2013

Trail counter calibration: the search for influences in Sequoia and Kings Canyon National Parks

Thomas R. (Thomas Ryan) Laws
Western Washington University

Trail Counter Calibration:
The Search for Influences in Sequoia and Kings Canyon National Parks

By

Thomas Ryan Laws

Accepted in Partial Completion
Of the Requirements for the Degree
Master of Science

Kathleen L. Kitto, Dean of the Graduate School

ADVISORY COMMITTEE

Chair, Dr. Paul Stangl

Dr. Andy Bach

Dr. Preston Schiller

MASTER'S THESIS

Thomas Laws
May 8, 2013

Trail Counter Calibration:
The Search for Influences in Sequoia and
Kings Canyon National Parks

A Thesis
Presented to
The Faculty of
Western Washington University

In Partial Fulfillment
Of the Requirements for the Degree
Master of Science

By
Thomas Ryan Laws
May 2013

Abstract

In National Parks across the country planners are currently experimenting with the use of automated counting devices as a means for estimating visitor use on trails. However, little is understood in regards to counter accuracy due to just recently becoming routinely used. Calibration as a result is becoming a standard practice to increase the accuracies of the data received. Even with this increase in use though, little research has been performed to better understand where calibration correction coefficient values should lie based on specific trail characteristics. This study contributes to the understanding of calibration and counter accuracy by using passive-infrared trail counters and time-lapse photography from May to September of 2012 to evaluate if the trail characteristics use, width, and slope are correlated with the correction coefficients received after calibration within Sequoia and Kings Canyon National Parks. Results found that strong correlations at a 95% confidence interval exist between the examined trail characteristics width and slope, and the trail calibration coefficients received. These results represent both an initial step to better understand how certain trail characteristics influence trail counter accuracy, suggests what methods are most preferable to increase these accuracies when calibrating, and encourage managers to use more stringent forms of calibration.

Acknowledgements

I would like to first and foremost extend my gratitude to my chair and committee members, Dr. Paul Stangl, Dr. Andy Bach, and Dr. Preston Schiller for guiding me along during times of adversity, being understanding and encouraging with my many topic variations, and always willing to help in any way they could. Additionally, I owe much of my research to Bret Meldrum, Chief of Yosemite National Park's Visitor Use and Social Science Branch, who along with Dr. Erik Murdock, the Student Conservation Association, and the National Park Service allowed me to conduct my research all summer in the Sierra Nevadas. Finally, a special thanks also goes out to Josh Jones who sent me several articles of related literature while in the field, Hannah Slater who continually helped revise my work, my parents, Ken and Judy Laws, who have always supported me, and many other friends and family who all helped in various ways throughout this process.

Table of Contents

List of Figures and Tables

Figures

Tables

List of Abbreviations

SEKI....................Sequoia and Kings Canyon National Parks

COC2....................Congress Trail 2

GSC2....................Upper Sherman Tree Trail

GSC3....................Lower Sherman Tree Trail

GGC2....................Grant Grove Trail 2

GGC3....................Grant Grove Trail 3

PLC....................Pear Lakes Trail

TFC....................Tokopa Falls Trail

TLC....................Twin Lakes Trail

CHAPTER I

Introduction

The National Park Service currently has great need to better understand the movement of visitors in order to make more informed planning decisions for park protection and management (Pettebone et al., 2008). At the same time management agencies around the world are currently testing the capabilities of using automated trail counters as a means to efficiently monitor visitor movement (Gracia-Longares, 2005; Lindsey et al., 2006; Ross, 2005; SNH, 2002). However, with no standardization in the calibration methods of these automated trail monitors there is a high priority for further investigation in this field in order to determine proper practices (Pettebone et al; 2010). As a result of this need the principle objective of this study is to evaluate if the trail characteristics overall use, width, and slope are correlated with the correction coefficients received after calibration. If evidence that trail traits can influence counter accuracy is found, regardless of the calibration method used correction coefficients can be estimated on trails prior to calibration. This ability will both help better understand the results obtained from trail counters and increase the likelihood of their accuracy. Additionally, this knowledge will help direct planners to the most ideal installation locations on trails and further the understanding of these devices, and the calibration process itself, in this growing field.

1.1 ***Research Hypothesis and Goal of Research***

Trail characteristics such as overall use, slope, and width have a distinct effect on correction coefficients when calibrating trail counters (CVC, 2012; Gracia-Longares, 2005; Greene-Roesel et al., 2008; Kuutti, 2012; Lue, 2006; Maldonado et al., 2011; Ozbay et al., 2010; Pettebone et al., 2008; Rauhala et al., 2002; Rupf-Haller et al., 2006; Schneider et al., 2009; Turner et al., 2007; Yang et al., 2010). With strong correlations, these traits can help predict the general range of correction coefficients before analysis of trail use done. Along with understanding how counters should behave when being placed on a trail with certain traits, these results will also help inform planners on the best locations for counter placement. For example, if a positive correlation between a trail's width and the correction coefficients received after calibration is found, this result will encourage resource managers to place counters on trail sections where it naturally bottlenecks. By doing this counters will become more accurate, lowering the multiplication factor of the correction coefficient, and minimizing the error of the mechanical counts to the trail's true count. Furthermore, the goal of this research is to increase the knowledge-base of this young but rapidly growing field.

1.2 Current Trends

The impacts of growing visitation rates in national parks have become one of the most fundamental concerns within park planning, policy, and management

(Burns et al., 2010). Growth rates in Yosemite National Park for example were recently found to be accompanied by negative consequences including: traffic congestion, parking shortages, visitor crowding, concentrated air pollution, noise pollution, wildlife impacts, and roadside vegetation disturbance (White, 2007). Furthermore, it has become common in peak months to see lines of personal automobiles miles long at national park entrance stations waiting to gain access (Upchurch, 2006). These negative impacts of increased visitation have also been documented in similar research ranging from the northeast shores of Acadia National Park to the continental divide in Rocky Mountain National Park (Haas, 2001; Holly, 2009; Lynch et al., 2011; Pettebone et al., 2011; Wadsworth, 2009).

In national parks such as Sequoia and Kings Canyon (SEKI[1]), located in the Sierra Nevada Mountain Range of California, visitation rates have yet to reach the critical levels where many of these issues occur. As more and more people visit national parks however, even historically low-use parks are now at risk. For example, when looking specifically at Sequoia and Kings Canyon National Parks, the National Park Service found that the total annual visitation rate increased 5% annually from 2010 to 2012 alone (NPS, 2012). Additional influences including the closure of several California state parks and the flow of visitors escaping the congestion in Yosemite National Park will likely send this visitation growth in SEKI even higher.

---

[1] Sequoia and Kings Canyon National Parks are commonly referred to as SEKI and both terms will be used interchangeably throughout this thesis.

While the greatest threat to the national parks is their increasing popularity, Robert E. Manning of the University of Vermont's School of Natural Resources believes the situation is more complex (Manning, 2002). This complexity is largely a result of the National Parks Service's contradictory missions of providing natural areas for the enjoyment of all people while at the same time conserving the scenery, natural and historic objects, and wildlife for generations to come (Manning, 2002). Manning also stresses that the quality of visitor experiences in national parks may be just as important as protecting the natural landscapes and species within them (Manning, 2002). By decreasing issues such as congestion in national parks, a better experience for visitors occurs (Manning, 2001). This, in turn, bestows deeper public appreciation and support for conservation practices within parks (Manning, 2001). By balancing the challenges of increased visitation and the opportunities for growth, the National Park Service has begun searching for ways to efficiently address the issues of increasing visitor numbers (Manning, 2002; White, 2007). However, before solutions can be enacted a stronger understanding of the situation itself, and the methods to reach those solutions, must be known.

1.3 Future Planning

The problems of overcrowding and trail congestion, increased noise pollution, and the stress of navigating through complex park systems all act as indicators that change must occur in national parks across the country (White, 2007). By understanding visitor movements within park areas that are believed to be at risk for increasing congestion, parks can begin planning for the increase in use before it arrives. For proactive planning within national parks to be implemented on a meaningful scale however, it is necessary to understand the tendencies and patterns of park visitors in general (Dilworth, 2003). One such method to examine these patterns is by counting overall use on trails. This understanding can help better create the strategies for managing these areas and their increasing numbers.

With concern that events such as increasing visitation were slowly becoming a reality, as a precautionary measure in 1978 Congress passed The National Parks and Recreation Act (Prato, 2001). Under this Act, parks are required to create detailed management plans (Haas, 2001). Mandated by the National Park Service, each park is obligated both to keep track of visitor numbers and design visitor carrying capacities to be used in this general management plan (Prato, 2001). However, with constraints such as limited funding and personnel, often times visitor use monitoring is narrowed to entrance stations only (Muhar et al., 2002). Thus, the overall understanding of visitor movement within parks is often generalized and vague (Muhar et al., 2002). For larger parks with the luxury to examine visitor flows more closely, one of the first analyses often done is that of visitor movement on trails throughout the park (Pettebone et al., 2010).

Traditionally this in-depth research has been accomplished by manually counting visitors on trails. With the advancement of technology however, mechanical counters including passive-infrared sensors are becoming increasingly popular (Hadwen et al., 2007; Kahler and Arnberger, 2008; Lue, 2006; Yang et al., 2010). While both inexpensive and able to be used almost anywhere, one downside when using these mechanical counting devices can be their inaccuracies (Kahler and Arnberger, 2008; Watson et al., 2000). For example, counting devices can be triggered not only by visitor events, but by wildlife, moving vegetation, rain, sunlight, and temperature change (Gasvoda, 1999; Muhar et al., 2002).

To correct this problem the process of calibration is often used. Specifically, calibration is the method of examining the accuracy of a counting device (Watson et al., 2000). This comparison is performed by counting the number of events that pass by the counter over a given amount of time while simultaneously counting these same events via another method with proven accuracy (Rauhala et al., 2002; TRAFx, 2012). Once complete, a correction coefficient is obtained by comparing the mechanical counts to that of the proven method's counts (Rupf et al., 2006). Two results often occur: either one, an overestimation bias is found (meaning that the counter included events that it should not have) or two, an underestimation bias is received (meaning that the counter did not include events that it should have) (Watson et al., 2000).

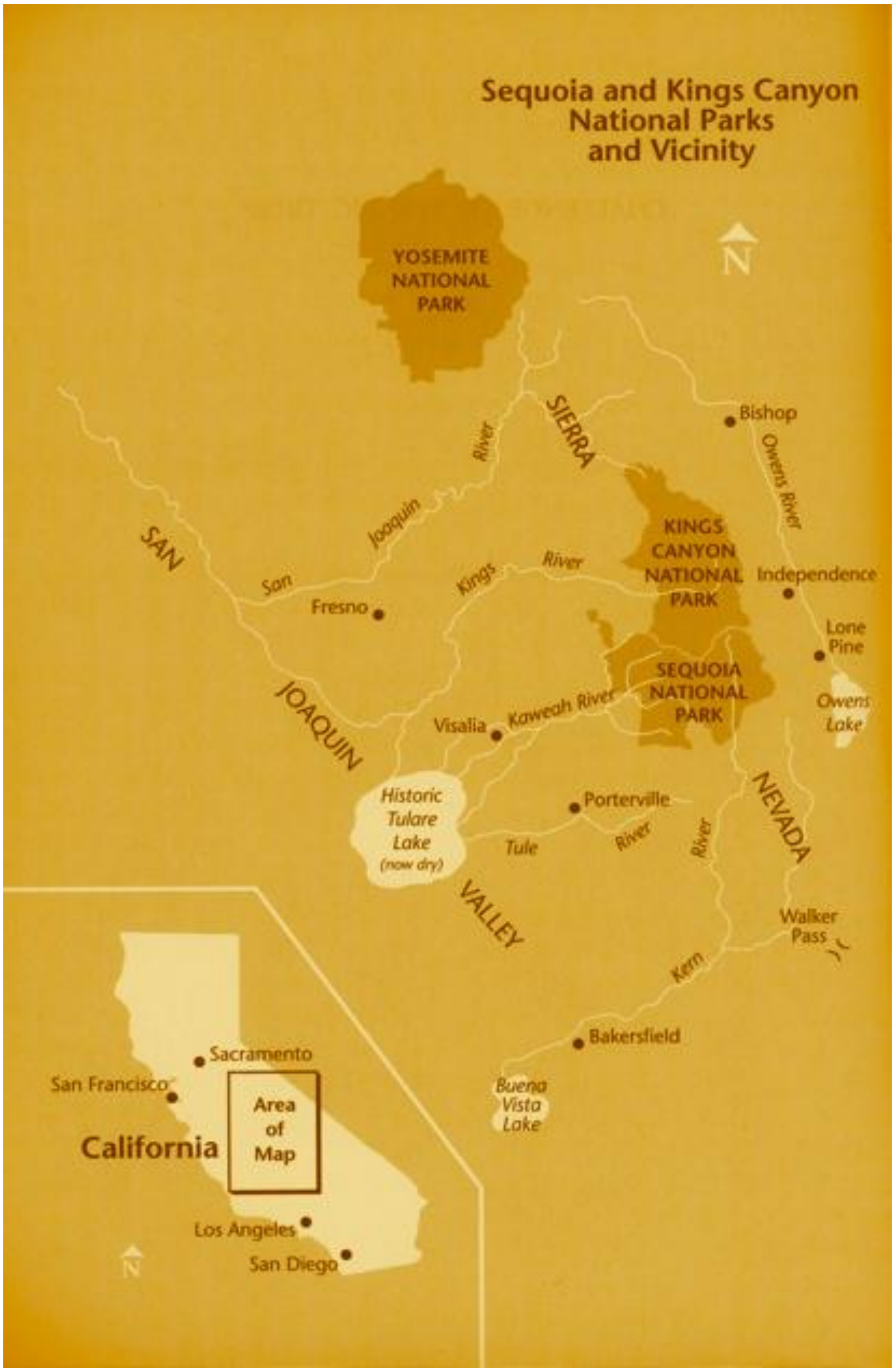
While this method of calibrating raw data has been fully accepted throughout the research world and academia, no standardization has occurred with how long this process needs to be carried out (Brandenburg, 2001). As a result calibration estimation methods can varying from only five minutes necessary to multiple days over a given season (Davenport et al., 2003; Gracia-Longares, 2005; Lindsey et al., 2006; Muhar et al., 2002; Ross, 2005; Watson et al., 2000). Along with this variation in methods, currently little is understood behind the influences of counter accuracy (Bates et al., 2007; Gracia-Longares, 2005; Pettebone et al., 2010). As this information is lacking, it is difficult to determine if an effective and accurate calibration took place.

Many parallels can be seen from the unknowns of this growing field and that of the start of transportation modeling. In transportation modeling, techniques have evolved over time as a deeper understanding of the field has occurred (Hensher and Button, 2005). This can especially be seen from the advancements made in the early 1950's by the Chicago Area Transportation Study and the Detroit Area Traffic Study (Brunton, 1970). Beginning with the research performed at these sites, it was realized that transportation modeling and planning could become powerful tools in city design (Hensher and Button, 2005). Instead of simply building additional highways in areas with congestion, it was found that transportation modeling could inform planning efforts about the potential of alternatives such as denser residential areas or improved connectivity (Brunton, 1970). While transportation modeling has had time and research to further its understandings, the study of visitor movement with trail counters and calibration has only recently begun. As a result much of the field is still largely in its infancy, with many questions and assumptions that still need to be answered and analyzed.

Focusing on Sequoia and Kings Canyon National Parks specifically (Figure 1), the aim of this study is to examine the calibration of infrared trail counters to determine if certain trail characteristics including trail slope, width, and overall use influence correction coefficients. To do this, mechanical passive-infrared devices were installed on various trails throughout both parks to examine typical visitor movements. Calibration was then performed using time-lapse cameras set up in proximity to the counters. Once complete, correction coefficients were established to determine inaccuracies and better understand how mechanical counting devices are affected by a trail's surroundings. These findings should: help to predict coefficients of certain trails prior to calibration by understanding the influences that a trail's traits have on counters, determine ideal installation locations depending on the traits of a given trail, and broaden the understanding of trail counter calibration and the proper methods behind calibration in general.

If relationships are found, these results will give natural resource managers a better understanding of the likely accuracy a counter will have on a certain trail, regardless of calibration method used. Furthermore, if trail characteristics do influence correction coefficients this knowledge can both help predict where coefficients should lie before calibration has begun and help further understand the calibration process in general. To strengthen these assumptions however, further

Figure 1 – Sequoia and Kings Canyon National Parks



(Dillsaver and Tweed, 1990)

study is required in other recreation areas to examine the compatibility of these results. Nonetheless, natural resource managers worldwide will be able to use these findings in a generalized form to make more informed decisions on future planning, policy, and management at their sites. Although many of the issues attributed with increased visitation are not yet present within Sequoia and Kings Canyon, this study establishes a benchmark that may prove to be a proactive first-step against future increases.

Sequoia and Kings Canyon National Parks make an ideal location for this research due to both their rich history and future forecast of increasing visitation growth. Sequoia National Park was the second national park to be established in 1890 and General Grant National Park, (now Kings Canyon), was created third later that year (Dillsaver and Tweed, 1990). Summed up perfectly by Dillsaver and Tweed, while "several early national parks, notably Yellowstone and Yosemite, have received prolonged and serious attention from historians and other students of the national parks idea, other parks have not been so fortunate, although their stories are every bit as important" (pp. x, 1990). This statement resounds strongly with SEKI, which contains many ecological and geological wonders, as well as a rich history comparable to few other national parks.

The following chapters of this work include: *Literature Review, Methodology, Analysis and Discussion of Findings,* and *Conclusions*. The *Literature Review* will summarize the history of Sequoia and Kings Canyon National Parks and review contemporary practices in the study of visitor movement and trail counter calibration worldwide. The following chapter, *Methodology*, will describe the equipment used, study area, and research methods. The *Analysis and Discussion of Findings* section will present and review the results of the research. The *Conclusions* section will summarize the work, propose recommendations for future research, and also examine a few limitations to the study and its results.

CHAPTER II

Literature Review

2.1 Sequoia and Kings Canyon National Parks

Located in the south-central Sierra Nevada Mountains in California, Sequoia and Kings Canyon National Parks extends from the western foothills near the San Joaquin Valley to the eastern crest of the range (Caprio and Lineback, 2000). Fresno and Visalia are the two main satellite cities from SEKI and Squaw Valley and Three Rivers are the gateway communities near both entrances (Dilworth, 2004). Having one of the most extreme contrasts topographically of any national park – elevations varying from 485 to 4,392 m (1,600 to 14,495 ft.) – Sequoia and Kings Canyon National Parks are largely wilderness areas with over 90% of the nearly 364,217 hectares (900,000 acres) managed as such (White, 2004).

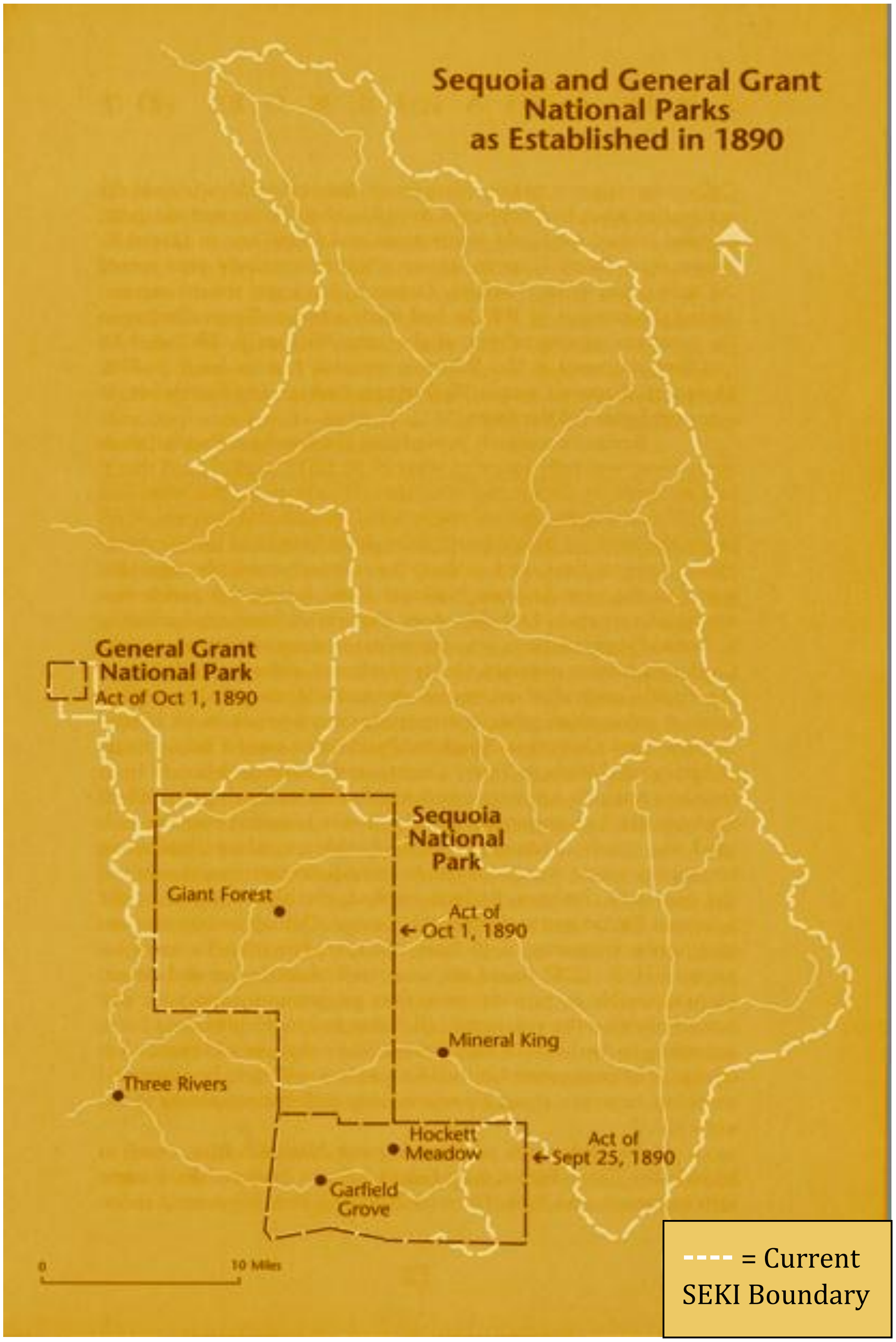
Before the arrival of Europeans to North America, the Sequoia and Kings Canyon National Parks region was inhabited by four distinct Native American tribes: the Monache, Tubatulabal, Owens Valley Paiute, and Yokut (White, 2004). Each of these communities moved a great deal within the southern Sierra Nevadas, having summer camps to escape the valley heat as well as specific areas for hunting, gathering, and trading (White, 2004). While the Spanish explorer Captain Pedro Fages was the first European to document seeing the Sierra Nevadas in 1772, due to the unforgiving landscape few explored the area until the colonization of the San Joaquin Valley in the mid 1850's (Strong, 1968; White, 2004).

As development and growth increased across California following the Gold Rush, eyes soon turned to the Sierra Nevadas for resources such as minerals and timber. Despite the fact that the giant sequoia has brittle wood that shatters when felled, the cutting of the big trees began at an alarming rate in the late 1800's (Strong, 1968). At this time George W. Stewart, the editor and publisher of the *Visalia Delta*, took it upon himself to ensure the remainder of the sequoia trees were protected from further logging (Strong, 1968). Writing columns about the precarious situation of the big trees, Stewart's campaign was soon picked up all across the state and eventually in Congress.

After years of campaigning, on September 25th, 1890 President Benjamin Harrison signed the bill establishing Sequoia National Park as the Nation's second national park, forever protecting the big trees from economic interests (Keith, 1989; Orsi et al., 1993). On the following week of October 1st, 1890 a second bill was passed through Congress and President Harrison, tripling the size of the new Sequoia National Park and creating Yosemite and General Grant National Parks as well (Figure 2) (Orsi et al., 1993; Strong, 1968). What is most interesting about this second bill is that still today historians are not sure of who was behind it, or how so much land was set aside so easily and quickly (White, 2004).

In the following decades in Sequoia and General Grant, managers spent much

Figure 2 – Map of Historic SEKI Boundaries



(Dillsaver and Tweed, 1990)

of the time figuring out exactly what it meant to be a national park, how one should be run, and how much development should occur (Mackintosh, 1999). This period of self-discovery largely occurred until the mid-1910s, when the National Park Service was founded (Mackintosh, 1999). During this time much of Sequoia National Park was still in the possession of private land owners, making the park swiss-cheese-like with alternating pockets of protected and unprotected lands (Keith, 1989). Realizing the importance for the big trees to have a continuous area of land under protection, in 1915 for the first time in history Congress set aside $50,000 for the purchase of privately-owned lands containing sequoia groves within the park (Keith, 1989). While much land was purchased back for the growth of the park, not all expansion efforts during this time were met with equal success (Orsi et al., 1993).

In 1917 two separate bills for expansion were defeated in Congress due to a variety of opposition. Arguments against park expansion varied from the rugged environment of the Sierras already being enough for protection, to cattlemen deeming the summer grazing lands in the mountains a necessity for survival (Orsi et al., 1993). The US Forest Services argued additionally that the timber and mineral value was too great to be lost by an expansion bill and hydroelectric power companies such as the Los Angeles Bureau of Power and Light and the San Joaquin Light and Power Company both claimed that the building of dams in parks would be a necessity for future growth throughout California (Orsi et al., 1993). As this opposition continued to fuel the debate of keeping Sequoia and General Grant National Parks the way they were, NPS superintendent Steven Mather chose to settle on an expansion plan that left out many of the most controversial lands (White, 2004). Instead, Mather focused on much of the seldom-visited Eastern-Sierras with the Kern Canyon and Mount Whitney (White, 2004). Out of this compromise on July 3rd, 1926 President Calvin Coolidge signed the bill adding more land to Sequoia National Park, increasing its reputation as a top-tier national park (Keith, 1989).

By the late 1930s talk was once again in the air about expanding the park to gain the Kings Canyon and Tehipite Valley lands omitted in the 1926 bill (Dillsaver and Tweed, 1990). With less opposition this time around, in 1940 these lands were added to the National Park Service, however, this time in the newly established Kings Canyon National Park (Keith, 1989). Directly adjacent to Sequoia National Park from the north, Kings Canyon absorbed the former General Grant National Park, and was soon administered along with Sequoia as one unit, 'SEKI', by 1942 (Keith, 1989).

Nearly 35 years later Sequoia National Park saw one final expansion with the addition of the Mineral King Valley (Orsi et al., 1993). Surrounded by the park on three sides since the 1926 expansion, Mineral King was the Forest Service's last enclave within the national park (White, 2004). In 1978 the Forest Service finally set the groundwork for development on this land to occur, allowing it to be developed as a ski resort by the Walt Disney Productions Company. Outcry against the Forest Service's plan was soon heard across the country due to the land being a game reserve (Orsi et al., 1993). Unable to progress with development as a result of the controversial nature of the project, Congress decided to end any more debate by adding the land to Sequoia National Park later that year, establishing the parks current boundaries (White, 2004).

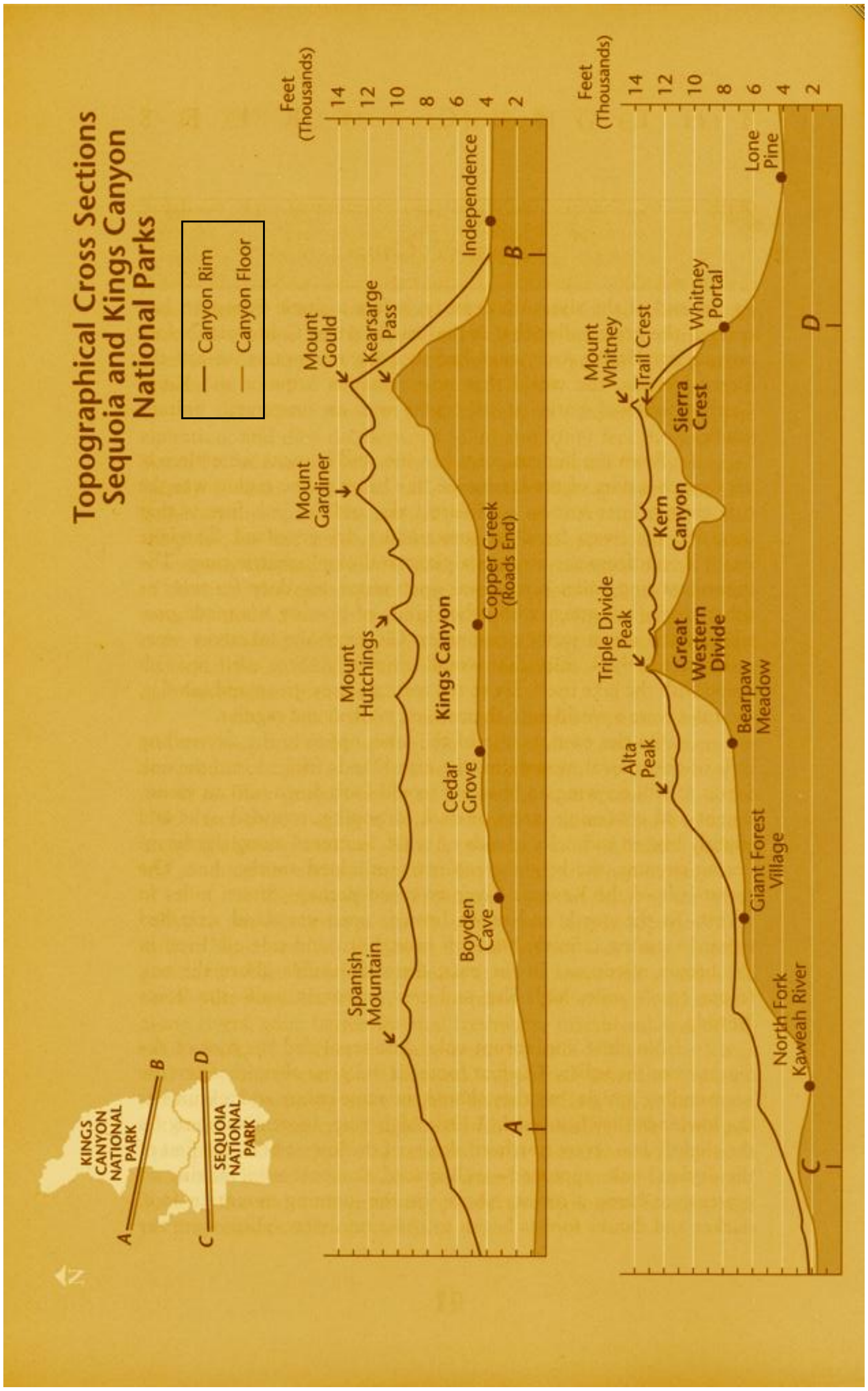
In regards to ecological rarities, SEKI is famous for the Sequoia Dendron Giganteum, commonly called giant sequoias or the 'Big Trees' (Strong, 1968). One of three species of redwoods, the giant sequoia can be found naturally in the Sierra Nevadas in a belt roughly 418 kilometers (260 miles) long and 24 kilometers (15 miles) wide (Keith, 1989). Additionally, these trees also only lie between elevations of 1,371 to 2,286 meters (4,500 to 7,500 feet) above sea level (White, 2004). Sequoia National Park's gem is the General Sherman Tree, one of the largest Sequoias topping out at 83 meters (275 feet) tall, weighing well over 1,385 tons, having a base-diameter of 11 meters (37 feet), and aged at over 2,500 years old (Keith, 1989).

Geologically, the southern section of the Sierra Nevadas within SEKI also presents some of the most unique landscapes in the range. Few other places in the entire United States can one experience such extreme vertical reliefs; with the base of the parks beginning just above sea level in the San Joaquin Valley and climbing to Mt. Whitney, the tallest mountain in the continuous U.S. at 4,418 meters (14,495 feet) (Figure 3) (Dillsaver and Tweed, 1990). In another example, the Middle Fork of the Kaweah River starts at over 3,657 meters (12,000 feet) high and in less than 48 air kilometers (30 miles) one can follow this flow all the way down to the valley floor just above sea level (Dillsaver and Tweed, 1990).

Historically, Sequoia and King Canyon National Parks have also been innovators in park policy and natural resource management (Dillsaver and Tweed, 1990; Strong, 1968). Established to commemorate the 40th anniversary of California's admission to the Union, Sequoia was the first national park in California, a predecessor to General Grant (later Kings Canyon), Yosemite, Lassen Volcanic, Joshua Tree, Death Valley, Redwood, Channel Islands, and Pinnacles National Parks (Strong, 1969). In 1931 further history was made when Horace Albright, the National Park Service's second director, placed 'pillow limits' (quotas on overnight visitors) on Giant Forest campgrounds and lodging as a way to combat growing congestion (Dillsaver and Tweed, 1990). While at the time seeming rather insignificant, this policy was one of the first to take action against overuse by limiting tourism development (Dillsaver and Tweed, 1990). Thanks to the foresight for the need to protect these sensitive areas, after SEKI's success policies such as this soon began to take hold across the National Park Service and other natural recreation areas worldwide (Dillsaver and Tweed, 1990).

By the 1960's another historic moment would also occur that would alter forest management forever (Orsi et al., 1993). Concerned and unable to determine

Figure 3 – SEKI Elevation Profile



(Dillsaver and Tweed, 1990)

why no new sequoias had grown in the previous half-century, park administrators began an all-out movement to find out why their park's most valuable assets were no longer reproducing (Keith, 1989). Ecologist Richard Harvesvelgt came up with the answer soon after. Going directly against the long-established practice of suppressing fires throughout the parks, Harvesvelgt argued that fire was actually beneficial to the big trees (Orsi et al., 1993). It was determined that sequoia cones will wait up to 20 years until a fire comes by, dries them out, and allows seeds to fall onto fresh mineral soil with little surviving competition (Keith, 1989). With the fire suppression that had been occurring an abnormal accumulation of fuel in the forests began to develop, resulting in extremely destructive fires instead of occasional low-burning ones (Keith, 1989). After several small tests were met with resounding results, by the 1970's the policy of fire suppression was a thing of the past (Dillsaver and Tweed, 1990). Prescribed burns and the monitoring of natural fires became a service-wide policy, making it the oldest of its kind and one that can now be seen in forests around the world (Bancroft et al., 1985; Keith, 1989; Orsi et al., 1993).

2.2 The Current Situation

Throughout much of the planning world the study of visitor movement has become a vital measurement with any site examination (Hadwen et al., 2007). Especially in vulnerable and iconic sites, visitor monitoring is now necessary to examine visitor use and activity (Hadwen et al., 2007). Additionally, in low-use areas such as Sequoia and Kings Canyon National Parks the examination of visitors on trails can describe conditions and identify trends before they become permanent (Leung and Marion, 1999a; Leung and Marion, 1999b; Pettebone et al., 2009). A perfect example of this can be seen from research of Australia's highest mountain, Mount Kosciuszko (Hadwen et al., 2007). When examined throughout the year, visitor use appears relatively low; however, Mount Kosciuszko actually experiences high variability with the vast amount of visitation occurring on holidays. While a typical site with such minimal annual use would seem a low priority to study, in this situation Mount Kosciuszko actually experiences severe damage to its alpine vegetation during these high levels of use (Hadwen et al., 2007). With the alarming number of State Park closures in California, the recent Hanta Virus outbreak in Yosemite National Park, and the increasing number of SEKI visitors from Southern California, the Park Service predicts that soon Sequoia and Kings Canyon National Parks will begin to experience increased visitation (NPS, 2009). If trends hold true, congestion and the other negative effects associated with too many visitors will likely follow (White, 2007).

The monitoring of visitors on trails provides information that can be used for planning, policy creation, management, resource allocation, performance standards, marketing, and safety (Newsome et al., 2002; Wardell and Moore, 2004). For example the New Zealand's Department of Conservation uses the information on visitor numbers and flow vital for a variety of planning tasks in park management

(Cessford et al, 2002). These data are used to help justify visitor services and staff resources, inform performance reporting, identify user trends and make future predictions, schedule maintenance, and locate visitor impact and movement (Cessford et al. 2002). In addition to these tasks, baseline data of visitor use are necessary for the success and overall understanding of natural resource areas (Pettebone et al., 2008).

Mitigating harmful acts and protecting areas for future generations, resource managers must perform a balancing act between conserving areas in their natural state while encouraging recreational use and enjoyment (Wardell and Moore, 2004). The National Park Service in particular has mirrored this dualistic approach by promoting tourism while attempting to keep areas as natural as possible (Haas, 2001; Sellars, 1997). As early as the Organic Act of 1916 and the Wilderness Act of 1964, parks have been mandated to conserve scenery, natural and historical objects, and wildlife while encouraging public enjoyment and quality visitor experiences (Pettebone et al., 2009; Prato, 2001).

Even with these mandates however, it was not until the National Parks and Recreation Act of 1978 and the Transportation Equity Act for the 21st Century (TEA-21) of 1998 that the monitoring of visitor movements within parks truly became a system-wide practice (Prato, 2001). Required to create a general management plan that includes the 'identification and implementation of commitments for visitor carrying capacities for all areas of the unit,' the National Parks and Recreation Act for the first time made it mandatory that visitor movements be monitored with detail (Haas, 2001; Prato, 2001). TEA-21 further requires the Secretary of the Interior to coordinate directly with the Secretary of Transportation to study overall movement patterns and alternative transportation needs within parks, providing additional reason for parks to collect and monitor visitor movements (Wadsworth, 2009).

Today, visitor crowding and movement have become one of the most studied aspects of outdoor recreation and natural resource management (Fleishman et al., 2004; Graefe et al., 1990; Lime, 1996; Manning, 1985; Manning et al., 1996; Shelby and Heberlein, 1986; Stewart and Cole, 2001; Vaske, 2008). When looking toward the future, the study of visitor movement and congestion will likely become integral for natural resource managers and planners (Vaske, 2008). With growth in visitation leading to adverse ecological impacts on a physical, chemical, and biological level, agencies and resource managers have begun monitoring visitors as a way to mitigate these complex impacts (Buckley, 2004; Hadwen et al., 2007; Kuss et al., 1990; Leung and Marion, 2000; Newsome et al., 2002). While agencies attempt to gather site-specific information on their individual areas, until the recent use of automated trail counters large amounts of detailed data were often impossible.

Traditionally large scale investments in visitor monitoring could only be conducted by major natural resources areas due to limited funding, staff, and computing system requirements (Buckley, 2003; Hadwen et al., 2007; Worboys et al., 2005). As a result visitation is often only measured at entrance stations as overall counts, providing no further detail to where people are going once inside. In recent research by Hadwen et al. (2007) it was determined that when generalizing visitation over an entire park too many variables exist to extract meaningful information. When this simplification occurs, the information that is produced is often misleading due to the dispersion of visitors once within a park never being truly homogeneous (Hadwen et al., 2007; Hammitt and Cole, 1998; Marion and Farrell, 2002). Examining how wilderness managers collect visitor use data, in a survey completed by McLaran and Cole (1993) it was found that 63% of managers use a 'best guess' approach (Watson et al., 2000). Research by Pettebone et al. (2008) also found that lack of funding, logistical problems caused by the size of the area, and number of access points, and lack of time in a season all can account for why this estimation method can occur (Watson et al., 2000). Simply not having the knowledge of alternatives was also found to be a main reason (McLaran and Cole, 1993). These findings further promote the need to better understand the growing field of mechanical trail counting and the influences to its accuracy.

In another example of agencies making decisions based on questionable data, Muhar et al. (2002) recently investigated the systematic monitoring of recreational uses and visitor flows in several European countries. Results from this study found that in the few areas that performed visitor monitoring, it was completed on an adhoc basis with no prior planning (Muhar et al., 2002). Additionally, improvised one-day counting results were often extrapolated to the typical visitor patterns as a whole, without concern for outliers, inaccuracies, and generalizations (Muhar et al., 2002). The more reliable the data can be the increased likelihood that the final outcomes and results are equally as meaningful and accurate. As the old saying goes, 'garbage in, garbage out,' no matter how good the final model is, without reliable and accurate data results can only be trusted so far (Cessford et al., 2002).

One way to increase the opportunity for smaller protected areas to gather meaningful visitor movement data is with the recent advancement in mechanical counting technologies. Including active and passive infrared counters, acoustic counters, radar, pressure pads, seismic sensors, and magnetic sensors, development in mechanical counting devices allows a lower-cost solution than to pay someone to stand by a trail and manually count visitors (Kahler and Arnberger, 2008). With detailed data necessary to produce accurate visitor movement estimations, automated counting devices can meet this need with little adjustment from the status quo (Green-Roesel et al., 2008). Perhaps most importantly, automated pedestrian counting devices present a viable alternative to manual counting and best-guessing with negligible labor costs and technical understanding (Greene-Roesel et al., 2008). Mechanical counters also are becoming more and more attractive to resource managers due to the minimal level of disturbance they have on visitors, further making long-term, continuous visitor counting practical

(Pettebone et al., 2008; Watson et al., 2000).

While most commonly used in nations such as Australia (McIntyre, 1999), Finland (Rauhala et al., 2002), and New Zealand (Cessford et al., 2002), recently the use of automated trail counters has begun to spread worldwide and especially in the United States (Arnberger et al., 2005). In a study by Lynch et al. (2002) from the Department of Park, Recreation and Tourism Resources at Michigan State University, results from a survey on the use of mechanical counting devices found dozens of state trail programs and federal agencies all using mechanical devices. Even with this increase in use it is surprising to note that little research has been performed to evaluate the quality and accuracy of the data produce by differing methods, even though the need for reliable information is so great (Arnberger et al., 2005). While the benefits that go along with using mechanical trail counters are high, counting errors are known to occur that can question accuracy; encouraging further exploration into the field (Pettebone et al., 2010).

2.4 Calibration

When using counting devices as a means to measure visitor use, some level of error is expected to occur (Kahler and Arnberger, 2008). Whether the counter output experiences an overestimation bias (the counter continually registers something it should not count), or an underestimation bias (the device does not count something it should) the procedure of calibration is conducted to account for that given error (Watson et al., 2000). Counter calibration is a process that involves measuring the number of visitors that pass an automated counting device and then comparing that number to the device's total (Ross, 2005). Measuring these counts often occurs by manual on-site counting by a worker, remotely via cameras and time lapse photography, or mechanically by automated counting equipment. Generating two counts when complete (the true count measured by the observer and the mechanical count measured by the counting device), a ratio of these counts, also known as a correction coefficient, can be derived to determine the amount of counter error (Ross, 2005). With the difference in totals showing the amount of error the counter generates, this coefficient can then be multiplied to additional counter readings to produce a more accurate estimate of the true number of events on a given trail (Davenport et al., 2003; Ross, 2005). This method of developing correction coefficients has become the most accepted throughout calibration research and assumes that the relationship between use and accuracy is linear (Pettebone et al., 2010; Rupf et al., 2006; Rupf-Haller et al., 2006; Svajda, 2009; Yang et al., 2010).

The importance of calibration when dealing with automated counting devices cannot be stressed enough (Pettebone et al., 2010, Ross, 2005). For example, Rupf et al. (2008) recently conducted a study of acoustic slab sensor calibration on trails in the Swiss National Park to examine accuracies. Running during the month of July, manual counts were conducted over a two-day period and results were then compared to determine the level of accuracy. Upon completion, trails were found to have differences of up to 50% from what the counter produced compared to the actual number (Rupf et al., 2006; Svajda, 2009). The over/underestimation bias experienced with mechanical counters can become especially precarious for data sets ranging over entire seasons, greatly misrepresenting the true use (Pettebone et al., 2010).

Underestimation is the mostly likely error to occur and can result from a variety of factors. For example, problems occur with infrared counting devices when: two people walk side by side and only are counted as one, visitors in tight groups not allowing the counter's beam to reset, children on top of one's shoulders or one lower than the counter height missing the beam completely, runners or cyclists moving too quickly to be registered by the device, or someone wearing heavy clothing that does not release enough thermal energy to be detected by the sensor (Figures 4,5,6, and 7) (Cessford and Muhar, 2003; Gasvoda 1999; Kahler and Arnberger, 2008; Lindsey et al., 2006; Ross, 2005).

Overestimation is another issue that can occur and has its own set of scenarios for this to happen. For example, counters being triggered inadvertently by wildlife, background noise such as moving branches, visitors tampering with devices, and environmental factors such as direct sunlight in the lens and heavy rain have all been reported to trigger false counts (Figures 8 and 9) (Cessford and Muhar, 2003; Gasvoda, 1999; Kahler and Arnberger, 2008; Ross, 2005). In both of these situations

Figure 4 – Miscount Examples: Congested Group A

Figure 5 – Miscount Examples: Congestion Group B

Figures 4 and 5: In this sequence, the counter is overwhelmed by activity. While in reality 10 individuals pass by, the counter's beam is likely only broken once, resulting in severe error.

Figure 6 – Miscount Examples: Boy on Shoulders

Figure 7 – Miscount Examples: Two at a Time

Figures 6 and 7: In these two examples, counter error occurs when two visitors cross the counter simultaneously, being recorded as only one event.

calibration becomes imperative to insure the accurate estimation of each trail examined.

Traditionally achieved by having someone manually observe and count the same trail for a certain amount of time, recently another approach of using video surveillance has been tested when calibrating (Arnberger et al., 2005; Gasvoda, 1999; Muhar et al., 2002; Rauhala et al., 2002; Watson et al., 1998; Watson et al., 2000). By using mechanical counting devices and video surveillance the amount of data that is able to be collected in a given research season has increased

Figure 8 – Miscount Examples: Bear Passing Sensor

Figure 8: In this figure a miscount occurs on a low use trail when a bear passes the infrared trail counter and registers as an event.

Figure 9 – Miscount Examples: Deer Examining Lens

Figure 9: In this example miscount occurs when a curious deer stops to examine the trail counter and consequently causes multiple false events to be registered.

tremendously while the cost of doing so has stayed about the same (Pettebone et al., 2010). For the first time agencies with low research budgets are now able to monitor visitor movement and flow on a level that produces meaningful results (Svajda, 2009). As a result, over the past decade the use of video surveillance has begun to take off as a means of calibrating visitor counters (Arnberger et al., 2005; Watson et al., 2000).

While the calibration process has become universally accepted and required by just about every major planning association, no agreement has been made as to how exactly it should be performed (Pettebone et al., 2010). By each agency having a different approach, follow-up studies have become increasingly difficult to administer (Pettebone et al., 2010). Additionally, no method of accuracy-checking exists since similar trails for different agencies are measured by different processes.

For Example, in 2005 Gracia-Longares estimated visitor use in Yellowstone National Park using automated trail counters. A total of four hours was chosen to be the amount of time necessary for adequate calibration accuracy. Each trail was then recorded at different time increments with one 4-hour period, four 1-hour periods, eight 30-minute periods, and sixteen 15-minute periods chosen. Once complete Gracia-Longares (2005) examined the precision of each different result and found the highest variance of the mechanical count from the actual count in the singular four-hour period and the lowest variance in the sixteen 15-minute periods. Concluding the biggest increase in precision occurs during the 1-hour periods and 30-minute periods, Gracia-Longares recommends that bins in these ranges should be used for counts and that one-hour calibration time is needed for appropriate accuracy (Gracia-Longares, 2005; Pettebone et al., 2010).

In a similar study of snowmobile use on trails in Voyageurs National Park active infrared counters were used to monitor recreation patterns during the 2001-2003 winter seasons (Davenport et al., 2003). During this research manual counting of one-to-two hours was used for calibration; stating that this was adequate for accurate correction coefficients (Davenport, 2003; Tomes and Knoch, 2009). In a study of the Danube Floodplains National Park by Muhar et al. (2002) several methods of visitor monitoring were also examined. From these results yet another differing suggestion of only 15 minutes per hour of calibration time was found necessary for trail monitors (Brandenburg, 2001; Muhar et al., 2002). In one of the most comprehensive calibration studies examining visitor use on trailheads in Yosemite National Park, Pettebone et al. (2010) conducted nine 1-hour direct observations for the calibration of two automated visitor monitors during a pilot study. This approach was then followed by 20-hours of calibration for six different trails (Pettebone et al., 2010). When examining the error ratios for each calibrated trail, results found that at 15-minute intervals a total of five hours of observation should be conducted to promote greater accuracy and reliability of the data (Pettebone et al., 2010).

Several natural resource management agencies choose not to use time in their calibration methods all together. In Scottish natural resource sites, Scottish Natural Heritage (SNH) instead recommends that at least 100 visitors should be reported for adequate calibration (SNH, 2002). SNH further encourages counter testing by conducting a 'walk test' (SNH, 2002). In this test a researcher crosses the infrared beam 50 times and measures the count given by the trail counter; if results are above or below 10% of the actual value, additional calibration should be considered before proceeding (Ross, 2005; SNH, 2002). The Australian Alps Liaison Committee (AALC) also tends to focus on calibration requirements other than the amount of time necessary (Pitts, 1994). In the AALC fieldwork exercise report, calibration is most concerned with gaining both weekday and weekend counts, while the amount of time is more depending on the 'consistency' of the results (Pitts, 1994; Ross, 2005). To accomplish this once the calibration process has occurred statistics are run to determine if the data has a wide variation (Ross, 2005). If variation is not found the AALC recommends additional calibration sessions, however, the time needed to acquire adequate results can greatly vary (Ross, 2005).

To make the calibration process more disorganized, several research articles fail to mention their processes all together (Lindsey et al., 2006; Watson et al., 2000). Examining inter-urban trails in Indianapolis, Indiana in a study by Lindsey et al. (2006) from February 2001 to July 2005 a total of 442 hours of calibration observations from 28 locations were acquired. While he does mention that observations were taken at five-minute intervals, a division found nowhere else in the literature, no further mention occurs as to how the calibration process occurred (Lindsey et al., 2006). Pettebone et al. (2010) also comments on this problem elaborating that while several studies exist that express the need for concrete methods to promote accuracy, few take the next step in examining possible solutions.

Watson et al. (2000) perhaps is the best example of such a study, going into detail about which sampling methods are most appropriate for a given location, how statistical analyses should be complete, and what factors should be looked out for.

While the requirement of observer-based calibration is encouraged several times throughout his work, no mention of a proper sampling time is found (Pettebone et al., 2010; Watson et al., 2000). Bates et al. (2007) presents another example from his work on visitor use in Rocky Mountain National Park. Calibrating mechanical counters over a three-day period in the summer of 2004, no further detail is given on the calibration methods used (Bates et al., 2007).

Additional literature has focused on the comparison of counting devices, stressing the need for further research, then failing to elaborate further (Cessford and Muhar, 2003; Kahler and Arnberger, 2008; Muhar et al., 2002). As the variation in calibration methods indicates, it is becoming increasingly important that as more agencies and researchers begin using trail counters a better understanding of calibration processes must exist.

Fortunately, alternatives can be found to acquire a better understanding of calibration without calling for a massive standardization project of calibration methods worldwide. One such approach is to start from the source, examining the trail characteristics and influences that cause counter inaccuracy and require calibration in the first place. While few studies have yet to directly examine the causes for inaccuracies, several have inadvertently reached meaningful results when researching other traits of trail counters (CVC, 2012; Gracia-Longares, 2005; Kuutti, 2012; Lue, 2006; Maldonado et al., 2011; Ozbay et al., 2010; Pettebone et al., 2008; Rauhala et al., 2002; Yang et al., 2010).

The first example of a potential influence that has been noted regularly in the literature is trail width and the resulting visitor spacing (CVC, 2012; Gracia-Longares, 2005; Pettebone et al., 2010; Rauhala et al., 2002; Ross, 2005; Rupf-Haller et al., 2006). Greene-Roesel et al. (2008) provides one such finding in his research for University of California, Berkeley's Safe Transportation Research Center. Reviewing commercially available counting devices on city streets in Berkeley, results found a consistent error when measuring pedestrians walking on narrow streets (Greene-Roesel et al., 2008). Concluding that this result was an outcome of pedestrians moving tightly together, this issue has also been confirmed by Gracia-Longares, (2005), Raoul et al., (2004), and Turner et al., (2007) in outdoor urban and wilderness environments (Greene-Roesel et al., 2008).

Examining calibration methods and visitor use on trails in Yosemite National Park, Pettebone et al. (2010) also hypothesizes that width is an influence on accuracy, however his conclusions actually contrasts those of Greene-Roesel et al. (2008). Noticing that the infrared trail counter beam was ineffective with two visitors walking side-by-side, Pettebone notes that counters should be installed in areas where this is less likely to occur; i.e. narrower trails (Pettebone et al., 2010; Rauhala et al., 2002). Cessford et al. (2002) and results from the Credit Valley Conservation Technical Report Series (2012) have also reached similar conclusions noting that in areas where pedestrians were forced to walk single file accuracies were much higher (Gracia-Longares, 2005).

Testing acoustic slab sensors in the Swiss National Park, Rupf-Haller et al. (2006) has also found width to be a potential issue with trail counter accuracy. Even though using a different type of counter entirely, results of this study further concluded that the width of a trail effected error rates (Rupf-Haller et al., 2006). Noting that on wide trails people once again had the habit of walking side-by-side, this tendency resulted in both visitors passing the slab at the same time, registering only one event (Raoul et al., 2004; Rupf-Haller et al., 2006). Additionally, results indicated that since each of the four trails monitored had underestimation biases related to their given width, this was likely to be a key influence on counter accuracy (Muhar et al. 2002; Ross 2005; Rupf-Haller et al., 2006).

Volume has also become a known influence with trail accuracy (Greene-Roesel et al., 2008; Kahler and Arnberger, 2008; Kuutti, 2012; Ozbay et al., 2010; Yang et al., 2010). In a study of the proper applications for automatic pedestrian counters by Rutgers University, the New Jersey Department of Transportation, and US Department of Transportation, results of pedestrian counters were found to vary greatly at sites with high-volume (Ozbay et al., 2010). Examining a total of five mixed-use trails in New Jersey, when calculating accuracies results witnessed reoccurring error rates of roughly -5% at low use locations and as much as -28% at high use locations suggesting that trail use may play a major role in counter accuracy (Ozbay et al., 2010). Yang et al. (2010) posted similar results with low use trails having -1% overall error and high use trails with -25% overall error. In research comparing video monitoring methods in the Donau-Auen National Park in Vienna, Austria, Kahler and Arnberger (2008) came across similar results when noticing the high discrepancies of trail monitor readout during times of high use (Greene-Roesel et al., 2008).

Interestingly, the US Department of Agriculture and US Forest Service's handbook on methods for recreational use monitoring has concluded conflicting results (Watson et al., 2000). Providing step by step guidance in the use of visitor counters, Watson et al. (2000) warns that while mechanical counters can work efficiently for high levels of use, as pedestrian volume *declines* so does counter accuracy. Gracia-Longares (2005) has also reached this conflicting conclusion in his study of the spatial patterns of visitors in Yellowstone National Park. From his work Gracia-Longares (2005) recommends that on low use trails automated trail counters should be avoided all together, instead suggesting the use of trailhead diaries, ranger monitoring, or simulation models to obtain accurate use estimates.

To further obscure the understanding of user volume influence on automated counters, research by Schneider et al. (2009) and Turner et al. (2007) both determined that accuracies are not affected by overall use (Greene-Roesel et al., 2008). Examining short-term pedestrian counting on intersections in Alameda County, California, Schneider et al. (2009) observed that during times of high volume (>400 Pedestrians per hour) and low volumes (<100 pedestrians per hour) no significant variation in error rates were seen, suggesting that accuracy is unrelated to pedestrian flow (Kuutti, 2012). When comparing the capabilities of TRAFx, Jammar, and Diamond trail counters in College Station and Austin, Texas, Turner et al. (2007) also found that in controlled tests of pedestrian spacing and volume each device evenly undercounted events (Kuutti, 2012).

Trail slope has become an additional concern with mechanical trail counter accuracy although much less is known about its potential effects. For example, in articles by Pettebone et al. (2010) and Watson et al. (2000) careful consideration is stressed when installing counters on areas with differentiating slope. However, both articles fail to state how slope can be an issue, just acknowledging that an influence may exist (Pettebone et al., 2010; Watson et al., 2000). Studying photoelectric counting systems on main trailheads at Du Wu Mountain in Southern Taiwan, Lue (2006) directly notes a relationship between slope and accuracy. Finding that in her research downhill moving continually caused data error, Lue (2006) also fails however to then elaborate why this might be the case.

Although pointing to the opposite conclusion that steeper trails may actually improve trail counter accuracies, the results from Farrell and Marion (2002) and Maldonado et al. (2011) perhaps hold some of the reason as to why experts are mindful of trail slope. In 2002 Farrell and Marion first examined trail impacts to visitation in Torres del Plaine National Park, Chile, and found that trail slope increases erosion while decreasing a trail's 'tread boundary' (which results in incised trails that are narrow). This narrowing of trails would likely lead to visitors moving single file, a trait mentioned previously that may influence an increase in accuracies (Cessford et al., 2002; Gracia-Longares, 2005; Rauhala et al., 2002). Creating simulation models to examine influential factors of visitor movement in natural areas, Maldonado et al. (2011) has also hypothesized on the influence slope has on narrowing visitor movement. Finding a diversity of movement in areas with low slope and a restriction of movement in areas with high slope, this suggests that in areas of low slope visitors are likely to spread out (walk side-by-side) and in areas of high slope are likely to condense (walk in line) regardless of trail size (Maldonado et al., 2011).

While each of these potential trail characteristics have been linked to influencing automated trail counter accuracies, little is understood on what exactly that relationship is (Pettebone et al., 2010). As witnessed in the literature, results on how a trail's traits can influence calibration is mixed, revealing a vital gap in the understanding of trail monitoring research (CVC, 2012; Gracia-Longares, 2005; Kuutti, 2012; Lue, 2006; Maldonado et al., 2011; Ozbay et al., 2010; Pettebone et al., 2008; Rauhala et al., 2002; Yang et al., 2010).

CHAPTER III

Methodology

Two prominent questions examined in this study include:

1. Do the trail characteristics volume, width, and slope have an effect on the calibration and accuracy of trail counters?
2. Can a relationship be seen between these trail traits and the resulting correction coefficients of certain trails on a statistical level?

3.1 Research Equipment and Process

Keeping in line with prior literature, a direct data collection method was selected to achieve the study objectives and accurately monitor visitor movements (Muhar et al., 2002; Svajda, 2009). In this study three main pieces of equipment were used in the field to gather trail information. For trail counters and data management the generation III TRAFx infrared trail counter and TRAFx Dock from TRAFx Research Ltd. were used (Figures 10, 11, and 12). To calibrate these counters, the Plot Watcher Pro time-lapse camera from Day 6 Outdoors, LLC was also installed at each location (Figures 13 and 14).

Currently on the market there are three main types of photoelectric infrared counters: active infrared, passive infrared, and target reflective (Muhar et al., 2002). With active infrared counters, body mass is used to break an invisible beam crossing a path (Yang et al., 2010). Passive infrared counters work in a similar fashion, however instead relying on infrared heat emitted by pedestrians when crossing to register an event (Yang et al., 2010). Similar to active infrared counters, target reflective counters work the same way; however requiring an additional mirror plate on the opposite side of a sensing area to connect the counting beam (Yang et al., 2010).

The passive-infrared counter was chosen over the active and target-reflective for this study due to the benefits of having a low cost, small size and weight, a low power consumption, an adjustable sensitivity, being widely available, not affected by wet or foggy weather, and the ability to include time and date data (Bu et al.,

Figure 10 – Equipment: TRAFx Counter in the Field A

Figure 10: The Generation III TRAFx infrared counter operates by the grey scope sensing changes in temperature. When such change occurs, an event is recorded onto the counter, which is stored in the camouflage box to protect it from the elements.

Figure 11 – Equipment: TRAFx Counter in the Field B

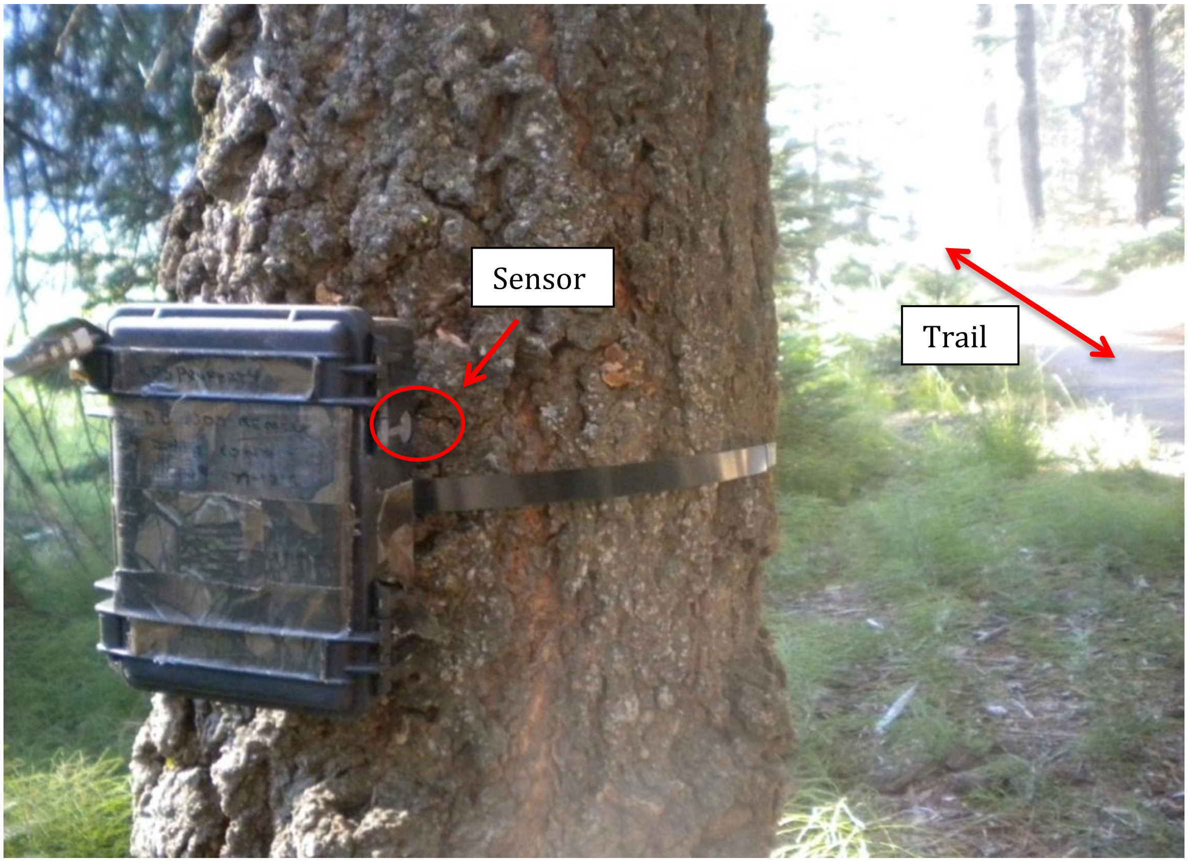


Figure 11: All TRAFx counters were used on trails in a similar fashion to the picture above. To limit data corruption due to weather and tampering, counters were placed into locked, waterproof plastic boxes. These boxes were then installed to trees via black aluminum banding and placed a specified distance from each trail. In all circumstances, the infrared sensor was aimed to be level with the ground and positioned to 'hit' at roughly the waist of an average adult visitor.

Figure 12 – Equipment: TRAFx Shuttle in the Field

Figure 12: The TRAFx G3 Dock was used to hold and transport counter data from the field for later analysis. Connecting easily with the TRAFx trail counter, this device was used for quick extraction without bringing attention to the counter's locations. Once data were obtained transfer to a computer was done seamlessly, requiring only a quick reformatting from text file to an Excel spreadsheet.

Figure 13 – Equipment: PlotWatcher Pro Camera in the Field A

Figure 13: Mounted to trees by either aluminum banding or screws as seen above, the PlotWatcher Pro was used in the field to calibrate trail counters.

Figure 14 – Equipment: PlotWatcher Pro Camera in the Field B

Figure 14: Powered by eight AA batteries, the PlotWatcher Pro comes with a variety of formatting options. Able to preview the location of the camera shot, data is recorded on micro SD cards, which were then transferred to a computer for analysis.

2007; Cessford et al., 2002; Cessford and Muhar, 2003; Greene-Roesel et al., 2008). By having only the change in an infrared signature be the trigger of a count, infrared counters also allow for a 'passive detection' (Cessford et al., 2002). Unlike traditional types of visitor counters such as a revolving turn-wheel gate, by being completely passive data is recorded in the most real-world setting possible, with visitors passing without disturbance or knowledge of being counted (Warnken, 2008).

Chosen specifically due to its extensive use by the US Department of the Interior and US National Park Service, the generation III TRAFx infrared trail counter is one of the most versatile counters on the market (Pettebone et al., 2008). The TRAFx trail counter also has the ability to count all general traffic on trails and paths including hikers, joggers, horseback riders, snowmobiles, and cyclists (TRAFx Data Net, 2012). Furthermore, in a study by Turner et al. (2007) a total of five pedestrian sensors were tested with the results that the TRAFx sensors performed the most accurate (Yang et al., 2010). In research conducted by Pettebone et al. (2010) examining trail use in Yosemite National Park, Pettebone also determined that the TRAFx counter behaves similarly enough to both the EcoCounter and Trailmaster counters that all three could be used interchangeably in future studies.

The main difference between the TRAFx infrared trail counter and similar products is that it does not require an additional receiving reflector unit to operate, greatly decreasing the potential for additional error to occur. With an infrared micro sensor scope designed to count events when warm moving objects pass by, the TRAFx infrared trail counter has a detection range of 6m (20ft) and has a memory capacity of over 400 million counts (TRAFx, 2012a). This counter design also has a battery life of approximately three years, is water resistant, and has an operating temperature range between -40C (-40F) and +50C (122F) (TRAFx Data Net, 2012).

Working along with the TRAFx infrared trail counter, the TRAFx G3 Dock is used to retrieve data from counters in the field (TRAFx, 2012b). Once downloaded, the TRAFx G3 dock can easily upload data to a computer (TRAFx, 2012b). The TRAFx Dock allows the user to download data from counters in the field without having to bring in a computer. This device has the capability to download and store the data of up to 375 counters, or roughly 275,000 lines of data, and has a battery life of up to six months (TRAFx.com, 2012). Once downloaded, the TRAFx dock produces the counted results in text format that can then easily be opened in Microsoft Excel or IBM SPSS.

With the convenience of being able to 'be' on all eight trails at once, time-lapse cameras were installed to monitor and calibrate the TRAFx trail counters. Once installed, time-lapse photography allows the user to not only monitor travel patterns remotely, but also precise visitor characteristics such as direction, number, and type (Ross, 2005). Taking photos at fixed intervals, time-lapse video recorders have long been used for surveillance for things such as wildlife and private property, only recently being used for visitor movement research and calibration purposes (Arnberger et al., 2005; Muhar et al., 2002). Arne Arnberger from the Institute for Landscape Development, Recreation, and Conservation Planning at the University of Natural Resources and Applied Life Sciences in Vienna, Austria is perhaps the biggest supporter of video monitoring in academia (Arnberger et al., 2002; Arnberger and Brandenburg, 2002). While Arnberger's work has largely consisted of studying visitor use in Vienna's inner-urban forests, he has also established an extensive background of other research uses (Arnberger et al., 2005). Time-lapse photography has also been a method used for monitoring river recreation use, use in urban and suburban parks, forests, national parks, examining visitor behavior in urban open spaces, and visitor movement at World Heritage sites (Arnberger, 2003; Arnberger and Brandenburg, 2002; Arnberger and Hinterberger, 2003; Arnberger et al., 2005; Madden and Love, 1982; Manghabati, 1989; Marnell, 1977; Muhar and others, 1995; Osamu, 2000; von Janowsky and Becker, 2003; Vander Stoep, 1986; Whyte, 1980). In each of these studies the use of time-lapse photography has been met with success and encouragement for future use (Arnberger and Eder, 2006).

Furthermore, the Institute of Transportation Studies at University of California, Berkeley recommends the use of time-lapse cameras over traditional manual methods when accuracy is imperative (Greene-Roesel et al., 2008). This endorsement is supported from research concluding that video recordings are advantageous over manual counting methods since they give the viewer the ability to review tapes multiple times (Greene-Roesel et al., 2008). In 2005 Arnberger et al. also determined that video monitoring is preferable over traditional methods especially when reliable data of visitor numbers is the biggest concern. Ross (2005) further supports this reasoning in his study for New Zealand's Department of Conservation. From his findings the procured tapes not only have the capability to be reviewed at high speeds, but video monitors also gain the ability to rewind or stop work when needed, something impossible with field observers (Arnberger et al., 2005).

Arguments against the use of time-lapse cameras do exist however. It is often cited that the analysis of time-lapse photography can be just as costly in terms of staff time as compared to manual field observers (Cessford and Muhar, 2003; Kahler and Arnberger, 2008; Ross, 2005). Additionally, ethical aspects can come into question when using time-lapse imagery by inadvertently intruding on a visitor's privacy (Muhar et al., 2002). Vandalism risks are also more likely due to cameras being left unguarded and the curious nature of passing visitors (Muhar et al., 2002; Ross, 2005). Equipment and maintenance costs can also be further determents of using time-lapse cameras in similar research (Cessford and Muhar, 2003).

Chosen for its convenient viewing software, ease of use, and low price, the PlotWatcher Pro's primary function in this study was to take the place of a human manually counting for trail calibration. With image interval options of 1, 2, 3, 5, 10, 20, 30 seconds or 1, 3, 5, 10, 20, 30, 60 minutes, this allows the resulting data to be viewed more as a smooth-running video than a compilation of time-lapse pictures (Day 6 Outdoors, 2010). The PlotWatcher Pro has a battery life of up to four months or between 750,000 and 1,000,000 individual video frames (Day6outdoors.com, 2012). Duration of operation can be set by manual start/stop times or based on available lighting with the sunrise and sunset (Day 6 Outdoors, 2010).

Data gathered from the PlotWatcher Pro was received in the form of a SDHC card up to 32 GB in size. These cards can be easily viewed on the provided GameFinder software. This program not only allows for forward and reverse frame review at different speeds, but also comes with the 'MotionSearch' feature where frames are scanned internally for signs of movement (Day 6 Outdoors, 2010). Due to this convenience, the GameFinder software was the primary tool of video analysis in this study.

For each of the eight trail locations, placement of TRAFx infrared trail counters and PlotWatcher Pro time-lapse cameras were set up with careful consideration of their surroundings. Prior to the installation of these units, the frequency, timing, and location of each device was carefully determined following recommendations from Buckley (2003), Buckley (2004), Eagles et al. (2002), and Hadwen et al. (2007). Specifically, TRAFx counters were programmed to run continuously in one-hour bins and the PlotWatcher Pro time-lapse cameras were set to run from sunrise to sunset at one-to-five second intervals depending on the location from the trail and overall visibility of each counter.

Following previous examples from literature, the installation of both devices were set at locations perceived most appropriate to encourage accurate counts while discouraging vandalism and environmental influences (Figures 15, 16, and 17) (Watson et al., 2000). However, in some instances these effects were unavoidable (Figures 18, 19, 20, 21, 22, 23, 24, and 25). With the TRAFx counters, rails or trees within five feet from the trail were chosen for placement to promote the highest percentage of precise counts. Raised roughly three to four feet from the ground, (about waist height), the counters were placed in metal security boxes and then attached to their selected tree/railing with aluminum banding. The location and placement of these devices was met with the utmost consideration due to the possibility of counts being triggered from undesired events such as wildlife, moving foliage, and sunlight (Cessford and Muhar, 2003; Gasvoda, 1999; Muhar et al., 2002).

When calibrating the TRAFx counters, trees roughly five-to-twenty feet off the trail were selected to hold the PlotWatcher Pro cameras. Installed with either the same aluminum banding or mounted directly onto the tree, the time-lapse camera devices were typically installed five feet from the ground and in a location that promoted high visibility while limiting the chance of visitor recognition and tampering. Cameras were installed where traffic would be visible for long distances to help improve the accuracy when later going through the video footage (Watson et al., 2000). Each infrared counter and time-lapse camera was also given an individual name to better structure and organize the data for future analysis

Figure 15 – In Use Example 1: GGC2

Figure 15: In this example the attempt to blend both the trail counter and time-lapse camera into the natural setting was done to limit the amount of attention received by visitors.

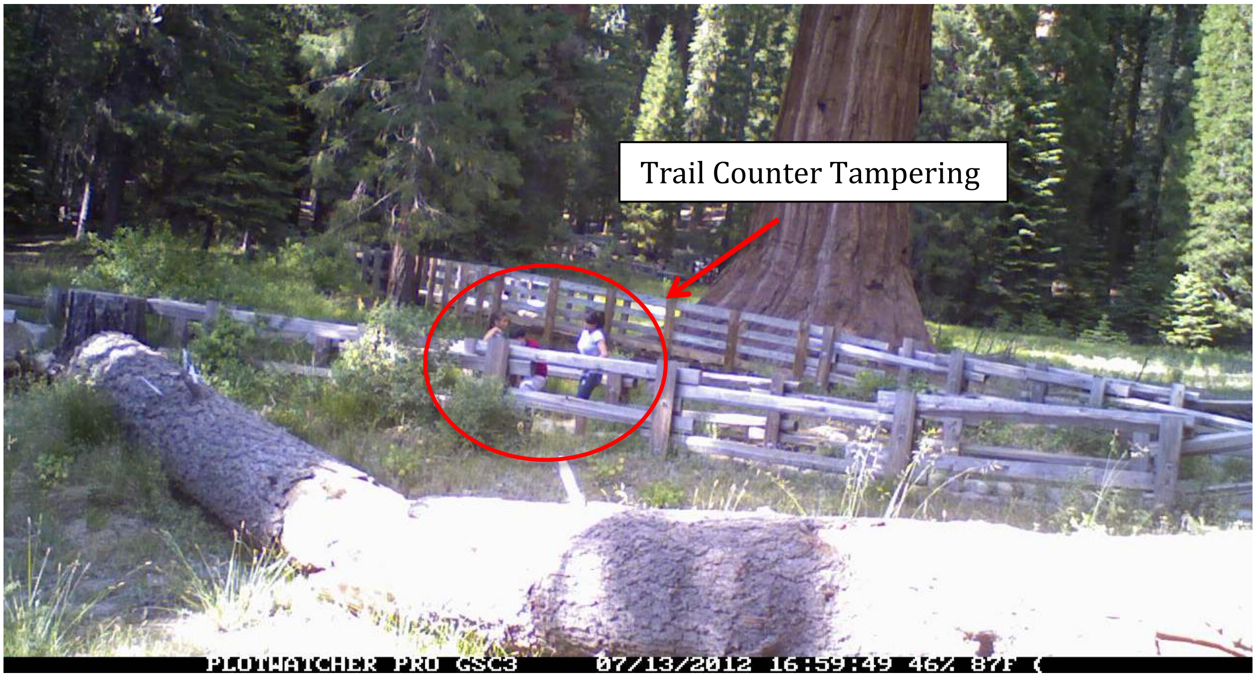
Figure 16 – In Use Example 2: View from Counter

Figure 16: This view from the infrared trail counter demonstrates the distance time-lapse cameras were often placed when calibrating.

Figure 17 – In Use Example 2: View from Camera

Figure 17: This alternate view from the time-lapse camera demonstrates the distance from the trail counter and the approximate trail view received when calibrating.

Figures 18 – Tampering Examples: In Action



Figures 19 – Tampering Examples: In Action

Figures 18 and 19: In these two figures the act of tampering with trail counters is observed from the calibrating time-lapse cameras

Figure 20 – Tampering Examples Continued: Tape Over Lens

Figure 20: In this tampering example camouflage tape from the counter's casing was placed over the lens.

Figure 21 – Tampering Examples: Sensor Pulled

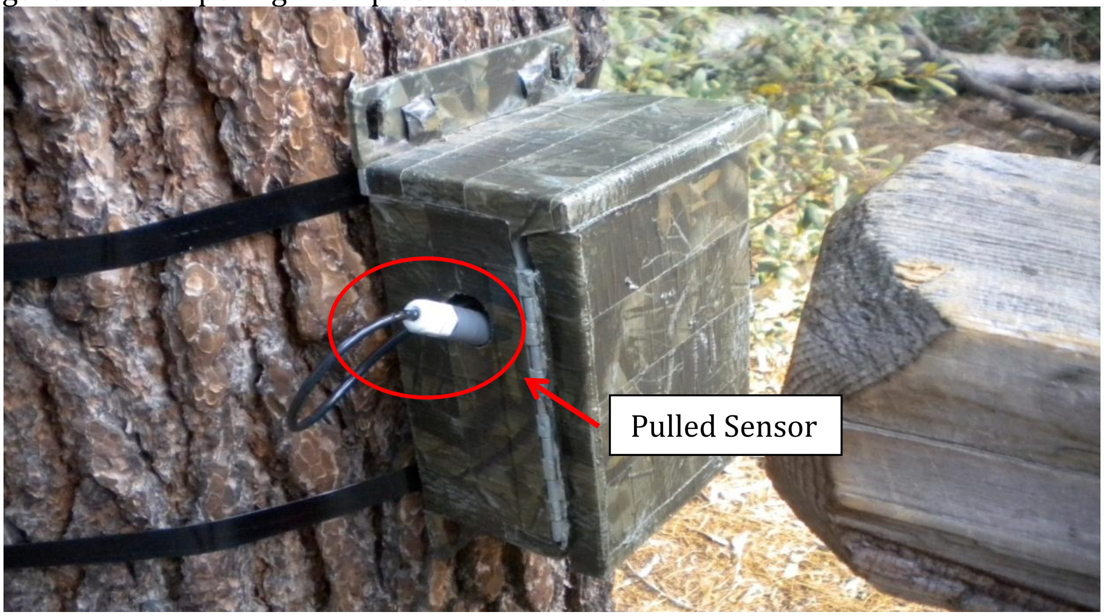


Figure 21: In this tampering example, the counter's infrared counting scope was pulled from the box then jammed back in.

Figure 22 – Tampering Examples: Sensor Jammed In

Figure 22: In this example the infrared trail counter lens has been punctured, then shoved back into the protective box casing.

Figure 23 – Unforeseen Issues: Sun in Lens

Figure 23: In this example poor placement of the time-lapse camera results in the morning sun blinding the lens.

Figure 24 – Unforeseen Issues: Bug on Lens

Figure 24: Here almost immediately after installation a bug climbed over half the camera lens resulting in limited visibility.

Figure 25 – Unforeseen Issues: Nest in Lens

Figure 25: At this site the calibration process was set back due to a caterpillar making its cocoon directly over the lens.

(Pettebone et al., 2008). Pettebone et al.'s calibration method during his 2010 research in Yosemite National Park was used for this study. From the literature this method was chosen over others due to it having the most stringent requirements to promote accuracy. Requiring five-hours of calibration time per trail, (the highest recommended amount of time in the literature), this number was further extended in this study to 20 total hours of direct observation per trail. This increase in calibration time was due to the TRAFx counters only measuring counts in 1-hour interval bins. Since the counters used in Pettebone's research were able to record data in 15-minute intervals, to ensure similar accuracies the calibration time was increased fourfold to account for the lower-resolution bins obtained from the TRAFx counters (Pettebone et al., 2010).

To determine slope an inclinometer was used in the center of each trail underneath where the infrared beam would pass. Lying flat on the ground, the device was place on a .3 meter clipboard (12 inches) to average the slope over the potential pick-up area of the sensor. At the same location, a tape measure was run from both sides of the trail to determine trail width (Figures 26, 27, and 28). Trails having asphalt this was measured by examining where it began and ended and with dirt trails this was measured by determining the boundaries where continuous, normal use had occurred.

Figure 26 – Data Gathering: Trail Width and Slope

Figure 26: On trails without asphalt width was measured based on the average boundaries visitors most often used when walking.

Figure 27 – Data Gathering: Slope

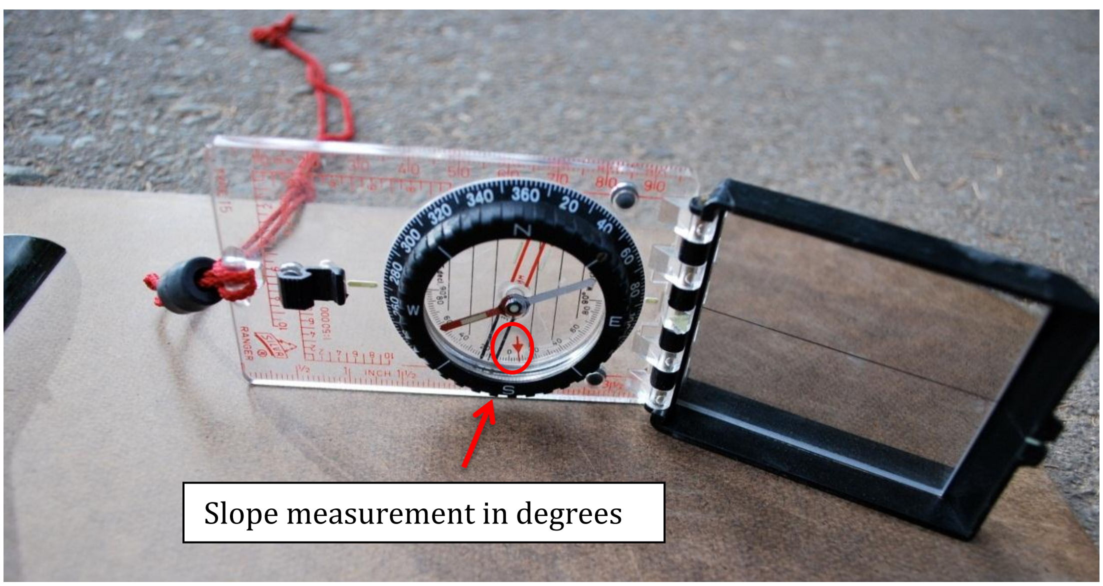


Figure 27: Trail slope was measured by placing an inclinometer flat on the ground and observing the degree change.

Figure 28 – Data Gathering: Trail Width

Figure 28: At each trail, width was measured by placing a measuring tape flat across the area seeing most traffic.

Installed and running between May and September 2012 (Table 1), units were checked regularly for vandalism, potential equipment failure, battery life, and memory (Watson et al., 2000). Although having the ability to run the entire summer without downloading or changing the batteries, TRAFx units were checked every one-to-two weeks and downloaded using the TRAFx shuttle to ensure the data recorded were backed up and saved in multiple locations (Figure 29). Depending on the frequency of the time-lapse photography, the PlotWatcher Pro cameras were either checked every four days to change the batteries and SD card, checked bi-weekly, or allowed to run out of batteries and picked up on a later date.

Table 1 – Trail Calibration Times

Trail Code	Trail Name	TRAFx Operational Dates	Dates Calibrated
COC2	Congress Trail 2	8/2-8/29	8/23-8/29
GSC2	Upper Sherman Trail	5/27-9/25	5/28-7/22
GSC3	Lower Sherman Trail	5/27-9/25	5/28-7/16
GGC2	Grant Grove 2 Trail	5/25-9/25	8/1-8/14
GGC3	Grant Grove 3 Trail	5/26-9/25	8/14-8/27
PLC	Pear Lakes Trail	5/13-8/2	7/19-7/27
TFC	Tokopa Falls Trail	5/13-9/25	5/15-6/18
TLC	Twin Lakes Trail	5/13-7/17	5/15-6/18

Figure 29 – Data Gathering: TRAFx Counts

Figure 30: In this figure the download process of trail counts is demonstrated using the TRAFx infrared trail counter, the TRAFx shuttle, and a field computer.

Microsoft Excel was used to synthesize the data into a single format (Table 2) (Pettebone et al., 2008). When examining the PlotWatcher Pro photography, Table 3 was used to translate the data into numerical form[2]. This process was done by manually counting visitors as they passed by the TRAFx counter, taking note of the day, time, visitor type, and direction. Once complete, twenty individual hours from each trail were selected randomly to proceed with the calibration process (Pettebone et al., 2010). Correction Coefficients were then determined using the formula in Figure 30 by dividing the manual counts of each trail by the mechanical counts. Once a correction coefficient was received this was then done for each additional hour then averaged overall (Davenport et al., 2003; Ross, 2005; Rupf et al., 2006; Svajda, 2009; Yang et al., 2010).

Table 2 – Trail Characteristics

Trail	Width (Meters)	Slope (Degrees)	Total Use	TRAFx Counts	Correction Coefficient
COC2	1.68	2	1006	565	1.92
GSC2	3.15	1	5281	3743	2.06
GSC3	3.05	6	3711	2364	1.54
GGC2	3.81	7	2892	1364	2.09
GGC3	3.1	5	1531	874	1.78
PLC	1.73	13	133	115	1.23
TFC	1.96	4	402	341	1.20
TLC	1.3	3	77	67	1.17

[2] See appendix for each individual trail's raw data and descriptives.

Table 3 – Example Collection Sheet

Day	Time	Inbound	Outbound	Overnight Visitors	Day Visitors	Total Visitors	TRAFX Visitor Total	Correction Coef	Comments
Totals and Coef Average									

Percent Inbound	
Percent Outbound	
Percent Overnighter	
Percent Day User	

Figure 30 – Calibration Coefficient Equation

$$cf = mean\left(\sum \frac{m}{a}\right)$$

Figure 30: Calibration Coefficients were received by dividing the manual counts of each trail by the mechanical counts, then taking the average over all 20 hours measured. In the formula above, cf = Calibration Coefficient, m = manually collected counts, and a = automatically collected data using the TRAFx infrared counters (Rupf et al, 2006).

When examining if a correlation exists between trail characteristics and the correction coefficients given, 'total use' was decided as a variable due to it being a common concern with trail counter accuracy (Cessford et al., 2002; CVC, 2012; Gracia-Longares, 2005; Kuutti, 2012; Lue, 2006; Schneider et al.,2009; Rupf-Haller et al., 2006; Turner et al., 2007). Use was further examined due to the great range in prior findings from having a positive influence, negative influence, or no influence at all (Gracia-Longares, 2005; Greene-Roesel et al., 2008; Schneider et al.,2009). 'Trail width' was also selected for its continued citation in literature with the idea that the wider the trail the more likely visitors would walk side by side, only registering one person with the trail counter when in reality two passed (CVC, 2012; Gracia-Longares, 2005; Kuutti, 2012; Lue, 2006; Maldonado et al., 2011; Ozbay et al., 2010; Pettebone et al., 2008; Rauhala et al., 2002; TRAFx, 2012; Yang et al., 2010). 'Trail slope' was selected as the final trail characteristic to be examined due to the uncertainty of its influence on counter calibration and to test the hypothesis that when visitors climb steep trails, they are more likely to align in single file (Farrell and Marion 2002; Maldonado et al., 2011). If true, the results should indicate that steeper trails have lower correction coefficients (and are therefore more accurate) when using trail counters (Lue, 2006; Pettebone et al., 2008). Furthermore, the goal when testing each of these potential factors is to determine if these trail trails can effect trail calibration on a level that has statistical significance (Lue, 2006; Muhar and Brandenburg, 2002; Muhar et al., 2002; Pettebone et al., 2008; Ross, 2005; Rauhala et al., 2002; Watson et al., 2000).

For the following statistical tests IBM's SPSS statistical software was used to analyze results. SPSS was chosen due to its ease of use and wider capability compared to Microsoft Excel. To determine if a correlation exists between these factors of total use, trail width, and trail slope and the correction coefficients produced, three statistical tests were examined including the Shapiro-Wilk normality test, the Kruskal-Wallis variance test, and Spearman's Rho rank correlation test. To begin the statistical analysis, a test for normality was completed on the data to determine which latter tests were most appropriate. Examining the distributions of each value given on all eight trails, the Shapiro-Wilk test was selected over the Kolmogorov-Smirnov test because of its strengths with smaller samples and each trail having only 20 data points (Hollander and Wolfe, 1999).

Determining that the data are not normally distributed and that trail calibration figures did not fit directly to a bell curve (Section 4.1), the next step before running a correlation is to determine if a variance existed between samples. The nonparametric equivalent to the one-way ANOVA test, the Kruskal-Wallis variance test was chosen due to working best with mixed-normality samples. From this test hypotheses are tested to determine if the data from each trail comes from different samples. In comparing the null hypothesis (that the population distributions are identical), with the alternate hypothesis (that the population distributions are not identical), the results of this test will either accept or reject the null hypothesis (Vaughan, 1998). With accepting the null hypothesis, this means that each sample is not significantly different from another and that all likely came from the same population. If the alternate hypothesis is accepted, then it can be stated that the differences in samples are unlikely to have occurred by chance and each come from a different population (Vaughan, 1998).

When running a correlation analysis, the nonparametric Spearman's Rank Correlation Test (also known as Spearman's Rho) was selected as the best choice to examine the relationship of the three trail characteristics and correction coefficients (Conover, 1999). Compared to the Pearson's Rho correlation test, since the data are non-normal the Spearman's Rho is best fit for running a correlation. In research presented by Bishara and Hittner (2012), the Spearman's Rho test was actually found to be the preferred method for correlation analysis. Fowler (1987) additionally found that across non-normal distributions Spearman's Rho is both more powerful and tends to preserve type 1 errors better than Pearson's Rho (Bishara and Hittner, 2012). Spearman's Rho also was determined to be more powerful when running one-tail tests for mixed-normal and non-normal distributions (Zimmerman and Zumbo, 1993). To run Spearman's Rho rank correlation test trails were first ranked numerically with no assumed order (1 = Twin Lakes Trail, 2 = Tokopa Falls Trail, 3 = Pear Lake Trail, 4 = General Sherman 3 Trail, 5 = Grant Grove 3 Trail, 6 = Congress Trail, 7 = General Sherman 2 Trail, and 8 = General Grant Trail 2) (Table 4). This act of ranking may be one of the most beneficial steps when using Spearman's Rho (Bishara and Hittner, 2012). When ranking the data, this causes any outliers to contract toward the center of the distribution, minimizing the potential of inaccurate results (Fowler, 1987; Gauthier, 2001).

Table 4 – Assigned Trail Numbers

Trail	Assigned Number	Width (Meters)	Slope (Degrees)	Total Use	Correction Coefficient
COC2	6	1.68	2	1006	1.92
GSC2	7	3.15	1	5281	2.06
GSC3	4	3.05	6	3711	1.54
GGC2	8	3.81	7	2892	2.09
GGC3	5	3.1	5	1531	1.78
PLC	3	1.73	13	133	1.23
TFC	2	1.96	4	402	1.20
TLC	1	1.3	3	77	1.17

In all of these tests, perhaps the greatest assumption made is that the data presented comes from a random sample (Ebdon, 1985). For inferential statistics the need for a randomized sample can be the key from separating truly valuable data from meaningless results. To have data not from a random sample, the chance for misrepresentation and inaccuracies in the results becomes so high great caution must be placed when accepting results (Ebdon, 1985).

3.2 Trail Selection

Within SEKI, 16 trails were selected for study. While trail popularity was a major consideration during selection, characteristics including length, type (day use vs. overnight), accessibility, trail surface, slope, width, and overall use were also factors examined to achieve a heterogeneous sample. Of the 16 trails selected only eight were eventually used. This was due to the lack of data received by the eight rejected trails, specifically a result of tampering and technological errors. The eight trails eventually chosen for this study consist of the Congress Trail 2, the Upper Sherman Tree Trail, the Lower Sherman Tree Trail, the Grant Grove Trail 2, the Grant Grove Trail 3, Pear Lakes Trail, Tokopa Falls Trail, and the Twin Lakes Trail (Table 5, Figure 31).

Table 5 – Trail Locations

Trail Code	Trail Name	UTM X	UTM Y
COC2	Congress Trail 2	343420.89mE	4049834.18mN
GSC2	Upper Sherman Trail	323888.58mE	4068632.31mN
GSC3	Lower Sherman Trail	323807.38mE	4068644.98mN
GGC2	Grant Grove 2 Trail	343393.23mE	4050163.18mN
GGC3	Grant Grove 3 Trail	343281.60mE	4049803.54mN
PLC	Pear Lakes Trail	344846.75mE	4051553.89mN
TFC	Tokopa Falls Trail	346314.75mE	4052535.39mN
TLC	Twin Lakes Trail	344931.57mE	4053581.01mN

The Congress Trail 2 (COC2) is located in the Giant Forest and is a medium use trail (25-150 people per hour). Adjacent to the General Sherman Tree trails, the Congress trail sees the majority of its users spur off from here, coming from either the Upper or Lower Sherman parking lots. Being entirely paved, this trail is also one of the best options for handicapped visitors, making up a small percentage of its overall use. The Congress trail has a low slope of two degrees, and having a width of 1.68 meters (5' 6") is considered narrow compared to the other seven trails studied. Located at the UTM GPS coordinates[3] (11N 343420mE, 4049834mN), the TRAFx trail counter was operated between 8/2/2012 and 8/29/2012 and was calibrated between 8/23/2012 and 8/29/2012.

[3] For the following coordinates the Universal Transverse Mercator (UTM) format was used from zone 11 in the northern hemisphere.

Figure 31 – Trail Locations Map

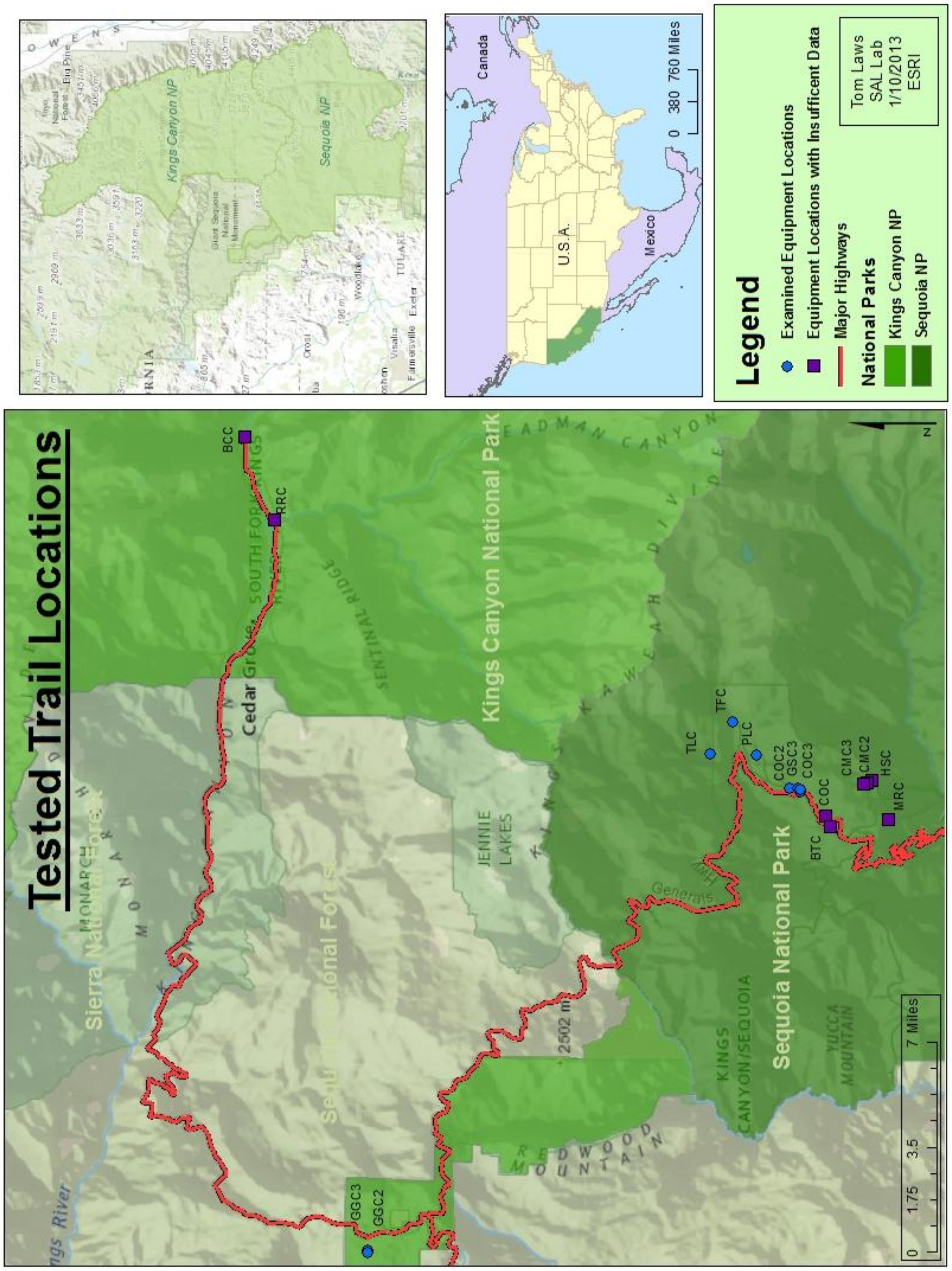


Figure 31: This map depicts the original 16 trails selected for this study, along with final eight eventually used. Additionally, SEKI is shown in relation to California and the rest of the United States.

The Upper Sherman Tree Trail (GSC2) is also located in the Giant Forest and is part of the heaviest used trail in both Sequoia and Kings Canyon National Parks (>150 people per hour). With the main attraction being the General Sherman Tree, the Upper Sherman Tree counter experiences a higher number of inbound visitors than outbound. These results of higher inbound numbers are likely due to the steep slope of the trail down to the General Sherman Tree that leaves visitors electing to take the shuttle bus back to the top. The placement of the trail counter was at a relatively flat stretch making GSC2 the lowest-slopped trail in the study at only one degree. Additionally, GSC2 was the second widest trail at 3.15 meters (10' 4") and was located at the GPS coordinates (323888mE, 4068632mN). The Upper Sherman Trail's TRAFx counter ran between 5/27/2012 and 9/25/2012 and was calibrated between 5/28/2012 and 7/22/2012.

The Lower Sherman Tree Trail (GSC3) is located in the Giant Forest and is also part of the heaviest used trail in both SEKI (>150 people per hour). While the vast majority of users are going to the General Sherman Tree via the upper and lower parking lots, spur routes such as the Congress Trail 2 also see use. The Lower Sherman Tree trail segment used for this study can be found at the GPS coordinates (323807mE, 4068644mN) and is just beyond the handicapped parking lot and Lower Sherman shuttle stop. The Lower Sherman Trail is the third widest of the eight studied at 3.05 meters (10') and has a medium slope of six degrees. Additionally, this trail is also one that is completely paved and handicap-accessible, had a TRAFx counter up between 5/27/2012 and 9/25/2012, and was calibrated between 5/28/2012 and 7/16/2012.

The Grant Grove Trail 2 (GGC2) is the heaviest used trail in Kings Canyon National Park (>150 people per hour). Leading to the General Grant Tree, this trail is paved and is a loop along with the Grant Grove Trail 3. Having the largest width of all the trails studied at 3.81 meters (12' 6"), GGC2 is one of the main stops for major tour busses and at times will see large waves of visitors going inbound and outbound. With a slope of seven degrees, the Grant Grove trail 2 is the second steepest trail studied. GGC2 can be located at the UTM GPS coordinates (343393mE, 4050163mN). A TRAFx trail counter was installed here from 5/25/2012 to 9/25/2012 and was calibrated between 8/1/2012 and 8/14/2012.

Connected with GGC2, the Grant Grove Trail 3 (GGC3) is a second option when visiting the General Grant Tree. Leaving from the same parking lot, GGC3 is a medium use trail (25-150 people per hour), relatively wide at 3.1 meters, (10' 2"), and has a medium slope of five degrees. Also paved and prone to experience large waves of visitors due to tourist busses, the Grant Grove Trail 3 is located at the GPS coordinated (343281mE, 4049803mN). The TRAFx trail counter for this site was operational between 5/26/2012 and 9/25/2012 and was calibrated between 8/14/2012 and 8/27/2012.

The Pear Lakes Trail (PLC) is one of the main trails examined consisting primarily of over-night visitors. Having a low use (<25 people per hour), this trail experiences a large amount of inbound hikers during the morning hours followed by a large outbound percentage in the evening hours. With a slope of 13 degrees, this is the steepest trail of the eight studied and also is one of the narrowest having a width of 1.73 meters (5' 8"). The Pear Lakes Trail has very convenient access from the Wolverton parking lot, and is located at the GPS coordinates (344846mE, 4051553mN). The TRAFx trail counter here was operational between 5/13/2012 and 8/2/2012 and was calibrated from 7/19/2012 to 7/27/2012.

The Tokopa Falls Trail (TFC) is located in the Lodgepole area of the park and is a medium use trail (25-150 people per hour). Used as a short day-use trail for visitors, the Tokopa Falls are approximately 2.7 kilometers from the trailhead. While this provides the predominate use of the trail, anglers alongside the Marble Fork of the Kawea River and rock climbs recreating on the various formations nearby also make up a small percentage of users. The Tokopa Falls trail segment used for this study can be found at the GPS coordinates (346314mE, 4052535mN) and the trail consists of hard, compact soil with the a narrow width at 1.96 meters (6' 5") and the medium slope of four degrees. The Tokopa Falls Trail TRAFx counter was operational between 5/13/2012 and 9/25/2012 and was calibrated between 5/15/2012 and 6/18/2012.

The Twin Lakes Trail (TLC) is also located in the Lodgepole camping area of the park and is very low use (<25 people per hour). Used primarily for the destinations of the Twin Lakes (approximately 10.94 kilometers from the trailhead), JO Pass (10.62 kilometers), and Silliman Pass/Ranger Lake (14 kilometers), the Twin Lakes trail also enters a network of trails with the potential of leading to the Jennie Lakes Wilderness, Kings Canyon, and the John Muir Trail. The Twin Lakes trail is predominately used by overnight users however both day-hikers to the Twin Lakes and pack animals for longer trips are also witnessed. Located at the GPS coordinates (344931mE, 4053581mN) the trail segment selected consists of moderately hard, compacted soil and is the narrowest trail of the eight at 1.3 meters (4’ 3”). Also having a low slope of three degrees, TLC had a TRAFx trail counter installed from 5/13/2012 to 7/17/2012 and a PlotWatcher Pro camera running from 5/15/2012 to 6/18/2012.

CHAPTER IV

Analyses and Discussion of Findings

4.1 Results and Discussion

Shapiro-Wilk

Requiring a significance level above .05 (95% confidence interval) to be normally distributed, results in Table 6 found trails TLC (.004), PLC (0.00), COC2 (0.013), and GSC2 (0.00) all to be non-normally distributed. This result suggests that for these four trails when correction coefficients are plotted results do not fit on a normal curve.

Table 6 – Shapiro-Wilk Results

Tests of Normality

TRAIL		Shapiro-Wilk			
		Statistic	df	Sig.	Distribution
COEF	1	0.846	20	0.004	Non-N.
	2	0.919	20	0.094	Normal
	3	0.728	20	0	Non-N.
	4	0.919	20	0.093	Normal
	5	0.958	20	0.512	Normal
	6	0.872	20	0.013	Non-N.
	7	0.488	20	0	Non-N.
	8	0.945	20	0.303	Normal

Examining reasons why this to be the case, no obvious similarities were found when comparing the normally distributed trails to the ones not normally distributed. However, the likely reasoning behind this result is the small sample for each individual trail. Statistically, as sample size increases outliers are smoothed-out over the entire distribution, increasing normality if it exists (Vaughan, 1998). In this situation the four non-normal trails likely contain outliers that, while normal, skew the data due to its small size of only 20 data points per trail.

This result of having non-normal data nevertheless is acceptable due to the infinite number of influences real-world data can experience. Furthermore, Hollander and Wolfe (1999) argue that statistically non-normal data and methods are actually more realistic and compatible than that of parametric, normal distributions. From their book, *Nonparametric Statistical Methods*, Hollander and Wolfe (1999) give six main points supporting this view:

1. Nonparametric methods require few assumptions about the underlying populations from which the data are obtained.
2. Nonparametric procedures enable the user to obtain exact P-values for tests, exact coverage probabilities for confidence intervals, exact experimentwise error rates for multiple comparison procedures, and exact coverage probabilities for confidence bands without relying on assumptions that the underlying populations are normal.
3. Nonparametric techniques are often thought easier to both apply and understand than their normal theory counterparts.
4. Although at first glance most nonparametric procedures seem to sacrifice too much of the basic information in the samples, theoretical investigations have shown that this is not the case.
5. Nonparametric methods are relatively insensitive to outlying observations
6. Nonparametric procedures are applicable in many situations where normal theory procedures cannot be utilized. Many nonparametric procedures require just the ranks of the observations, rather than the actual magnitude of the observation, whereas the parametric procedures require the magnitudes (Pp.1, Hollander and Wolfe, 1999).

Kruskal-Wallis

Once the data set was determined to contain both normally and non-normally distributed points the Kruskal-Wallis H Test was run to see if a variance exists between samples. Using a 95% confidence interval, results found a probability significance of .000 that the samples come from the same population. Receiving such a low assumption significance, this outcome leaves behind little doubt that this result is inaccurate. Rejecting the null hypothesis, the assumption that each trail is significantly different can be made (Table 7). When examining the mean ranks of each trail, differences further suggest the uniqueness of each trail.

Table 7 – Kruskal-Wallis H Test Results

Ranks

	TRAIL	N	Mean Rank
COEF	1	20	41.30
	2	20	47.78
	3	20	46.90
	4	20	89.90
	5	20	113.88
	6	20	95.48
	7	20	81.65
	8	20	127.13
	Total	160	

Test Statistics[a,b]

	COEF
Chi-Square	68.644
df	7
Asymp. Sig.	.000

a. Kruskal Wallis Test

b. Grouping Variable: TRAIL

This result is of great importance. To be able to say that the data from each of these trails comes from a separate population strengthens the belief that the results found in this study could be assumed to hold true on other trails. Additionally, by proving that trails come from different populations this insures that no bias could have occurred by the exact same influences at each site. Having multiple populations also shows that each trail is truly unique from the others and no bias from a certain trait is occurring.

Spearman's Rho

When testing for relationships between the trail factors of trail width, overall use, and trail slope with the given correction coefficients, results from the Spearman's rank-order test provided mixed findings (Table 8). First, examining trail width and the correction coefficients given, a strong positive correlation of .738 was recoded above the 95% confidence interval (two-tailed significant of .037). This result suggests that it is very likely that a positive relationship occurs with the 120 trail times examined and their given widths and calibration correction coefficients, (in this case the wider the trail the less accurate an automated trail counter will be). Testing total use and the correction coefficients found almost identical results with a strong positive correlation of .762 and a confidence interval well above 95% at a significance .028. Once again this result shows with some certainty that a positive relationship exists between a trail's overall volume pattern and its correction coefficient received post calibration (in this case the higher volume a trail experiences the less accurate automated trail counters will be). When using Spearman's Rho to test the relationship between the 120 counts for trail slope and the correction coefficients no correlation was seen, with a -.071 coefficient at a two-tailed significance level of .867 received (in this case slope does not influence the accuracy of automated trail counters). This result suggests that if any influence were to occur between trail slope and infrared trail counter accuracy it would be at a level so small it is likely not statistically significant at a 95% confidence interval.

Table 8 – Spearman's Rho Results

Width v. Correction Coefficient		Results
Spearman's Rho	Correlation:	0.738*
	Significance:	0.037
Use v. Correction Coefficient		Results
Spearman's Rho	Correlation:	0.762*
	Significance:	0.028
Slope v. Correction Coefficient		Results
Spearman's Rho	Correlation:	-0.071
	Significance:	0.867

*. Correlation is significant at the 0.05 level (2-tailed).

When examining the results of the Spearman's Rank correlation test, finding that correlations exist between both trail-width and trail-use with their resulting correction coefficients is absolutely vital to trail calibration research. By demonstrating that patterns can be seen on SEKI trails (for example that high use on a trail means that more often the infrared beam will be broken for long periods of time which, in turn, means a high amount of error is likely to occur), agencies worldwide, regardless of the calibration process they use, can use this information as a guideline to test their results on any particular trail. When comparing results to the literature, while several findings align with previous research, due to conflicting hypotheses on potential influences, this was not always the case (CVC, 2012; Gracia-Longares, 2005; Greene-Roesel et al., 2008; Kuutti, 2012; Lue, 2006; Maldonado et al., 2011; Ozbay et al., 2010; Pettebone et al., 2008; Rauhala et al., 2002; Rupf-Haller et al., 2006; Schneider et al., 2009; Turner et al., 2007; Yang et al., 2010).

For example, while the results found for a relationship between overall use and trail counter accuracies are in line with the hypotheses of Greene-Roesel et al. (2008), Kahler and Arnberger (2008), Kuutti, (2012), Ozbay et al. (2010) and Yang et al. (2010), further examination is needed to determine why Gracia-Longares (2005), Schneider et al. (2009), Turner et al. (2007), and Watson et al. (2000) came to different conclusions. Suggesting a negative relationship between trail use and counter accuracy, Gracia-Longares (2005) and Watson et al. (2000) both reach conclusions that low use trails are often more inaccurate than high volume sites when using automated trail counters. While these results were opposite of what was found in this study, this hypotheses may still hold true for *extremely* low sites

(>5 people per day). On such trails, overestimation biases from moving foliage or passing wildlife would influence the data much more than on higher volume trails, resulting in larger inaccuracies (Cessford and Muhar, 2003; Gasvoda, 1999; Kahler and Arnberger, 2008; Ross, 2005).

Schneider et al. (2009) and Turner et al. (2007) also reached a different conclusion that total volume has no influence on trail calibration. While the calibration methods used in these tests were not significantly different to what was used in research finding differing results, one notable difference is that in both instances test locations took place at road intersections in urban environments (Schneider at al., 2009; Turner et al. 2007). This detail suggests that perhaps additional influences are at work affecting counter calibration in urban environments compared to ones in a wilderness setting; IE stricter 'trail' boundaries (roads, fences, and buildings).

Additionally, this result demonstrates the importance of retrieving detailed calibration data. By finding the relationship that as a trail's volume increases the accuracy of a counter goes down, this shows that a calibration factor at a low use time cannot effectively be used at that exact site at a high use time. One way to help increase these accuracies then would be to encourage more detailed and lengthy calibration methods that attempt to include all aspects of trails use (such as weekend, weekday, high use, low use, and holiday collection times).

The Spearman's Rho findings from trail slope also encourage further examination to determine what amount, if any, slope has on influencing trail counter calibration. Showing that no relationship exists between correction coefficients and trail slope, this result contradicts the work of Lue (2006), Pettebone et al. (2010), and Watson et al. (2000). It is important to note that once again additional factors may have been at play in this result. For example, the General Grant Tree 2 Trail had the second highest slope of seven degrees, encouraging people to condense and walk single file; however, this trail also was one of the widest and most used, two traits found to instead decrease counter accuracy (Cessford et al., 2002; Farrell and Marion, 2002; Maldonado et al., 2011; Pettebone et al., 2010). In this situation if slope did indeed affect counter accuracy, additional research on this should indicate it.

Correlation results from the trail characteristic width, (the one trait examined where the literature unanimously agreed on a common influence with counter accuracy), matched all prior findings (CVC, 2012; Gracia-Longares, 2005; Pettebone et al., 2010; Rauhala et al., 2002; Ross, 2005; Rupf-Haller et al., 2006). This outcome is very encouraging, stressing to natural resource planners the importance to take trail width into consideration when calibrating automated trail counters. Additionally, this result shows the need of considering natural bottlenecks on trails for installation sites to increase the likelihood of visitors walking one-by-one (Cessford et al., 2002; Greene-Roesel et al., 2008; Raoul et al., 2004).

CHAPTER V

Conclusion

5.1 Summary

In protected areas worldwide and specifically US National Parks increasing visitation numbers have begun straining the very same ecosystems natural resource managers are trying to preserve (Manning, 2002). As a result, planners are now examining visitor movement to better understand how it can impact these ecosystems (Gracia-Longares, 2005; Lindsey et al., 2006). With the advancement of technology, mechanical counters including passive-infrared sensors are becoming increasingly popular as a means of estimating visitor use on trails (Hadwen et al., 2007; Kahler and Arnberger, 2008; Lue, 2006; Ross, 2005; SNH, 2002; Yang et al., 2010). These pedestrian counting devices are both inexpensive and able to be used almost anywhere, however, are known to be inaccurate (Kahler and Arnberger, 2008; Watson et al., 2000).

Calibration, the process of comparing a sample of manual visitor counts to those taken from an automated trail counter, is becoming a standard practice to increase the accuracies of the data received. However, surprisingly little research has been performed to examine the relationship between calibration correction coefficient values and specific trail characteristics (Davenport et al., 2003; Ross, 2005; Rupf et al., 2006; Svajda, 2009; Yang et al., 2010). One approach to increase such understandings is to examine the influences that cause trail counter inaccuracy and require the use of calibration in the first place. By doing this, planners will gain a better understanding of the processes and tendencies of automated trail counters in the field.

This study contributes to the understanding of visitor movement monitoring by using passive-infrared trail counters and time-lapse photography from May to September 2012 to evaluate if the trail characteristics use, width, and slope are related to the correction coefficients received after calibration within Sequoia and Kings Canyon National Parks. Using a direct data collection method, 160 hours of calibration data were gathered on eight different trails within SEKI (Muhar et al., 2002; Svajda, 2009). Once collected the Shapiro-Wilk normality test, Kruskal-Wallis variance test, and Spearman's rank correlation test were ran to determine the statistical relationships each trail trait had on each of the 160 correction coefficients received.

Spearman's Rho correlation determined that strong correlations at a 95% confidence interval existed between the trail trait width and the trail calibration coefficients received. This finding therefore suggests that a trail's width does indeed influence the accuracies of automated trail counters; with the wider a trail is the less accurate a counter becomes. A trail's pedestrian volume and the correction coefficients received when calibrating found similar correlations at 95% confidence intervals. This finding also therefore suggests that use on a trail plays a role in the accuracy of a counter; with the higher use a trail experiences the less accurate a counter becomes. Results of the Spearman's Rho correlation test also determined that trail slope has no statistical significant influence on trail counter accuracy at a 95% confidence interval. This finding suggests that slope does not need to be taken as seriously as previously thought when installing and calibrating automated trail counters.

These findings provide an added clarity to the conflicting suggestions of prior research by increasing the understandings of trail calibration in this developing field (Ozbay et al., 2010; Gracia-Longares, 2005; Lindsey et al., 2006; Pettebone et al., 2010; Watson et al., 2000). Due to this disagreement in prior literature however further examination is still highly encouraged (CVC, 2012; Gracia-Longares, 2005; Greene-Roesel et al., 2008; Kuutti, 2012; Lue, 2006; Maldonado et al., 2011; Ozbay et al., 2010; Pettebone et al., 2008; Rauhala et al., 2002; Rupf-Haller et al., 2006; Schneider et al., 2009; Turner et al., 2007; Yang et al., 2010). As this topic continues to be research these discrepancies should be better explained and understood. Further examination on trails with vastly different traits, such as an urban vs. wilderness environment, should also increase these understandings.

By demonstrating strong correlations between trail use, width, and trail counter accuracy, these traits can help take a step toward creating predictions of where correction coefficients will likely lie based on the location of a trail counter prior to calibration being performed. The results give natural resource managers a better understanding of the likely accuracy a counter will have on a certain trail, regardless of calibration method used, and further increases final calibration accuracies by incorporating these prior assumptions. Additionally, by knowing that counters preform more accurately on lower volume and narrower trails, this knowledge can aid in the installation of counters before research begins. For example, placing counters on a section of trail where it naturally bottlenecks will increase the accuracy of the counter and lower the multiplication factor of the correction coefficient.

Understanding that trail use and counter accuracy are highly related to each other also provides valuable insight. This result demonstrates the importance of retrieving detailed calibration data by showing that a calibration factor at a low use time cannot effectively be used at that exact site at a high use time. One way to help increase these accuracies then would be to encourage more detailed and lengthy calibration methods that attempt to include all aspects of trails use (such as weekend, weekday, high use, low use, and holiday collection times).

Determining that slope has a minimal statistical influence on trail counter accuracy also provides resource managers with valuable information. By knowing this, less consideration can be taken when installing counters on trails with heavy slope, saving valuable time during vital busy seasons.

5.2 Recommendations

When installing automated trail counters, the findings of this study can greatly contribute to the ideal placement to promote accuracy. For example, to limit the negative effects of the wideness of a trail on counter accuracy, it is recommended that counters be placed in areas where trails naturally bottleneck, limiting the potential for visitors to walk side by side. Additionally, to limit the influence of pedestrian volume on counters it is recommended that counters not be placed near viewpoints or iconic sites where people often pause and take pictures. By instead installing these devices in areas between such sites, this will increase the likelihood of a continuous flow of visitors instead of congested groups. In an urban setting this recommendation can also be used by placing counters away from traffic signals where pedestrians are likely to stop.

One recommendation for future research in this field is to further examine the calibration process across scientific and academic communities. Through the success and promise that mechanized visitor counting has shown, it is evident that this method of monitoring visitor movement is here to stay (Hadwen et al., 2007; Kahler and Arnberger, 2008; Lue, 2006; Yang et al., 2010). Contradictory recommendations for the length of time necessary for proper trail calibration results in not only a great disconnect from different planning communities and organizations but also the inability for current work to be reexamined in the future with ease (Brandenburg, 2001; CVC, 2012; Gracia-Longares, 2005; Kuutti, 2012;

Muhar et al., 2002; Pettebone et al., 2010). By examining such methods more closely, more efficient and accurate practices will likely be revealed. This examination may also potentially limit contradictory results in the literature by administering research only with the highest calibration standards.

In addition, it is also recommended that further research take place on other trail characteristics that can affect the accuracy of trail counters and the coefficients given when calibrating them. While every trail is different, by examining additional characteristics beyond width, slope, and overall use an all-around better understanding of trail counter accuracy and its potential influences will increase the final accuracy and ease of calibration. Such possible other traits include outside temperature (20 degrees F vs. 80 degrees F), weather (sun vs. rain), and visitor speed (walking vs. jogging). Knowing the effects of other trail traits on the calibration process and correction coefficients will further strengthen the confidence of the results. This will particularly be accomplished by incorporating more of the real-world influences into the calibration process. One example of this need for more understanding can be seen from the literature's disagreement of how pedestrian volumes can play a role in correction coefficients and if Schneider at al. (2009) and Turner et al's. (2007) conflicting results were due to additional unseen urban environmental effects (Cessford and Muhar, 2003; Gasvoda, 1999; Kahler and Arnberger, 2008; Ross, 2005).

It is also recommended in future research to examine trails in different parks and recreation areas. While the eight trails selected for this study all had unique traits, the conditions found on these trails in an alpine environment may vary greatly to that of a similar trail in a different location. Once again Schneider at al. (2009) and Turner et al.'s (2007) conflicting results may be an example of this. By testing these results in different areas a stronger understanding should occur of the effects environmental influences have on trail monitoring and counter calibration. This further understanding should once again help advance counting and calibration methods when using mechanical counters.

5.3 Limitations

One limitation found with this study is the narrow scope of the research only examining eight trails. When this topic is further explored increasing the number of trails studied to better compare and contrast the correction coefficients given should strengthen the confidence of the results.

Furthermore, stronger precautionary steps with trail counter placement techniques should be used. Having an initial 16 different trails for this study, due to the high amount of vandalism that occurred (Refer to Figures 18, 19, 20, 21, and 22), much of the corresponding data became so sparse it was unable to be used. For a similar study it is recommended that the trail counters be better hidden, or signage be set in place explaining the reason for the counters as ways to limit the amount of vandalism and tampering that occurs (Pettebone et al., 2010; Watson et al., 2000).

With the PlotWatcher Pro time-lapse cameras one further limitation arose when using the daylight sensor mode. When taking photos at one-second intervals on this setting file corruption routinely occurred, resulting in the majority of midday hours to be lost. As a result once again several of the study locations were removed due to the limited number of calibration hours to compare with the trail counter counts. For sites that were able to have 20-hours of calibration footage, this problem also may have led to skewness of the data; with more morning and evening hours than normally would have occurred. If repeated it is also recommended that this style of time-lapse cameras be set at larger intervals than one-second to reduce the chance of file corruption occurring.

CHAPTER VI

Bibliography

Arnberger, Arne and B. Hinterberger. "Visitor Monitoring Methods for Managing Public Use Pressures in the Danube Floodplains National Park, Austria." Journal for Nature Conservation (2003): 260-267.

Arnberger, Arne and Christiane Brandenburg. "Visitor Structure of a Heavily Used Conservation Area: The Danube Floodplains National Park, Lower Austria." Monitoring and Management of Visitor Flows in Recreational and Protected Areas. 2002. 7-13.

Arnberger, Arne and Renate Eder. "Monitoring Recreational Activities in Urban Forests using Long-Term Video Observation." Forestry (2007): 1-15.

Arnberger, Arne. Modeling Social Carrying Capacites of Recreation Areas - The Recreation Area Wienerberg. Unpublished Doctoral Dissertation. Vienna, Austria: BOKU - Univeristy of Natural Resources and Applied Life Sciences, 2003.

Arnberger, Arne, Wolfgang Haider and Christiane Brandenburg. "Evaluating Visitor-Monitoring Techniques: A Comparison of Counting and Video Observation Data." Environmental Management (2005): 317-327.

Bancroft, Larry, et al. "Evolution of the Natural Fire Management Program at Sequioa and Kings Canyon National Parks." Symposium and Workshop on Wilderness Fire. Missoula, Montana: USDA Forest Service Technical Report, 1985. 1-12.

Bates, M., G. Wallace and J.J. Vaske. Estimating Visitor Use in Rocky Mountain National Park. Report for Rocky Mountain National Park. Fort Collins, CO: Colorado State University, Human Dimensions in Natural Resource Unit, 2007.

Berk, Richard A. Regression Analysis - A Constructive Critque. Thousand Oaks, California: Sage Publications, Inc., 2004.

Beunen, Raoul, Catharinus F. Jaarsma and Rob N.A. Kramar. "Counting of Visitors in the Meijendel Dunes, The Netherlands." Journal of Coastal Conservation (2004): 109-118.

Bishara, Anthony J. and James B. Hittner. "Testing the Significance of a Correlation with Non-normal Data." Psycological Methods (2012): 399-417.

Brandenburg, C. Registration and Modeling of Visitor Loads in Recreational and Protected Areas. PhD Thesis. Vienna, Austria: University of Vienna, 2001.

Bruton, M.J. Introduction to Transportation Planning. Birmingham: Hutchinson Education, 1970.

Bu, Fanping, et al. Estimating Pedestrian Accident Exposure: Automated Pedestrian Counting Devices Report. Technical Report for CalTrans. Berkeley, California: Safe Transportation Research & Education Center, Institute of Transportation Studies (UCB), UC Berkeley, 2007.

Buckley, R. C. "Ecological Indicators of Toursit Impacts in Parks." Journal of Ecotourism (2003): 54-66.

—. Environmental Impacts of Ecotourism. Cambridge, Massachusetts: CABI Publishing, 2004.

Burns, Robert C., Arne Arnberger and Eick von Ruschkowski. "Scocial Carrying Capacity Challenges in Parks, Forests, and Protected Areas." International Journal of Sociology (2010): 30-50.

Caprio, Anthony C. and Pat Lineback. "Pre-Twentieth Century Fire History of Sequoia and Kings Canyon National Park: A Review and Evaluation of Our Knowledge." Fire in California Ecosystems: Integrating Ecology, Prevention, and Management. San Diego, California, 1997. 1-31.

Cessford, Gordon and Andreas Muhar. "Monitoring Options for Visitor Numbers in National Parks and Natural Areas." Journal for Nature Conservation (2003): 240-250.

Cessford, Gordon, Stuart Cockburn and Murray Douglas. "Developing New Visitor Counters and their Applications for Management." Monitoring and

Management of Visitor Flows in Recreational and Protected Areas. 2002. 14-20.

Conover, W.J. Practical Nonparametric Statistics. Hoboken, New Jersey: John Wiley & Sons, Inc., 1999.

CVC, Credit Valley Conservation. Lands Monitoring Program - Trail Counting Equipment. CVC Technical Report. Credit Valley, Canada: Credit Valley Conservation, 2012.

Davenport, Mae A., et al. Snowmobile Use in Voyageurs National Park: A Visitor Use Estimation Tool. Final Report for Voyageurs National Park, National Park Service. St. Paul, Minnesota: University of Minnesota, Department of Forest Resources, 2003.

Diagle, John J. "Transportation Research Needs in National Parks: A Summary and Exploration of Future Trends." The George Wright Forum. 2008. 57-64.

Dilsaver, Lary M. and William C. Tweed. Challenge of the Big Trees - A Resource History of Sequoia and Kings Canyon National Parks. Three Rivers, CA: Sequoia Natural History Association, Inc., 1990.

Dilworth, Ginni. "Visitor Perceptions of Intelligent Transportation Systems in a National Park." Northeastern Recreation Research Symposium. Bolton Landing, New York: U.S. Forest Service, Northeastern Research Station, 2004. 158-163.

Dilworth, Virginia Ann. Visitor Perceptions of Alternative Transportation Systems and Intelligent Transportation Systems in National Parks. Dissertation. College Station, Texas: Texas A&M University - Office of Graduate Studies, 2003.

Ebdon, Davis. Statistics in Geography. Oxford, UK: Blackwell Publishing, 1992.

Farrell, Tracy A. and Jeffery L. Marion. "Trail Impacts and Trail Impact Management Related to Visitation at Torres del Paine National Park, Chile." Ontario Research Council on Leisure (2002): 21-59.

Fleishman, L., E. Feitelson and I. Salomon. "The Role of Cultural and Demographic Diversity in Crowding Perception: Evidence from Nature Reserves in Isreal." Tourism Analysis (2004): 23-40.

Fowler, R. "Power and Robustnessin Product-Moment Correlation." Applied Psychological Measurement (1987): 419-428.

Gasvoda, Dave. Trail Traffic Counters - Update. Guide. USDA Forest Service. Missoula, MT: Technology and Development Program, 1999.

Gauthier, T. "Detecting Trends Using Spearman's Rank Correlation Coefficient." Environmental Forensics (2001): 359-362.

Gracia-Longares, M. Study of Spatial Patterns of Visitors Using Mechanical Counters, GPS, and GIS Technology in the Slough Creek Subregion of Yellowstone National Park. Master's Thesis. Bozeman, MT: University of Montana, 2005.

Graefe, A.R., F.R. Kruss and J.J. Vaske. "Recreation Impacts and Carrying Capacity: A Visitor Impact Management Framework." National Parks and Conservation Association (1990).

Greene-Roesel, Ryan, et al. Effectiveness of a Commercially Available Automated Pedestrian Counting Device in Urban Environments: Comparison with Manual Counts. Report. Berkeley, California: Safe Transportation Research & Eduaction Center, Institute of Transportation Studies (UBC) UC Berkeley, 2008.

Haas, Glenn E. "Visitor Capacity in the National Park System." NPS Social Science in Review (2001): 1-28.

Hadwen, Wade L, Wendy Hill and Catherine M Pickering. "Icons Under Threat: Why Monitoring Visitors and their Ecological Impacts in Protected Areas Matters." Ecological Management & Restoration (2007): 177-181.

Hammitt, W. E. and D. N. Cole. Wildland Recreation: Ecology and Management. New York, NY: John Wiley & Sons, Inc., 1998.

Hensher, David A. and Kenneth J. Button. Handbook of Transport Modelling. Oxford, UK: Elsevier Ltd, 2005.

Hollander, Myles and Douglas A Wolfe. Nonparametric Statistical Methods. New York, New York: John Wiley & Sons, Inc., 1999.

Holly, Frank Matthew. Incentives and Disincentives for Day Visitors to Park and Ride Public Transportation at Acadia National Park. Thesis. Clemson, South Carloina: Clemson University - Graduate School, 2009.

Kahler, Albert and Arne Arnberger. "A Comparison of Passive Infrared Counter Results with Time Lapse Video Monitoring at a Shared Urban Recreational Trail." MMV4. Vienna, Austria, 2008. 485-489.

Keiter, Robert B. "The National Park System: Visions for Tomorrow." National Resources Journal (2010): 71-110.

Keith, Sandra L. Sequoia National Park - An Illustrated History. Santa Barbara, CA: Sequoia Communications, 1989.

Kuss, R. F., A. R. Graefe and J. J. Vaske. Visitor Impact Management. Review. National Parks and Conservation Association. Washington, DC, 1990.

Kuutti, Jussi. A Test Setup for Comparison of People Flow Sensors. Licentiate's Thesis. Helsinki, Finland: Aalto University, School of Electrical Engineering, Department of Electronics, 2012.

Lawson, Steven R., et al. "Proactive Monitoring and Adaptive Management of Social Carrying Capacity in Arches National Park: An Application of Computer Simulation Modeling." Journal of Environemntal Management (2003): 305-313.

Lawson, Steven R., Jeffrey C. Hallo and Robert E. Manning. "Measuring, Monitoring and Managing Visitor Use in Parks and Protected Areas Using Computer-Based Simulation Modeling." Monitoring, Simulation, and Management of Visitor Landscapes. Tucson, Arizona: The University of Arizona Press, 2008. 175-189.

Leung, Y. and J. L. Marion. "Recreation Impacts and Management in Wilderness: A State-of Knowledge in Review." Wilderness Sciences in a Time of Change Conference. Ogden, Utah: USDA Forest Service, 2000.

Leung, YF and JL Marion. "Assessing Trail Conditions in Protected Areas; Application of a Problem-Assesment Method in Great Smoky Mountains National Park, USA." Environmental Conservation (1999b): 270-279.

—. "The Influence of Sampling Interval on the Accuracy of Trail Impact Assessment." Landscape and Urban Planning (1999a): 167-179.

Lime, D. W. Congestion and Crowding in the National Park System: Guidelines for Management and Recreation. Report. University of Minnesota. St. Paul, MN: Univeristy of Minnesota, 1996.

Lindsey, G. and D.B.L. Nguyen. "Use of Greenway Trails in Indiana." Journal of Urban Planning and Development (2004): 213-217.

Lindsey, Greg, et al. "Neighborhood Correlates of Urban Trail Use." Journal of Physical Activity and Health (2006): 139-157.

Lue, Chi-Chuan. "Estimating Visitor Use with a Photoelectric Counting System: A Calibration Study." Poceedings of the Third International Conference on Monitoring and Management of Visitor Flows in Recreational and Protected Areas. Rapperswill, Switzerland: University of Rapperswill, 2006. 13-17.

Lumley, Thomas, et al. "The Importance of the Normality Assumption in Large Public Health Data Sets." Public Health (2002): 151-169.

Lynch, Emma, D. Joyce and K. Fristrup. "An Assessment of Noise Audibility and Sound Levels in U.S. National Parks." Landscape Ecology (2011): 1297-1309.

Lynch, Joel, et al. Measuring and Monitoring Trail Use: A Nationwide Survey of State and Federal Trail Managers. Michigan Department of Transportation Study. East Lansing, Michigan: Department of Park, Recreation and Tourism Resources - Michigan State University, 2002.

Mackintosh, Barry. "The National Park Service - A Brief History." 1999. The National Park Service.

—. The National Parks: Shaping the System. Washignton, D.C.: Harpers Ferry Center - National Park Service, 2005.

Madden, K. and K. Love. "User Analysis: An Approach to Park Planning and Management." American Society of Landscape Architects (1982).

Maldonado, Ana, Monica Wachowicz and Antonio Vaz'ques-Hoehne. "Movement Surface: a Multilevel Approach for Predicting Visitor Movement in Nature Areas." Environment and Planning B: Planning and Design (2011): 864-878.

Manghabati, A. Einfluss des Tourismus auf die Hochgebirgslandschaft am Biespiel des Nationalpark Berchtesgaden. Forschungsbericht (Research Report). Munich: Berchtesgaden National Park, 1989.

Manning, R. E. "Crowding Norms in Backcountry Settings: A Review and Synthesis." Journal of Leisure Research (1985): 75-89.

Manning, R. E., et al. "Crowding Norms at Frontcountry Sites: A Visual Approach to Setting Standards of Quality." Leisure Science (1996): 39-59.

Manning, Robert E. "How Much is Too Much? - Carrying Capacity of National Parks and Protected Areas." Monitoring and Management of Visitor Flows in Recreations and Protected Areas (2002): 306-313.

—. "Visitor Experience and Resource Protection: A Framework for Managing the Carrying Capacity of National Parks." Journal of Park and Recreation Administration (2001): 93-108.

Marion, J. L. and T. A. Farrell. "Management Practices the Concentrate Visitor Activities: Camping Impact Management at Isle Royale National Park, USA." Journal of Environmental Management (2002): 201-212.

Marnell, L. F. "Methods for Counting River Recreations Users." River Recreation Management and Research Symposium. St. Paul, MN: USDA Forest Service, North Central Forest Experiment Station, 1977. 77-82.

McClaran, M. P. and D. N. Cole. Packstock in Wilderness: Uses, Impacts, Monitoring, and Management. General Techinical Report. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, 1993.

McIntyre, N. "Towards Best Prectice in Visitor Use Monitoring Processes: A Case Study of Australian Protected Areas." Parks and Leisure (1999): 24-29.

Melville, Simon and Juha Ruohonen. "The Development of a Remote-Download System for Visitor Counting." Working Paper. 2004.

Muhar, A., R. Zemann and M. Lengauer. "Permanent Time-Lapse Video Recording for the Quatification of Recreational Activities." Proceedings: Decision Support Systems 2001. Bethesda, MD: American Societ for Photogrammetry and Remote Sensing, 1995. 219-229.

Muhar, Andreas, Arne Arnberger and Christiane Brandenburg. "Methods for Visitor Monitoring in Recreational and Protected Areas: An Overview." Monitoring and Management of Visitor Flows in Recreational and Protected Areas. 2002. 1-6.

Newsome, D., S.A. Moore and R.K. Dowling. "Natural Area Tourism: Ecology, Impacts, and Management." Aspects of Toursim 4. Channel View Publications, 2002.

NPS. Table 9 2011 and 2012 Forcast of Recreation Visits. 2009. 2012 <http://www.nature.nps.gov/stats/forecasts/forecast1112.pdf>.

Orsi, Richard J., Alfred Runte and Marlene Smith-Baranzini. Yosemite and Sequoia - A Century of California National Parks. Berkeley and Los Angeles, CA: University of California Press, 1993.

Osamu, K. Studies of Recreational Activities on Sites. Research Report. Investigation Methods for Recreational Ise of Natural Landscape. Tsukuba-Shi, Ibaraki, Japan: National Institute for Environmental Studies, 2000.

Outdoors, Day 6. "PlotWatcher Pro Game Surveillance System - Know Where to Hunt." User Manual. 2012.

Ozbay, Kaan, et al. Automatic Pedestrian Counter. Report. Trenton, NJ: New Jersey Department of Transportation, 2010.

Pettebone, David, et al. Estimating Visitor Use in Yosemite National Park. Report for Yosemite National Park. Fort Collins, Colorado: Colorado State University, Center for Protected Area Management & Training, 2008.

—. "Estimating Visitors' Travel Mode Choices Along the Bear Lake Road in Rocky Mountain National Park." Journal of Transport Geography (2011): 1210-1221.

Pettebone, David, Peter Newman and Steven R. Lawson. "Estimating Visitor Use at Attraction Sites and Trailheads in Yosemite National Park using Automated Visitor Counters." Landscape and Urban Planning (2010): 229-238.

Pettebone, David, Peter Newman and Theobald David. "A Comparison of Sampling Designs for Monitoring Recreational Trail Impacts in Rocky Mountain National Park." Environmental Management (2009): 523-532.

Pitts, David. Australian Alps Liaison Committee - Visitor Monitoring Strategy. Report. Canaberra: Environment Science and Services, Australian Alps Liaison Committee, 1994.

Polsky, Eric, Cynthia Maloney and Gary Ritter. "The State of Intelligent Transportation Systems in the National Park System." Report. 2001.

Prato, Tony. "Modeling Carrying Capacity for National Parks." Ecological Economics (2001): 321-331.

Rauhala, J., J. Erkkonen and H. Iisalo. "Standardisation of Visitor Counting: Experiences from Finland." The First Conference on Monitoring and Management of Visitor Flows in Recreational and Protected Areas. Vienna, Austria: University of Natural Resources and Applied Life Sciences, Vienna, 2002. 258-263.

Ross, Julian. Visitor Counters in Parks: Management Practice for Counter Calibration. Department of Conservation Technical Series 33. Wellington, New Zealand: Department of Conservation, 2005.

Rupf, R., M. Wernli and R. Haller. "How to Elaborate Precise Visitor Numbers?" Fourth International Conference on Monitoring and Management on Visitor Flows in Recreational and Protected Areas. Montecatini Terme, Italy, 2008. 14-19.

Rupf-Haller, Reto, Michael Wernli and Flurin Filli. "Visitor Counting with Acoustic Slab Sensors in the Swiss National Park." Thrid International Conference on Monitoring and Management of Visitor Flows in Recreational and Protected Areas. Rapperswil, Switzerland: University of Applied Sciences Rapperswil, Switzerland, 2006. 13-17.

Schneider, R., et al. Pedestrian and Bicycle Data Collection in United States Communites: Quantifying Use, Surveying Users, and Documenting Facility Extent. Washington, DC: U.S. Department of Transportation, Office of Natural and Human Environment, 2005.

Sellars, R. "Preserving Nature in National Parks: A History." London, UK: Yale University Press, 1997.

Shelby, B. and T. A. Herberlein. Carrying Capacity in Recreation Settings. Corvallis, OR: Oregon State University Press, 1986.

SNH (Scottish Natural Heritage). Calibration Factors for Automatic People Counters - Guidance for Site Managers. Unpublished. Edinburgh, UK: Scottish National Heritage, 2002.

Stewart, W. P. and D. N. Cole. "Number of Encounters and Experience Quality in Grand Canyon Backcountry: Consistently Negative and Weak Relationships." Journal of Leisure Research (2001): 106-120.

Strong, Douglas Hillman. Tress . . . Or Timber? - The Story of Sequoia and Kings Canyon National Parks. Three Rivers, CA: Sequoia National History Association, 1968.

Švajda, Juraj. "Contribution for Improvement of Visitor Monitoring in the Tatra National Park ." Eco.mont (2009): 13-18.

Tomes, Patricia A. and Carl Knoch. Ghost Town Trail 2009 User Survey and Economic Impact Analysis. Impact Analysis. Washington, DC: Rails-to-Trails Conservancy, 2009.

TRAFx. "TRAFx G3 Dock." TRAFx - Count on us. 2012a.

—. "TRAFx Infrared Trail Counter." TRAFx - Count on us. 2012b.

TRAFx, Research LTD Data Net. "TRAFx Manual." TRAFx Advanced Counting Systems. 2012.

Turner, S., et al. Testing and Evaluation of Pedestrian Sensors. Report. Texas Transportation Institute. College Station, Texas: Texas A&M University, 2007.

Upchurch, Jonathan. "Service Times and Capacity at National Park Entrances." 2006.

Vander Stoep, G.A. The Effect of Personal Communication and Group Incentives on Depreciative Behavior by Organized Groups in a National Park. PhD Thesis. College Station, Texas: Texas A&M, 1986.

Vaske, Jerry J. and Lori B. Shelby. "Crowding as a Descriptive Indicator and an Evaluative Standard: Results from 30 Years of Research." Leisure Science (2008): 111-126.

Vaughan, Eva D. Statistics - Tools for Understanding Data in the Behavioral Sciences. Upper Saddle River, New Jersey: Prentice-Hall, Inc., 1998.

von Janowsky, J. and G. Becker. "Characteristics and Needs for Different User Groups in the Urban Forest of Stuttgart." Journal for Nature Conservation (2003): 251-259.

Wadsworth, Rueben Edward. Shuttle to Serenity: The History and Impact of Zion National Park's Transportation System. Thesis. Las Vegas, Nevada: University of Nevada, Las Vegas - University Libraries, 2009.

Wagar, J. Alan and Joel F. Thalheimer. Trail Results of Net Count Procedures for Estimating Visitor Use at Developed Recreation Sites. Research Note. Ogden, Utah: Intermountain Forest & Range Experiment Station - United States Department of Agriculture Forest Service, 1969.

Wardell, Matthew J. and Susan A. Moore. Collection, Storage & Applicatin of Visitor Use Data in Protected Areas - Guiding Principles and Case Studies. Technical Report. Gold Coast, Australia: CRC for Sustainable Tourism Pty Ltd., 2004.

Warnken, Jan and Michael Blumenstein. Monitoring Visitor Use in Australian Terrestrial and Marine Protected Areas - Practical Applications of Technologies. Technical Report. Gold Coast, Australia: CRC for Sustainable Tourism Pty Ltd., 2008.

Watson, A. E., R. Cronn and N. A. Christensen. Monitoring Inter-Group Encounters in Wilderness. General Technical Report. Fort Collins, CO: USDA, Forest Service, Rocky Mountain Research Station, 1998.

Watson, Alan E., et al. Wilderness Recreation Use Estimation: A Handbook of Methods and Systems. General Technical Report. Ogden, Utah: U.S.

Department of Agriculture - Forest Service - Rocky Mountain Research Station, 2000.

White, Dave D. "An Interpretive Study of Yosemite National Park Visitors' Perspectives Toward Alternative Transportation in Yosemite Valley." Environmental Management (2007): 50-62.

White, Mike. Sequoia National Park - A Complete Hiker's Guide. Berkeley, CA: Wilderness Press, 2004.

Whyte, W. H. The Social Life of Small Urban Spaces. Washington, DC: The Conservation Foundation, 1980.

Worboys, G. L., M. Lockwood and T. De Lacy. Protected Area Management: Principles and Practice. Melbourne, Vic.: Oxford University Press, 2005.

Yang, Hong, Kaan Ozbay and Bartin Bekir. "Investigating the Performance of Automatic Counting Sensors for pedesdtrian Traffic Data Collection." 12th WCTR. Lisbon, Portugal, 2012. 1-11.

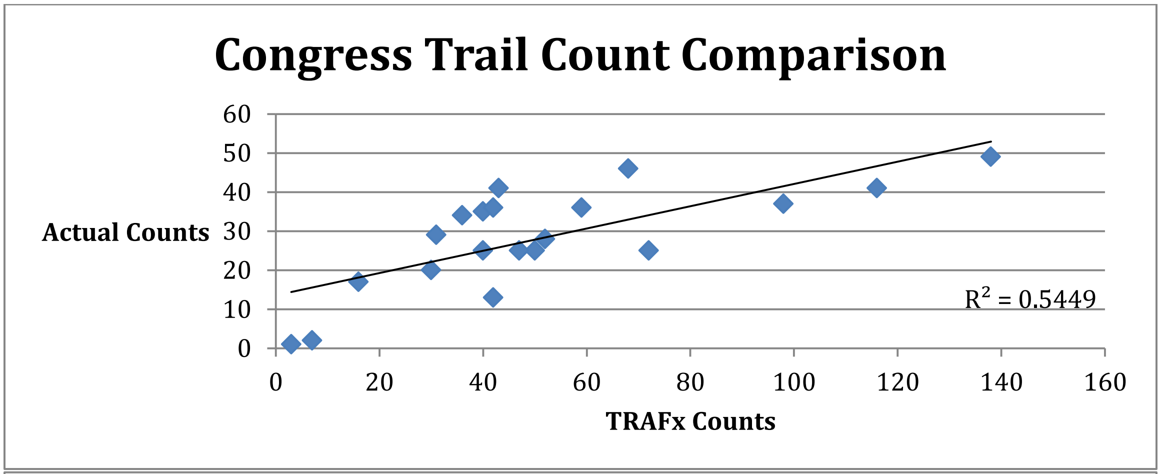
Zimmerman, D.W. and B.D. Zumbo. "Significance Testing of Correlation Using Scores, Ranks, and Modified Ranks." Educational and Psychological Measurement (1993): 897-904.

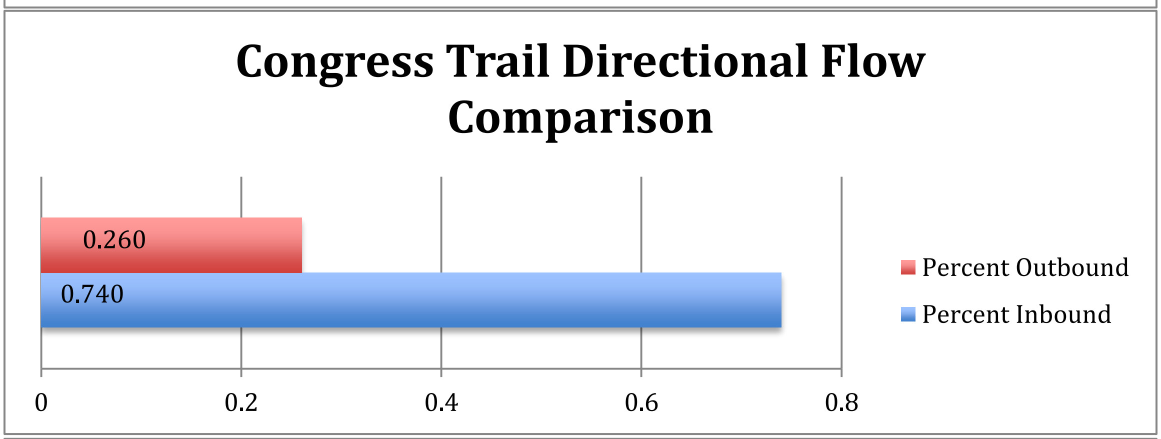
CHAPTER VII

Appendix

7.1 List of Additional Figures

Figure 32 – COC2 Summary Data





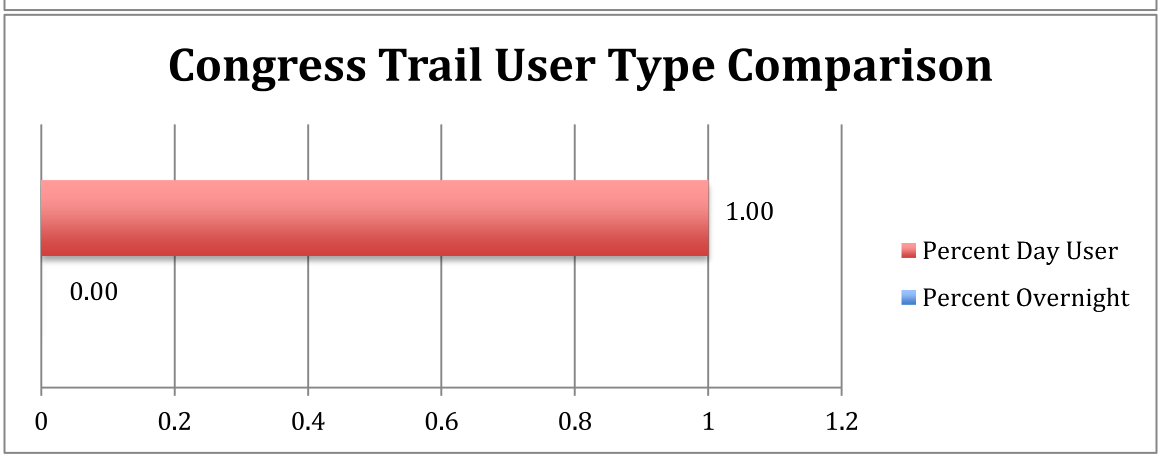
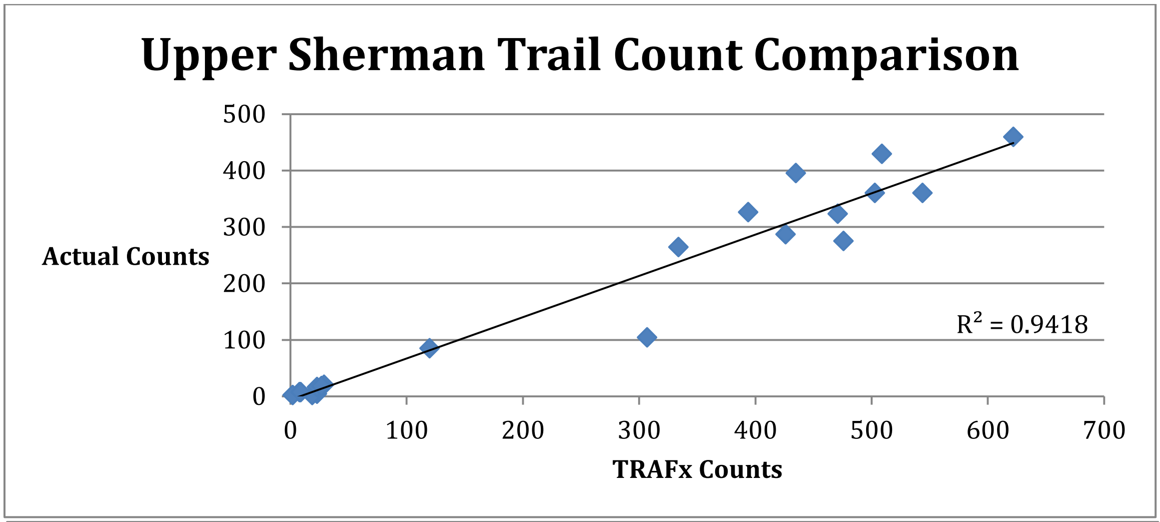
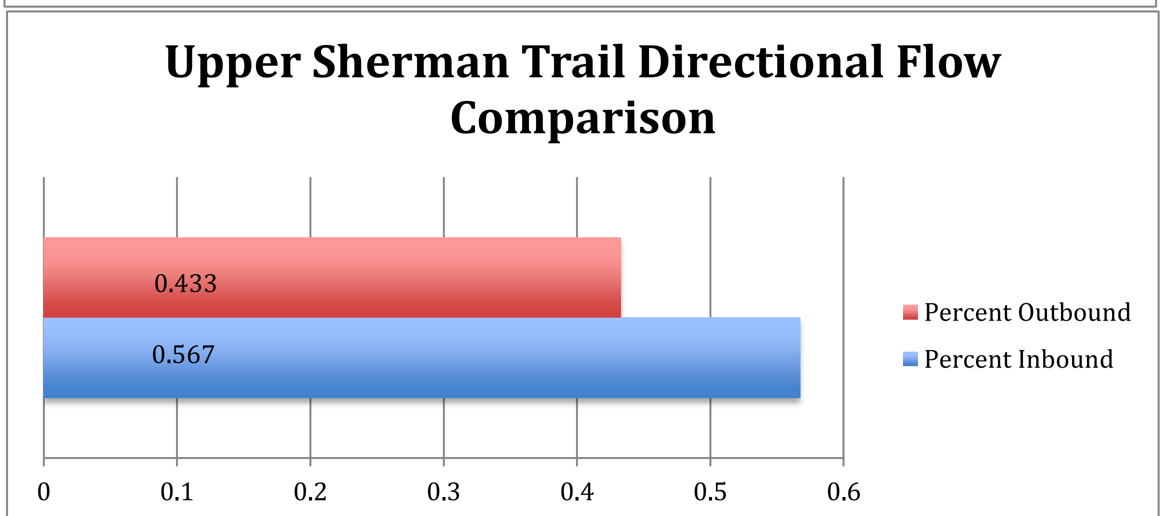


Figure 33 – GSC2 Summary Data





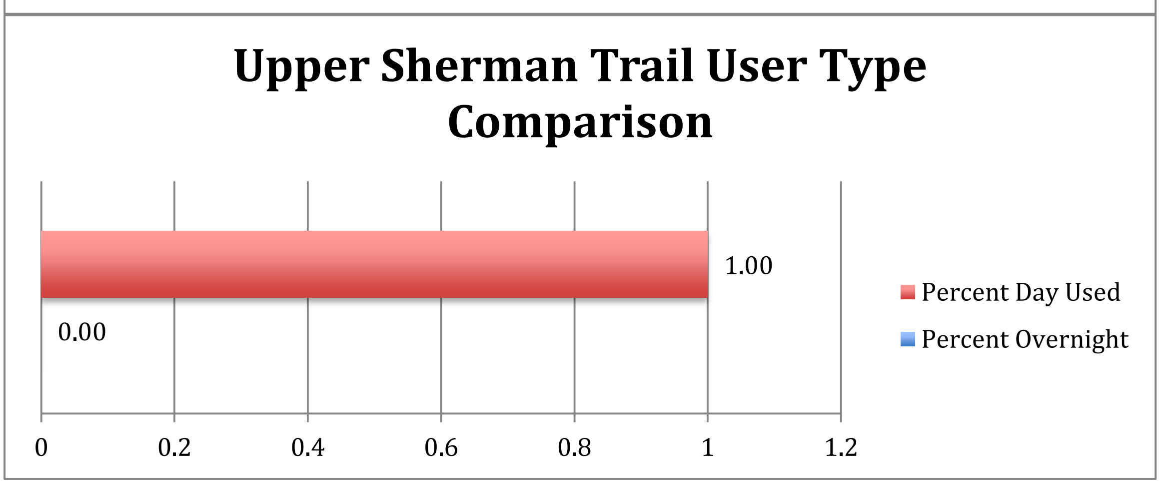
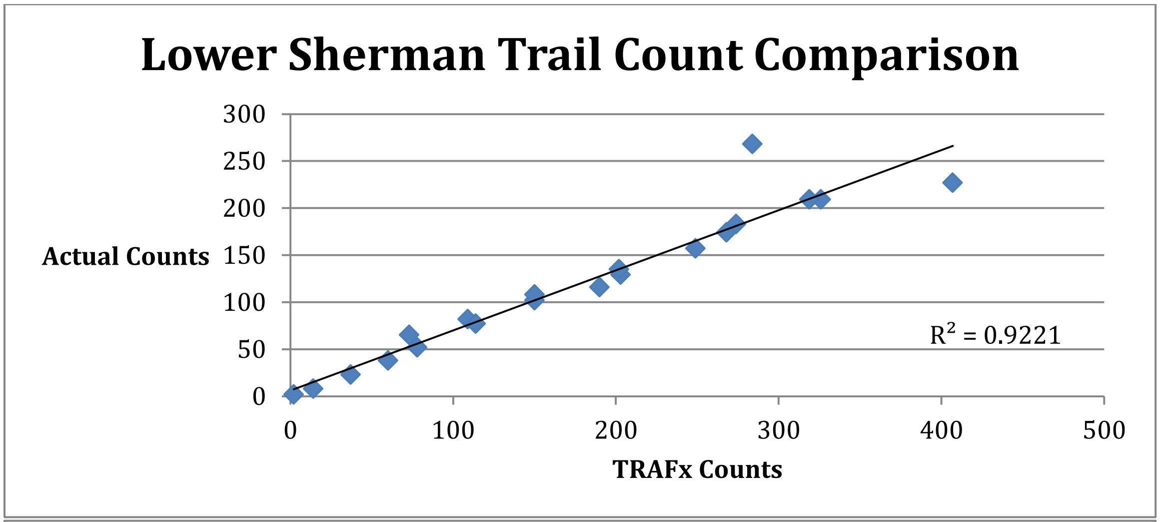
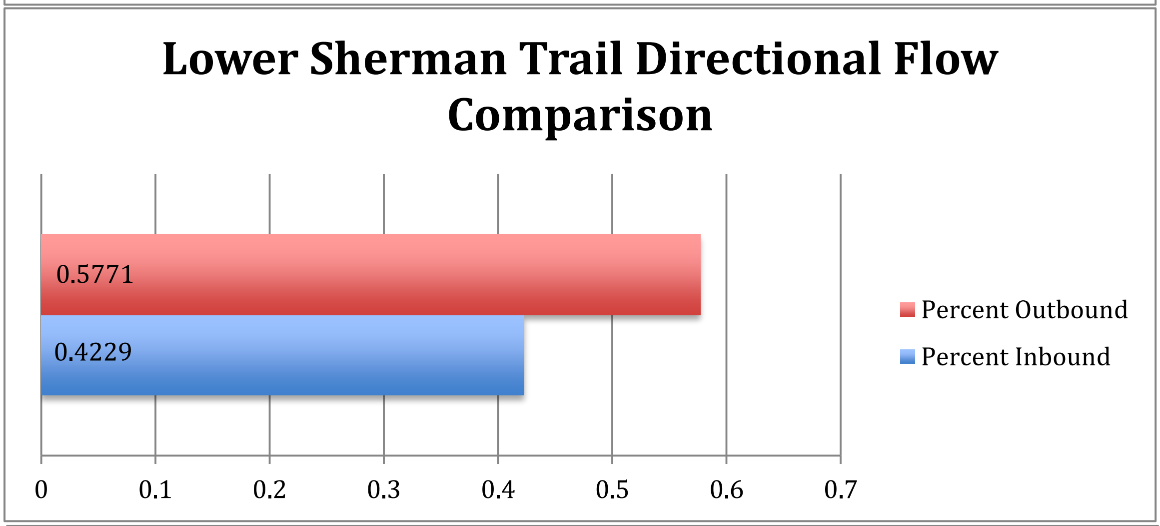


Figure 34 – GSC3 Summary Data





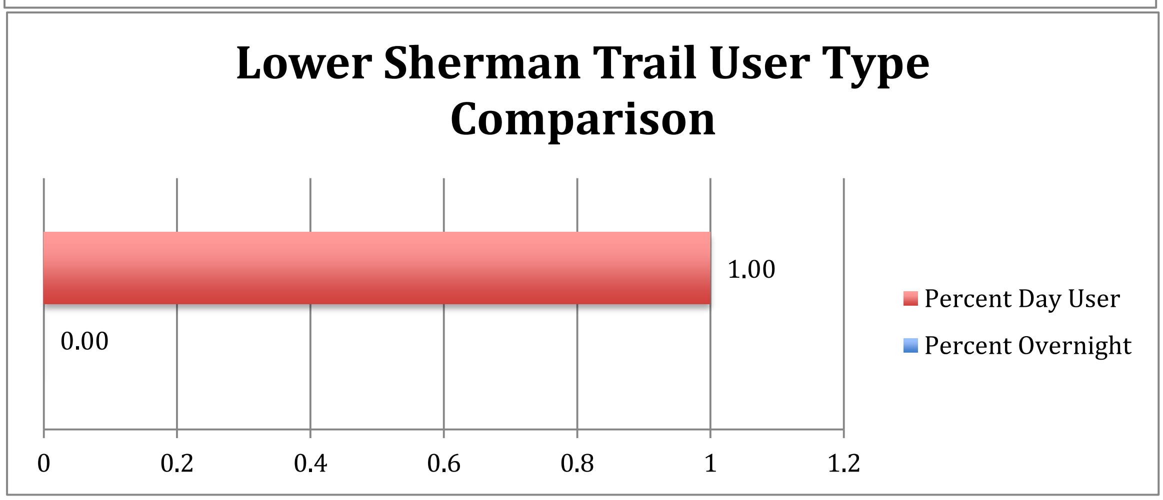


Figure 35 - GGC2 Summary Data

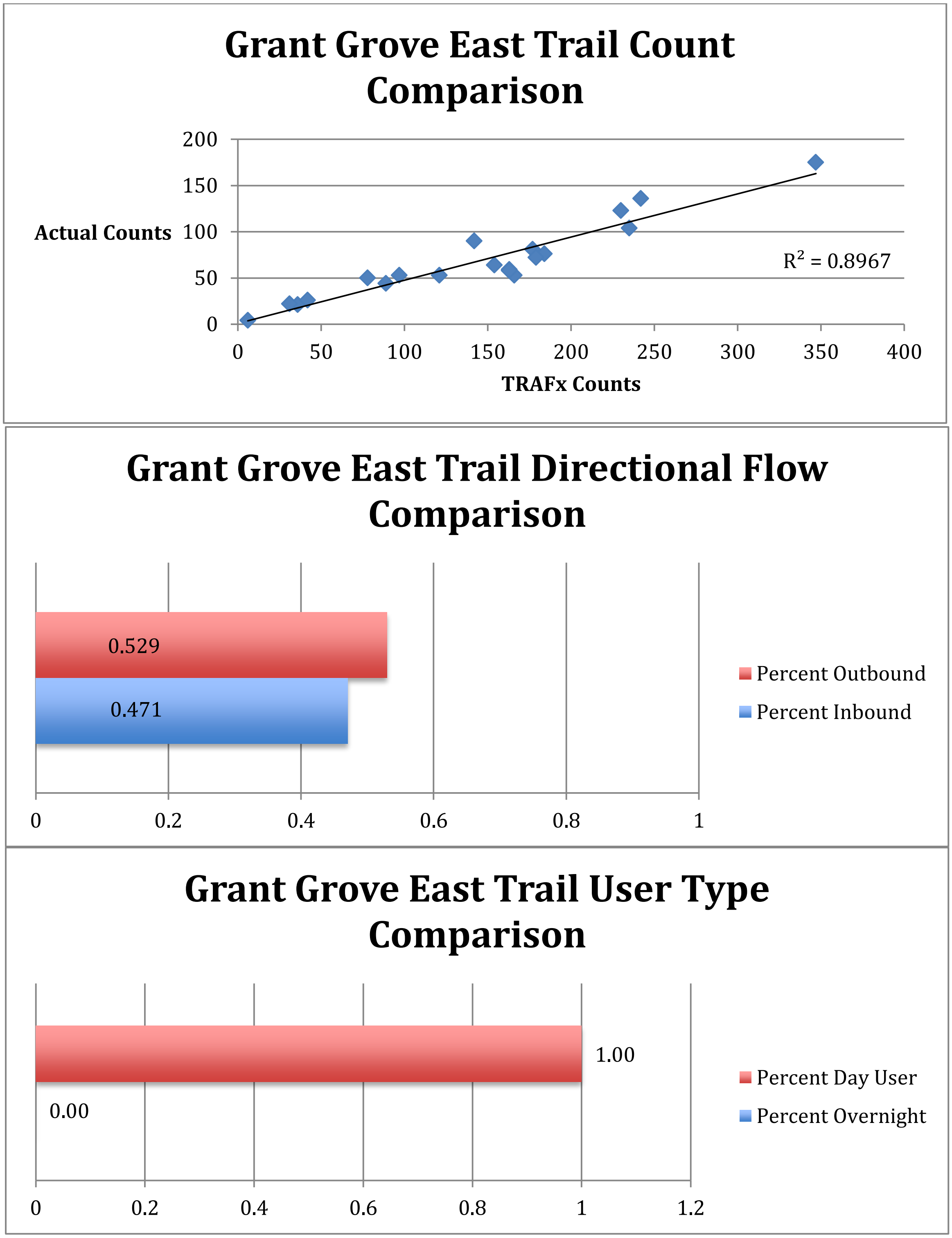
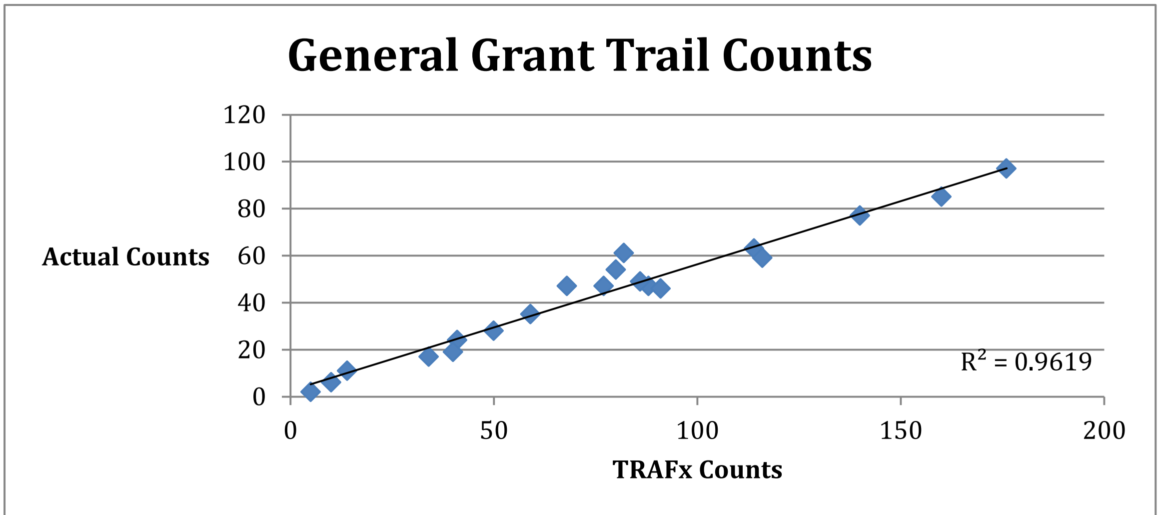
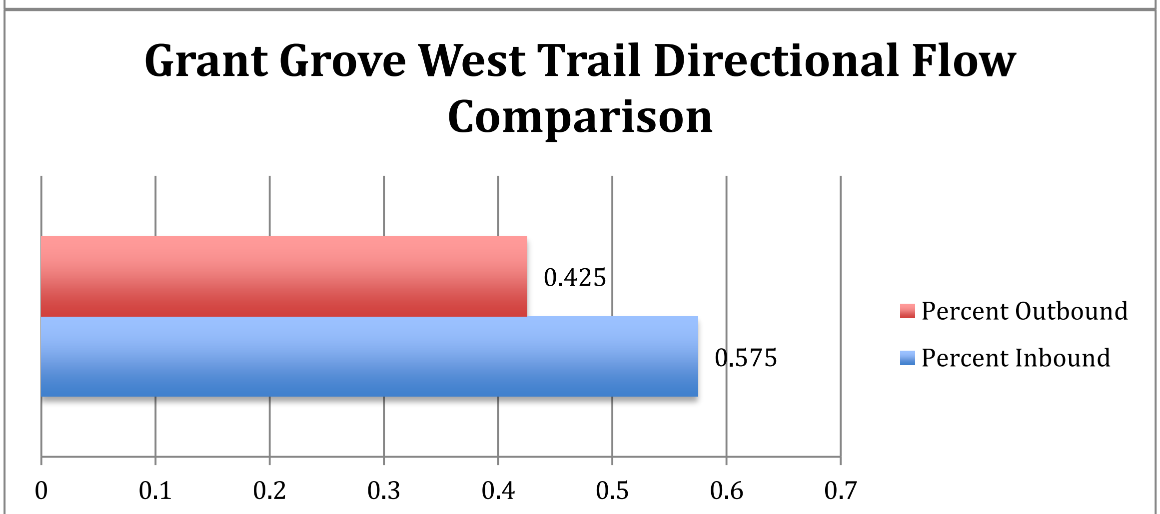


Figure 36 – GGC3 Summary Data





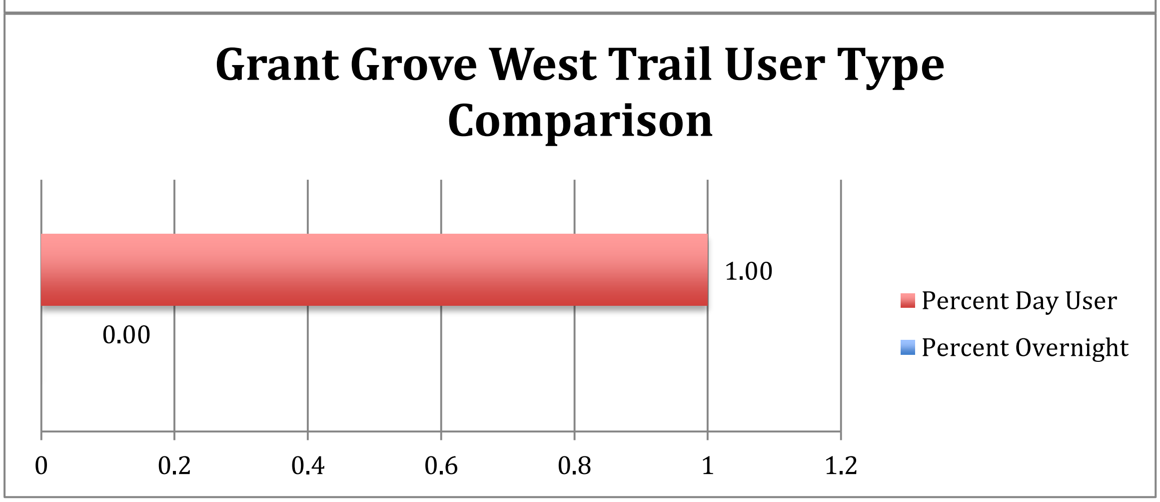
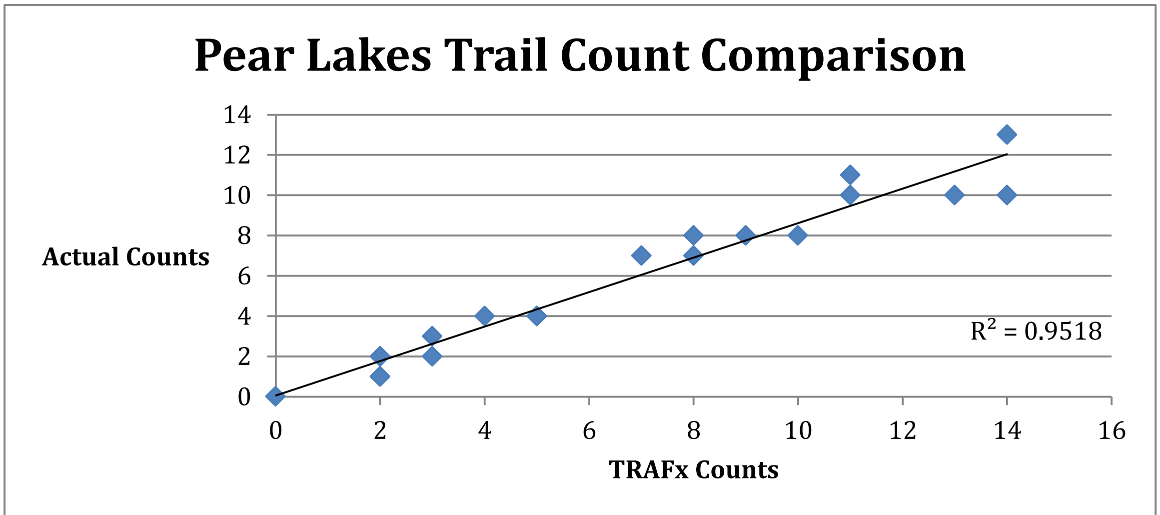
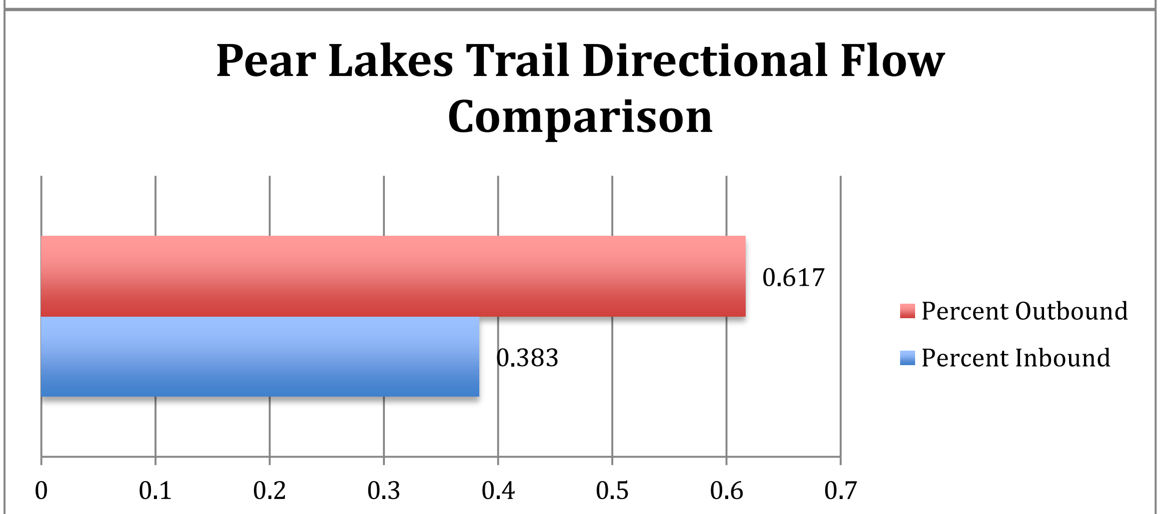


Figure 37: PLC Summary Data





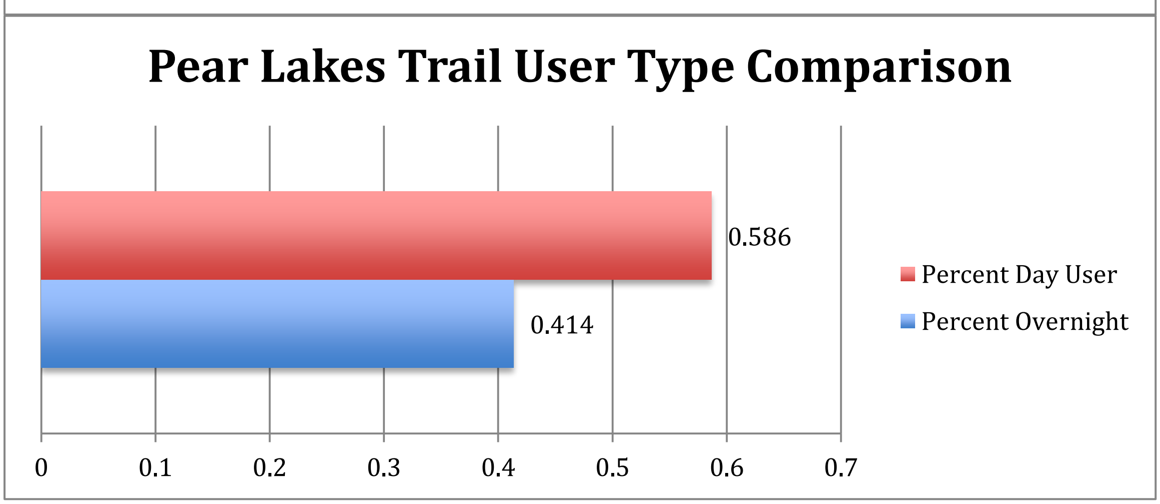
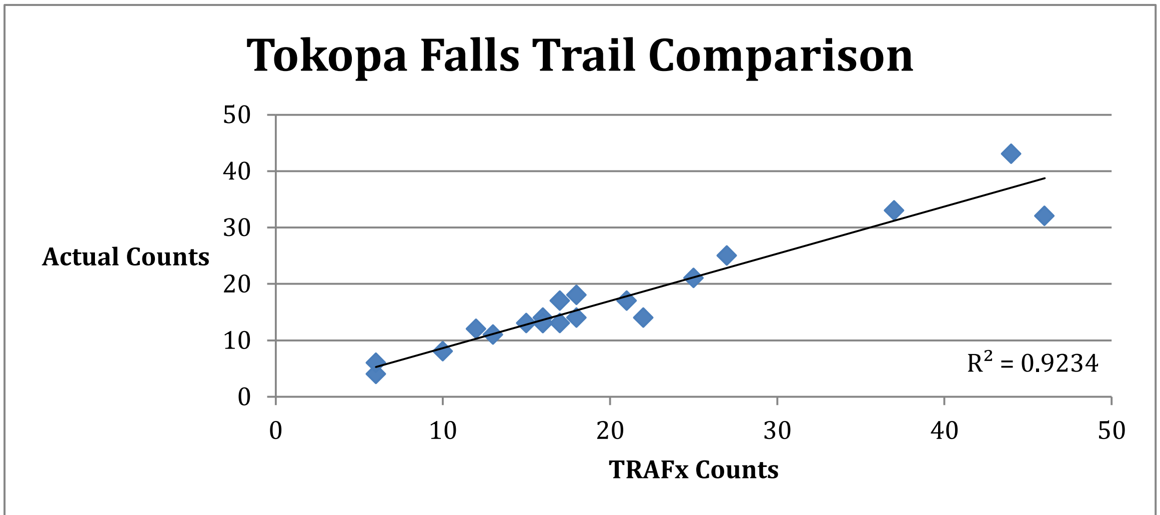
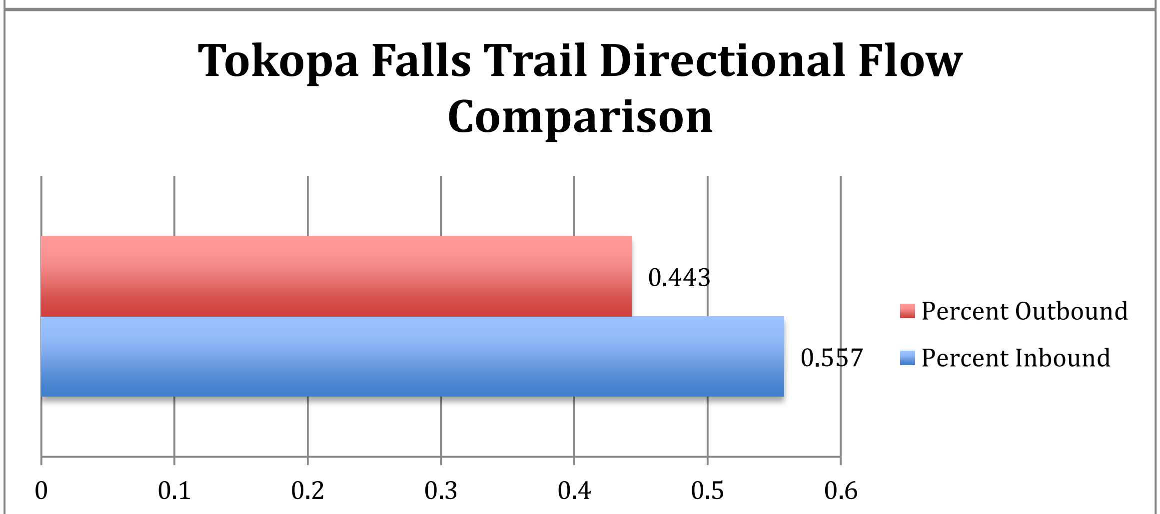


Figure 38 – TFC Summary Data





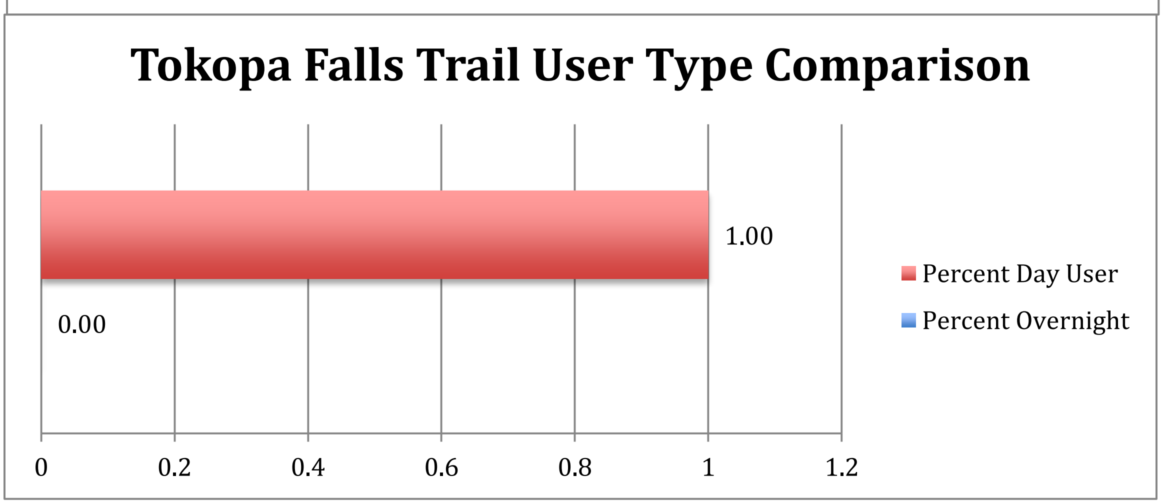


Figure 39 – TLC Summary Data

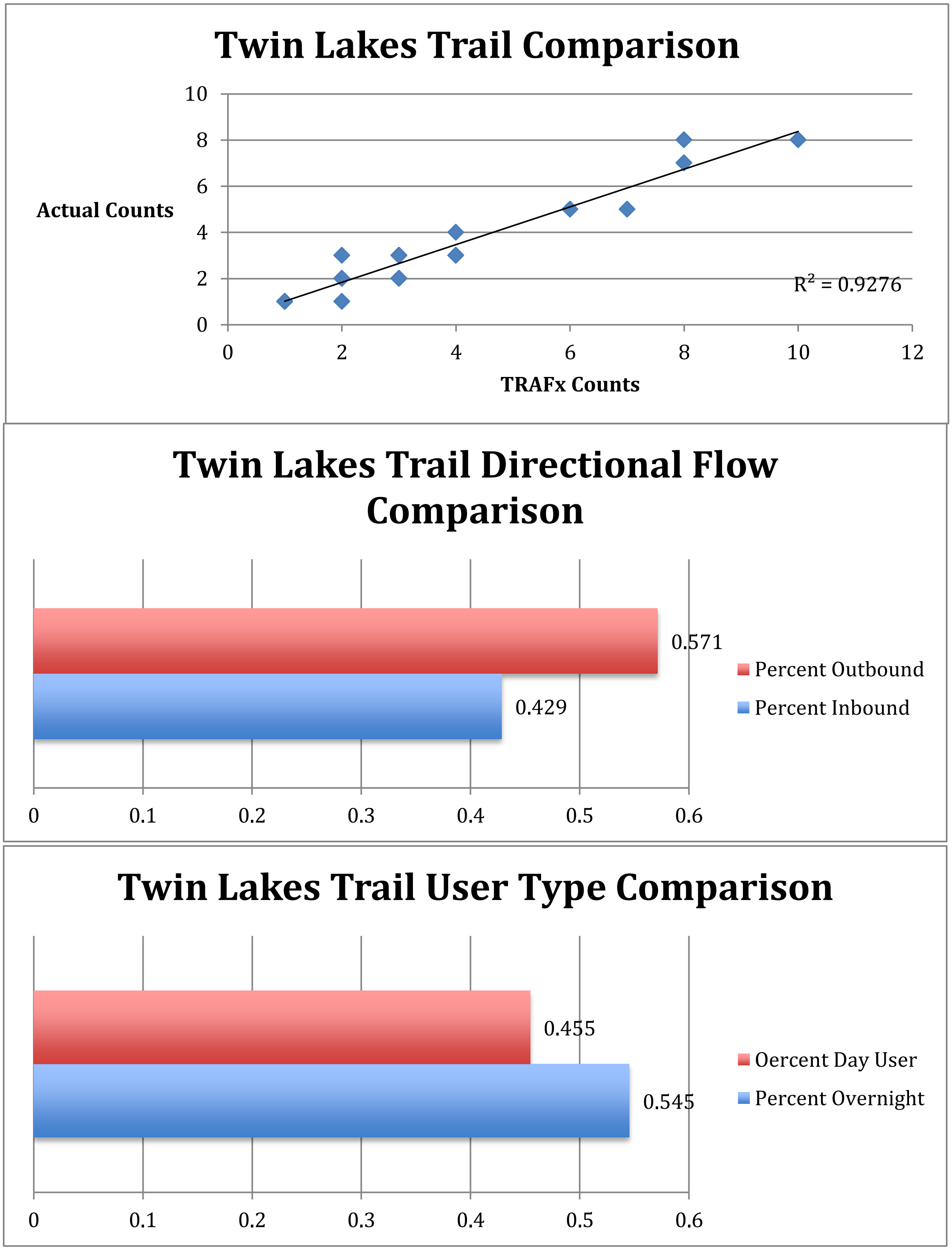
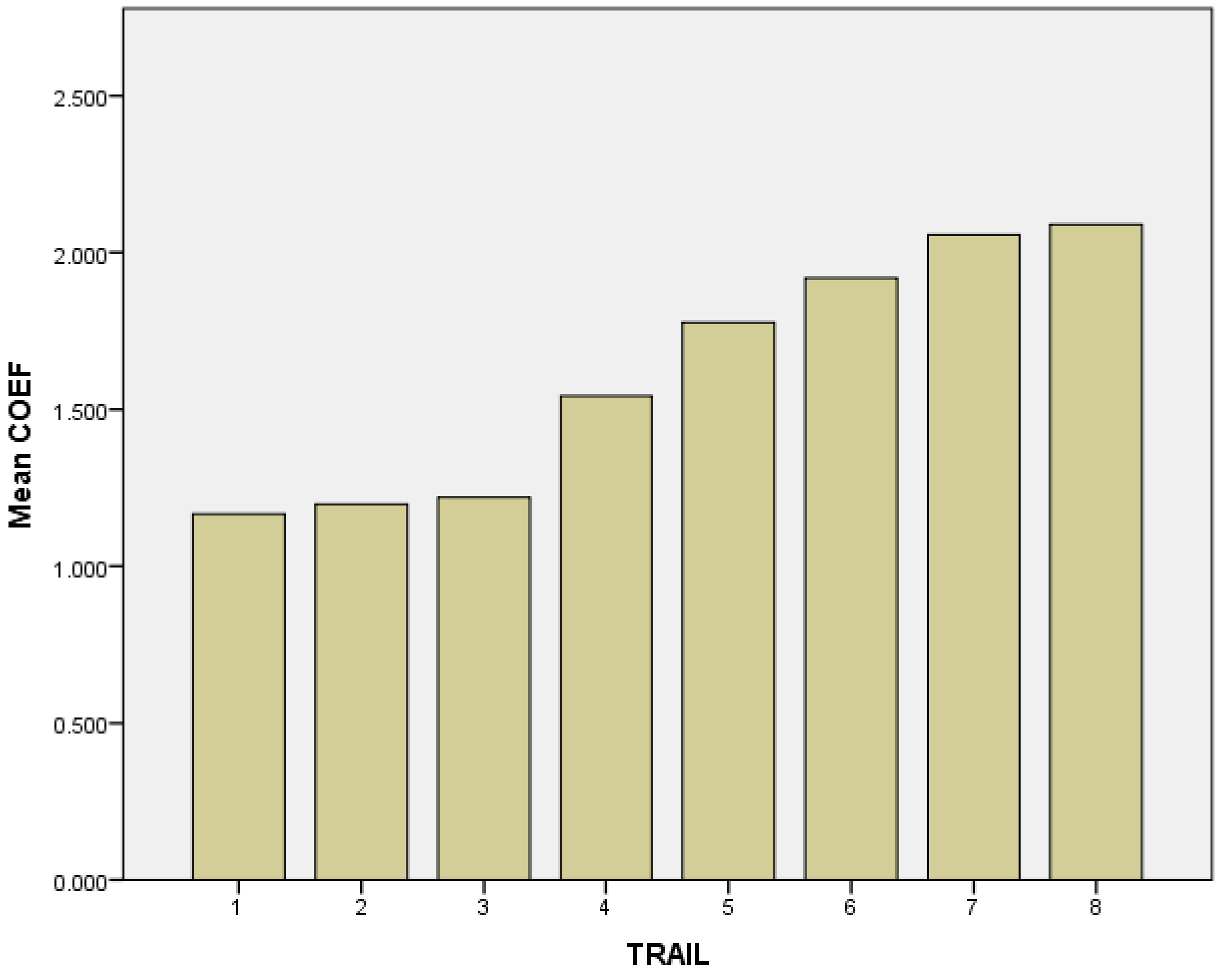


Figure 40 – Trail Coefficient Comparison



7.2 List of Tables

Table 9 – COC2 Observed Counts

Day	Time	Inbound	Outbound	Overnight Visitors	Day Visitors	Total Visitors	TRAFX Visitor Total	Correction Coef
8/10/12	12:00	105	33	0	138	138	49	2.816326531
8/10/12	13:00	74	42	0	116	116	41	2.829268293
8/10/12	14:00	57	11	0	68	68	46	1.47826087
8/25/12	15:00	65	33	0	98	98	37	2.648648649
8/25/12	16:00	32	8	0	40	40	35	1.142857143
8/25/12	17:00	33	10	0	43	43	41	1.048780488
8/26/12	15:00	38	4	0	42	42	36	1.166666667
8/26/12	16:00	25	25	0	50	50	25	2
8/26/12	17:00	7	9	0	16	16	17	0.941176471
8/27/12	15:00	34	18	0	52	52	28	1.857142857
8/27/12	16:00	23	7	0	30	30	20	1.5
8/27/12	17:00	24	18	0	42	42	13	3.230769231
8/28/12	11:00	28	8	0	36	36	34	1.058823529
8/28/12	12:00	64	8	0	72	72	25	2.88
8/28/12	13:00	39	1	0	40	40	25	1.6
8/28/12	14:00	43	16	0	59	59	36	1.638888889
8/28/12	15:00	36	11	0	47	47	25	1.88
8/28/12	16:00	25	6	0	31	31	29	1.068965517
8/29/12	8:00	3	0	0	3	3	1	3
8/29/12	9:00	7	0	0	7	7	2	3.5
Totals and Coef Average		762	268	0	1030	1030	565	1.9643288

Percent Inbound		0.739806
Percent Outbound		0.260194
Percent Overnighter		0
Percent Day User		1

Table 10 – GSC2 Observed Counts

Day	Time	Inbound	Outbound	Overnight Visitors	Day Visitors	Total Visitors	TRAFX Visitor Total	Correction Coef
6/28/12	14:00	286	190	0	476	476	275	1.730909091
6/28/12	15:00	196	198	0	394	394	326	1.208588957
6/29/12	7:00	19	4	0	23	23	4	5.75
6/29/12	8:00	19	0	0	19	19	2	9.5
6/29/12	11:00	180	127	0	307	307	104	2.951923077
6/29/12	12:00	192	142	0	334	334	264	1.265151515
6/29/12	15:00	240	195	0	435	435	395	1.101265823
6/29/12	16:00	203	223	0	426	426	287	1.484320557
6/30/12	7:00	4	4	0	8	8	7	1.142857143
6/30/12	8:00	22	7	0	29	29	20	1.45
6/30/12	9:00	97	23	0	120	120	85	1.411764706
6/30/12	15:00	293	216	0	509	509	429	1.186480186
6/30/12	16:00	263	208	0	471	471	323	1.458204334
7/1/12	7:00	0	2	0	2	2	2	1
7/1/12	8:00	16	7	0	23	23	16	1.4375
7/1/12	14:00	351	271	0	622	622	459	1.355119826
7/1/12	15:00	322	222	0	544	544	360	1.511111111
7/1/12	16:00	270	233	0	503	503	360	1.397222222
7/21/12	7:00	8	1	0	9	9	7	1.285714286
7/21/12	8:00	15	12	0	27	27	18	1.5
Totals and Coef Average		2996	2285	0	5281	5281	3743	2.056406642

Percent Inbound		0.567317
Percent Outbound		0.432683
Percent Overnighter		0
Percent Day User		1

Table 11 – GSC3 Observed Counts

Day	Time	Inbound	Outbound	Overnight Visitors	Day Visitors	Total Visitors	TRAFX Visitor Total	Correction Coef
7/10/12	13:00	94	155	0	249	249	157	1.585987261
7/10/12	15:00	121	163	0	284	284	268	1.059701493
7/10/12	16:00	93	175	0	268	268	174	1.540229885
7/10/12	17:00	67	136	0	203	203	129	1.573643411
7/10/12	18:00	42	67	0	109	109	82	1.329268293
7/10/12	19:00	38	35	0	73	73	65	1.123076923
7/11/12	7:00	1	1	0	2	2	2	1
7/11/12	8:00	7	7	0	14	14	8	1.75
7/11/12	9:00	32	28	0	60	60	38	1.578947368
7/11/12	10:00	39	39	0	78	78	52	1.5
7/11/12	11:00	63	87	0	150	150	102	1.470588235
7/12/12	10:00	66	48	0	114	114	77	1.480519481
7/12/12	12:00	212	195	0	407	407	227	1.792951542
7/12/12	13:00	150	176	0	326	326	209	1.559808612
7/12/12	14:00	116	158	0	274	274	183	1.49726776
7/12/12	15:00	122	197	0	319	319	209	1.526315789
7/12/12	16:00	74	128	0	202	202	135	1.496296296
7/12/12	17:00	82	108	0	190	190	116	1.637931034
7/12/12	18:00	52	98	0	150	150	108	1.388888889
7/12/12	19:00	13	24	0	37	37	23	1.608695652
Totals and Coef Average		1484	2025	0	3509	3509	2364	1.475005896

Percent Inbound		0.422913
Percent Outbound		0.577087
Percent Overnighter		0
Percent Day User		1

Table 12 – GGC2 Observed Counts

Day	Time	Inbound	Outbound	Overnight Visitors	Day Visitors	Total Visitors	TRAFX Visitor Total	Correction Coef
8/9/12	15:00	38	146	0	184	184	76	2.421052632
8/9/12	16:00	103	74	0	177	177	81	2.185185185
8/9/12	17:00	119	123	0	242	242	136	1.779411765
8/9/12	18:00	32	65	0	97	97	53	1.830188679
8/10/12	15:00	68	86	0	154	154	64	2.40625
8/10/12	16:00	139	96	0	235	235	104	2.259615385
8/10/12	18:00	29	60	0	89	89	44	2.022727273
8/11/12	8:00	24	12	0	36	36	21	1.714285714
8/11/12	9:00	90	52	0	142	142	90	1.577777778
8/11/12	10:00	136	94	0	230	230	123	1.869918699
8/11/12	11:00	184	163	0	347	347	175	1.982857143
8/11/12	17:00	45	121	0	166	166	53	3.132075472
8/12/12	7:00	12	19	0	31	31	22	1.409090909
8/12/12	8:00	26	16	0	42	42	26	1.615384615
8/13/12	9:00	40	38	0	78	78	50	1.56
8/13/12	14:00	81	98	0	179	179	72	2.486111111
8/13/12	15:00	53	68	0	121	121	53	2.283018868
8/13/12	16:00	56	107	0	163	163	59	2.762711864
8/13/12	17:00	78	85	0	163	163	58	2.810344828
8/14/12	7:00	3	3	0	6	6	4	1.5
Totals and Coef Average		1356	1526	0	2882	2882	1364	2.080400396

Percent Inbound		0.470507
Percent Outbound		0.529493
Percent Overnighter		0
Percent Day User		1

Table 13 – GGC3 Observed Counts

Day	Time	Inbound	Outbound	Overnight Visitors	Day Visitors	Total Visitors	TRAFX Visitor Total	Correction Coef
8/22/12	14:00	77	83	0	160	160	85	1.882352941
8/22/12	15:00	29	59	0	88	88	47	1.872340426
8/22/12	16:00	47	39	0	86	86	49	1.755102041
8/22/12	17:00	36	23	0	59	59	35	1.685714286
8/23/12	7:00	3	2	0	5	5	2	2.5
8/23/12	9:00	63	17	0	80	80	54	1.481481481
8/23/12	11:00	65	49	0	114	114	63	1.80952381
8/23/12	12:00	67	73	0	140	140	77	1.818181818
8/23/12	14:00	55	22	0	77	77	47	1.638297872
8/23/12	15:00	64	27	0	91	91	46	1.97826087
8/23/12	16:00	76	40	0	116	116	59	1.966101695
8/24/12	8:00	2	8	0	10	10	6	1.666666667
8/24/12	9:00	16	18	0	34	34	17	2
8/24/12	17:00	26	42	0	68	68	47	1.446808511
8/24/12	18:00	22	19	0	41	41	24	1.708333333
8/25/12	8:00	12	2	0	14	14	11	1.272727273
8/25/12	9:00	42	8	0	50	50	28	1.785714286
8/25/12	10:00	56	26	0	82	82	61	1.344262295
8/25/12	11:00	112	64	0	176	176	97	1.81443299
8/25/12	17:00	10	30	0	40	40	19	2.105263158
Totals and Coef Average		880	651	0	1531	1531	874	1.776578288

Percent Inbound		0.574788
Percent Outbound		0.425212
Percent Overnighter		0
Percent Day User		1

Table 14 – PLC Observed Counts

Day	Time	Inbound	Outbound	Overnight Visitors	Day Visitors	Total Visitors	TRAFX Visitor Total	Correction Coef
7/24/2012	7:00	1	0	0	1	1	1	1.000
7/24/2012	8:00	2	0	0	2	2	1	2.000
7/24/2012	13:00	4	4	3	5	8	8	1.000
7/24/2012	14:00	5	6	7	4	11	10	1.100
7/24/2012	15:00	5	9	4	10	14	10	1.400
7/24/2012	19:00	4	7	0	11	11	11	1.000
7/25/2012	7:00	7	0	7	0	7	7	1.000
7/25/2012	8:00	3	1	2	2	4	4	1.000
7/25/2012	11:00	7	2	2	7	9	8	1.125
7/25/2012	12:00	0	13	8	5	13	10	1.300
7/25/2012	13:00	0	8	0	8	8	7	1.143
7/25/2012	14:00	0	2	0	2	2	2	1.000
7/26/2012	7:00	2	0	0	2	2	2	1.000
7/26/2012	8:00	3	0	3	0	3	2	1.500
7/26/2012	11:00	3	11	11	3	14	13	1.077
7/26/2012	12:00	2	1	1	2	3	3	1.000
7/26/2012	13:00	2	3	5	0	5	4	1.250
7/26/2012	14:00	0	5	0	5	5	4	1.250
7/26/2012	15:00	0	10	2	8	10	8	1.250
7/27/2012	7:00	2	0	0	2	2	1	2.000
Totals and Coef Average		52	82	55	79	134	116	1.231

Percent Inbound	0.38806
Percent Outbound	0.61194
Percent Overnighter	0.41045
Percent Day User	0.58955

Figure 15 – TFC Observed Counts

Day	Time	Inbound	Outbound	Overnight Visitors	Day Visitors	Total Visitors	TRAFX Visitor Total	Correction Coef
5/14/12	9:00	11	6	0	17	17	13	1.307692308
5/14/12	18:00	0	12	0	12	12	12	1
5/14/12	19:00	2	8	0	10	10	8	1.25
5/15/12	9:00	3	3	0	6	6	4	1.5
5/15/12	10:00	8	7	0	15	15	13	1.153846154
5/15/12	12:00	6	0	0	6	6	6	1
5/17/12	11:00	9	7	0	16	16	13	1.230769231
5/17/12	12:00	10	6	0	16	16	14	1.142857143
5/18/12	13:00	18	7	0	25	25	21	1.19047619
5/18/12	14:00	24	22	0	46	46	32	1.4375
5/18/12	15:00	11	16	0	27	27	25	1.08
5/18/12	16:00	21	16	0	37	37	33	1.121212121
5/19/12	9:00	11	2	0	13	13	11	1.181818182
5/19/12	10:00	40	4	0	44	44	43	1.023255814
5/19/12	18:00	4	18	0	22	22	14	1.571428571
5/21/12	11:00	11	6	0	17	17	17	1
5/21/12	12:00	7	11	0	18	18	18	1
5/21/12	13:00	7	9	0	16	16	13	1.230769231
5/21/12	14:00	13	5	0	18	18	14	1.285714286
5/21/12	19:00	8	13	0	21	21	17	1.235294118
Totals and Average		224	178	0	402	402	341	1.197131667

Percent Inbound		0.5572139
Percent Outbound		0.4427861
Percent Overnighter		0
Percent Day User		1

Table 16 – TLC Observed Counts

Day	Time	Inbound	Outbound	Overnight Visitors	Day Visitors	Total Visitors	TRAFX Visitor Total	Correction Coef
6/10/12	8:00	3	0	2	1	3	3	1
6/10/12	10:00	3	5	8	0	8	8	1
6/10/12	11:00	2	2	4	0	4	3	1.333333333
6/10/12	12:00	0	2	2	0	2	3	0.666666667
6/11/12	9:00	0	1	1	0	1	1	1
6/11/12	16:00	0	3	0	3	3	2	1.5
6/14/12	17:00	0	6	0	6	6	5	1.2
6/15/12	7:00	1	0	1	0	1	1	1
6/15/12	11:00	7	0	4	3	7	5	1.4
6/16/12	9:00	8	0	6	2	8	7	1.142857143
6/16/12	10:00	4	0	0	4	4	3	1.333333333
6/16/12	12:00	2	0	0	2	2	1	2
6/16/12	14:00	0	3	0	3	3	2	1.5
6/16/12	15:00	1	3	0	4	4	4	1
6/16/12	16:00	0	3	0	3	3	3	1
6/16/12	19:00	0	3	3	0	3	3	1
6/17/12	10:00	0	1	1	0	1	1	1
6/17/12	12:00	2	8	8	2	10	8	1.25
6/17/12	14:00	0	2	0	2	2	2	1
6/18/12	9:00	0	2	2	0	2	2	1
Totals and Average		33	44	42	35	77	67	1.166309524

Percent Inbound		0.42857
Percent Outbound		0.57143
Percent Overnighter		0.54545
Percent Day User		0.45455

Table 17 – COC2 Descriptive Statistics

Descriptives

			Statistic	Std. Error
Total Visitors	Mean		50.30	7.688
	95% Confidence Interval for Mean	Lower Bound	34.21	
		Upper Bound	66.39	
	5% Trimmed Mean		48.06	
	Median		42.50	
	Variance		1182.221	
	Std. Deviation		34.383	
	Minimum		3	
	Maximum		138	
	Range		135	
	Interquartile Range		36	
	Skewness		1.176	.512
	Kurtosis		1.319	.992
TRAFX Visitor Total	Mean		28.25	2.923
	95% Confidence Interval for Mean	Lower Bound	22.13	
		Upper Bound	34.37	
	5% Trimmed Mean		28.61	
	Median		28.50	
	Variance		170.934	
	Std. Deviation		13.074	
	Minimum		1	
	Maximum		49	
	Range		48	
	Interquartile Range		16	
	Skewness		-.608	.512
	Kurtosis		.058	.992

Table 18 – GSC2 Descriptive Statistics

Descriptives

			Statistic	Std. Error
TRAFX Visitor Total	Mean		187.15	38.624
	95% Confidence Interval for Mean	Lower Bound	106.31	
		Upper Bound	267.99	
	5% Trimmed Mean		182.33	
	Median		184.00	
	Variance		29835.924	
	Std. Deviation		172.731	
	Minimum		2	
	Maximum		503	
	Range		501	
	Interquartile Range		342	
	Skewness		.161	.512
	Kurtosis		-1.783	.992
Total Visitors	Mean		264.05	51.252
	95% Confidence Interval for Mean	Lower Bound	156.78	
		Upper Bound	371.32	
	5% Trimmed Mean		258.72	
	Median		320.50	
	Variance		52534.682	
	Std. Deviation		229.204	
	Minimum		2	
	Maximum		622	
	Range		620	
	Interquartile Range		452	
	Skewness		.015	.512
	Kurtosis		-1.828	.992

Table 19– GSC3 Descriptive Statistics

Descriptives

			Statistic	Std. Error
Total Visitors	Mean		185.55	27.827
	95% Confidence Interval for Mean	Lower Bound	127.31	
		Upper Bound	243.79	
	5% Trimmed Mean		183.44	
	Median		170.00	
	Variance		15486.892	
	Std. Deviation		124.446	
	Minimum		2	
	Maximum		407	
	Range		405	
	Interquartile Range		224	
	Skewness		.168	.512
	Kurtosis		-1.227	.992
TRAFX Visitor Total	Mean		118.20	17.146
	95% Confidence Interval for Mean	Lower Bound	82.31	
		Upper Bound	154.09	
	5% Trimmed Mean		116.33	
	Median		112.00	
	Variance		5879.853	
	Std. Deviation		76.680	
	Minimum		2	
	Maximum		268	
	Range		266	
	Interquartile Range		126	
	Skewness		.234	.512
	Kurtosis		-.834	.992

Table 20 – GGC2 Descriptive Statistics

Descriptives

			Statistic	Std. Error
Total Visitors	Mean		144.60	18.931
	95% Confidence Interval for Mean	Lower Bound	104.98	
		Upper Bound	184.22	
	5% Trimmed Mean		141.06	
	Median		158.50	
	Variance		7167.726	
	Std. Deviation		84.662	
	Minimum		6	
	Maximum		347	
	Range		341	
	Interquartile Range		102	
	Skewness		.354	.512
	Kurtosis		.277	.992
TRAFX Visitor Total	Mean		68.20	9.331
	95% Confidence Interval for Mean	Lower Bound	48.67	
		Upper Bound	87.73	
	5% Trimmed Mean		65.83	
	Median		58.50	
	Variance		1741.221	
	Std. Deviation		41.728	
	Minimum		4	
	Maximum		175	
	Range		171	
	Interquartile Range		42	
	Skewness		.947	.512
	Kurtosis		1.047	.992

Table 21 – GGC3 Descriptive Statistics

Descriptives

			Statistic	Std. Error
Total Visitors	Mean		76.55	10.671
	95% Confidence Interval for Mean	Lower Bound	54.22	
		Upper Bound	98.88	
	5% Trimmed Mean		75.00	
	Median		78.50	
	Variance		2277.208	
	Std. Deviation		47.720	
	Minimum		5	
	Maximum		176	
	Range		171	
	Interquartile Range		68	
	Skewness		.451	.512
	Kurtosis		-.260	.992
TRAFX Visitor Total	Mean		43.70	5.848
	95% Confidence Interval for Mean	Lower Bound	31.46	
		Upper Bound	55.94	
	5% Trimmed Mean		43.06	
	Median		47.00	
	Variance		684.011	
	Std. Deviation		26.154	
	Minimum		2	
	Maximum		97	
	Range		95	
	Interquartile Range		40	
	Skewness		.225	.512
	Kurtosis		-.484	.992

Table 22 – PLC Descriptive Statistics

Descriptives

			Statistic	Std. Error
Total Visitors	Mean		6.65	.995
	95% Confidence Interval for Mean	Lower Bound	4.57	
		Upper Bound	8.73	
	5% Trimmed Mean		6.61	
	Median		6.00	
	Variance		19.818	
	Std. Deviation		4.452	
	Minimum		0	
	Maximum		14	
	Range		14	
	Interquartile Range		9	
	Skewness		.298	.512
	Kurtosis		-1.224	.992
TRAFX Visitor Total	Mean		5.75	.873
	95% Confidence Interval for Mean	Lower Bound	3.92	
		Upper Bound	7.58	
	5% Trimmed Mean		5.67	
	Median		5.50	
	Variance		15.250	
	Std. Deviation		3.905	
	Minimum		0	
	Maximum		13	
	Range		13	
	Interquartile Range		8	
	Skewness		.191	.512
	Kurtosis		-1.249	.992

Table 23 – TFC Descriptive Statistics

Descriptives

			Statistic	Std. Error
Total Visitors	Mean		20.10	2.473
	95% Confidence Interval for Mean	Lower Bound	14.92	
		Upper Bound	25.28	
	5% Trimmed Mean		19.44	
	Median		17.00	
	Variance		122.305	
	Std. Deviation		11.059	
	Minimum		6	
	Maximum		46	
	Range		40	
	Interquartile Range		11	
	Skewness		1.226	.512
	Kurtosis		1.091	.992
TRAFX Visitor Total	Mean		17.05	2.153
	95% Confidence Interval for Mean	Lower Bound	12.54	
		Upper Bound	21.56	
	5% Trimmed Mean		16.33	
	Median		14.00	
	Variance		92.682	
	Std. Deviation		9.627	
	Minimum		4	
	Maximum		43	
	Range		39	
	Interquartile Range		8	
	Skewness		1.339	.512
	Kurtosis		1.728	.992

Table 24 – TLC Descriptive Statistics

Descriptives

			Statistic	Std. Error
Total Visitors	Mean		3.85	.582
	95% Confidence Interval for Mean	Lower Bound	2.63	
		Upper Bound	5.07	
	5% Trimmed Mean		3.67	
	Median		3.00	
	Variance		6.766	
	Std. Deviation		2.601	
	Minimum		1	
	Maximum		10	
	Range		9	
	Interquartile Range		4	
	Skewness		1.060	.512
	Kurtosis		.234	.992
TRAFX Visitor Total	Mean		3.35	.494
	95% Confidence Interval for Mean	Lower Bound	2.32	
		Upper Bound	4.38	
	5% Trimmed Mean		3.22	
	Median		3.00	
	Variance		4.871	
	Std. Deviation		2.207	
	Minimum		1	
	Maximum		8	
	Range		7	
	Interquartile Range		3	
	Skewness		1.071	.512
	Kurtosis		.306	.992

Table 25 – Extended Spearman's Rho Results

Correlations

Width v. Correction Coefficient			Width	Correction Coefficient
Spearman's rho	Width	Correlation Coefficient	1.000	.738*
		Sig. (2-tailed)	.	.037
		N	8	8
	Correction Coefficient	Correlation Coefficient	.738*	1.000
		Sig. (2-tailed)	.037	.
		N	8	8

*. Correlation is significant at the 0.05 level (2-tailed).

Use v. Correction Coefficient			Total Use	Correction Coefficient
Spearman's rho	Total Use	Correlation Coefficient	1.000	.762*
		Sig. (2-tailed)	.	.028
		N	8	8
	Correction Coefficient	Correlation Coefficient	.762*	1.000
		Sig. (2-tailed)	.028	.
		N	8	8

*. Correlation is significant at the 0.05 level (2-tailed).

Slope v. Correction Coefficient			Slope	Correction Coefficient
Spearman's rho	Slope	Correlation Coefficient	1.000	-.071
		Sig. (2-tailed)	.	.867
		N	8	8
	Correction Coefficient	Correlation Coefficient	-.071	1.000
		Sig. (2-tailed)	.867	.
		N	8	8