than climatic factors. Park records that indicate an overall increase in visitation over time support this trend as well as the model. The increased visitation that was predicted for the cool season under both scenarios indicates that visitors do prefer an "ideal temperature range". Over time this could lead to a shift in time frame of tourist season from "spring/early summer" to more of a winter season in "December-February" but the overall annual visitation will not change much.

The second essay focused on estimating the implied fiscal value of ecosystem and landscape services associated with tourism in Big Bend National Park using a traditional and an alternative form of a zonal travel cost model. The only difference between the two models was how the total trip cost was calculated; with the traditional model the total trip cost increased with increasing zonal distance from Big Bend. However, the total trip cost varied in relation to zonal distance because it took into account the average zonal visitor income instead of just the typical average wage rate used in the traditional model. I believe that this allows the alternate model to provide a more accurate representation of value. The traditional model predicted an overall value of $1,301,446,000.00 for ecosystem and landscape services, while the estimated value predicted by the alternate model was slightly higher at $1,422,244,000.00. The demand curves for the two models are almost identical. Visitors who spent less than $500 appear to be sensitive to increases in cost indicated by the steep negative slope of both curves however, it appears that visitors who spend more than $500 for their visit to the park are less concerned with cost. This suggest those visitors are drawn to the park and get other benefits from the park besides food, entertainment or lodging and that the value they perceive from those benefits outweigh the high cost of travel.

Both climate change scenarios in essay one predicted increased overall visitation even as climate conditions become more severe; this will cause the estimated value for the ecosystem and landscape services derived from the ZTC in essay two to increase as well. Under RCP 4.5 and 8.5 climate change scenarios annual visitation was projected to be 319.083 and 322,385, respectively with more visits occurring in cooler temperatures. The RCP 4.5 scenario had a projected increase of 8.83% in overall visitation. However, under the more severe conditions of the RCP 8.5 scenario visitation was projected to increase by 9.96% overall. Taking into consideration the projected effect of climate change on visitation the value of the natural resources that contribute to tourism at the park will increase. Under the RCP 4.5 scenario the value predicted by the traditional and alternate models increased to US$1,416,363,682 and US$1,547,828,145, respectively. Under the RCP 8.5 scenario the value predicted by the traditional and alternate models increased to US$1,431,070,022 and US$1,563,899,502, respectively.

This means that the tourism industry in and around Big Bend National Park might not be as susceptible to the negative impacts predicted to occur elsewhere because of climate change. Further, response to the visitor survey indicated a decline in the number of visitors traveling to the park to participate in activities like plant identification, wildlife viewing and birding however, tourism trends shift frequently if these activities where to regain popularity then I believe the park would face harsher implications. As I stated in previous sections the climate of the area is predicted to become hotter and drier with higher frequencies of extreme weather, which could have major impacts on the on the unique plant and animal community leading to a loss of biodiversity. A study by Bell found that the ability of the soil microbial community to maintain functional resilience over the time span of a year could be impaired in response to increased soil temperature due to climate change in the Chihuahuan Desert environment (Bell et al. 2009). Johnson *et al.* found that C_3 shrublands and C_4 grasslands respond differently to rising atmospheric CO^2 levels. They observed that the biomass of C_3's increased from near 0 to 50%, while the biomass of C_4's decreased by 25% as CO^2 concentrations reached 350 ppm (Johnson et al. 1993). A multiyear study by Wondzell indicated a significant increase in the conversion of the C_4 grasslands in the area to C_3 shrublands in the area due to increased desertification and they noted a decline in the diversity of winter annuals (Wondzell and Ludwig 1995). A study by Svejcar *et al.* noted that Southern desert lands act as sources of atmospheric Carbon (C) kept in balance by native grasslands and other environments acting as Carbon sinks but droughts limit the ability of rangelands to uptake C causing them to become sources of atmospheric Carbon. As droughts become more frequent the sources of atmospheric Carbon will increase while the ability and/or availability of natural sinks declines (Svejcar et al. 2008). Natural communities could become disassembled giving way to the formation of niche communities.

Overall, these findings suggest that climate and/or climate change is not a deciding factor that influences visitor's decision to visit the park; other factors such as cost seem to be more important. Therefore, as the effects of climate change become more severe visitation will continue to increase. From a management prospective I believe that it would be okay to shift funding and resources into conserving and preserving the natural resources and ecosystems that comprise the park, focusing on native plants, maintaining biodiversity and preserving unique species.

Based on the climate model the overall temperature of the park is expected to increase while precipitation is predicted to decrease over time. However, extreme weather events such as, droughts or floods that are portrayed by the media as an effect of climate change will not have much of an influence on overall park visitation. The results showed that precipitation was correlated to average minimum temperature but I pointed out that the relationship was not statistically stable. Average mean temperature is the most consistent temperature variable in both the monthly and the seasonal models. My results suggested that although visitation continues to rise visitors prefer cooler temperatures. Based on my findings and the findings of others, I discussed in the literature review, I believe that the park's tourist season will shift. Instead of having a primary tourist season in March and April as the temperature increases over time visitors will visit more frequently in the cooler months of November and December, which serves as a secondary tourist season currently.

Mitigating and responding to the projected shift in visitation patterns as well as the potential loss of desert grasslands and biodiversity will require park management to be extremely knowledgeable about all aspects of the past and present condition of the park. Communication between all levels of management and public input will become increasingly important as compromises between management goals and limited resources require consideration of climate science, public values and socioeconomic factors.

REFERENCES

Agnew, M. D., and J. P. Paluikof. 2002. Climate Impacts on the Demand for Tourism:1–10.https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=9&cad=rja&uact=8&ved=0ahUKEwjIkvuUwvTNAhVHPCYKHbg5AhAQFghbMAg&url=http%3A%2F%2Fwww.mif.uni-freiburg.de%2Fisb%2Fws%2Fpapers%2F04_maureen.pdf&usg=AFQjCNFSU4RaieGMpYtn-z57t4KOH9b97w

Ahern, J. 2012. Urban landscape sustainability and resilience: the promise and challenges of integrating ecology with urban planning and design. Landscape Ecology 28:1203–1212.

Amelung, B., and S. Nicholls. 2014. Implications of climate change for tourism in Australia. Tourism Management 41:228–244.

Arrow, K., B. Bolin, R. Costanza, P. Dasgupta, C. Folke, C. S. Holiing, B.-O. Jansson, S. Levin, K.-G. Mäler, C. Perrings, and D. Pimentel. 1995. Economic Growth, Carrying Capacity, and the Environment. Science 268:520–521.

Avila, F. B., A. J. Pitman, M. G. Donat, L. V. Alexander, and G. Abramowitz. 2012. Climate model simulated changes in temperature extremes due to land cover change. Journal of Geophysical Research 117:D04108.

Badola, R., S. A. Hussain, B. K. Mishra, B. Konthoujam, S. Thapliyal, and P. M. Dhakate. 2010. An assessment of ecosystem services of Corbett Tiger Reserve, India. The Environmentalist 30:320–329.

Baerenklau, K. A., A. González-Cabán, C. Paez, and E. Chavez. 2010. Spatial allocation of forest recreation value. Journal of Forest Economics 16:113–126.

Balmford, A., B. Fisher, R. E. Green, R. Naidoo, B. Strassburg, R. Kerry Turner, and A. S. L. Rodrigues. 2010. Bringing Ecosystem Services into the Real World: An Operational Framework for Assessing the Economic Consequences of Losing Wild Nature. Environmental and Resource Economics 48:161–175.

Barkmann, J., K. Glenk, A. Keil, C. Leemhuis, N. Dietrich, G. Gerold, and R. Marggraf. 2008. Confronting unfamiliarity with ecosystem functions: The case for an ecosystem service approach to environmental valuation with stated preference methods. Ecological Economics 65:48–62.

Bell, C. W., V. Acosta-Martinez, N. E. McIntyre, S. Cox, D. T. Tissue, and J. C. Zak. 2009. Linking Microbial Community Structure and Function to Seasonal

Differences in Soil Moisture and Temperature in a Chihuahuan Desert Grassland. Microbial Ecology 58:827–842.

Bigano, A., J. M. Hamilton, D. J. Maddison, and R. S. J. Tol. 2006. Predicting tourism flows under climate change. Climatic Change 79:175–180.

Boontho, C. 2013. An Economic Analysis of Phu Kradueng National Park. World Academy of Science, Engineering and Technology:337–341.

Boyd, J., and S. Banzhaf. 2007. What are ecosystem services? The need for standardized environmental accounting units. Ecological Economics 63:616–626.

Brandt, J., A. A. Christensen, S. R. Svenningsen, and E. Holmes. 2012. Landscape practice and key concepts for landscape sustainability. Landscape Ecology 28:1125–1137.

Broecker, W. S. 1975. Climatic change. Science 189:460–463.

Buckley, L., and M. Foushee. 2012. Footprints of climate change in US national park visitation. International Journal of Biometeorology 56:1173–1177.

Burkett, V. R., D. A. Wilcox, R. Stottlemyer, W. Barrow, D. Fagre, J. Baron, J. Price, J. L. Nielsen, C. D. Allen, D. L. Peterson, G. Ruggerone, and T. Doyle. 2005. Nonlinear dynamics in ecosystem response to climatic change: Case studies and policy implications. Ecological Complexity 2:357–394.

Butler, R. (n.d.). Seasonality in Tourism. London. https://php.library.tamu.edu/search/search_all.php.

Chapter 15. Travel Cost Method of Valuing Environmental Amenities. 2006. Chapter 15. Travel Cost Method of Valuing Environmental Amenities:1–6.

Chen, N., H. Li, and L. Wang. 2009. A GIS-based approach for mapping direct use value of ecosystem services at a county scale: Management implications. Ecological Economics 68:2768–2776.

Clawson, M., and J. L. Knetsch. 1956. Economics of Outdoor Recreation. The Johns Hopkins Press, Baltimore.

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. V. O'Neill, J. Paruelo, R. G. Raskin, P. Sutton, and M. van den Belt. 1997. The value of the world's ecosystem services and natural capital. Nature 387:253–260.

Coulson, R. N., and M. D. Tchakerian. (n.d.). Basic Landscape Ecology. (M. D. TchakerianTexas A&M University. Knowledge Engineering Laboratory, Eds.). KEL Partners, INC., College Station , TX.

Cox, P. M., R. A. Betts, C. D. Jones, S. A. Spall, and I. J. Totterdell. 2000. Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model. Nature 408:184.

Cumming, G. S., P. Olsson, F. S. Chapin, and C. S. Holling. 2012. Resilience, experimentation, and scale mismatches in social-ecological landscapes. Landscape Ecology 28:1139–1150.

Dale, V. H., K. L. Kline, S. R. Kaffka, and J. W. A. Langeveld. 2012. A landscape perspective on sustainability of agricultural systems. Landscape Ecology 28:1111–1123.

Diaz, D. 2002. The Viability and Sustainability of International Tourism in Developing Countries. Geneva.

Dixon, J., and P. B. Sherman. (n.d.). Economics of Protected Areas. Ambio 20:68–74.

Dramstad, W. E., and W. J. Fjellstad. 2012. Twenty-five years into “our common future”: are we heading in the right direction? Landscape Ecology 28:1039–1045.

ESRI Data & Maps. 2014. ESRI Data & Maps. http://www.arcgis.com/home/group.html?owner=esri&title=ESRI%20Data%20%26%20Maps&content=all&q=zip&t=group.

Fleming, C. M., and A. Cook. 2008. The recreational value of Lake McKenzie, Fraser Island: An application of the travel cost method. Tourism Management 29:1197–1205.

Freeman, A. M., III, J. A. Herriges, and C. L. Kling. 2014. The measurement of environmental and resource values: theory and methods. Routledge.

Gössling, S., and C. M. Hall. 2006. Uncertainties in Predicting Tourist Flows Under Scenarios of Climate Change. Climatic Change 79:163–173.

Haines-Young, R., M. Potschin, 2010. The links between biodiversity, ecosystem services and human well-being. In D.G. Raffaelli & C.I.J. Frid (Eds), *Ecosystem Ecology: A new Synthesis*. 110-139. Cambridge University Press

Herbert, J. M. 2004. Predicting climate change in Big Bend National Park, Texas.

Hobbs, R. J., and D. A. Norton. 1996. Towards a Conceptual Framework for Restoration Ecology. Restoration Ecology 4:93–110.

Hodges, D. G., J. Fogel, V. H. Dale, K. O. Lannom, and M. L. Tharp. (n.d.). Economic Effects of Projected Climate Change on Outdoor Recreation in Tennessee. Pages 17–32 *in* J. Gan and S. Grado et al, editors. Global Change and Forestry. Nova Science Publishers, Inc.

Johnson, H. B., H. W. Polley, and H. S. Mayeux. 1993. Increasing CO₂ and Plant-Plant Interactions: Effects on Natural Vegetation. Vegetatio 104/105:156–170.

Jones, B., and D. Scott. 2006. Climate Change, Seasonality and Visitation to Canada's National Parks. Journal of Park and Recreation Administration 24:42–62.

Knetsch, J. L. 1963. Outdoor Recreation Demands and Benefits. Land Economics 39:387–396.

Labor Force Statistics from the Current Population Survey. 2011. Labor Force Statistics from the Current Population Survey. Bureau of Labor Statistics. http://www.bls.gov/cps/minwage2010.htm.

Lindenmayer, D. B., and S. A. Cunningham. 2012. Six principles for managing forests as ecologically sustainable ecosystems. Landscape Ecology 28:1099–1110.

Loomis, J., and J. Crespi. 1999. Estimated effects of climate change on selected outdoor recreation activities in the United States. The impact of climate change on the United States economy:289–314.

Mace, G. M., K. Norris, and A. H. Fitter. 2012. Biodiversity and ecosystem services: a multilayered relationship. Trends in Ecology & Evolution 27:19–26.

Maps and GIS Services. 2006. Network Analyist Dataset. Texas A&M University Libraries College Station, TX

Martin-López, B., E. Gomez-Baggethun, P. L. Lomas, and C. Montes. 2009. Effects of spatial and temporal scales on cultural services valuation. Journal of Environmental Management 90:1050–1059.

McCarthy, J.J., O. Canziani, N.A. Leary, D.J.Dokken and K.S. White (Eds.) Climate Change, I. C. 2001. Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York

Musacchio, L. R. 2013. Cultivating deep care: integrating landscape ecological research into the cultural dimension of ecosystem services. Landscape Ecology 28:1025–1038.

Myer, D., and K. Dewer. 1999. A New Tool for Investigating the Effect of Weather on Visitor Numbers. Tourism Analysis 4:145–155.

National Climate Change Viewer. (n.d.). National Climate Change Viewer. United States Geological Survey. http://www.usgs.gov/climate_landuse/clu_rd/nccv/viewer.asp.

National Climate Data Center. (n.d.). National Climate Data Center. NOAA. https://www.ncdc.noaa.gov/data-access.

National Park Service. (n.d.). National Park Service. National Park Service. http://www.nps.gov/bibe/index.htm.

Park Reports. (n.d.) National Park Service. National Park Service.https://irma.nps.gov/Stats/Reports/Park/BIBE

Perry, A. 2006. Will Predicted Climate Change Compromise the Sustainability of Mediterranean Tourism? Journal of Sustainable Tourism 14:367–375.

Phaneuf, D. J., and V. K. Smith. 2005. Recreation demand models. *in* K.-G. Mäler and J. Vincent, editors. Handbook of Environmental Economics, Valuing Environmental Changes. Elsevier, Amsterdam.

Pickering, C. 2011. Changes in demand for tourism with climate change: a case study of visitation patterns to six ski resorts in Australia. Journal of Sustainable Tourism 19:767–781.

Pongkijvorasin, S., and V. Chotiyaputta. 2013. Climate change and tourism: Impacts and responses. A case study of Khaoyai National Park. TMP 5:10–17.

Potschin, M., and R. Haines-Young. 2012. Landscapes, sustainability and the place-based analysis of ecosystem services. Landscape Ecology 28:1053–1065.

Proceedings of the First International Workshop on Climate, Tourism and Recreation, edited by A. Matzarakis and CR de Freitas, Porto Carras, Neos Marmaras, Halkidiki, Greece. (n.d.). Proceedings of the First International Workshop on Climate, Tourism and Recreation, edited by A. Matzarakis and CR de Freitas, Porto Carras, Neos Marmaras, Halkidiki, Greece.

Root, T. L., J. T. Price, K. R. Hall, S. H. Schneider, C. Rosenzweig, and J. A. Pounds. 2003. Fingerprints of global warming on wild animals and plants. Nature 421:57.

Scott, D., and G. McBoyle. 2001. Using a "tourism climate index" to examine the implications of climate change for climate as a tourism resource: Commission on Climate, Tourism and Recreation, International Society of Biometeorology. Frelburg, Germany. 69–88.

Scott, D., B. Jones, and J. Konopek. 2007. Implications of climate and environmental change for nature-based tourism in the Canadian Rocky Mountains: A case study of Waterton Lakes National Park. Tourism Management 28:570–579.

Shafer, S. (n.d.). Visitor Data. College Station.

Sirotnak, S. (n.d.). Big Bend GIS data.

Social Explorer. (n.d.). Social Explorer. http://www.socialexplorer.com.

Stehr, N., and H. von Storch. 1994. The Social Construct of Climate and Climate Change.

Stepp, E., editor. (n.d.). AAA Reveals 4.8 Percent Rise in Cost to Own, Operate Vehicle in 2010 Edition of "Your Driving Costs." 2015 edition. AAA. http://newsroom.aaa.com/2010/04/2010-your-driving-costs/.

Svejcar, T., R. Angell, J. A. Bradford, W. Dugas, W. Emmerich, A. B. Frank, T. Gilmanov, M. Haferkamp, D. A. Johnson, H. Mayeux, P. Mielnick, J. Morgan, N. Z. Saliendra, G. E. Schuman, P. L. Sims, and K. Snyder. 2008. Carbon Fluxes on North American Rangelands. Rangeland Ecology & Management:465.

Termorshuizen, J. W., and P. Opdam. 2009. Landscape services as a bridge between landscape ecology and sustainable development. Landscape Ecology 24:1037–1052.

The Economics of Ecosystems and Biodiversity. (n.d.). The Economics of Ecosystems and Biodiversity. http://www.teebweb.org.

United States Census Bureau. (n.d.). United States Census Bureau. http://www.census.gov/popest/about/terms.html.

United States Department of Transportation. (n.d.). United States Department of Transportation. Office of the Assistant Secretary for Research and Technology. http://www.rita.dot.gov/bts/home.

Uysal, M., C. Jurowski, F. P. Noe, and C. D. McDonald. 1994. Environmental attitude by trip and visitor characteristics: US Virgin Islands National Park. Tourism Management 15:284–294.

Verburg, P. H., S. Asselen, E. H. Zanden, and E. Stehfest. 2012. The representation of landscapes in global scale assessments of environmental change. Landscape Ecology 28:1067–1080.

Welch, D. 2008. What should protected area managers do to preserve biodiversity in the face of climate change? Biodiversity 9:84–88.

Wiens, J. A. 2012. Is landscape sustainability a useful concept in a changing world? Landscape Ecology 28:1047–1052.

Willemen, L., L. Hein, and P. H. Verburg. 2010. Evaluating the impact of regional development policies on future landscape services. Ecological Economics 69:2244–2254.

Wondzell, S., and J. A. Ludwig. 1995. Community dynamics of desert grasslands: influences of climate, landforms, and soils. Journal of Vegetation Science 6:377–390.

Wu, J. 2013. Landscape sustainability science: ecosystem services and human well-being in changing landscapes. Landscape Ecology 28:999–1023.

Zandersen, M., and R. S. J. Tol. 2009. A meta-analysis of forest recreation values in Europe. Journal of Forest Economics 15:109–130.

Zurlini, G., I. Petrosillo, K. B. Jones, and N. Zaccarelli. 2012. Highlighting order and disorder in social–ecological landscapes to foster adaptive capacity and sustainability. Landscape Ecology 28:1161–1173.

APPENDIX

Table A-1: Variable Correlations in Relation to Recorded Visits

	Year	Visits	TPCP	MMXT	MMNT	MNT	Population	Average Gas Price	Mean Income	Mean Age
Year	1	0.428**	-0.019	-0.011	0.050	0.023	0.895**	-0.028	0.911**	0.934**
Visits	0.428**	1	0.293**	0.172**	0.248**	0.216**	0.388**	0.157**	0.425**	0.406**
MMXT	-0.011	0.172**	0.354**	1	0.963**	0.989**	-0.002	0.066	-0.005	-0.016
TPCP	-0.019	0.293**	1	0.354**	0.501**	0.436**	-0.050	0.103*	-0.007	-0.005
MMNT	0.050	0.248**	0.501**	0.963**	1	0.989**	0.039	0.102*	0.049	0.046
MNT	0.023	0.216**	0.436**	0.989**	0.989**	1	0.020	0.090	0.026	0.022
Population	0.895**	0.388**	-0.050	-0.002	0.039	0.020	1	0.241**	0.794**	0.786**
Average Gas Price	-0.028	0.157**	0.103*	0.066	0.102*	0.090	0.241**	1	0.137**	0.003
Mean Income	0.911**	0.425**	-0.007	-0.005	0.049	0.026	0.794**	0.137**	1	0.967**
Mean Age	0.934**	0.406**	-0.005	-0.016	0.046	0.022	0.786**	0.003	0.967**	1

* Significant at the 0.01 level
** Significant at the 0.05 level

Table A-2: Seasonal Model Comparison

Model	R_2	RMSE
Q_1-0-0	0.564	6079.43660
Q_1-1-0	0.563	6034.48948
Q_2-0-0	0.405	7079.68056
Q_2-1-0	0.386	7121.50727
L_A-0-0	0.526	5982.16678
L_A-1-0[(1)]	0.375	6869.01604
L_B-0-0	0.663	6051.01003
L_B-1-0[(2)]	0.626	6267.18539
Q_1-0-1	0.495	7029.40586
Q_1-1-1	0.480	6993.28429
Q_2-0-1	0.341	7967.47929
Q_2-1-1	0.331	8055.98186
L_A-0-1	0.435	6520.39386
L_A-1-1	0.435	6446.93361
L_B-0-1	0.622	6740.14168
L_B-1-1[(3)]	0.608	6910.05856

The first set of letters represents transformation type where Q_1 is quadratic model that contains both the temperature predictor and the transformed temperature predictor. Q_2 indicates a quadratic model that contains only the transformed temperature predictor. L_A represents a linear model above the max visitation temperature, whereas L_B indicates a linear model below the max visitation temperature. The second number is a 0 or 1 indicating whether the model contains all predictor variables or just the significant ones respectively. Lastly, a 0 or a 1 indicates whether MMNT or MNT respectively is used as the temperature predictor.

(1) First time that MNT was more powerful than MMNT

(2) Slightly less powerful than equivalent model that uses MNT

(3) No added predictors were actually significant but gas price was close so I included it

Table A-3: Projected Temperature and Precipitation Under RCP 4.5 and 8.5 Scenarios

RCP 4.5 (2075-2099)

Month	TPCP (mm/day)	MMNT℃	MMXT℃	MNT ℃
Jan	0.3	2.5	19.6	11.05
Feb	0.3	4.2	22	13.1
Mar	0.2	7.7	26.3	17
Apr	0.4	12.8	31.5	22.15
May	0.8	17.7	35.3	26.5
Jun	1.3	21.7	37.4	29.55
Jul	1.8	22.4	36.9	29.65
Aug	1.4	21.9	36.3	29.1
Sept	1.7	19	33.5	26.25
Oct	1	13.7	30	21.85
Nov	0.4	7.2	23.9	15.55
Dec	0.3	3.1	19.7	11.4

RCP 8.5 (2075-2099)

Month	TPCP (mm/day)	MMNT ℃	MMXT℃	MNT ℃
Jan	0.2	4.3	21.7	13
Feb	0.2	6.1	24.3	15.2
Mar	0.2	9.6	28.6	19.1
Apr	0.3	14.9	33.9	24.4
May	0.8	20	38	29
Jun	1.2	23.9	39.9	31.9
Jul	1.8	24.7	39.3	32
Aug	1.5	24.3	38.5	31.4
Sept	1.7	21.6	36	28.8
Oct	1	16.2	32.6	24.4
Nov	0.4	9.4	26.2	17.8
Dec	0.2	5	21.9	13.45

Table A-4: Calculated Total Trip Cost for Traditional Zonal Travel Cost Model

Buffer Distance (miles)	150	300	450	600	750	900	1,050	1,200	1,350	1,500	1,650	1,800	1,950
Average Distance (miles)	128.041443	388.8088594	554.5760521	655.8334821	873.3922562	1008.760949	1,207.94	1,404.00	1,510.74	1,728.45	1,922.44	2,083.31	2,305.60
Round Trip Average Distance (miles)	256.08	777.62	1109.15	1311.67	1746.78	2017.52	2415.88	2807.99	3021.47	3456.90	3844.88	4166.62	4611.19
Distance Cost/Mile (59.6¢)	$152.63	$463.46	$661.05	$781.75	$1,041.08	$1,202.44	$1,439.86	$1,673.56	$1,800.80	$2,060.31	$2,291.55	$2,483.30	$2,748.27
Average Time (minutes)	181.2374819	498.5388712	656.1749102	794.8383785	1000.19363	1,117.35	1,323.42	1,566.22	1,636.27	1,860.78	1,956.67	2,073.86	2,276.70
Round Trip Average Time (minutes)	362.47	997.08	1312.35	1589.68	2000.39	2234.70	2646.84	3132.44	3272.55	3721.56	3913.35	4147.72	4553.39
Cost/Minute (12¢)	$43.50	$119.65	$157.48	$190.76	$240.05	$268.16	$317.62	$375.89	$392.71	$446.59	$469.60	$497.73	$546.41
Average Total Travel Cost/ Trip	**$196.12**	**$583.11**	**$818.54**	**$972.51**	**$1,281.13**	**$1,470.61**	**$1,757.49**	**$2,049.46**	**$2,193.50**	**$2,506.90**	**$2,761.15**	**$2,981.03**	**$3,294.68**

Table A-5: Calculated Total Trip Cost for Alternate Zonal Travel Cost Model

Buffer Distance (miles)	**150**	**300**	**450**	**600**	**750**	**900**	**1,050**	**1,200**	**1,350**	**1,500**	**1,650**	**1,800**	**1,950**
Average Distance (miles)													
Round Trip Average Distance (miles)	256.08	777.62	1109.15	1311.67	1746.78	2017.52	2415.88	2807.99	3021.47	3456.90	3844.88	4166.62	4611.19
gallon of gas (at 27.5mpg at 65mph	9.31	28.28	40.33	47.70	63.52	73.36	87.85	102.11	109.87	125.71	139.81	151.51	167.68
Cost per mile at $2.66/gal	$24.77	$75.22	$107.29	$126.87	$168.96	$195.15	$233.68	$271.61	$292.26	$334.38	$371.91	$403.03	$446.03
Average Time (minutes)	362.47	997.08	1312.35	1589.68	2000.39	2234.70	2646.84	3132.44	3272.55	3721.56	3913.35	4147.72	4553.39
Time Value /hr	$17.65	$47.79	$47.79	$47.79	$47.79	$47.79	$11.76	$20.59	$17.65	$11.76	$47.79	$47.79	$47.79
Time Cost of Travel	$106.61	$794.24	$1,045.38	$1,266.29	$1,593.45	$1,780.09	$518.78	$1,074.95	$962.67	$729.43	$3,117.25	$3,303.95	$3,627.09
Average Total Travel Cost/ Trip	**$131.38**	**$869.46**	**$1,152.66**	**$1,393.16**	**$1,762.41**	**$1,975.24**	**$752.46**	**$1,346.56**	**$1,254.93**	**$1,063.80**	**$3,489.15**	**$3,706.97**	**$4,073.12**

Table A-6: Average Monthly Temperature and Precipitation for Big Bend National Park

Month	**Average Max Temperature (°F)**	**Average Min. Temperature (°F)**	**Monthly Average Precip. (inches)**
January	60.9	35.0	.46
February	66.2	37.8	.34
March	77.4	45.3	.31
April	80.7	52.3	.70
May	88.0	59.3	1.50
June	94.2	65.5	1.93
July	92.9	68.3	2.09
August	91.1	66.4	2.35
September	86.4	61.9	2.12
October	78.8	52.7	2.27
November	68.5	42.3	.70
December	62.2	36.4	.57

Credit: National Parks Service/Department of the Interior

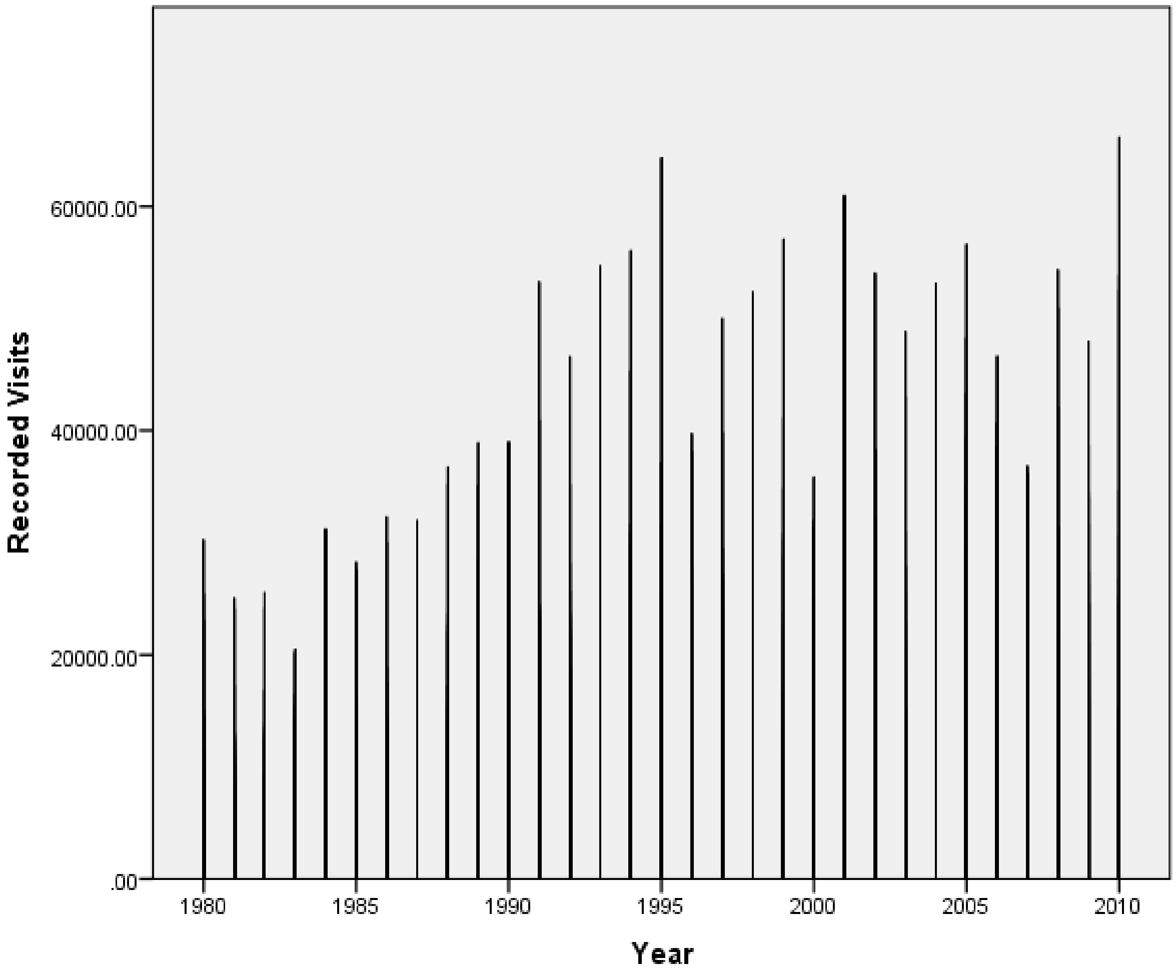


Figure A-1: Change In Visitation Over Time
(1) Visitation increased over time.

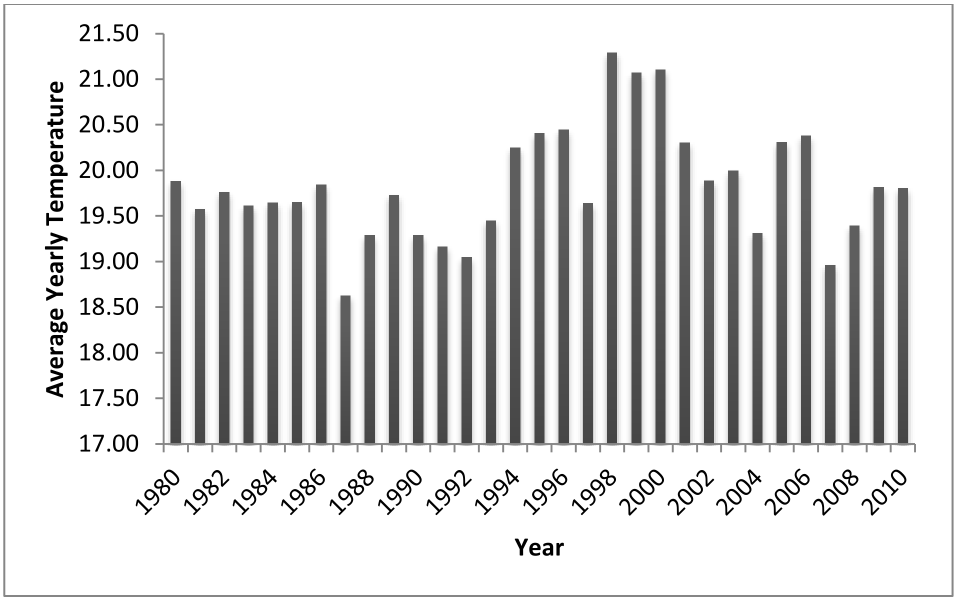


Figure A-2: Change In Average Temperature (MNT) Over Time

* Temperature measured in ºC

(1) Slight variation over time

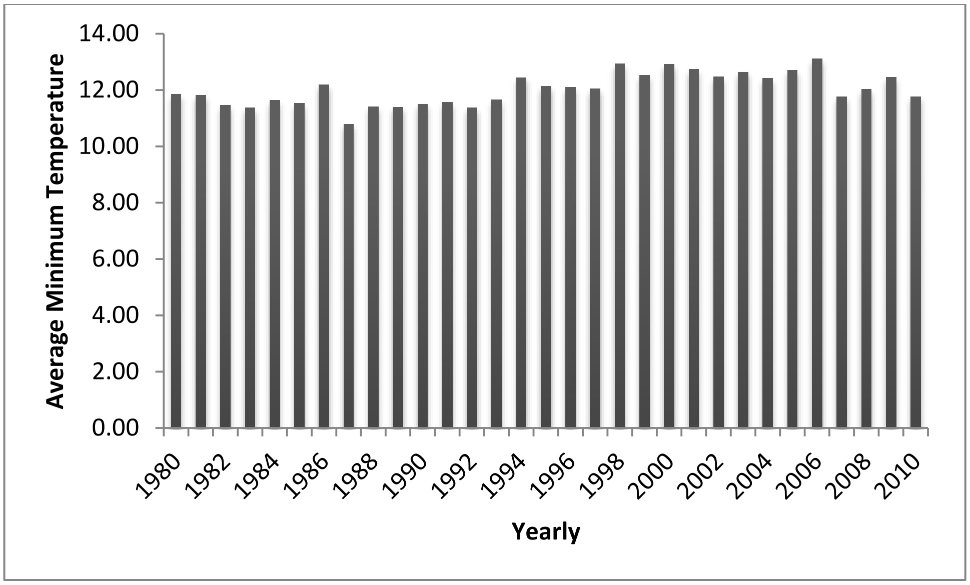


Figure A-3: Change In Average Minimum Temperature (MMNT) Over Time

* Temperature measured in ºC

(1) Overall no significant change

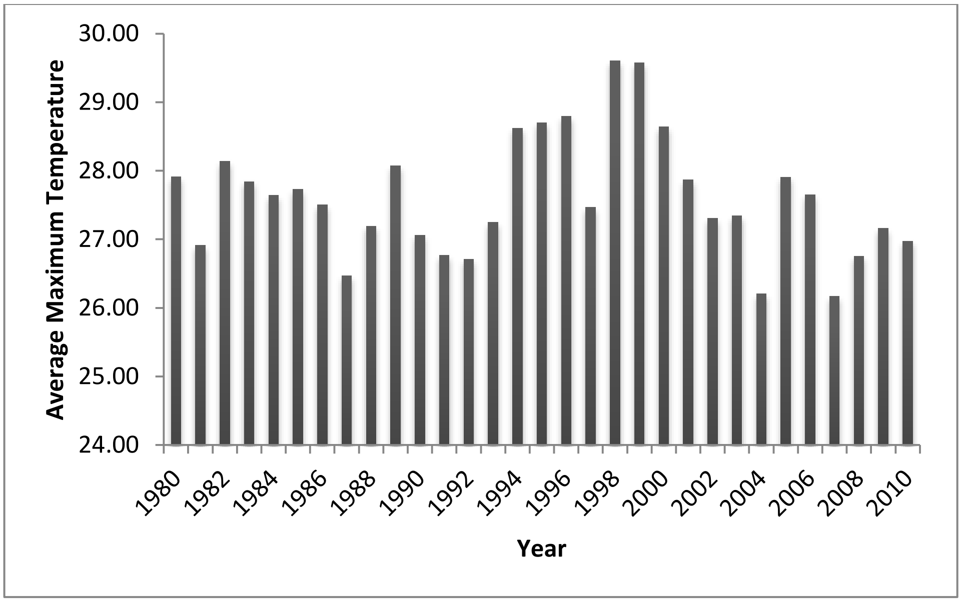


Figure A-4: Change In Average Maximum Temperature (MMXT) Over Time

* Temperature measured in ºC

(1) Overall no significant change

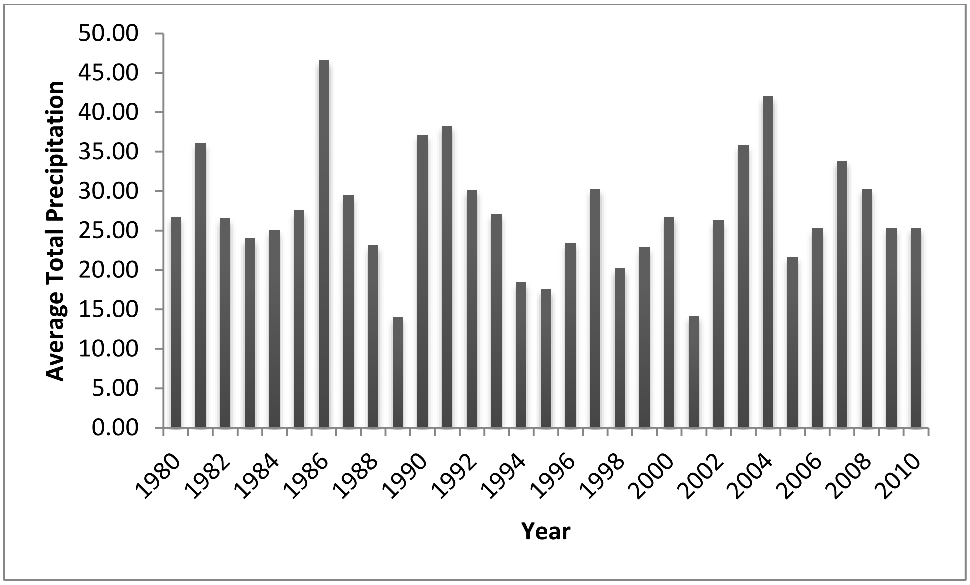


Figure A-5: Change In Average Total Precipitation (TPCP) Over Time

* Precipitation measured in mm

(1) Amount varied over time

(2) Significantly wetter years correspond to years when MNT and MMXT were higher

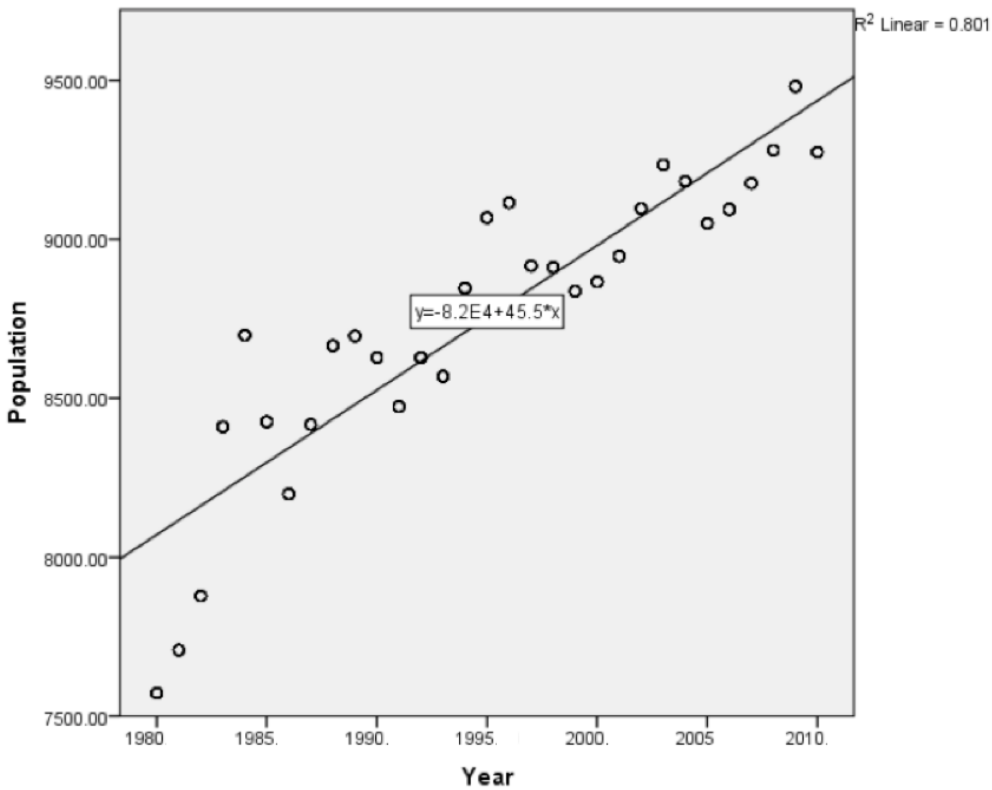


Figure A-6: Change in the Population of Brewster Co. Over Time

(1) Population increases over time.

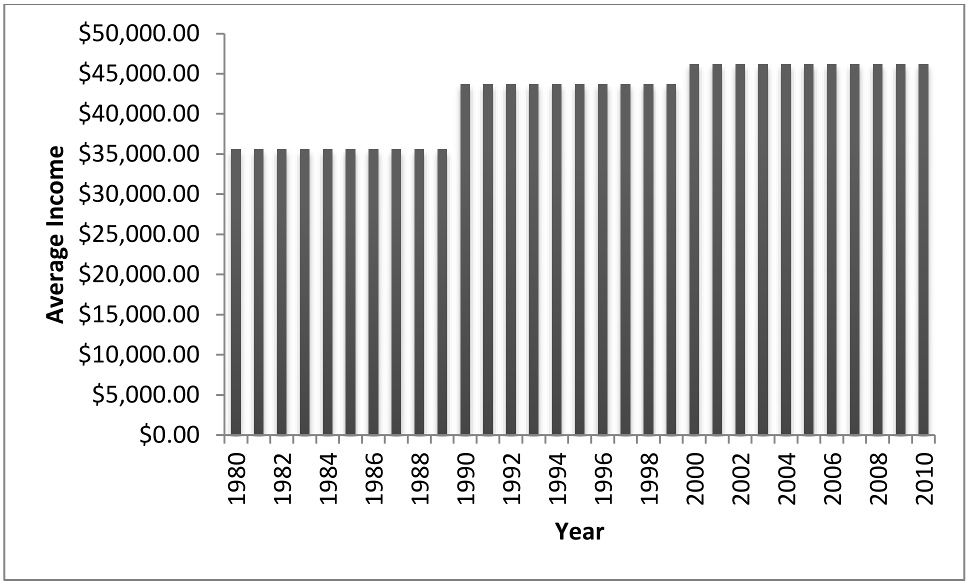


Figure A-7: Change in Average Income Over Time for Brewster Co.

(1) Income increases over time

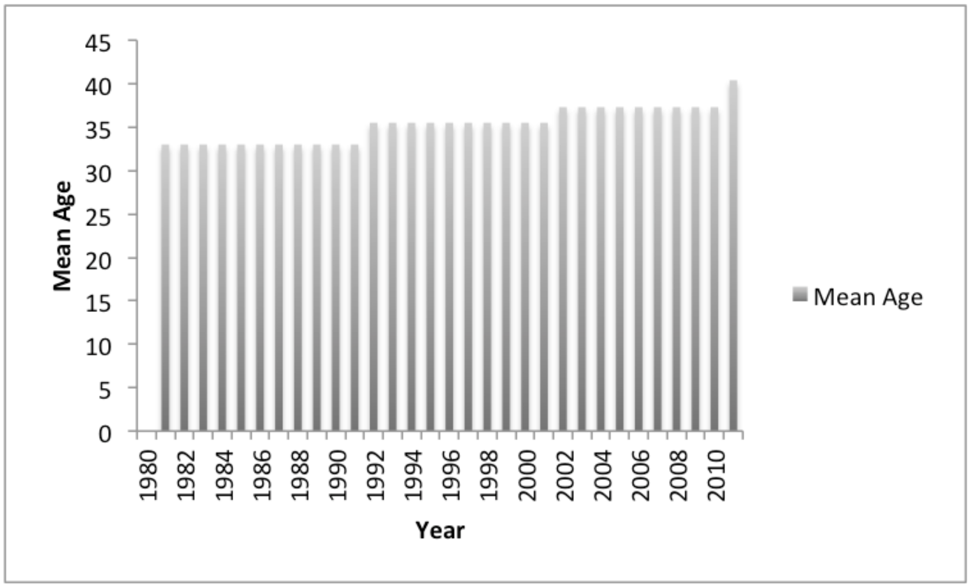


Figure A-8: Change in Mean Age Over Time

(1) Mean age slightly increases

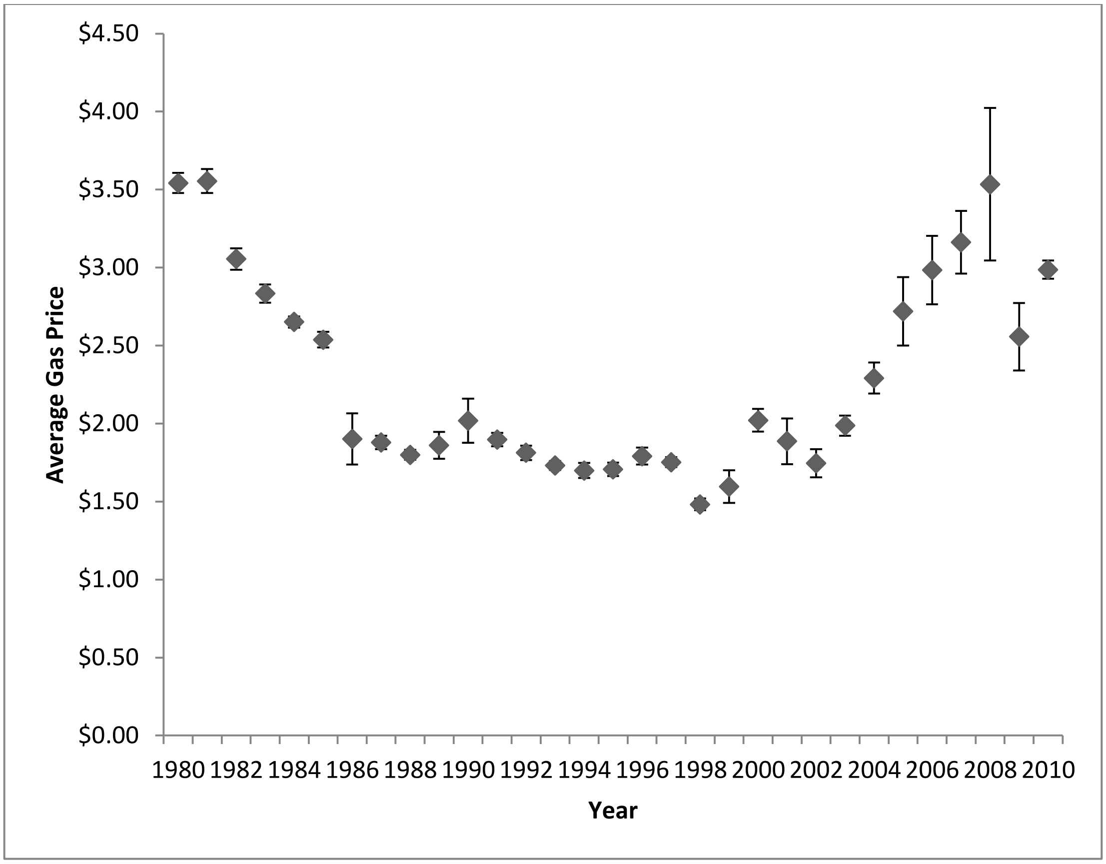


Figure A-9: Change in the Average Gas Price Over Time

(1) Gas prices fluctuate over time to reflect the oil and gas market at the time

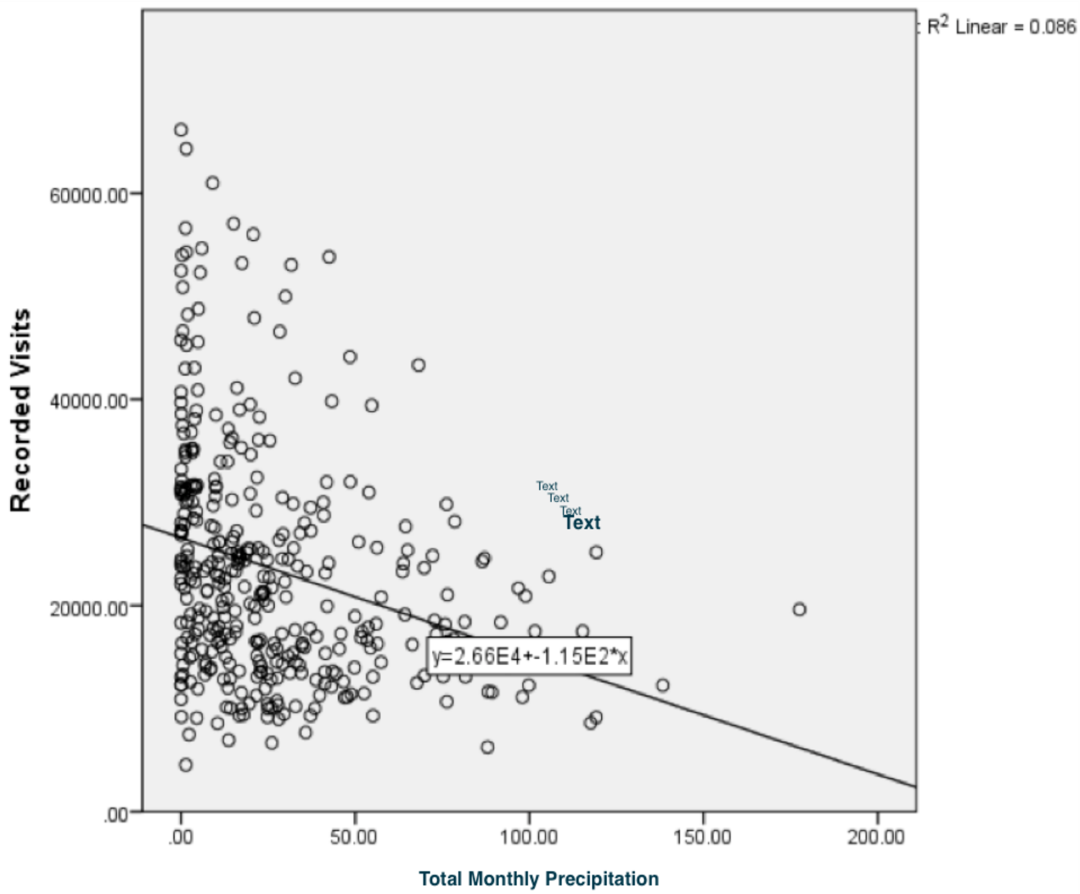


Figure A-10: Effect of Total Precipitation on Visitation

- Precipitation measured in mm

(1) As precipitation increases visitation decreases

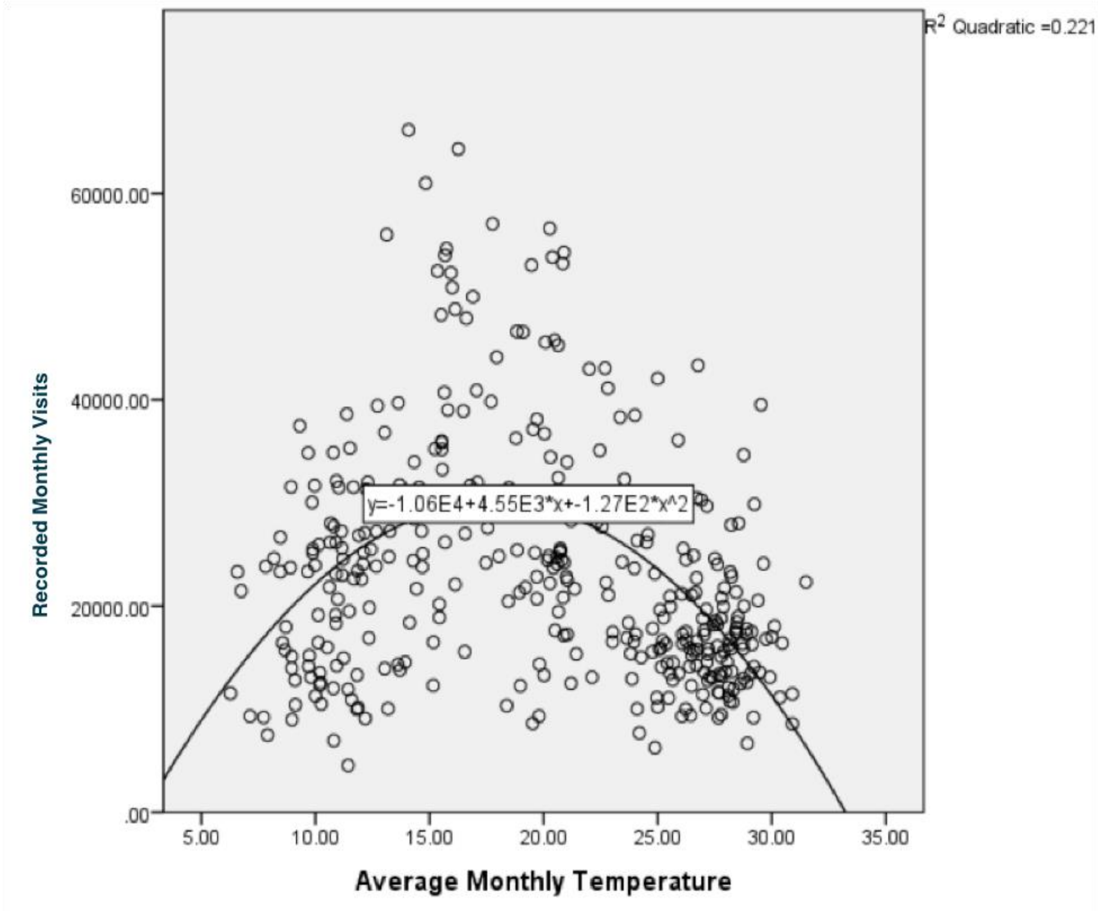


Figure A-11: Effect of Mean Temperature (MNT) on Visitation

* Temperature measured in ºC

(1) Visitation increases as temperature increases to a point then begins to fall as temperature continues to rise.

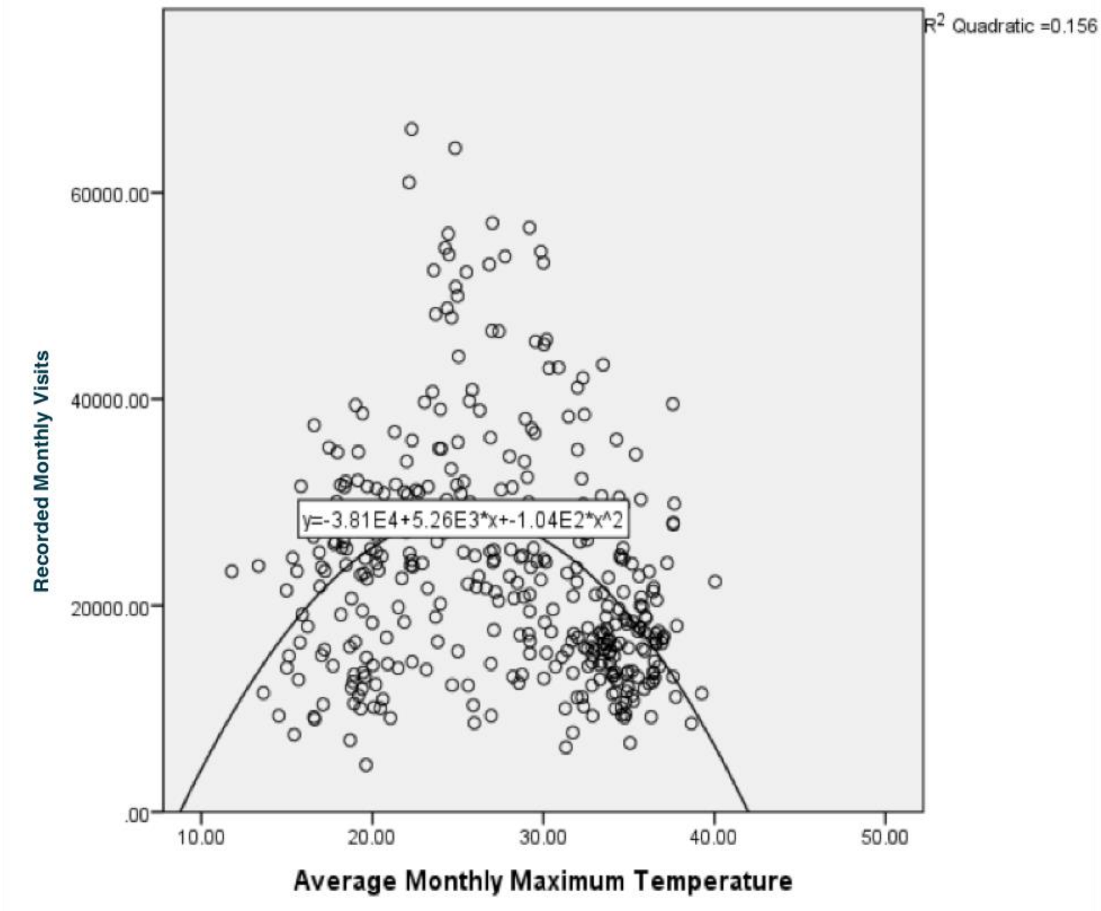


Figure A-12: Effect of Maximum Temperature (MMXT) on Visitation

* Temperature measured in ºC

(1) Visitation increases as temperature increases to a point then begins to fall as temperature continues to rise.

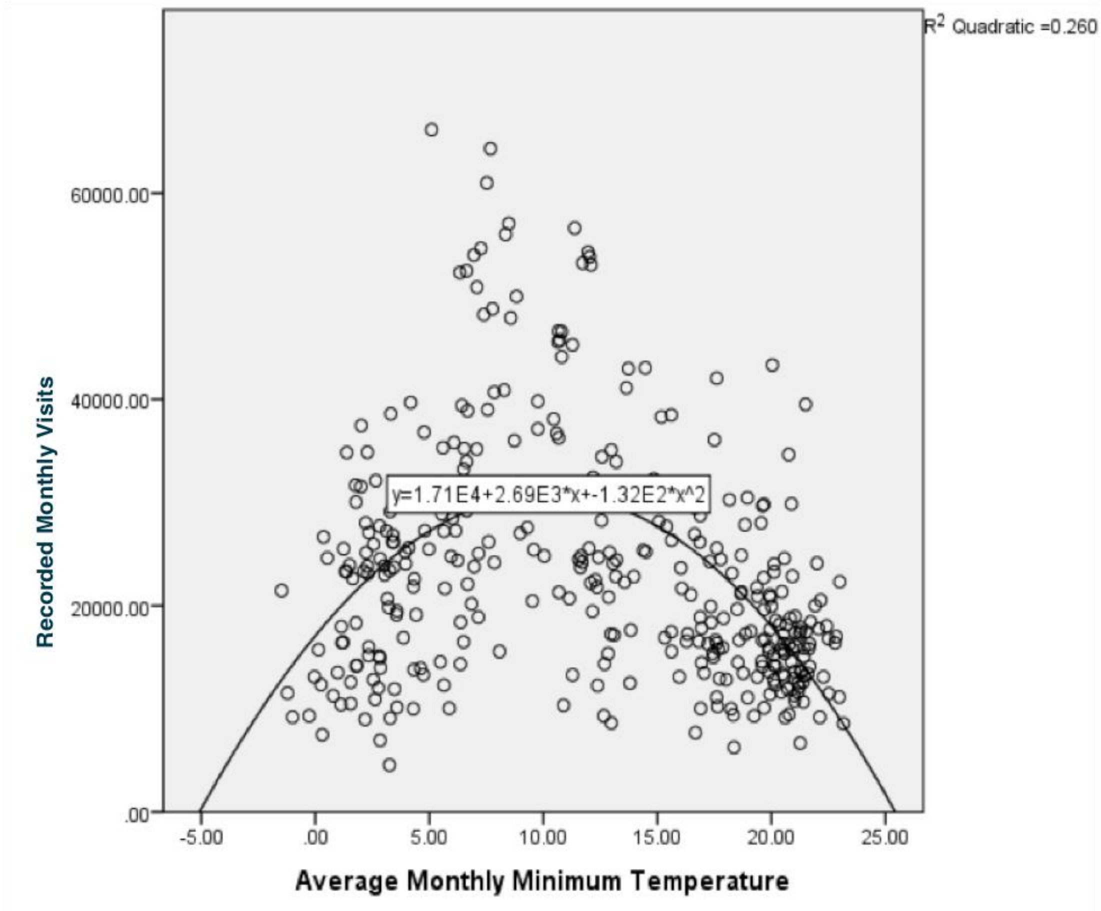


Figure A-13: Effect of Minimum Temperature (MMNT) on Visitation

* Temperature measured in ºC

(1) Visitation increases as temperature increases to a point then begins to fall as temperature continues to rise.

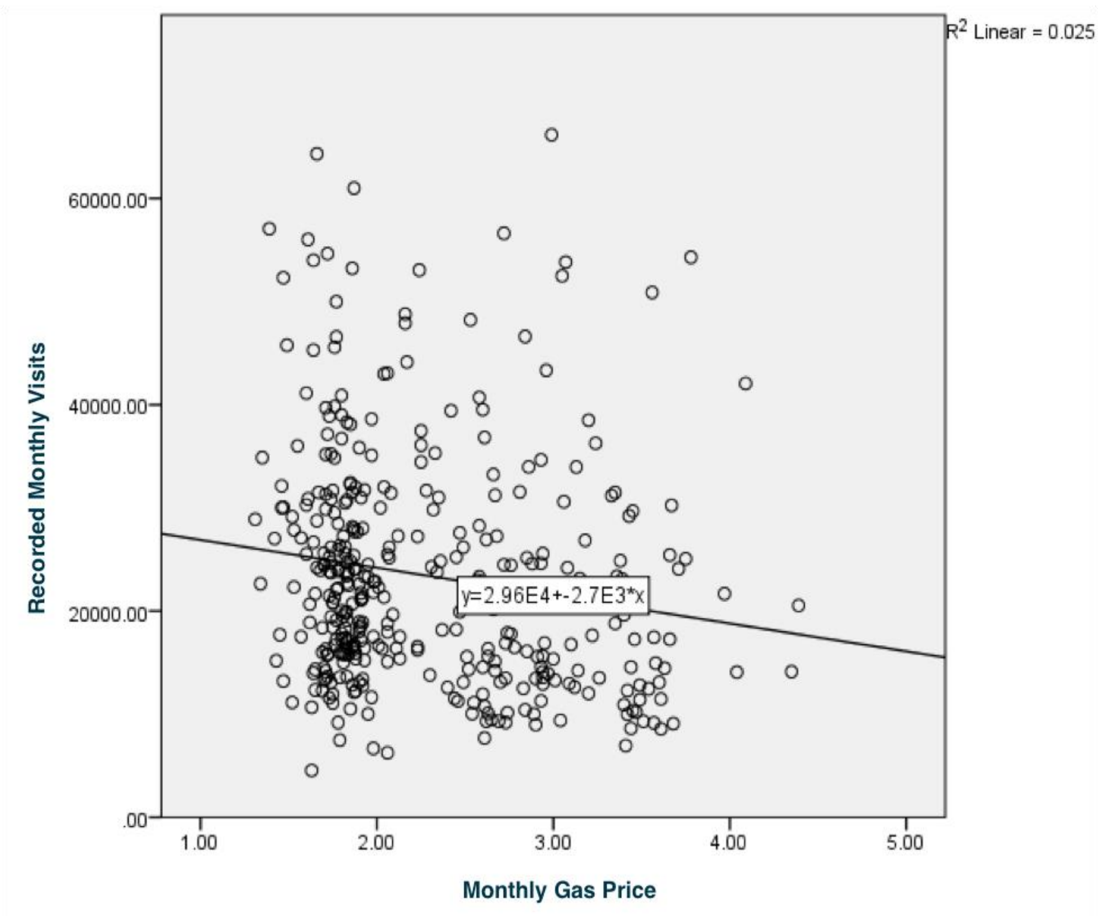


Figure A-14: Effect of Gas Price on Visitation

(1) As gas price increases visitation decreases

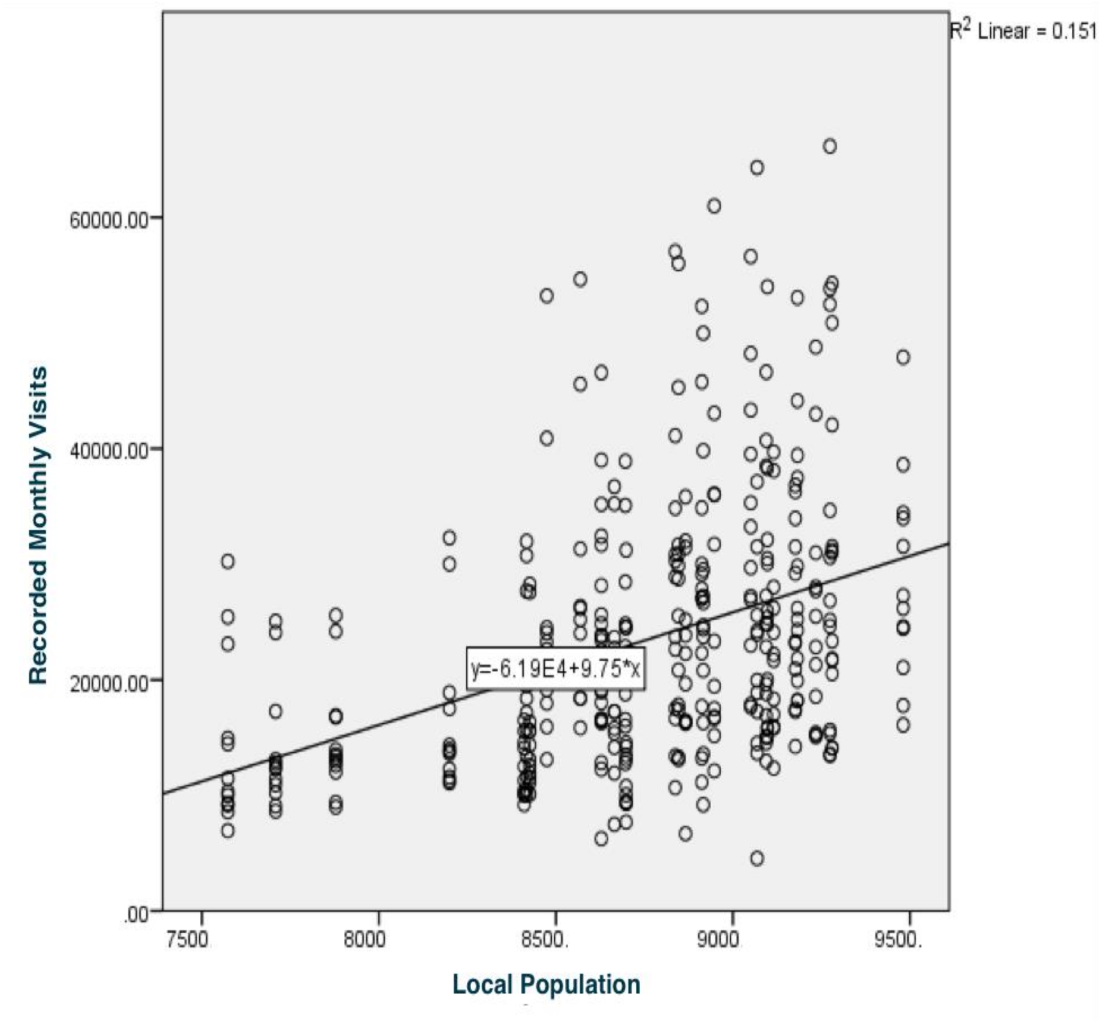


Figure A-15: Effect of Population on Visitation

(1) As the local population grew visitation increased

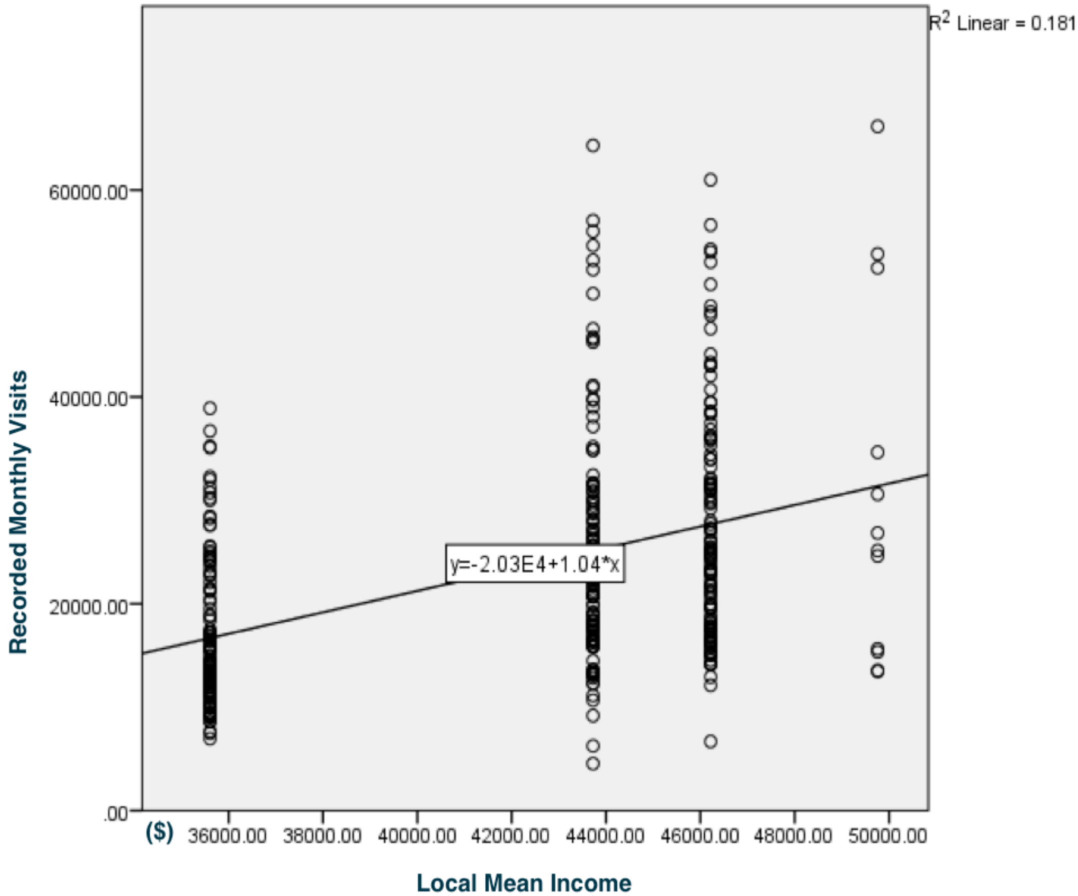


Figure A-16: Effect of Average Income on Visitation

(1) As park visitation increased the average income in the surrounding area increased and vice versa

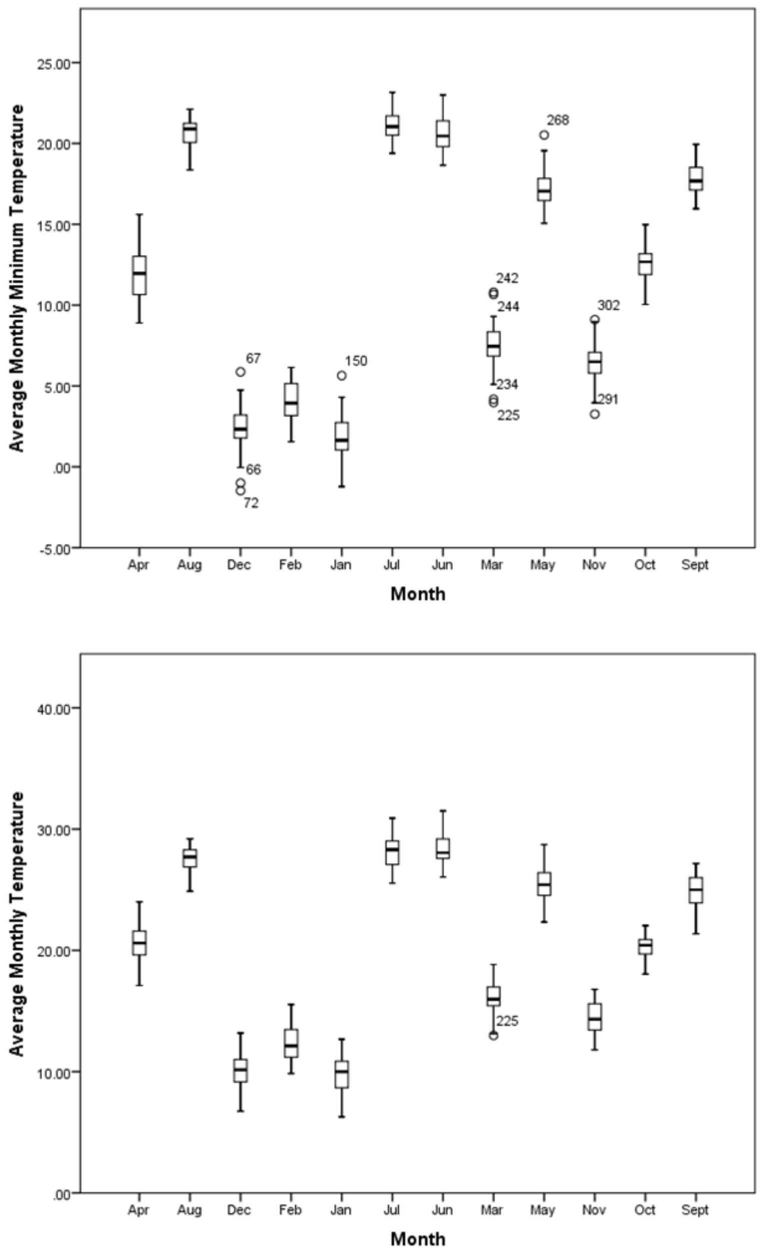
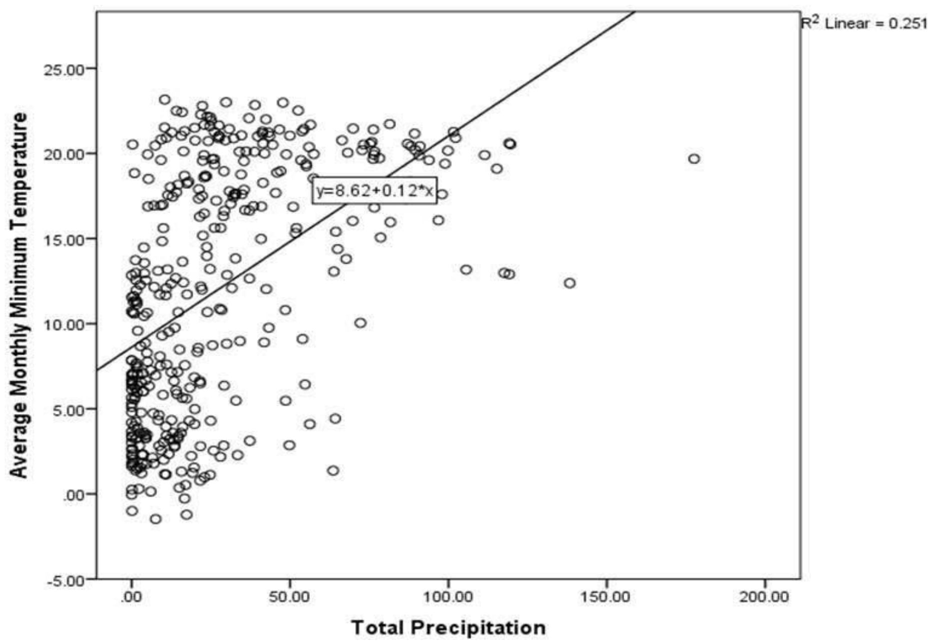


Figure A-17: Stability Comparison Between MMNT and MNT

(1) MNT has a tighter grouping and more concise uniform margin of error so it's presumed more stable than MMNT



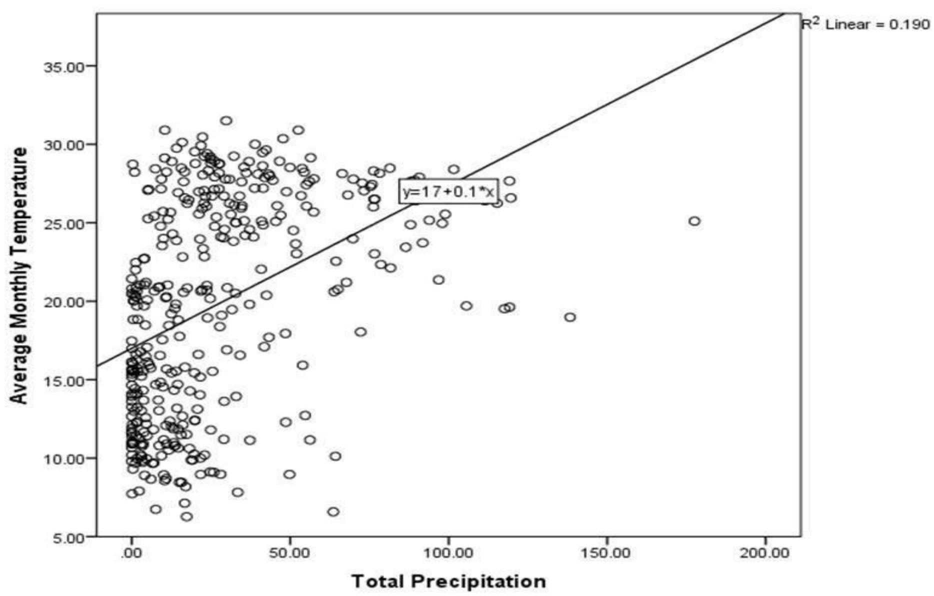
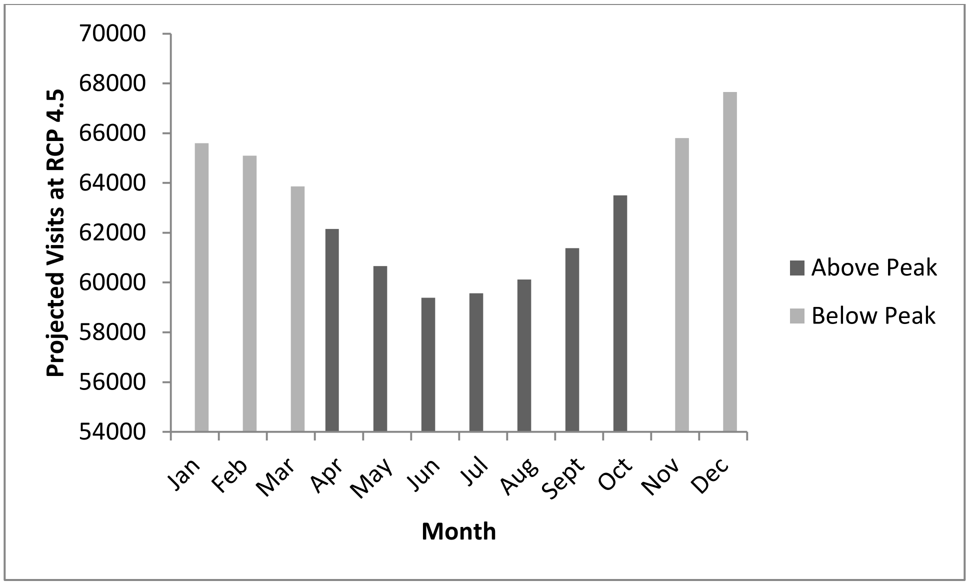
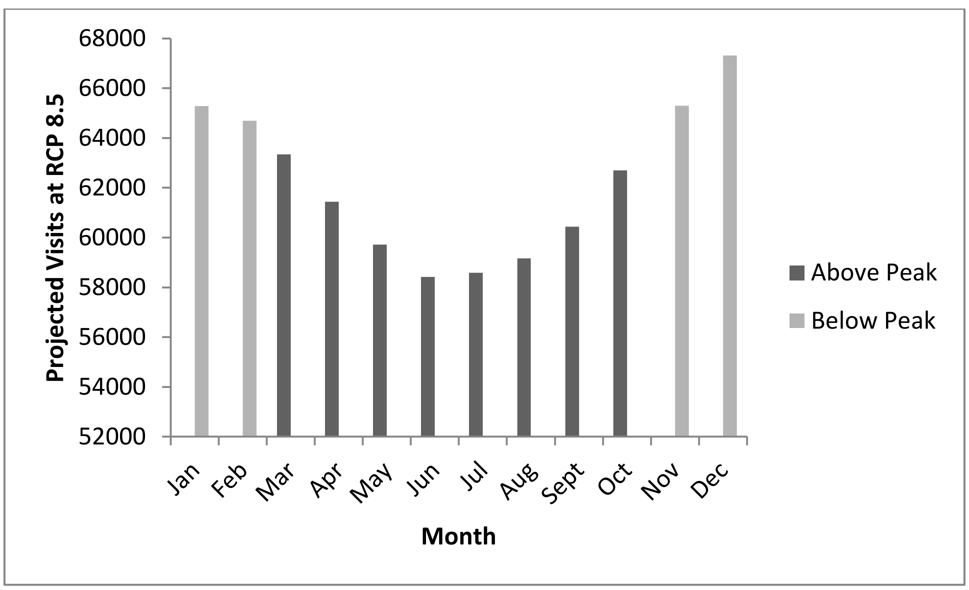


Figure A-18: Comparison of the relationship between TPCP, MMNT and MNT
(1) TPCP is significantly correlated to MMNT



a)



b)

Figure A-19: Comparison of Seasonal Projected Visits Under Climate Change Scenario- a) RCP 4.5, b) RCP 8.5

* Year span covered (2075-2099) for both models, used a median value of 2085

**Gas Price estimate was assumed constant and carried over from data

***MNT was derived from the average of MMXT and MMNT so it is susceptible to the variation between the two variables, the USGS model doesn't project MNT

1) Difference between RCP 4.5 and 8.5 shows that it will get warmer creating less variation between seasonal temperatures. However, precipitation is less affected there is only a slight variability in precipitation.

2) The projected visitation patterns is similar for both scenarios, under the RCP 8.5 scenario there were slightly less visits overall and the warm season expanded by 1 month. The RCP 4.5 scenario projected more visits overall. Projected visitation under both scenarios was more correlated in the "below peak" visitation season.

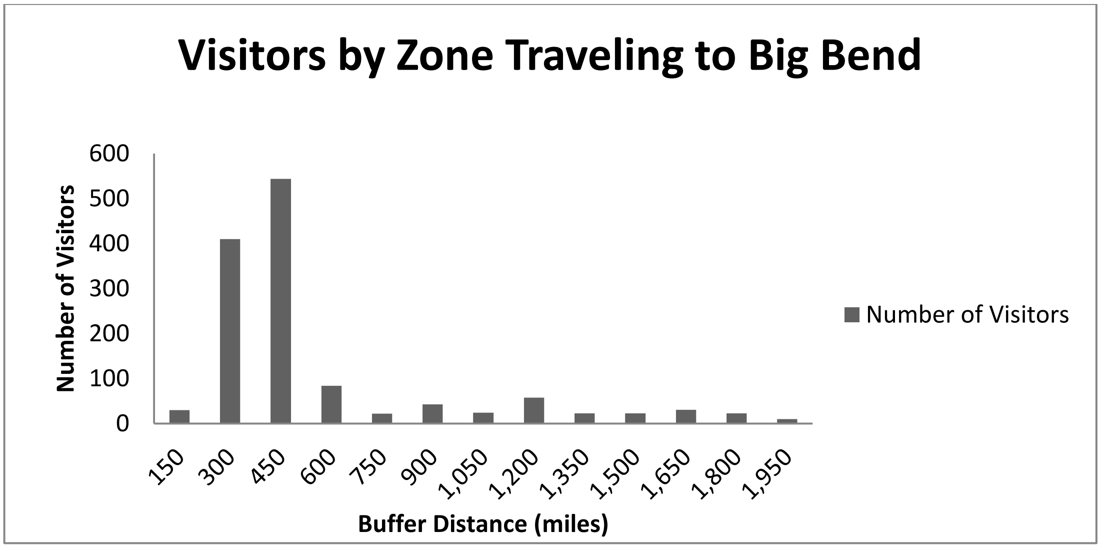


Figure A-20: Number of Visitors per Zone

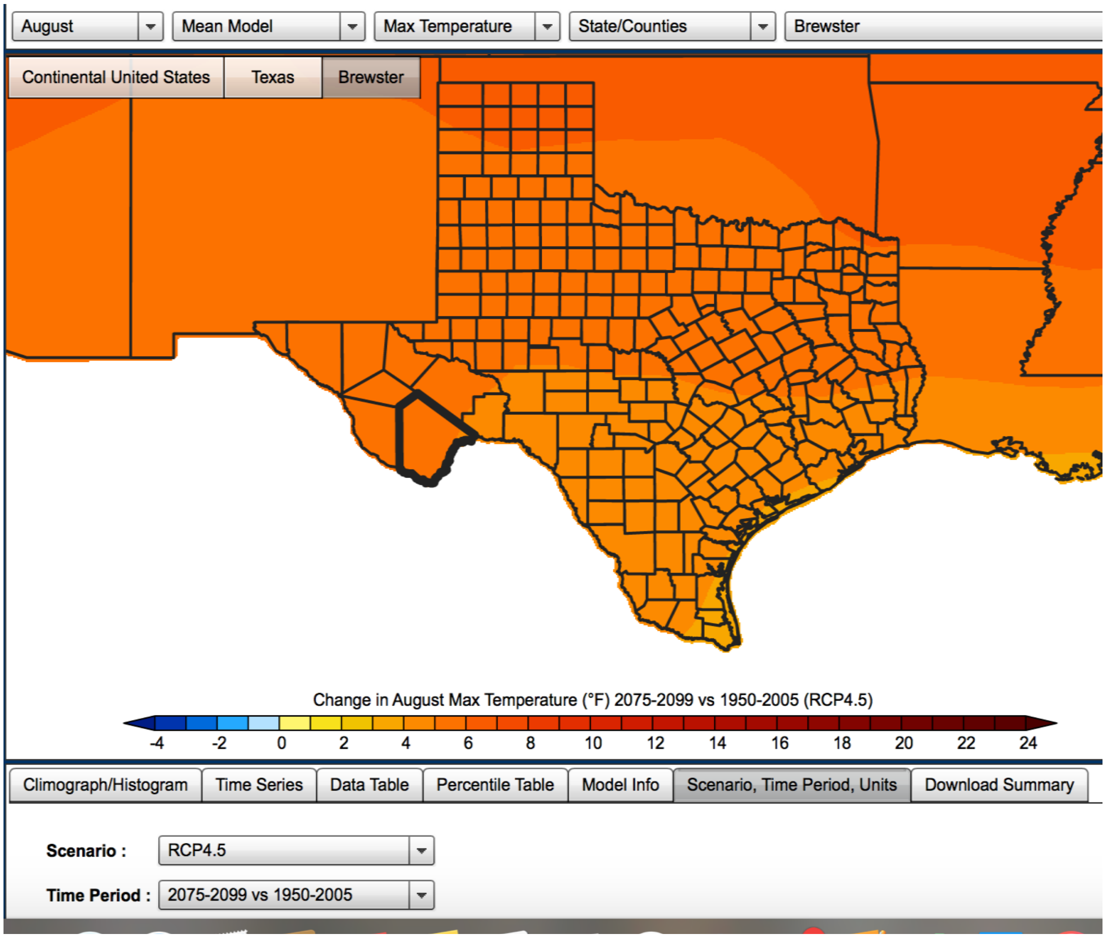


Figure A-21: USGS Maximum Mean Temperature Prediction Coverage Under the RCP 8.5 Scenario

Credit: U.S. Geological Survey / Department of the Interior/USGS