ABSTRACT

NABER, MICHAEL DAVID. Integrating Trail Condition Assessment with Recreation Demand Modeling of Mountain Bikers in the Research Triangle, North Carolina. (Under the direction of Yu-Fai Leung and Aram Attarian.)

Few studies have integrated recreation ecology-derived measures in an effort to understand recreation demand. This study attempts to model mountain-biking demand using user survey data with actual visitor-impact data and site characteristics. As one of the fastest growing outdoor recreation pursuits over the past two decades, mountain biking has been identified by land managers as a significant management issue. This research focused on a specific research question: to what extent can trail-condition data help explain mountain-biking demand?

This study included six biking trails located in central North Carolina. Focus groups were conducted prior to trail surveys to elicit preferences in biking-trail characteristics. Trail conditions associated with visitor use were measured at sampling points along each mountain-biking trail. Due to multi-collinearity, trail-assessment data were normalized and grouped into three indices based on logical relationships of individual variables, representing a trail's physical challenge, resource degradation, and facility development. Social demographic data were collected from 398 mountain bikers via survey. Descriptive statistics and travel-cost model were realized using STATA for Windows.

Among the social demographic data collected, household income, mountain-biking-organization membership, and biking on weekends were significant determinants of demand, as were all three trail indices. Using maximum likelihood estimation, maximizing the challenge index predicted an increase of 1.6 annual mountain-biking outings, maximizing

trail development predicted an increase of 2.7 annual outings, and minimizing trail-condition issues predicted an increase of 10.7 annual outings.

This study supports the notion that mountain bikers prefer trails in good environmental condition. This information supports managers who prioritize sustainable trail design as much as trail challenge and development when building new trails or maintaining current trails. With the increasing emphasis on sustainable trails and user preferences, this study provides empirical support of integrating impact-monitoring data into recreation demand analysis.

Integrating Trail Condition Assessment with Recreation Demand Modeling of Mountain Bikers in the Research Triangle, North Carolina.

by
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DEDICATION

"It is not the critic who counts; not the man who points out how the strong man stumbles, or where the doer of deeds could have done them better. The credit belongs to the man who is actually in the arena, whose face in marred by dust and sweat and blood; who strives valiantly; who errs, who comes short again and again, because there is no effort without error and shortcoming; but who does actually strive to do the deeds; who knows great enthusiasms, the great devotions; who spends himself in a worthy cause; who at the best knows in the end the triumph of high achievement, and who at the worst, if he fails, at least fails while daring greatly, so that his place shall never be with those cold and timid souls who neither know victory nor defeat."

—Teddy Roosevelt at the Sorbonne in Paris, France on April 23, 1910

I would like to dedicate this work to my wife, Jennifer Maag Naber.

BIOGRAPHY

Michael David Naber was born in Grand Island, Nebraska in 1973 to David and Lorraine Naber. He spent his elementary years in Grand Island. His teen years were spent in Omaha, Nebraska. He went into the United States Marine Corps immediately after high school in 1991. After his discharge, Michael attended college at Concordia University in Seward, Nebraska, where he graduated with a B.A. in Biology and Geography under the guidance of Dr. John Kinworthy in May of 2000. He continued his studies at Akron University, Ohio. While at Akron University, Michael worked closely with Anthony Gareau at Cuyahoga Valley National Park and with Debbie King from the Department of Geography. After graduating with an M.S. in 2002, he joined the department of Parks, Recreation, and Tourism Management at North Carolina State University as a doctoral student under Dr. Hugh Devine and then Dr. Yu-Fai Leung and Dr. Aram Attarian.

Michael has recently taken a position as Lecturer of Geosciences, for Behrend College of Penn State University, Erie, Pennsylvania, under Dr. Tony Foyle.

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CHAPTER 1

INTRODUCTION

Mountain biking, an activity that takes place primarily on trails, fire roads, abandoned logging roads, and public lands, has increased exponentially in the past 30 years. Widmer (1997) reported that in 1983, 20,000 mountain bikes were sold in the United States. In 10 years, the number had catapulted to 20 million. The National Survey on Recreation and the Environment (2008) estimated that 42 million Americans (18% of the population) had biked off-road in the previous year and that 12.7 million of these people were in the South and Southeastern United States. The growing popularity of mountain biking has made it a factor in the increased use of public lands. An example is the Slickrock Trail located in Moab, Utah. In 1983, approximately 1,000 mountain bikers used this trail (International Mountain Bicycling Association [IMBA], 1994); in 1996, the figure was 160,000 (Bureau of Land Management [BLM], 1996a, 1996b, 1996c).

This increase in participation and the associated impacts of mountain biking on natural resources have not come without public scrutiny. The consequences of mountain biking have caused land managers to identify this outdoor recreation activity as the most significant new use issue facing recreation managers (Cessford, 1995b). This is consistent with the finding that the most common problems reported by managers of trails and campsites in natural areas are those due to recreational impacts (Washburne, 1982). Increased trail degradation has been one of the most prominent issues on trails (Schuett, 1997).

1.1 Problem Statement

A common management reaction to overuse and its resultant environmental degradation has been closing or limiting the use of park trails to mountain bikers (Sprung, 1997). Kelley (1994) reported that the National Park Service imposed restrictions on the Headlands area of the Golden Gate National Recreation Area located in Marin County, California. This restricted mountain biking to fire roads within the recreation area, effectively banning mountain biking from almost all single-track trail and from one-third of the park's 13,000 acres. Sprung (1995) reported that based upon perceptions of trail degradation, the City Council of Redmond, Washington voted to ban mountain biking completely from Redmond's Watershed Preserve Area.

Limiting access to mountain biking courses results in an unmet demand for recreation resources for this growing user group. The first step to address this problem is to better understand the factors that influence mountain-biking recreation demand. By understanding site environmental attributes and users' demand, managers will be better able to identify and prioritize the management of facilities and trail impacts. This knowledge will also be of value in decisions regarding the allocation of resources for this sport and in developing new trails.

1.2 Theoretical Foundation

Modeling the demand for recreational mountain biking with a travel-cost approach falls within the domain of neoclassical utility maximization. The costs that a mountain biker incurs for a mountain bike outing include the opportunity cost of time and the travel cost, which are proportionate to the round-trip time and distance. It is assumed that a given mountain biker will balance these costs with the satisfaction (utility) of an outing and that given a choice between alternate sites will choose the site that offers the most favorable ratio of cost to satisfaction (Fletcher, Adamowicz, & Graham-Tomasi, 1990). In theory, the distance a recreationist is willing to travel to a site (or the number of repeat trips a recreationist is willing to make) is proportional to the site's attractiveness (Parsons, 2003). Therefore, if the attractiveness of a site can be improved, users will be willing to travel further or make a greater number of trips to the site. In this model, the site has no "intrinsic" quality or value that is not accounted for by the travel-cost method, although this method does not measure nonuser benefits of a site (Ravenscraft & Dwyer, 1978). Applying the aforementioned costs and assumptions, mountain-biking recreation demand can be estimated by evaluating the association between annual outing and cost.

The travel-cost method was originally developed in the 1960s to estimate recreation demand. The original model has since been extended to include site characteristics of multiple destinations (Ravenscraft & Dwyer, 1978). The treatment of changes in recreation-site quality, positive or negative, in the single-site travel-cost model fails to take into consideration all substitute effects among sites (Freeman, 1979). An example of this situation would be if sites were actually substitutes and a number of single-site models were used to assess benefits, benefit estimation would be biased because substitution possibilities among sites would not be completely considered. In order to avoid an upward or downward bias in estimation, a more complete system of demand is necessary, such as the multiple-site travel-cost model (Caulkins, Bishop, & Bouwes, 1986).

For many recreational problems, the single-site travel-cost model is inadequate or inappropriate because an individual's decision to participate in a given recreational activity is rarely based on just one site or travel cost (Freeman, 2003). There are usually many alternative sites that can offer comparable experiences. Only if sites are identical and travel costs are the same, is it appropriate to aggregate the problem into a single demand model for the activity. However, ignoring substitute sites eliminates substitution possibilities and leads to an overstatement of the benefits associated with improving the quality of a site (Caulkins, Bishop, & Bouwes, 1986).

In reality, recreation sites are infrequently identical or the same distance from an individual's home. This fact actually assists researchers in trying to value environmental-quality measures. The valuation of environmental quality through demand modeling requires the observation of variations in environmental quality (Parsons, 2003). If sites encompass varying environmental-quality levels and are subject to different costs of access, then observations of use will expose individual tradeoffs between quality and income (Caulkins, Bishop, & Bouwes, 1986). The absence of substitute site qualities and prices in travel-cost models would make it impossible to examine the effect of changes in destination characteristics at more than one site (Freeman, 2003).

Since the seminal article by Stevens (1966), recreation demand models have incorporated site characteristics for different types of recreation. In the fishing literature, commonly used site characteristics include some measure of catch, the fishing site's size, water depth, and various measures of water quality (Englin & Lambert, 1995). Similarly, hunting studies have included harvest and other measures of site quality (Creel & Loomis, 1990). Mountain biking studies have included wildfire effects (Hesseln, Loomis, Gonzalez-Caban, & Alexander, 2003) and other measures of hypothetical site quality (Morey, Buchanan, & Waldman, 2002). Though this approach could be used to model demand for a variety of consumptive recreational activities, this study focused on mountain-biking demand and the role of trail quality.

Following the previous literature (Hesseln, Loomis, Gonzalez-Caban, & Alexander, 2003), mountain bikers are assumed to prefer to ride on trails of better aesthetic quality—less degraded rather than more degraded. Thus, an ideal quality measure would be specific and exogenous and would facilitate comparison between trails. Adverse trail conditions are an optimal measure, as they are exogenous to the trail user. A measure of mountain-biking quality is needed that is relevant to each individual mountain biker. Accordingly, some estimate of expected trail quality enters the consumer's demand function as an explanatory variable. The estimate is based on the mountain biker's self-reported annual outings. In this study, the issue of trail quality was addressed by developing a recreation demand model that consisted of the total number of trips demanded during the year.

1.3 Study Purpose and Hypotheses

The purpose of this study was to determine the effect of trail attributes, particularly trail challenge, trail condition, and trail development, on recreation demand. This study incorporated the use of geospatial technologies (geographic information systems, global positioning systems, and remote sensing) in the gathering, deriving, and analysis of site environmental attributes. The research followed an integrative approach using travel cost and trail condition analysis methods to further understand mountain-biker behavior. A secondary purpose was to develop new techniques that will allow land managers and agencies to make the most informed decisions when designing current and future mountain biking trails that will best serve this group of recreation resource users. Direct observations of trail conditions were evaluated in conjunction with revealed user preferences to determine whether trail challenge, trail condition, or trail development measures showed a relationship with revealed past outing patterns.

The travel-cost-modeling portion of this study quantifies site environmental attributes to determine their influence on the demand for mountain biking trails, using data on the annual outings of mountain bikers to mountain biking trails in the Triangle area of North Carolina.

The major questions that this study answered are as follows:

1. Which site environmental attributes influence users' demand for mountain biking?
2. How accurately can users' demand of mountain-biking trails in light of their revealed preference be predicted?

The final purpose of this study was to develop a travel-cost model that characterizes the annual trail demand of mountain bikers, in order to better understand the extent to which site environmental attributes explain mountain-biking trail demand.

The key hypothesis of this study was

H_O: Site environmental-attribute quality does not influence mountain bikers' trail demand.

This will be tested against the alternative:

H_A: Site environmental-attribute quality influences mountain bikers' trail demand.

1.4 Study Approach

Survey results were evaluated in conjunction with direct observation through six mountain-biking trail condition surveys, to determine how the site environmental attributes of biking-trail development, biking-trail challenge, and biking-trail condition relate to revealed past outings. A travel-cost model was constructed to assess the effects of biking-trail/environmental quality, travel distance, and personal characteristics on the recreation demand for biking sites in Wake County, North Carolina. The model was generated using information from annual outings mountain bikers took to these six mountain biking trails in 2006 and the effects of site/environmental quality, personal characteristics, and travel distance on the site-selection decisions of mountain bikers. The remaining chapters consist of an analytical approach incorporating travel cost and trail-condition analysis methods to further understand mountain-biking user behavior.

1.5 Limitations

This study was limited in being conducted on local trails without much topographic, climatic, or geological variation. This may have left uncovered site environmental attributes that significantly influence mountain-biker visitation. White, Waskey, Brodehl, and Foti (2006) encountered similar difficulties in attempting to compare five mountain-biking study sites in the Southwestern United States.

Interviewing was conducted on-site to provide a maximum response rate, but non-users were absent from the data, and those that mountain bike only rarely were less likely to be sampled. Seasonal variation in mountain-biker habits may have influenced the sample, for even though mountain bikers were asked to estimate their annual trips, mountain bikers that ride primarily in one season may have been absent during the late fall and early winter in which the survey was taken. This would affect mountain bikers who ride primarily in the summer so as to take longer-daylight trips, and the higher-than-average costs they incur would not have been captured.

CHAPTER 2

LITERATURE REVIEW

This chapter will discuss the literature related to the study, beginning with studies on how site quality has influenced recreation demand. It will then move on to studies that have dealt specifically with mountain-biking demand. Next is a review of social demographic studies completed on mountain bikers, in order to compare their findings with those of this study. It will finish with trail-impact research from which relevant trail-impact measures will be derived for use in the current study.

2.1 Recreation Demand and Site Quality

Researchers have acknowledged and demonstrated the link between site quality and recreation demand. Fletcher, Adamowicz, and Graham-Tomasi (1990) reported that users' perceptions of site characteristics can influence their selection process and substitution of sites. Recreation demand models have incorporated site characteristics and have included angling (Englin & Lambert, 1995), tourism (Alavalapati & Adamowicz, 2000), and hiking and mountain biking (Hesseln, Loomis, & Gonzalez-Caban, 2004) as activities influenced by the site conditions in which they take place.

Researchers have employed site quality as a measure in fishing demand models based on either terrestrial aesthetics or water quality. Terrestrial aesthetic studies have included ratings (Train, 1998) and actual measures related to forested areas (Jones & Lupi, 1999). These studies found that measures related to terrestrial aesthetics were positively related to fishing demand. Water quality has been associated with site quality through its impact on the angler's experience, whether it be through simple aesthetics or through the health of the fish.

Measures of water and site quality have included perceptual ratings (Peters, Adamowicz, & Boxall, 1995), fish advisories (Parsons, Jakus, & Tomasi, 1999), Environmental Protection Agency standards (Hauber & Parsons, 2000), impacts (Jones & Lupi, 1999), secci depth (Lupi & Feather, 1998), and biological stress indices (Englin & Lambert, 1995). Some researchers have used specific measures based on dissolved oxygen, suspended solids, fecal coliform bacteria, acidity, phosphorus, lead, copper, polychlorinated biphenyls, toxins, and oil (Parsons & Kealy, 1994; Parsons & Needleman, 1992; Tay & McCarthy, 1994; Kaoru, 1995; Tay, McCarthy, & Fletcher, 1996; Montgomery & Needleman; 1997; Phaneuf, Kling, & Herriges, 1998). Generally, these studies suggest that fishing sites with better water quality are in higher demand than other fishing waters.

Studies have been conducted to model the interaction between tourism and site quality. Mlinari (1985) studied whether tourism activity depends on the quality of the environment, noting that site changes such as coastal water pollution and forest fires associated with tourism development in the Mediterranean were negatively associated with tourist visits. Inskeep (1987) found that if environmental expectations were not met, tourists may change their travel patterns. Alavalapati and Adamowicz (2000) considered tourism as an endogenous activity and modeled it as a function of both price and environmental damage. They specified environmental damage as a function of the output and the extent of land use in the production process. Simulations found that impacts of policy change differ with the type of environmental damage.

Research dealing with site quality in forest recreation was undertaken by Vaux, Gardner, and Mills (1984), who estimated the effects of burned areas on forest recreation demand. Results pointed to a negative relationship between higher intensity fires and recreation values. Studies have also evaluated the effects of fire on hiking and mountain biking in Colorado (Loomis, Gonzalez-Caban, & Englin, 2001), New Mexico (Hesseln, Loomis, Gonzalez-Caban, & Alexander, 2003), and Montana (Hesseln, Loomis, & Gonzalez-Caban, 2004). The latter two studies replicated Loomis et al. (2001) in an effort to assess the effects of fire on value and demand for hiking and mountain biking in these locations. In Hesseln et al. (2004), the net economic benefit to both user groups was $37 and demand decreased for both user groups as area burned increased and amount of burn visible from trail increased.

Siderelis, Moore, and Lee (2000) examined site quality and its influence on trail selection and return trips. The authors asked hypothetical questions based upon environmental problems and users' perceptions of how trail changes would influence trips taken. The authors estimated an increase of $15 in consumer surplus per trip and a marginal effect of a point-change improvement in trail quality on the demand for annual trips at 2.37 trips or a shift from 5.79 trips to 8.16 trips per annum. Findings suggested that users' perceptions of trail quality can be integrated into a recreation demand model, emphasizing that subjective impressions of trail quality/conditions influence user trail demand. This understanding of the relationship between trail condition and recreation demand is the focus of this research dealing specifically with mountain-biking demand.

2.2 Past Mountain-Biking Demand Studies

Few studies have attempted to characterize mountain-biking demand, with most having focused on the travel-cost variable as modeled by costs, benefits, and willingness to pay. None to date has examined the relationship between recreation impacts and user demand. The following is a review of relevant studies that have focused specifically on mountain-biking demand.

Recreation demand is determined from user preferences (e.g., viewscape, solitude) for recreation sites with economic valuation techniques (Haab & McConnell, 2002). Data are combined about sites visited in the past by respondents, including distance traveled, time taken to reach sites, and other measures of the physical attributes (Freeman, 2003). This analysis of recreation demand originated from a letter addressed by Hotelling (1947) to the National Parks Service. Hotelling posited that consumption of an outdoor recreation site's services requires the user to incur the costs of a trip to the site (Hotelling, 1947). These travel costs then serve as implicit prices (Freeman, 2003). Thus, costs reflect both people's distances from recreation sites visited and their specific opportunity costs of time.

Fix and Loomis (1997) estimated the economic benefits of mountain biking for the Slickrock Trail in Moab, Utah. Though their work did not address the influence of trail quality on mountain-biking trail selection, it was the first approach by economists to understand the recreation demand of mountain bikers. The authors used a count data estimator with a Poisson distribution where the dependent variable was the log of the number of trips to the trail. The authors constructed two recreation demand models, each of which contained the variables of travel cost and travel time to Moab and the prices of substitute mountain-biking trails. The first model included as substitute trails those locations close to the respondents' homes and with climate and geography similar to Moab's desert environment, whereas the second model included those locations close to the respondents' homes but with weather conditions similar to Moab. For both models, travel cost and travel time were negative and statistically significant, whereas substitute price coefficients were positive and significant. Age was negative for both models, though only significant for the first model. Income and skill level were tested in different specifications, but were not significant and thus not included in the final models.

In a later study and again using a count-data demand model, Fix, Loomis, and Eichorn (2000) revisited Moab, Utah. The authors addressed the endogeneity of travel costs by considering not only the endogenous costs (e.g., car, airfare, guide, lodging) but the exogenous imposed costs (reported cost of gas). To correct for the endogenous costs, the authors conducted an empirical test for the presence of endogeneity and corrected the travel cost coefficient, reducing overall estimates for consumer surplus by 12% compared to their earlier study.

Using data from a mail-in questionnaire distributed to mountain bikers who had registered with a local mountain-bike rental shop in 1994, Chakraborty and Keith (2000) compared standard and truncated count-data travel-cost models. The authors' stated intent was to improve on the estimates of economic benefits at the Slickrock Trail of the Moab, Utah mountain-biking area and extend them to the entire region that included Gemini Bridges Trail, Hidden Valley Trail, Merrimac Trail, Monitor Trail, and Poison Spider Trail. The sample population was 118 mountain bikers who reported on the total number of mountain-biking trips taken to Moab in the past 5 and 10 years, expenses (out of pocket) incurred in the last trip, and their demographics.

Travel cost was calculated as $0.25 per mile times round-trip distance traveled plus the opportunity cost of round-trip travel time. The latter was calculated by dividing round-trip travel distance by 50 mph and then multiplying by one-third of the user's hourly income based on 2,080 hours of work per year (52 weeks times 40 hours/week).

The authors estimated four demand models: two ordinary demand models that assumed the dependent variable was continuously distributed and two count-data models. Travel cost was found to be significant in all four demand models, whereas all other demographics and measures were found to be statistically insignificant.

In general, when estimating recreation demand, analysts expect (a) an over-dispersion in individual travel costs across a sample of visitors to the biking trail, (b) biking trail desirability to decline with outing cost, (c) seasonal outings to increase with desirable biking-trail characteristics, (d) seasonal outings to decrease with undesirable characteristics, (e) observance of a substantial period of time (i.e., season or year) during which people can make outings, perhaps to one or more biking trails, and (f) annual outings to each biking trail to be endogenous.

Though research has been done on mountain-biking demand, none thus far has included site-quality measures in a model to describe the relationship between site environmental attributes and mountain-biking demand.

2.3 Social Demographics

Since the 1930s, social scientists have explored the correlation of social demographics with recreation behavior (Manning, 1999). Early researchers found that social demographic variables relate to outdoor recreation patterns including age, income, occupation, residence, and stage in family life cycle (Sessons, 1961). Kelly (1980) was able to correlate two additional social demographic variables, education and race, with outdoor recreation participation. Age is inversely related to participation in many outdoor recreation activities; whereas stage in family life cycle is highly inter-correlated with age. Income and race influence participation in activities with high cost thresholds. Gender is related to participation in activities that are traditionally considered masculine (e.g., hunting). Occupation was not significantly related to participation in any of the recreation activities that were studied, except for cross-country skiing.

Data on the social demographics of mountain biking have primarily been limited to collection via on-site or general population surveys. In previous mountain-biking studies, social demographic information was used to categorize users. Several studies (Cessford, 1995a; Symmonds, Hammitt, & Quisenberry, 2000; Goeft & Alder, 2001; Chiu & Kriwoken, 2003) indicated that males tend to represent 80-90% of mountain bikers. Symmonds et al. (2000) and Cessford (1995a) found the majority of respondents to be in their 20s and early 30s. Additionally, Hollenhorst, Schuett, Olson, and Chavez (1995b) found that mountain bikers had a tendency to be young, highly educated, affluent, male, and from urban areas, with an average mountain-biking experience of 3.75 years.

Recreation studies have shown that social demographics can aid researchers in understanding and predicting recreation behavior (Manning, 1999). However, mountain-biker preferences have been explored only by one study in New Zealand (Cessford, 1995a), one study in the United States (Hollenhorst et al., 1995b), and one study in Australia (Goeft & Alder, 2001). Additional studies have focused on particular rider characteristics (i.e., behavior, demographics, and perceptions) that aid in describing rider preferences (Watson, Williams, & Daigle, 1991; Ruff & Mellors, 1993; Hollenhorst, Schuett, Olson, & Chavez, 1995a). Results from all of these studies suggest that riders prefer natural settings and good trails with a mix of features, such as changing slopes and curves. The aforementioned studies were predominately composed of males approximately 30 years of age. Goeft and Alder (2001) suggested that the results of these studies support the idea that mountain biking is consistent with other forms of adventure recreation whose participants search out a certain element of risk, excitement, and peak experiences (Ewert & Hollenhorst, 1989).

2.4 Trail Impacts

Recreation resource impacts and their study seem to overlap with social sciences and ecology. The field of recreation ecology has focused on the description of recreation-related impacts and the relationships with use characteristics like trail impacts and trail usage. The following discussion reviews previous studies, with a focus on the issues pertinent to mountain biking.

Trails are fundamental facilities in parks and natural areas, not only providing recreational opportunities and access to undeveloped areas, but defending the natural resources by focusing visitor-use impacts to tread surfaces. The construction of trails inherently results in some environmental impact; however, that can be exacerbated by post-construction degradation from their subsequent use (Marion & Wimpey, 2007). The deterioration of trails may influence user preferences. Trail impacts often lead to the aesthetic degradation of a recreational site. For example, severe erosion or root exposures are not only visually offensive but have the potential to negatively influence recreation experiences (Roggenbuck, Williams, & Watson, 1993).

If a trail is built correctly using sound design and quality construction materials, trail impacts attributable to construction will be minimal. Studies have documented the relationship between amount of use and typical forms of trail impact (Cole, 1983; Sun & Liddle, 1993). This relationship is curvilinear, meaning initial use will generate the most use-related impact in a relatively short time, after which incremental user-induced impact will decrease as time and use increase. The most common trail impacts are due to vegetation loss or change, soil erosion, compaction of soil, muddy tread, tree-root exposure, widening of tread, and social trails (Leung & Marion, 1996; Hammitt & Cole, 1998).

Hammitt and Cole (1998) noted that specific impacts (trail widening, braiding, and social trails) are due to or heavily influenced by visitor behavior. Avoidance of an obstruction is a major cause of trail widening. If a visitor encounters a severe issue such as muddiness, pooled water, trail rutting, or rocks, he or she will step around or circumvent the impact.

Leung and Marion (1996) discussed the influence of environmental factors in trail degradation. Some of these factors are vegetation type, topography, soil, and surface. Research into these factors is discussed below.

Vegetation loss can occur in conjunction with other types of impacts such as soil compaction and erosion. Soil erosion that results in ruts or holes, which do not allow water to leave the tread, can create muddy pockets on the trail, which aggravates trail widening by forcing users to go around the impact and trample surrounding vegetation (Marion, 1994).

Over time, loss of understory vegetation results in increased sunlight, allowing plants that require more light to out-compete shade-tolerant species (Marion & Wimpey, 2007).

Topography has been examined for its influence on trail degradation. Bratton, Hickler, and Graves (1979) documented the powerful relationship between tread slope and soil loss. As velocity and volume of runoff increase, the potential for erosion also increases. If the trail erodes to become lower than the surrounding area, it makes diversion of water off the trail difficult, causing further erosion (Marion & Wimpey, 2007). Additionally, as the grade of a trail increases, erosion becomes more substantial. Marion and Olive (2006) found that trails with grade of at least 16% had significantly more erosion than trails with a grade of 15% or less.

The orientation of the trail to the dominant landform and slope alignment angle are factors often overlooked by trail designers (Marion & Leung, 2001). If a trail directly ascends the fall line of a slope, it will have low slope alignment angle. In such trails, the side slopes will be relatively flat, rendering the trail susceptible to degradation because the low side slope will offer little to no resistance to water runoff or trail widening. Position of trail (i.e., hilltop, mid-slope, or valley floor) does not change the influence of a low slope alignment angle, which increases with magnitude of trail grade and amount of rainfall at higher elevations. Water entrapment on trails with low slope alignment and lower grades can perpetuate trail muddiness, leading to or increasing the possibility of trail widening. Trails that follow the surrounding contours have high slope alignment angles; such trails are considered side-hill trails. Due to their steep side slopes, side-hill trails confine users to the trail tread, reduce widening, limit social trails, and assist in trail tread drainage (Birchard & Proudman, 2000).

Soil types and soil characteristics have been investigated for their influence on trail impacts. Bryan (1977) found that soils with fine and uniform textures are predictably erodible and more likely to be incised. Any trails that cross consistently wet soils are more likely to be widened by users who seek to avoid puddles or mud in the tread. If trail soils are wet or muddy, they are more likely to erode, especially in conjunction with steeper grades (Welch & Churchill, 1986).

Studies examining surface characteristics usually observe the “roughness” of the trail tread (e.g., rockiness, presence or absence of roots). Weaver and Dale (1978) found that trails built on surfaces with high gravel or rock content are more resistant to erosion. In general, rock and gravel are more resistant to weather (e.g., water and wind) and in some cases can retain finer soils, much like a filter. Thus, trails containing rocks and stones offer a natural form of trail hardening by protecting the underlying soils.

Trail impact studies have primarily focused on inventorying the current condition or status of trails. To date, these measures of site quality have not been included within a travel-cost model of recreation demand, specifically mountain-biking recreation demand. The present study addresses this gap.

CHAPTER 3

METHODS

The methods used in this study sought to explore the usefulness of integrating field-survey data with on-site user-survey data in a recreation-demand model. The study questions and hypotheses were addressed through focus groups, an on-site user survey, and field surveys.

Two separate focus groups were conducted to solicit preferred biking-trail characteristics. Discussion was elicited through direct questions, ranking exercises, and key questions.

The on-site user survey was conducted at six Triangle, North Carolina mountain-biking trails to gather social demographic and economic information from a representative sample of Triangle mountain bikers for use in a travel-cost model of mountain-biker demand.

Field surveys collected information about trail impacts experienced at the same six trails. Landform characteristics that the literature has found to influence trail degradation were inventoried. The field assessment consisted of two separate surveys: one based on systematic point sampling to characterize general trail conditions and the other based on a census of extreme trail-impact problems.

The travel-cost model used was based on data from landform characteristics measured at mountain-biking trails and on digital data sources in the GIS environment, in conjunction with an on-site user survey. A significant aspect of this research was the use of these site environmental attributes with on-site user survey information to model the influence of site environmental attributes in a travel-cost model of mountain-biking demand.

3.1 Study Questions and Hypotheses

The purpose of this study was to determine the effect of trail attributes, particularly trail challenge, trail condition, and trail development, on recreation demand. The major questions this research addressed were

1. Which site environmental attributes influence users' demand for mountain biking?
2. How accurately can users' demand of mountain-biking trails in light of their revealed preferences be predicted?

This study addressed these questions by developing a travel-cost model that characterized the annual trail demand of Triangle mountain bikers, to better understand the extent to which site environmental attributes explained mountain-biking-trail demand.

The key hypothesis of this study was as follows:

H_O: Site environmental attribute quality does not influence mountain bikers' trail use.

This will be tested against the alternative:

H_A: Site environmental-attribute quality influences mountain bikers' trail use.

3.2 Selection of Mountain Biking Sites

The Research Triangle (commonly referred to as "the Triangle") is located in the piedmont region of North Carolina. It is defined by the cities of Raleigh, Durham, and Chapel Hill. The total population of this area as of 2004 was over 1.46 million. However, for the purposes of this study, the Triangle was deemed to consist of the following counties: Durham, Wake, Chatham, Orange, Johnston, and Lee (see Figure 3.1).

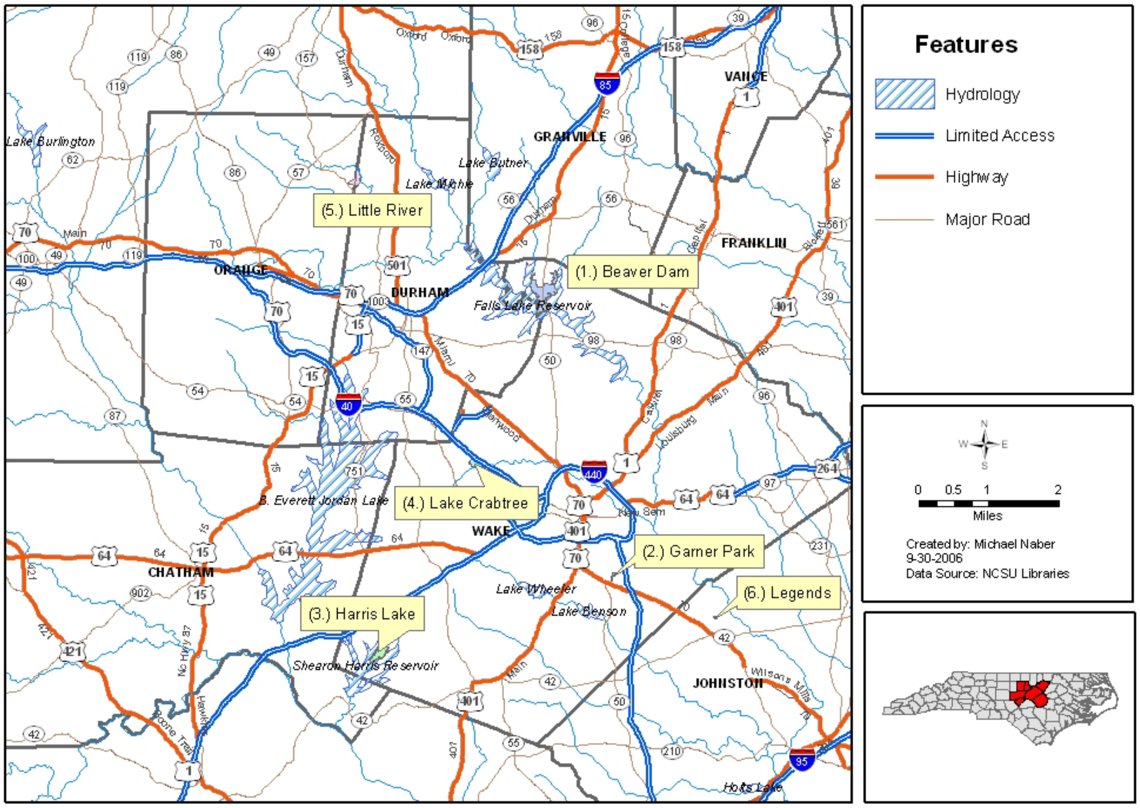

Figure 3.1. Triangle North Carolina, surveyed mountain biking sites map.

In a report by the USDA Forest Service, 16% of North Carolinians participate in mountain biking (Green, Van Dijk, Betz, & Cordell, 2007). Mountain bikers in the Triangle enjoy access to multiple regulated trails, and many unregulated trails in the area receive frequent use. Triangle Off Road Cyclists (TORC), which is the regional branch of the International Mountain Biking Association (IMBA), and the Southern Off Road Bicyclists Association (SORBA) count approximately 130 active members, though this is likely a small portion of the mountain-biking population in this area (Triangle Off Road Cyclists [TORC], 2008).

Mountain-biking trails in the Triangle were selected for study if they met each of the following criteria: (a) regulated legal trail, (b) defined land-management agency, (c) single-track mountain-biking trail, and (d) available trail information. An initial working list of biking trails consisted of all local mountain-biking trails that were legal to ride and where use was regulated. Because the researcher does not sanction the use of illegal biking trails, all illegal trail systems were deleted from the survey list. The legally administered trail systems are managed by the Corps of Engineers, Wake County Open Space, Garner Parks and Recreation Department, Orange County, and Durham County Parks and Recreation. The selected biking trails (see Figure 3.1) were single-track mountain-biking trails: (a) Beaver Dam State Recreation Area, (b) Lake Crabtree County Park, (c) Garner Recreation Park, (d) Harris Lake County Park (Hog Run Trail), (e) Little River Trails, and (f) Legend Park. Table 3.1 describes some of the basic situational characteristics of each trail. There is a substantial variation in site offerings and conditions, with trail length varying from almost 15 miles at Beaver Dam to under 2 miles at Garner Recreation Park. Average slope varies from a high of 8.68% at Legend Park to a low of 4.64% at Harris Lake. Also included are number of trail loops, median width, and an overall estimate of problems (issues) per mile.

3.3 Focus Group Methods

Focus groups were conducted to elicit preferences in biking-trail characteristics. They consisted of separate groups with female and male participants, each of which included riders of various skill levels, from novice to expert. Dialogue was stimulated through direct questions, ranking exercises, and key questions. The “long table approach” was used to organize information transcribed from focus-group sessions (Krueger & Casey, 2000). Three major themes presented themselves via analysis: biking-trail challenge, biking-trail development, and biking-trail condition.

Table 3.1

Triangle Mountain Biking Site Variables

Site	Miles	Average Slope (%)	Trail Loops	Median Width (cm)	Problems per mile
Beaver Dam	14.67	6.93	5	80	12.61
Garner	1.94	8.04	3	99	22.72
Harris Lake	8.34	4.64	5	75	12.34
Lake Crabtree	8.02	5.11	6	103	17.59
Little River	6.2	5.65	2	80	3.39
Legend Park	4.82	8.68	5	85	17.85

Note. Written and internet information is available on each of the six locations, (see Appendix 1).

The focus group consisted of members of Triangle Off Road Cyclists (TORC). The primary contacts, who were instrumental in building a rapport between the researcher and focus-group members, were the executive committee members of TORC and a representative from Wake County Open Space. Wake County officials support mountain-biking trails at Lake Crabtree Park with a memorandum of understanding with TORC for the upkeep and maintenance of the park's current trails. The author met with contacts at Lake Crabtree Park in May 2006 to discuss the purpose of the study and the selection process for members of the focus groups.

TORC leaders introduced the focus-group leader to potential participants who had various levels of experience as mountain bikers. As monetary incentives have been criticized as a possible means of bias, the researcher used location, snacks, and beverages as incentives

(Bloor, 2001). The focus groups were conducted on June 21, 2006 and September 28, 2006 in a conference room available at Lake Crabtree County Park. This locale was centrally located and familiar to focus-group participants, as the park is popular among Triangle mountain bikers.

Socio-demographic (age and marital status), skill level (beginner, intermediate, or expert), experience-use history, and group membership were collected via a self-completion questionnaire (Bloor, 2001). Video and audio recordings were used to collect the transcription of the focus-group discussion to eliminate problems of inaccurate or selective recall (Bloor, 2001).

During the focus-group discussion, predetermined questions acted as “focusing exercises,” in an effort to get the group to concentrate and interact on the subject matter (Bloor, 2001). The focusing exercises were presented in multiple forms: direct questions, ranking exercises, and key questions. The objective was not to illicit direct answers; rather, it was to stimulate group discussion in order to reveal the meanings and norms that lie beneath the members’ answers (Bloor, 2001). Groundbreaking questions began the focusing exercises. Questions such as “Please tell us your name and how long you have been mountain biking?” introduced the focus-group members to each other and to the researchers while revealing commonalities among participants. (See Appendix B for the list of groundbreaking questions.) Following the groundbreaking questions were the ranking and weighting of biking-trail preferences, which involved questions such as the following:

> In the mountain biking community, courses are made up of different types of challenges, obstacles, amenities, and designs. If your only limitation was choosing a Triangle NC trail, what trail characteristics would you be most concerned with when choosing a course to ride? (Please rank by importance and weight by their

contribution to the whole (i.e., 80%, 18%, 2%, some items may receive no weight).)

Each member in the group was then given a list of the following trail characteristics:

a. Distance to course (travel time)
b. Course length
c. Course challenge (topography, hills vs. flat land, tricks)
d. Regulated vs. unregulated
e. Remoteness
f. Naturalness
g. Safety (no unknown dangers on trails, aggressive animals, washouts, fallen trees)
h. Security (locking restrooms, lighting at parking lot, parking, no hiding places, criminals)
i. Amenities available (restroom, parking, water, picnic tables)
j. Site condition (erosion, litter, maintained vs. run down)
k. Other?

The group was then asked to rank the characteristics, from most important to least important. After the group had ranked the characteristics, participants were asked to weight them in importance. The rankings produced discussion that illustrated both differences and commonalities in preferences among members. The final task centered on personal preferences in biking-trail characteristics. As an example, “When you are planning to ride, on what do you base your choice of trail (design, maintenance, and trail conditions)?” (See Appendix B for the complete list of key questions.)

The confidentiality of the resulting data and how data would be analyzed and transcribed was explained to focus-group members.

The researcher transcribed each of the audio tapes from the focus groups. Facilitator and co-facilitator comments were bolded to make them easily visible. Krueger and Casey (2000) suggested using the "long-table approach," which has been adapted for use with word processing programs. The long-table approach is a systematic, sequential, and continuing process that pays attention to the critical qualities of transcripts, audiotapes, and notes from focus groups.

Weight or emphasis is given to comments or themes based on the following factors:

1. Frequency – How frequently something is said.
2. Specificity – The amount of detail of a comment.
3. Emotion – The degree of emotion, enthusiasm, passion, or intensity in a participant's answers.
4. Extensiveness – The number of "different" people saying the same thing.

With the summaries completed, themes were identified by conducting a content analysis of the questions.

3.3.1 Focus Group Results

The ranking exercises produced discussion that illustrated the differences and agreement within the groups. Course challenge ranked first in importance and carried the same weight as course development and course length. Though remoteness or feeling of naturalness ranked high in importance (third), it was weighted less than the themes ranked first, second, or fourth. Security and trail condition were less important themes in both ranking and weighting (Table 3.2).

3.3.2 Focus Group Themes

The themes obtained from the transcriptions cut across groups, even though emphasis may have been stronger with one group than the other. The repetition in group concerns enabled the author to interpret the importance of the domains.

Table 3.2

Focus Group Weighted Domains

Ranking	Weight	Domain
1	25%	Challenge
2	25%	Development
3	15%	Remoteness
4	25%	Course length
5	5%	Security
6	5%	Trail condition

3.3.2.1 Trail Challenge Theme

Steep slopes, long climbs, and length were themes that came up repeatedly in both focus groups. Participants (regardless of skill level) were virtually unanimous in their desire for longer bike trails and challenging courses. However, groups had difficulty deciding whether length of trail or challenge of trail was most important and participants often stated that they were inter-related.

3.3.2.2 Trail Condition Theme

Although the topic of trail condition was ranked last, the frequency and extensiveness of discussion within the focus groups indicated that it was important. Trail condition was associated with water on the trail, exposed roots, rocks, trail muddiness, trail safety, and trail width.

3.3.2.3 Trail Development Theme

Design and flow of bike trails was another frequently mentioned theme in both focus groups. Trail "flow" or the fit of the trail to the natural topography of the biking trail, variety of challenges, well-planned loops, and junctions between loops were some of the specific topics that fit into this category. Participants indicated that biking-trail development was important and weighted the domain equally with biking-trail challenge. Participants also revealed that remoteness was intimately related to course development, in that a well-designed course has a remote and natural feel regardless of actual geographic isolation. The groups only briefly discussed security, ranking it second to last.

3.4 On-site User Survey

The use of a randomized on-site survey, rather than a random household survey, was needed for a representative sample of mountain bikers. It was unlikely that a sample of households in the Research Triangle area could produce a representative sample of mountain bikers who visited the biking trails included in this study.

A temporally random-sampling strategy was developed to intercept users from October 16 to December 10, 2006. Moeltner and Shonkwiler (2005) used a similar sampling method that attempted a random yet evenly conducted on-site survey across six lakes in the Tahoe, California region.

Sampling occurred at six Triangle mountain-biking trails that met the following criteria: (a) regulated legal trail, (b) defined land management agency, (c) available trail information, and (d) single-track mountain-biking trails. The trails that met these criteria were Beaver Dam State Recreation Area, Lake Crabtree County Park, Garner Recreation Park, Harris Lake County Park, Little River Trails, and Legend Park. Attempts were made to intercept equal numbers of recreators at each of the six biking trails on selected weekdays and weekends. The time spent sampling at each biking trail was equal—15 hours on weekends (Friday–Sunday) and 6 hours on weekdays (Monday–Thursday). Because none of the six trails had records of trail-user counts, the nearby San-Lee Park (Lee County, NC) has kept a voluntary registration at the trailhead to their mountain-biking trail for approximately five years. This registration log was analyzed by check-in time, day of the week, and monthly usage to determine temporal patterns of use. The sampling dates in this study were in the months of September, October, and November. The same three-month period at San-Lee Park indicated that trail usage was highest during the late afternoon and early evening on weekdays and throughout the day on weekends. The interval from 1 p.m. to 6 p.m. accounted for 72% of mountain-biker sign-ins in September, 80% in October, and 67% in November. If riders signed in upon arrival and the average ride lasted approximately one hour, then the majority of riders exited the park between 2 p.m. and 7 p.m.

Averaging over the past five years, weekends accounted for 73% of visits to San-Lee Park in September, 75% in October, and 74% in November. In addition, biking-trail visits were split 75% weekend to 25% weekday. The sampling schedule was based on 3-hour blocks (see Table 3.3).

For each of the sample biking trails, weekend and weekday dates were randomly selected to ensure that each of the biking trails received adequate coverage and followed the 75% and 25% distribution among weekend days and weekdays. Sampling dates were selected through random draws with replacement, of dates for each sampled biking trail and 3-hour block. If the sampled biking trail was closed, the biking trail and time block were placed on the end of the sampling schedule until an alternative sample date was selected.

Table 3.3

Sampling Schedule

Day	8 a.m. – 11 a.m.	11 a.m. – 2 p.m.	2 p.m. – 5 p.m.	2:30 p.m. – 5:30 p.m.
Monday				X
Tuesday				X
Wednesday				X
Thursday				X
Friday			X	
Saturday	X	X	X	
Sunday	X	X	X	

At the end of their rides, all mountain bikers were intercepted at the trailheads or parking lots during the 3-hour blocks and given a questionnaire. The questionnaires were completed by respondents on-site. The intercept locations avoided interfering with the riders and allowed the respondents to reflect on their visits.

3.4.1 Data Collection

Eliminated from the sample were those persons who were under 18 years of age (the North Carolina State University Institutional Review Board requires a parental waiver for children under 18 to participate in research studies) and those persons who had previously responded. On two occasions, persons opted not to complete a questionnaire. A total of 413 users at the six biking trails were randomly intercepted, of which 398 provided complete and usable questionnaires (see Table 3.4).

Table 3.4

Sampling Counts with Percentage of Total Visits

Site	Weekday		Weekend		Total	
	Count	%	Count	%	Count	%
Beaver Dam	19	5	75	19	94	24
Garner Park	1	0	26	7	27	7
Harris Lake	14	4	83	21	97	24
Lake Crabtree	18	5	82	21	100	25
Legend Park	0	0	36	9	36	9
Little River	6	2	38	10	44	11
Total	58	15	340	85	398	100

3.5 Data Collection of On-site Quality Measures

A field survey and assessment were conducted from March 18 to April 6, 2007. The delay between on-site user survey collection and field surveying was due to the combination of high amounts of leaf litter in early winter and frequent precipitation that closed trails in early 2007.

Two types of data were collected from the field survey and assessment. The first type was from the point-measurement trail-assessment procedure, which provided details about the overall condition of the trail and two indicators of trail impacts (i.e., maximum trail incision, trail width). This allowed for objective measurements to be collected at random points on each trail. The second type was the problem assessment, which was a total trail inventory of specific problems at each trail and resulted in a categorical indicator of trail degradation problems. Problems included mud puddles, excessive root exposure, excessive width, and multiple trail treads. The two surveys yielded two distinct data sets to be evaluated separately and then integrated with indices into statistical models.

3.5.1 Point-based Trail Assessment

The point sampling method provides a linear sequence of values typically assessed at a fixed interval along a trail and summarized with descriptive statistics (Cole, 1991). This method was deemed the most appropriate for assessing trail descriptors along the length of the trail in this study.

Geographic Information System (GIS) and Global Positioning System (GPS) were used to identify systematic sampling points at specific intervals along the trail after a random start point near the trailhead. In order to accurately map sample points, survey locations were entered as waypoints into a professional-grade GPS unit, a Trimble Pathfinder Pro XRS differential GPS receiver. This system provided real-time, map-grade locations. Elevation and coordinate data were stored in a Trimble TSC1 data logger and later exported to a computer for analysis and creation of map products. The data collection system was mounted in a backpack with an integrated GPS/Beacon/Satellite differential antenna, which allowed the researcher to collect point, line, and area features accurate to 1 centimeter when within a 45-minute occupation time or 10 kilometers of a base station. This GPS unit was used for the duration of the survey.

Sampling intervals varied between 27 feet and 1,500 feet according to trail length, so that each trail was sampled at 10 or more points. Trails shorter than 300 feet were excluded from the study. Sample points for trails longer than 16,500 feet were 1,500 feet apart.

Because trail-tread boundaries are difficult to discern, width was rounded to the nearest 5 cm. A measuring tape (stretched tight) was used to measure the width (as the base from which the maximum depth of incision was measured). Trail grade; degree of slope; position, alignment, and direction of slope; presence of litter, vegetation, rock, and mud; and surrounding forest type and soil type were also measured. See Table 3.5 for trail descriptor variables and Appendix E for in-depth explanations of trail descriptor variables.

Most of the following descriptors were derived from a review of the literature (Monz, 2000) and others were associated with the themes raised in the focus-group discussions. Average slope, cumulative elevation change, cumulative elevation increase, surface length, and avoidable and unavoidable obstacles are trail descriptors associated with trail challenge, whereas the remaining trail descriptors are associated with trail development. Trail impact variables (erosion, excessive grade, exposed roots, and trail widening) were measured both as a count of these events per mile of trail and as a percentage of the trail influenced by these impacts.

Table 3.5

Trail Descriptors

Variable	Definition	Method*
Average slope	Change in slope averaged for entire trail.	PS
Average width	Trail tread width measured in centimeters, averaged for entire trail.	PS
Avoidable obstacles	Trail obstacle (≥ 6 inches) with option to bypass via side trail.	PS
Cum. elevation change (feet)	Cumulative total of absolute value of elevation change along total length of the trail.	PS
Cumulative increase (feet)	Total positive change in elevation (climb) along the total length of the trail.	PS
Sharp curves	Count of trail curves with radius of turn greater than 90 degrees and less than 10 ft in turning radius.	PS
Intersections	Count of all trail intersections that occur on trail system.	PS
Loops	Count of all trail segments or loops that occur within trail system.	PS

Table 3.5 (continued)

Trail Descriptors

Variable	Definition	Method*
Manmade features	Count of all manmade structures on trail (water bar, drainage dip, lateral drain, retaining wall, culvert, steps, and trail corduroy).	PS
Surface length (feet)	Linear measurement of trail.	PS
Trail alignment angle (mean)	Trail's alignment angle to the prevailing landform in the vicinity of the sample point, averaged for all sample points.	PS
Unavoidable obstacles	Trail obstacle (≥ 6 inches) with no option to bypass.	PS

*Note**.** Column indicates the method used for each variable (PS: Point Sampling, PA: Problem Assessment, T: Tally of facilities).

3.5.2 Problem Assessment Survey

The problem-assessment method characterizes trail conditions by providing statistics such as number and location of occurrences, feet, percentage of trail length, and aggregate distance for predefined trail-impact problems (Marion, 1994; Leung & Marion, 1999).

In this study, the type and length of each problem were noted in the GPS unit with a beginning and ending point. The following problems were recorded: excessive grades, widths greater than 40 feet, sections with root and rock exposure of greater than 30 feet in length, and sections of tread with muddy soil, erosion, multiple trail tread, or standing water greater than 10 feet in length. If a problem location was within approximately 45 feet of a systematic point location, the systematic survey location was skipped, the problem location was surveyed, and the next systematic point was included. This was done to avoid including problems in the population of point-measurement trail assessment. See Table 3.6 for definitions of trail impact variables and Appendix E for in-depth explanations of trail impact variables.

Table 3.6

Trail Impact Measures

Variable	Definition	Method*
Erosion events	Count of events on trail with soil erosion exceeding 4 inches in depth and extending ≥10 linear feet, per mile of trail.	PA
Grade events	Count of events on trail with a trail grade of >20%, extending ≥40 linear feet, per mile of trail.	PA
Maximum trail incision	Maximum depth from the original trail surface level to the current trail surface level, to the nearest centimeter.	PA
Percent litter	Percentage of trail width consisting of organic litter.	PA
Percent rock	Percentage of trail width consisting of naturally occurring rock.	PA
Percent root	Percentage of trail width consisting of tree roots.	PA
Percent soil	Percentage of trail width consisting of bare soil, including organic soil and sand.	PA

Table 3.6 (continued)

Trail Impact Measures

Variable	Definition	Method*
Percent trail eroded	Percentage of total trail with soil erosion exceeding 4 inches in depth.	PA
Percent trail grade	Percentage of total trail with grade exceeding 20%.	PA
Percent trail root	Percentage of total trail with top and sides of root exposed.	PA
Percent trail widening	Percentage of total trail with trail width exceeding 20% expansion in width.	PA
Root events	Count of events where top and sides of roots are exposed for ≥30 linear feet, per mile of trail.	PA
Widening events	Count of events where there is >20% expansion in trail width, extending ≥40 linear feet, per mile of trail.	PA
Locking restroom	Presence of locking restrooms.	T
Parking	Presence of dedicated parking lot.	T
Picnic tables	Presence of picnic tables.	T

*Note**.** Column indicates the method used for each variable (PS: Point Sampling, PA: Problem Assessment, T: Tally of facilities).

3.6 Construction of Site Environmental Attribute Indices

The use of indices to explain recreation site quality is not new to recreation demand research. Since Stevens (1966) included site quality (angling success) as a reflection of fishing quality, most multiple-site demand models have included some form of an attractiveness index. An attractiveness index complements the travel-cost model, enabling a better understanding of user decisions. Thus, any travel-cost model with more than one site should include some measure of the effect of a change in site attractiveness on trip-making behavior (Ravenscraft & Dwyer, 1978).

Ott (1978) defined an index as "a single number derived from two or more indicators." Research indices have recently been used in recreation research to reflect the quality of recreation resources (Brunsun, 1996; Hamilton, 1996), perceived recreation resource impacts (Vaske, Graefe, & Dempster, 1982), and the severity of recreation-influenced biophysical changes (Cole & Bayfield, 1993). The creation of attractiveness indices for use in travel-cost modeling usually takes into consideration some form of expert opinion, results of preference surveys, a proxy variable, or actual on-site observations. Each method has its advantages and disadvantages (for a detailed explanation of these methods see Ravenscraft & Dwyer, 1978). The purpose of each remains the same: to provide a condensed description of multi-dimensional environmental states by aggregating several variables into a single quantity (Ebert & Welsch, 2004).

The original purpose of this study was to investigate the ability of site environmental attribute variables to influence mountain-biking demand in the Triangle. With over 40 descriptors (variables) gathered in the initial trail assessments, multi-collinearity was likely.

The existence of multi-collinearity means there were strong correlations between independent variables, which can result in inflated variances of the parameter estimates (Wooldridge, 2006). An issue that may arise due to multi-collinearity, particularly for small to moderate samples such as in this study, is a lack of statistical significance of individual independent variables, even if the overall model is strongly significant. Multi-collinearity can also cause wrong signs and magnitudes of coefficient estimates and thus incorrect conclusions between independent and dependent variables. One approach to multi-collinearity is to combine the variables involved into a single meaningful variable. But with this study's variables being inherently associated but equally significant and meaningful in explaining site quality, the use of indices was adopted as an alternative to attempting to include large numbers of site environmental attributes in the model. Standardization and normalization of variables (Ebert & Welsch, 2004) was done to eliminate bias and allow recreation ecology-derived measures to be integrated into thematic indices defined by focus group members.

Because there were six mountain-biking trails, non-parametric correlations (Kendall's Tau) were computed with the eight on-site assessment measures used to examine the pattern of relationships. With eight measures for six biking trails, multi-collinearity among variables was an issue (see Table 3.7). When input into the travel-cost model, these eight measures were individually significant determinants of demand; however, when all eight measures were input together into the model, the model dropped variables that were considered multi-collinear. It was felt that individual measures over-generalized the quality of a given course and that grouping related variables into indices would more accurately represent the study trails and capture variation between trails. Consequently, measures were combined into site environmental attribute indices based on the themes derived from the focus groups.

Table 3.7

Correlation Table of Site Environmental Attribute Index Variables

	Miles	Cumulative elevation change	Erosion events per mile	Grade events per mile	Problems per mile	Intersections per mile	Median width	Loops
Miles	1	-	-	-	-	-	-	-
Cumulative elevation change	.56*	1	-	-	-	-	-	-
Erosion events per mile	-.44*	.00	1	-	-	-	-	-
Grade events per mile	-.05*	-.16*	.14*	1	-	-	-	-
Problems per mile	-.44*	.00	1.0*	.14*	1	-	-	-
Intersections per mile	-.49*	-.60*	.41*	.09*	.41*	1	-	-
Median width	-.25*	.18	.62*	-.05*	.61*	.02*	1	-
Loops	.12*	.49*	.27*	-.58*	.27*	-.15*	.48*	1

Note. *Correlation coefficients significant at the 5% level or lower.

3.6.1 Standardization

Individual variables are measured in different units over different ranges. This makes them difficult to compare. In order to aggregate variables into indices, they must be normalized or standardized to eliminate any bias or weight conferred by the units of measurement (Ebert & Welsch, 2004). To standardize variables and combine them into composite scores for each index (domain), the following formula was used[1]: $V_{ij} = [X_{ij} - Min(X_i)] / [Max(X_i) - Min(X_i)]$, where V_{ij} is the index value for trail j (j = 1,…,6) and site environmental attribute i (i = 1,…,20). The maximum (Max) and minimum (Min) values represented the extreme data ranges for each variable (Rouse, Haas, Schell, & Deering, 1973).

3.6.1.1 Trail Challenge Index

Trail challenge, trail development, trail length, distance to trail, and trail condition were identified as important to mountain bikers during the focus group discussions. The trail challenge index included trail miles and cumulative elevation change for the mountain-biking trail (see Table 3.8). The two measures were repeatedly mentioned together by focus group members as indicators of a course's challenge and difficulty.

[1] When using ordinal measures, rank ordering is an accepted method of explaining value differences (Trochim, 2001). In this study, however, the author sought to capture more of the variation between trail descriptors and between sites. Therefore, indices, as explained by Rouse et al. (1973), were used.

Table 3.8

Trail Challenge Index Variables

Biking trail	Miles	Cumulative elevation change (miles)	Index value
Beaver Dam	14.7	1.01	100
Garner	1.9	0.15	0
Harris Lake	8.3	0.39	39
Lake Crabtree	8.1	0.44	41
Legend Park	4.8	0.41	27
Little River	6.2	0.35	28

Note. The index ranged from 100, for the most challenging trail, to 0, for the least challenging trail.[2]

3.6.1.2 Trail Condition Index

The trail condition index (see Table 3.9) included measures of trail quality that dealt with erosion, tree root exposure, widening events, and the trail grade following the fall line instead of the contour of the land. The three site environmental attributes were interrelated: erosion events per mile, grade events per mile, and cumulative problems per mile.

[2] Optimally, all indices would range from 0 to 100. However, only the trail challenge index does, because a single trail (Beaver Dam) happened to have the maximum values in both categories of the index and a different trail (Garner) had the minimum values in both categories.

Table 3.9

Trail Condition Index Variables

Biking trail	Erosion events per mile	Grade events per mile	Problems per mile	Index Values
Beaver Dam	7.4	8.3	12.6	43
Garner Park	12.4	15.0	22.7	88
Harris Lake	3.8	14.6	12.3	27
Lake Crabtree	11.3	10.3	17.6	55
Legend Park	11.6	5.6	17.8	89
Little River	0.5	2.3	3.4	6

Note. The index ranged from 89, for the most trail condition issues, to 6, for the least trail condition issues.

3.6.1.3 Trail Development Index

The trail development index (see Table 3.10) reflected site environmental attributes involving the naturalness, design, and flow of mountain-bike courses and included intersections per trail mile, median trail width, and number of loops per course.

3.7 Travel Costs

Travel cost is a combination of the expenses in undertaking a mountain-biking outing. The average vehicle operating cost in North Carolina was $0.62 cents per mile (American Automobile Association, 2006). Costs included vehicle upkeep, depreciation, and fuel. Mileages to mountain-biking trails were measured as the linear driving distances from the zip code of a respondent’s residence or place of employment to each of the six mountain-biking trails visited over the past year. The latitude and longitude for those trails were obtained from the distance-mapping software by Google Earth Product Family (Google Earth, 2007). Google Earth was used because it became apparent that some respondents had confused the distances for one-way trips with round-trips. To remove possible discrepancies in the reported travel costs, measured mileage estimates rather than those stated by respondents were used to compute the travel costs. Mileage was multiplied by 2 for a round-trip distance and multiplied by $0.62 per mile, for the total travel cost to a given mountain-biking trail. Each respondent was asked about his or her incidental travel expenses for the last outing (i.e., excluding expenses related to his or her vehicle), which were then included in the overall trip cost (Parsons, 2003).

Table 3.10

Trail Development Index Variables

Biking trail	Intersections per mile	Median width (cm)	Number of loops	Index value
Beaver Dam	1.57	80	5	31
Garner	11.88	99	3	70
Harris Lake	6.71	75	5	42
Lake Crabtree	5.08	103	6	78
Legend Park	6.85	85	5	54
Little River	2.10	79	2	7

Note. The index ranged from 78, for the most developed trail, to 7, for the least developed trail.

Opportunity cost of travel time is calculated using an hourly wage rate and presumes a respondent's ability to work rather than mountain bike. Because information was not collected regarding each respondent's hourly wage, it was imputed by dividing the reported annual income by 52 weeks times 40 hours/week, or 2,080 hours (Parsons, 2003). Although the ratio of opportunity cost of travel time to hourly wage has not been satisfactorily resolved by economists, a ratio of one-third has become customary (Rosenthal, 1987). Therefore, for each respondent, the imputed hourly wage was multiplied by the constant value of one-third and the resulting value then multiplied by the round-trip time, as determined by Google Earth, for each of the six mountain biking trails. The four values of travel cost, daily access fee, incidental travel expense, and cost of travel time were summed as the measure of the trip costs to the destinations visited by a respondent.

3.8 Recreation Model Specification and Hypotheses

The demand function for recreation at a biking trail involves a relationship between the number of outings taken by an individual in a given period of time, the travel cost, site environmental attributes, and personal characteristics like annual income. This demand relationship was used in this study to estimate how the expected number of outings to mountain-biking trails is influenced by hypothetical changes in the site environmental attribute values. It was assumed that (a) individuals react to changes in travel costs as they would to any other price change, (b) each outing is to one biking trail only, so that travel costs can be clearly divided between biking trails, (c) time spent at a biking trail is constant for each visit, because the number of outings is the dependent variable in the demand equation, (d) travel time should be neutral—there should be no benefit or cost to the individual in travel, and (e) the wage rate is considered the opportunity cost of time (Rosenthal, 1987).

The number of annual mountain-bike outings to a biking trail is a non-negative integer with a discrete distribution (Smith, 1988). Because the users were intercepted on-site, the count-data of the annual number of outings to the six mountain biking trails were corrected for endogenous stratification and zero-truncation (Englin & Shonkwiler, 1995). That is, even though users were intercepted with a random-selection strategy, users who visit the mountain-biking trails more frequently were assumed to have a higher probability of being selected into the sample than less frequent users. The tendency to over-sample more frequent users is endogenous stratification. Because a user could not be observed to have zero outings, the error term in the statistical estimation of the demand function was truncated. Without this truncation, the statistical extrapolation outside the range of the observed number of outings would have been distorted.

Shaw (1988) corrected for these two possible issues by subtracting one from the quantity of outings to the recreation site where the respondent was intercepted. In addition, the data distributions of annual recreation outings tend to reflect an over-dispersion where the conditional mean does not equal the conditional variance, as with a Poisson distribution. The negative binomial estimator as opposed to the Poisson count-data estimator is applied to over-dispersed distributions to provide non-bias and consistent estimates (Cameron & Trivedi, 1986).

Because this study sought to determine the effects of site environmental attributes of mountain-biking trail conditions and of their hypothetical changes on recreation use at mountain-biking trails, it employed a recreation-demand equation relating the quantity of mountain-bike outings to the six mountain-biking trails and did not analyze each specific biking trail. The quality and site environmental attributes were assumed not to vary over the study's time frame of a year. The approach incorporates multiple mountain-biking trails in the Triangle and as well as the counts of outings to the trails. In essence, the proposed multiple-site count model generalizes to a single-site model by estimating the demands for a set of substitute sites over the past year (Freeman, 2003, p. 426).

In this study, a multiple-site count model made it possible to observe large quality variations, unlike the variation in quality with a single-site count model, which is often insufficient to determine individuals' responsiveness to quality changes (Freeman, 1979). Individuals choose to use sites based on the availability and quality of accessible alternatives.

A proper approach will observe behavior that accurately captures the choices available to the individual. Even when quality is not an issue, multiple-site models provide a more realistic specification of the recreationist's choice because the valuation of one site will depend on the existence of alternative, substitute sites. A model that ignores possible alternatives will be not be specified correctly (Caulkins, Bishop, & Bouwes, 1986). However, consolidating the site-specific counts into one dependent variable does limit the ability to infer welfare values of particular sites from the demand analysis. The multiple-site count model is estimated with the following recreation demand equation and a truncated negative binomial estimator (STATA Press, 2006, p. 246):

$$\text{EXPECTED (OUTINGS}_{ij}) = b0 - b1{*}\text{TRIP COST}_{ij} + b2{*}\text{ANNUAL INCOME}_i + b3{*}\text{CHALLENGE}_j + b4{*}\text{TRAIL CONDITIONS}_j + b5{*}\text{DEVELOPMENT}_j + b6{*}\text{PERSONAL CHARACTERISTICS}_i + \ldots + bn{*}\text{PERSONAL CHARACTERISTICS}_i + e_{ij}$$

The coefficient b0 refers to the constant term, b1,…,bn are the coefficients on the determinants of demand, each subscript i corresponds to a user, and each j corresponds to one of the six substitute biking trails. Of particular interest on the right-hand side of the equation are the site-environmental-attribute-index coefficients b3, b4, and b5, each of which represents the rate of change in expected outings from hypothetical changes in site environmental attributes. For these three coefficients, the following null hypotheses and the corresponding alternative hypotheses have been formulated.

H_O: b3 = 0; H_O: b4 = 0; H_O: b5 = 0 and alternatively,

H_A: b3 ≠ 0; H_A: b4 ≠ 0; H_A: b5 ≠ 0.

In summary, multiple methods were used to obtain the necessary data for this study, including focus groups, an on-site user survey, and field surveys. Indices were generated to group meaningful site environmental attributes from the field surveys, and travel-cost data were generated using data gathered from on-site surveys and a geographic information system.

CHAPTER 4

RESULTS

This chapter reports the results of the mountain-biker survey, including social demographic data and revealed preference data. It then describes the variables used in the model of mountain-biker demand and the results of these variables when used in the travel cost model. The chapter concludes with how the model confirms the alternate hypotheses and answers the research questions identified at the beginning of this study.

4.1 Description of Mountain-Biking Sample

Respondents traveled an average of 15.8 miles (SD=8.2) to biking trails and spent on the average 1.8 hours (SD=0.6), with an average ride distance of 10.3 miles (SD=5.0). Average group size was 2.7 individuals (SD=2.7). The riders were 83.2% male and averaged 35.8 years of age (SD=8.6), with an education level of 17.0 years. Average household income was $90,708 (SD=$50,157). Average number of outings per person was 11.9 (SD=18.4) during the survey period. Riders averaged 7.5 years (SD=5.8) of riding experience, and 26.3 % belonged to a mountain-biking organization. (See Table 4.1 for more information.)

4.2 Preferences and Characteristics of Mountain Bikers

Cessford (1995a) noted differences in mountain-biker preferences by skill level. Hence this study differentiated participants as novice, intermediate, or expert, and the results confirmed Cessford’s finding. Over one-third (38.6%) of female respondents considered themselves expert, whereas 46.5% and 14.8% ranked themselves intermediate and novice, respectively. This contrasted with figures of 61%, 33.6%, and 4.5% for expert, intermediate, and novice males. The difference in percentages between expert, intermediate, and novice males and females was significant (rank-sum, Pr > |z| = 0).

Table 4.1

Descriptive Statistics of Mountain-Biking Sample

Characteristic	Mean	SD
Average travel distance in miles (round trip)	15.8	8.2
Average time on-site (hours)	1.8	0.6
Average ride length (miles)	10.3	5.0
Group size	2.7	2.7
Male (%)	83.2	n/a
Average age (years)	35.8	8.6
Education (years)	17.0	2.9
Average household income (dollars)	90,708	50,157
Belong to mountain biking club (%)	26.3	n/a
Years of riding experience	7.5	5.8
Triangle outings in past year average (total)	11.9	18.4

The average length of mountain-biking experience reported by skill level was as follows: 9.2 years (SD=5.6) for experts, 5.2 (SD=5.0) for intermediates and 1.9 (SD=2.7) for novices. Average distances (self-reported) of mountain-bike rides by skill level were 11.3 miles (SD=5.1) for experts, 9.0 (SD=4.5) for intermediates, and 7.8 (SD=5.4) for novices. Mean annual outings of mountain bikers by skill level were 13.7 (SD= 20.1) for experts, 9.6

(SD=15.2) for intermediates, and 5.5 (SD=14.2) for novices. The difference in average annual outings among experts, intermediates, and novices was highly significant (rank-sum, $Pr > |z| = 0$). Thirty-six percent of experts, 10% of intermediates, and 0% of novices reported belonging to a mountain-biking organization. The difference in involvement between expert mountain bikers and the group of intermediates and novices was significant (rank-sum, $Pr > |z| = 0$).

4.3 Description of Model Variables

The mean number of annual trips taken by Triangle mountain bikers in 2006, as presented in Table 4.2, was 11.9 (SD=18.4), with a maximum of 159 trips per year and a minimum of 1. There was a large difference between the mean and the standard deviation. The dependent variable, annual outings, was over-dispersed because the variance was greater than the mean, a violation of the Poisson distribution assumption that the mean and variance be equal.[3]

The independent variables used in this study are presented in Table 4.2 and include the site-quality indices (i.e., trail challenge, trail condition, and trail development), respondent's income, whether the respondent belonged to a mountain-biking organization, and whether the mountain biker rides predominantly on weekends.

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[3] In a Poisson distribution, the mean and variance are equal. When the variance is greater than the mean, the distribution is said to display overdispersion. When there is overdispersion, the Poisson estimates are unreliable, with standard errors biased downward, yielding spuriously large z-values. Negative binomial regression is used to estimate count models when the Poisson estimation is inappropriate due to overdispersion (Chakraborty & Keith, 2000).

Table 4.2

Descriptive Statistics of Dependent and Independent Variables

Variable	Mean	Minimum	Maximum	SD
Annual outings	11.9	1	159	18.4
Travel cost	63.8	8	305	36.2
Challenge	47.2	0	100	30.8
Trail condition	49.5	6	89	24.6
Development	50.6	7	78	22.8
Income	90,709	10,000	500,000	50,157
Belong	.3	0	1	.4
Weekend	.7	0	1	.5

4.4 Zero-Truncated Negative Binomial Model

The results of the zero-truncated negative binomial model are listed in Table 4.3. The coefficients on all variables in the model were significant at the 99% confidence level. The travel cost coefficient was negative, implying that as travel costs increased, the demand (i.e., quantity of mountain-biking outings) decreased and vice versa. All the site-quality indices were statistically significant. The coefficient on the trail condition index was negative, which implied that as trail condition issues decrease, demand will increase. Trail challenge and development indices were positive, implying that these site quality indices positively influenced demand.

Table 4.3

Significant Determinants of Demand for Annual Outings*

Variable	Coefficient	SE	Mean	Marginal effect
Travel cost	-0.029	0.006	63.815	-0.135
Trail challenge index	0.009	0.003	47.160	0.043
Trail condition index	-0.022	0.007	49.515	-0.098
Trail development index	0.023	0.005	50.580	0.104
Income	0.00000837	0.00000157	90708	0.0000378
Belong to mountain biking organization	0.647	0.127	0.263	3.469
Ride on weekend	-0.806	0.138	0.688	-4.354
Constant	2.500	0.371	n/a	n/a
Summary Statistics				
Observations	1071			
Log likelihood	-3394			
Wald chi 2 (7)	205			
Prob > χ^2	0.00			

Notes. * All variables shown were significant at the 99% confidence level.
Log Likelihood - This is the log likelihood of the fitted model. It is used in the calculation of the Likelihood Ratio (LR) Chi-square test of whether all predictor variables' regression coefficients are simultaneously zero and in tests of nested models.
Wald chi2(7) - This is the Wald Chi-Square statistic. It is used to test the hypothesis that at least one of the predictors has a regression coefficient not equal to zero. The number in the parentheses indicates the degrees of freedom of the Chi-Square distribution used to test the Wald Chi-Square statistic and is defined by the number of predictors in the model (7).
Prob > chi2 - This is the probability of getting a Wald test statistic at least as extreme as the observed statistic under the null hypothesis, the null hypothesis being that all of the regression coefficients across both models are simultaneously equal to zero.

Among the social demographic variables, income and membership in a mountain-biking organization were positive coefficients and were also found to be highly significant, whereas riding primarily on weekends was a negative coefficient. Annual household income is an important determinant of how many annual outings mountain bikers take. Specifically, the marginal utility of money declines as household budget increases, so that greater affluence is likely to be associated with taking more mountain-biking outings. Membership in a mountain-biking organization is a highly significant and positive determinant of demand. This suggests that an individual who belongs to a mountain-biking organization will take more mountain-biking outings. The variable of whether an individual mountain bikes predominately on weekends or weekdays is a significant and negative determinant of demand. If one only takes outings on weekends, the potential to take more outings per year will be less than for someone who takes outings on weekdays and weekends.

The price elasticity of demand was -0.13.[4] In this instance, a 10% increase in price results in a 1.3% decrease in demand, which falls within the conventional range for price elasticity of demand for bicycling (-0.23) (Loomis & Walsh, 1997). The marginal effect of a point change in travel cost (in US dollars) on the demand for annual trips was -0.13 trips—0.04 for trail challenge, -0.10 for trail condition, and 0.10 for trail development, the marginal effects being computed at the means.[5]

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[4] Price elasticity of demand measures the extent that demand for a good is sensitive to price changes. In mathematical terms, Price Elasticity of Demand = (% Change in Quantity Demanded)/(% Change in Price). The higher a good's price elasticity, the more purchases decrease when price increases and the more purchases increase when price decreases. If price elasticity > 1, then demand is said to be "price elastic." If price elasticity < 1, then demand is said to be "price inelastic."

[5] Marginal effects representing the effects of changes in the number of outings for a one-unit change in a given factor are calculated as the mean number of outings multiplied by the estimated coefficient on that factor.

When examining predicted outings versus actual outings, the model under-predicts a total mean of 8.1 outings, versus the actual total mean outings of 11.9 (see Table 4.4). The total impact of each included variable was supported by a likelihood ratio test (Prob > χ^2 = 0). For example, the null hypothesis that the trail challenge index has no effect ($B_3 = 0$) is rejected.

Table 4.4

Mean Actual Outings Versus Mean Predicted Outings

Site	Actual	SD	Predicted	SD	Frequency
Beaver Dam	11.0	17.0	7.0	5.6	241
Garner Park	6.9	9.8	4.2	3.1	104
Harris Lake	11.4	15.4	6.2	6.9	208
Lake Crabtree	19.0	24.4	15.2	11.4	301
Legend Park	7.6	12.6	2.3	2.1	121
Little River	5.6	12.2	4.2	4.4	96
Total	11.9	18.4	8.1	8.8	1071

4.5 Hypothesis Testing

The study hypotheses were investigated using the *lincom* and *test* routines in the STATA Statistical package (Stata Corp, Version 9, 2006). The lincom routine compares the relative influence of two different variables within the same equation. The research hypotheses follow.

4.5.1 Research Hypotheses

H_O: Trail challenge = 0

H_O: Trail condition = 0

H_O: Trail development = 0

4.5.2 Hypothesis Testing and Results

To find the relationship among the site environmental attribute indices (challenge index, condition index, and development index), the lincom routine in STATA was used to calculate the linear combination effect of two coefficients, to determine if it was different from the individual coefficients. The results of the lincom routine showed that the effect of each index was significant in the model and distinct from the other two site environmental attribute indices at the $p < 0.01$ level or better. (See Table 4.5.)

Table 4.5

Lincom Routine Results

Test	Coefficient	Standard Error	Z–value	P >|z|
T1	0.0312109	0.0090064	3.47	.001
T2	-0.0136463	0.0043938	-3.11	.002
T3	-0.0448572	0.0125828	-3.56	.000

Note. T1: trail challenge – trail condition = 0
T2: trail challenge – trail development = 0
T3: trail condition – trail development = 0

The lincom routine confirms that the indices used in this model are significantly different from zero. The null hypotheses of no trail-challenge, no trail-condition, and no trail-development effects were rejected at the 99% confidence level. These three indices are important determinants of how many annual outings mountain bikers take to the six Triangle mountain-biking trails examined in this study. Social demographic variables and site environmental attribute indices used were found to be significant determinants of demand in the travel-cost model of mountain-biking demand.

CHAPTER 5

DISCUSSION

The purpose of this study was to determine the influence of trail attributes, particularly trail challenge, trail condition, and trail development, on mountain-biking recreation demand in the Triangle of North Carolina. This chapter begins by comparing the results of this study with those from previous mountain-biking research. A discussion of the important conclusions of this study follows, with an analysis of the selected variables in the model of mountain-biking demand and the effectiveness of site environmental attribute indices used. This is followed by a discussion of the management implications and theoretical contributions of this work. Finally, an examination of further questions raised by this study is presented along with possible avenues for future research.

5.1 Comparison of Results to Previous Research

5.1.1 Social Demographics

In this study, the mean age of respondents was 35.8 years, with a median of 35. This finding falls within the mean ages reported in previous studies. For example, Hollenhorst et al. (1995a) studied five national forests in Texas, West Virginia, and California and noted that the average age of respondents was "almost 30 years," but reported an average age of 38.2 for a national survey of IMBA members (Hollenhorst et al., 1995b). Fix and Loomis (1997) found the average age of respondents to be 27. Organizations like IMBA may consist of older mountain bikers, whereas younger mountain bikers are much more likely to be in school and less likely to have a full-time job.

The median household income for mountain bikers responding to this survey was $89,999, which is 186% of the median household income ($48,451) in the United States for year 2006 (U.S. Bureau of the Census, 2008). After adjusting for inflation, mountain bikers in this study earned more than the participants in previous studies. Mountain bikers surveyed in Chakraborty and Keith (2000) reported an average household income of $53,856, which was 139% of the median household income in the United States ($38,782) for year 1993 (U.S. Census Bureau, 2008). This was slightly higher than in Hollenhorst et al. (1995a), where 51.6% earned between $40,000 and $49,000, and Hollenhorst et al. (1995b), where 18.8% earned between $45,000 and $59,999. The incidence of higher income levels in the current study may be partly explained by the higher household incomes in some parts of the Triangle area. For example, three of the six zip codes with the most numerous respondents in this survey had median household incomes between $68,000 and $72,000 in the U.S. Census Bureau's 2000 data (U.S. Census Bureau, 2008), where the median household income for the nation as a whole was $41,994.

Triangle mountain-biker respondents had, on average, 17.0 years of education, with a median of 16.0, compared to a mean of 15.8 years in Chakraborty and Keith (2000) and a mean of 14.9 years in Hollenhorst et al. (1995a). Male mountain bikers in this study were a majority (83.2%). This was similar to other mountain biker survey samples, for example, Hollenhorst et al. (1995b) recorded 88% male, and Chakraborty and Keith (2000) 82.2%.

Mountain-biking experience averaged 7.5 years (SD=5.8), more than the 3.7 reported in Hollenhorst et al. (1995a) and the 5.9 found in Hollenhorst et al. (1995b). This disparity may be explained by the growing popularity of the sport. In 1995, when mountain biking was less established, there were fewer participants with extensive experience, mountain bike technology (e.g., reduced bike weight, improved front suspension, improved rear suspension, and after-market components) was evolving, and riding locations were limited.

Mountain-biking mileage per outing averaged 10.3 miles (SD=5.0), whereas Hollenhorst et al. (1995a) reported 14.1 miles and Hollenhorst et al. (1995b) 15.0 miles. The difference may be because in this study, outings were mostly undertaken after work or close to home, not as part of a vacation trip or weekend destination as in the Hollenhorst et al. studies. More likely is that Triangle trails are relatively short, with five out of six courses less than nine miles in length, and located on municipal properties. Other studies have been conducted on National Forests, Bureau of Land Management sites, or state forest sites, which have more land available for trail development.

5.1.2 Trail Resource Impacts

Previous studies collected data from trails used exclusively for mountain biking and documented mean trail widths lower than the current study's 92 cm. This contrasts with the mean trail width of 81 cm found by White et al. (2006) and 60 cm found by Marion and Olive (2006). Goeft and Alder (2001) found mean trail widths at two separate trails measured over a period of nine months to range from 45 cm to 65 cm. Possible reasons for wider trail width in this study are the geographic setting (e.g., soil type, vegetation type, and climate), the amount of trail usage, and trail design. Shorter trail lengths may also contribute to wider trails, as riders may repeat loops due to the lack of available trail mileage.

The mean trail incision on the Triangle trails studied was 5.6 cm, which was considerably higher than the mean trail incision, 3.8 cm, in White et al. (2006). Higher average slopes did not appear to explain the differences in average maximum trail incision between these two studies, as the 6.5% average slope on Triangle trails was slightly lower than the 7.6% reported by White et al. (2006).

5.2 Performance of Variables and Indices

5.2.1 Sample Heterogeneity

When examining mountain-biker characteristics and attitudes based on gender and skill level, some clear differences were evident. This study disclosed an unequal distribution of self-reported skill levels (expert, intermediate, or novice) when participants were grouped by gender. More than half of females considered themselves novice or intermediate (58 %). Several explanations were obtained from anecdotal sources (i.e., fellow mountain bikers, personal experience). One is that mountain biking may be gaining popularity faster among females than among males, which would imply a larger percentage of newcomers among women. Another is that females may be dropping out of mountain biking before reaching expert. A third is that male and female mountain bikers may have different impressions of what constitutes a given skill level.

5.2.2 Effectiveness of Selected Variables

The variables that were incorporated into the travel-cost model of mountain-biking demand were selected based upon their statistical significance and intuitive effect on predicting the number of annual trips. Variables used in the model consisted of travel cost, annual household income, whether the respondent belonged to a mountain-biking organization, whether the respondent predominately took outings on weekends, and three site environmental attribute indices—trail challenge, trail development, and trail condition.

5.2.2.1 Social Demographic Variables

The travel-cost variable in this study was statistically significant and negative and as in Chakraborty and Keith (2000), was found to be an important determinant in the valuation of leisure time. As the travel cost of an outing increases, the number of trips will decrease. Cost is directly determined by the time and distance to reach the mountain-biking trail. The Triangle is a relatively small geographic region. Even though all mountain-biking trails are within 60 miles of each other, the relative travel costs significantly influenced mountain-biker decision making.

Annual household income was found to be significant, suggesting that as household income increases, so does an individual's likelihood of taking more mountain-biking outings. Neither income nor other personal characteristics, which were tested in Chakraborty and Keith (2000) and Fix and Loomis (1997), were found to be significant.

Whether the respondent rode primarily on weekends was significant as a negative predictor for the number of annual mountain-biking outings. This could simply be reflecting that mountain bikers who are limited to weekend-only riding have less opportunity than mountain bikers who ride throughout the week.

5.2.2.2 Site Environmental Attribute Indices

The first research question asked which site environmental attributes influence users' demand for mountain-biking outings. The site environmental attributes explored in this study exhibited multi-collinearity. The author constructed indices to deal multi-collinearity. Each of the three indices (trail challenge, trail condition, and trail development) significantly influenced mountain-biking demand on the trails studied.

Trail challenge index, trail condition index, and trail development index contributed positively to the annual number of outings taken by study participants. The site challenge index had a median of 41, a standard deviation of 31, and a range between 0 (“trail had minimal challenge”) and 100 (“trail had maximum challenge”). The trail condition index had a median of 43, a standard deviation of 25, and a range between 6 (“trail had the least trail condition issues”) and 89 (“trail had the most trail condition issues”). The trail development index had a median of 42, a standard deviation of 23, and a range between 7 (“trail had the least development”) and 78 (“trail had the most development”).

5.2.2.2.1 Trail Challenge Index

When changing site measures within the range of values in the model (0 to 100), the challenge index brought about an increase of 0.08 annual outings per change in index point, from 5.3 expected annual outings to 13.5 expected annual outings (see Figure 5.1). Conversely, if the challenge index for the region’s trails decreases from 80 to 40, annual visits decreases by 3.5 trips per person. The mean number of annual outings per year for the population studied (11.9) falls within the range of predicted values of 5.3 to 13.5. If a trail is highly challenging, intermediate and novice mountain bikers may tend to avoid it.

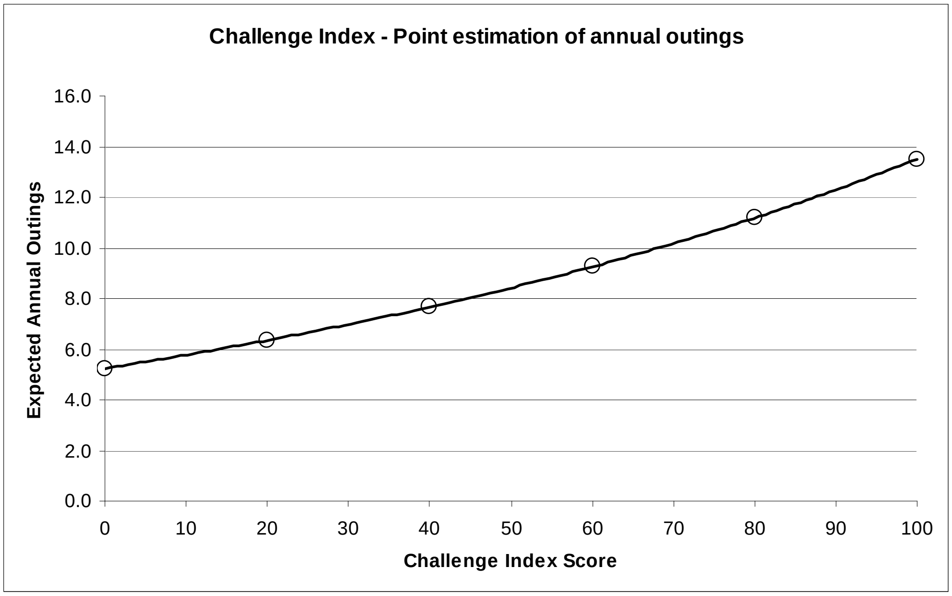

Figure 5.1. Point estimation of annual outings showing change in expected annual trips with change in trail challenge, all other variables held constant at their means.

5.2.2.2.2 Trail Condition Index

When changing site measures within the range of values in the model (6 to 89), the trail condition index brought about a decrease of 0.21 annual outings per index point, from 22.6 expected annual outings to 3.7 expected annual outings (see Figure 5.2). If trail condition index in the area were to improve from 72 to 56, annual outings would increase by 2.2 outings per person. The mean number of annual outings per year for the population studied (11.9) is computed to be between the second and third quintile, suggesting that even though trail condition may have a strong influence on expected annual outings, the model is not over-predicting this index.

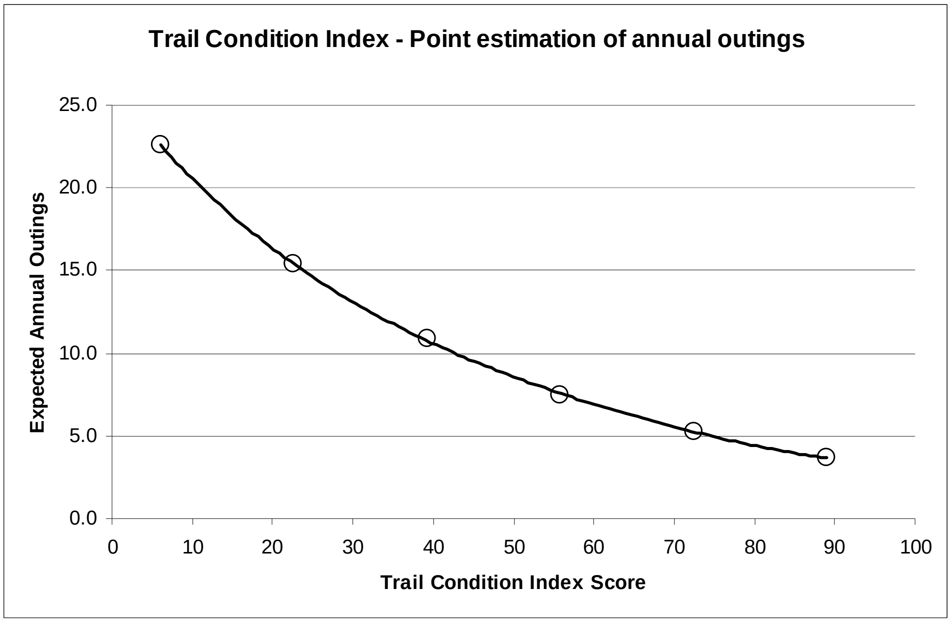

Figure 5.2. Point estimation of annual outings showing change in expected annual outings with change in trail condition, all other variables held constant at their means.

5.2.2.2.3 Trail Development Index

Changing site measures within the range of values in the model (7 to 78), the trail development index brought about an increase of 0.12 annual outings per index point, from 2.8 expected annual outings to 14.6 expected annual outings (see Figure 5.3). When modeling the decrease in trail development in the region from a score of 50 to 35, a decrease in 2.3 annual outings can be expected. The mean number of annual outings per year (11.9) falls above the fourth quintile, which is higher than expected and possibly points to under-prediction with this particular index.

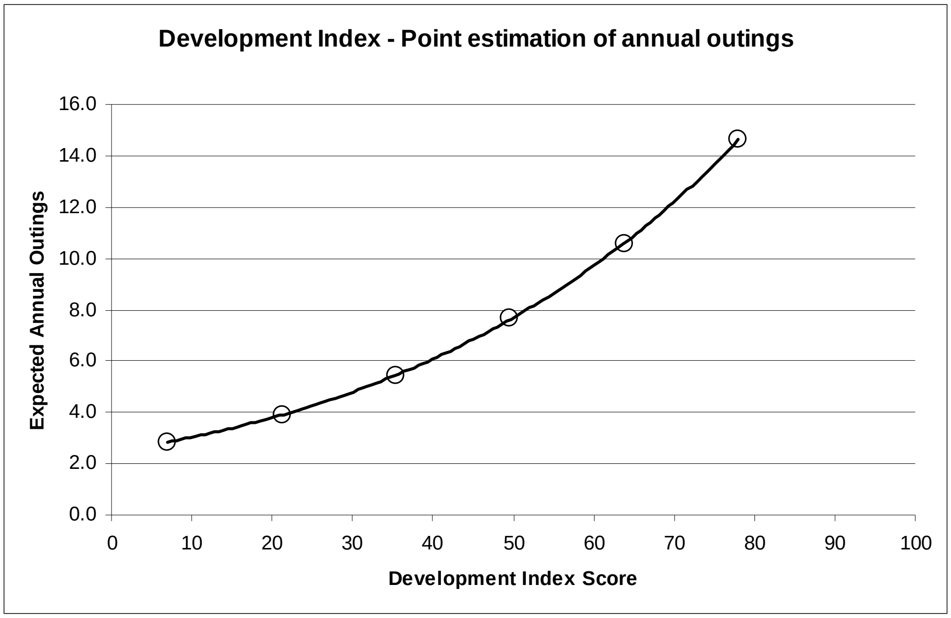

Figure 5.3. Point estimation of annual outings showing change in expected annual outings with change in trail development, all other variables held constant at their means.

5.2.2.2.4 Composite

Results of the site environmental attribute indices within the model support the findings of their importance as determinants of recreational mountain-biking site selection. The effect of the challenge index on expected annual outings was expected, given the interest in this feature by focus-group members. Though the challenge index was not the strongest of the indices, it potentially increased annual outings by 1.6 outings if this variable was maximized at each Triangle mountain-biking trail (see Figure 5.4). This small increase implies that increased challenge tends to discourage lesser skilled mountain bikers from using a course.

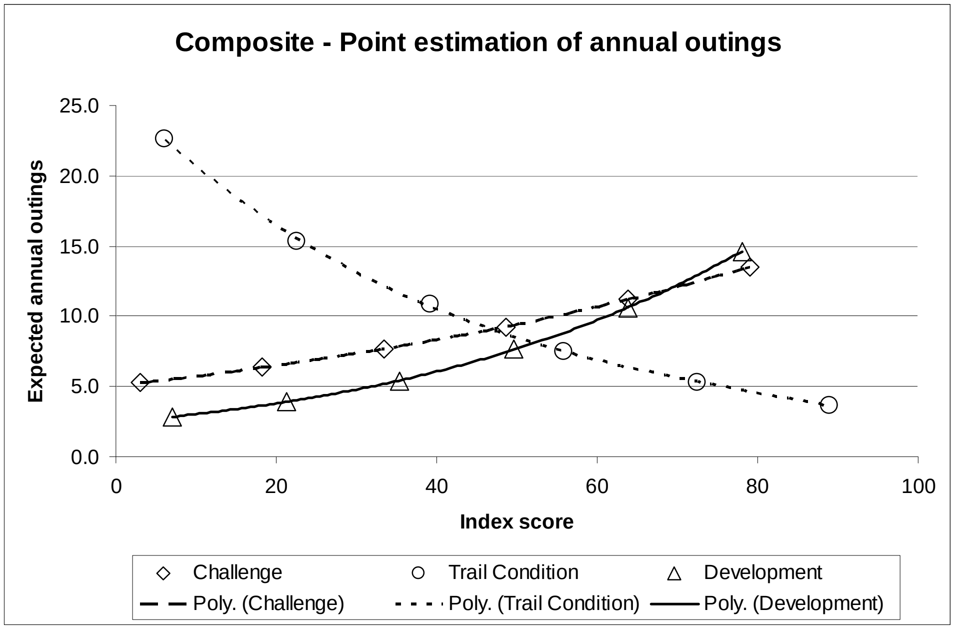

Figure 5.4. Site environmental attribute indices composite, third order polynomial trend lines.

In contrast to trail challenge, the concepts of trail condition and trail development tend to be perceived differently by various individuals. These two topics are the least transferable or measurable from one region to the next, as they are a product of geography, climate, and management situation of the region. When modeled and maximized, trail condition added 10.7 potential outings and trail development added 2.7. Their influence on expected mountain-biking outings was more substantial than the emphasis focus-group members placed on these variables. These findings are an initial approximation of modeling site environmental attributes and mountain-biker demand and are similar to the Siderelis, Moore, and Lee (2000) study of site quality and hiking trails in North Carolina. That study noted an estimated individual demand of 5.79 trail trips per annum, and when the ideal conditions of trail users were met, stated trips increased to 8.16 trips per annum. In the current study, outings (trip) changed similarly; when conditions were maximized, outings increased by 11. Essentially, the increase in outings was plausible if conditions were maximized.

The second research question asked how accurately users' demand for mountain-biking trails can be predicted from their revealed preferences. Applying the travel-cost model of mountain-biking demand explains the variation in predicted mountain-biking outing demand 42 percent of the time. The model consistently under-predicts mean outings per year to each trail in the study (see Figure 5.5). This under-prediction may be because the

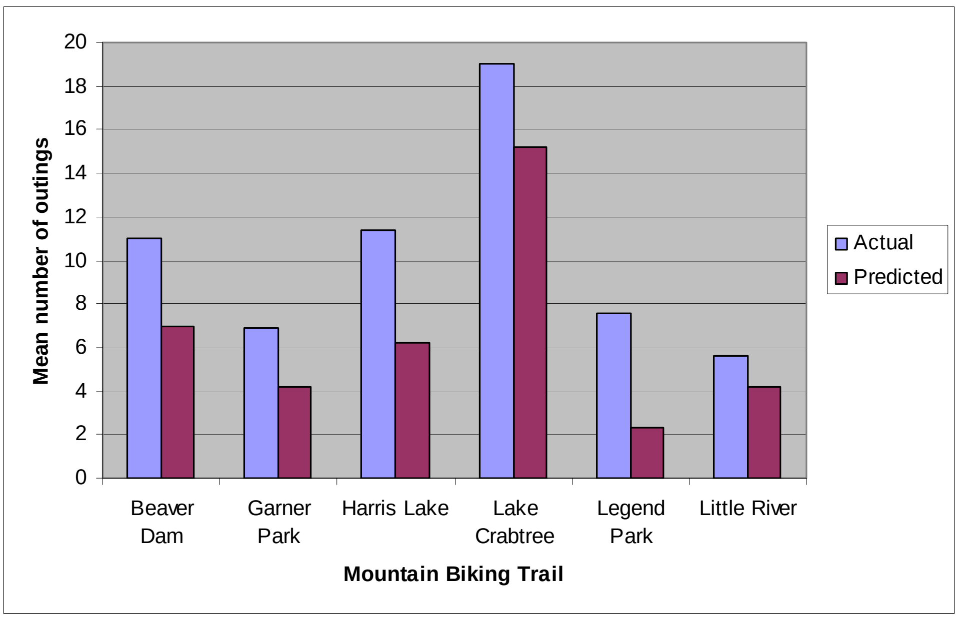

Figure 5.5. Actual and predicted mean annual outings per trail.

distribution of the dependent variable, annual outings in 2006, is skewed to the left, with a range of outings per year of 1–159, a mean of 12, and a median of 5 (see Table 4.2).

5.3 Management Implications

The incorporation of geospatial technologies in the gathering, deriving, and analyzing of site environmental attributes, coupled with travel-cost and trail-condition analysis methods, can aid in recreation management and planning. It does this by providing a comprehensive and reliable picture of what trail features are driving mountain bikers' selection processes. Studies have examined recreationists' stated preferences and their perceptions of environmental impacts, with mixed and sometimes inconsistent results (Manning, 1999). Management decisions focused on designing, building, maintaining, or updating mountain-biking facilities, when coupled with mountain bikers' revealed preferences, are more likely to provide the benefits these recreators seek.

In this study, trail challenge, trail condition, and trail development did significantly influence mountain-biking trail demand. This finding has important management implications. One is that appropriate management planning might reduce changes to trail quality and the need for visitor-management activities. Alterations to the current trail can be focused on those site environmental attributes that increase users' satisfaction (utility). If changes in the trail diminish users' satisfaction, current trail users might migrate to other mountain-biking trails. However, carefully planned modifications to site environmental attributes, aimed at diverse management issues, and might actually broaden the trail user base without displacing the original core mountain-biking group. Still, the relationships between the most important site environmental attributes and trail user satisfaction should be monitored at these locations.

Focus-group participants concurred that trail condition was not a high priority in selecting mountain-biking sites, supporting the prevailing perception held by researchers and land managers. However, this impression was contradicted by the preference data. According to the statistical model, differences in trail condition result in significant changes in the number of outings per year. In fact, the influence of trail condition appears to be greater than the combined influence of trail challenge and trail development.

An unintended but important finding became evident when comparing the results of the field surveys by trail. Little River Trail was built according to guidelines specifying five essential elements of sustainable trails (see Table 5.1). IMBA defines sustainable trails as low-maintenance trails that have minimal impact on natural systems (IMBA, 2004). The other five trails in this study were not originally built using these guidelines, although some sites have subsequently adopted these methods for building new trail segments. The results show the benefits of this type of trail design, primarily in the minimal impacts found at this location in comparison to all other trails (see Table 3.9). Little River's problems per mile (3.4) were less than one-third of that for the next best trail (12.3). This theme remained consistent through all the trail condition variables recorded, as in the case of erosion events per mile, where Little River had less than one-seventh the events than did the next best trail.

Recreation managers of natural areas must often weigh protecting the integrity of a natural resource against providing recreational access such as mountain biking. Though the cost and time may be larger at the outset of building a sustainable mountain-biking trail, this study suggests that proper design leads to superior conditions with fewer maintenance issues per mile of trail. If trail builders and management avoid sharp downhills, include outslopes and curves to reduce the erosional influence of slope and water, and avoid special resources (e.g., endangered species, protected species, erodible soils), many ecological and managerial benefits could be realized.

Table 5.1

Five Essential Elements of Sustainable Trails

Element	Explanation
The half rule	A trail's grade should not exceed half of the grade of the hillside or sideslope that the trail traverses.
The ten percent average guideline	An average trail grade of 10 percent or less is most sustainable.
Maximum sustainable grade	Before designing trails, it is essential to determine the maximum trail grades the trail will be able to sustain under local conditions (typically 15 to 20 percent).
Grade reversals	Climbing trails should include a spot at which the trail levels out and then changes direction, dropping subtly for 10 to 50 linear feet before rising again. This change forces water to exit the trail and discourages excessive speed.
Outslope	As the trail contours across a hillside, the outer edge of the tread should tilt slightly down and away from the high side. (IMBA recommends that all trail treads be built with 5 percent outslope.)

Aside from the ecological benefits of sustainable course design and maintenance, findings from this study indicate that mountain bikers prefer trails that are in good environmental condition. This information supports managers who prioritize sustainable trail design at least as much as trail challenge and trail development when building new trails or maintaining current ones. Even though initial costs are higher for sustainably built mountain-biking trails, these costs could be offset by charging access fees. Although user fees would be expected to decrease demand for trail use, Morey, Buchanan, and Waldman (2002) found mountain bikers willing to pay access fees for new or improved trails.

When asked to rank trail attributes by desirability, participants in both focus groups agreed that trail challenge was the "most important" attribute when choosing a mountain-biking trail (see Table 3.2). The model did indeed show that increasing trail challenge increases trail demand. If park and natural-area resource managers desire to serve the mountain-biker community, they may consider increasing the trail challenge at their mountain-biking sites. This could be done by offering Triangle mountain bikers portions (i.e., loops, trail segments) of the trail that have more cumulative elevation change or by integrating challenges throughout the entire trail. Adding more miles of trail is an alternative where sufficient land is available.

The influence of trail development may be less intuitive than that of the other trail attributes. The idea that mountain-bike-trail users prefer trails with more intersections, loops, and wider tread widths is contradicted by the focus group results, in which participants preferred trails with a "natural and remote" feel. Perhaps increased trail development is a result of increased trail demand rather than a cause of increased demand. Unfortunately, it is not possible to disentangle the cause from the results in this study. Novices and intermediate riders may prefer trails of less challenge and frequent less challenging trails more often. This may be indicative through the influence of trail challenge on trail demand being smaller than that of trail condition or trail development. Caution therefore should be exercised when interpreting the results of the trail development index on demand, especially for management uses.

Focus-group participants mentioned that numerous loops and intersections were unattractive because they made it easy for riders to become disoriented on the trail system. Some riders also felt that too many intersections interrupted the “flow” of their ride by making them focus on the upcoming intersection for possible traffic instead of on their ride. Focus-group members emphatically preferred trails having appropriate signage.

5.4 Theoretical Contributions

Stevens (1966) was the first to incorporate site attractiveness into a recreation-demand model. Subsequent studies of the relationship between site attractiveness and recreation demand have mostly used empirical measures such as water quality (Englin & Lambert, 1995) and hypothetical site quality (Morey, Buchanan, & Waldman, 2002). There has been no attempt to incorporate recreation-ecology measures into a recreation-demand model. This study utilized mountain-biking focus-group input to inform the use of specific existing recreation-ecology measures and successfully employ them in a mountain-biking recreation-demand model. Many of those measures (e.g., median trail width, erosion events per mile, grade events per mile, cumulative elevation change) are increasingly available for parks and protected areas. Recreation-ecology measures increased the model’s predictive ability and were significant determinants of mountain-biking demand. Ravenscraft and Dwyer (1978) stated that any recreation-demand model implicitly includes site attractiveness. This study better described features that influenced the attractiveness of mountain-biking sites. The three environmental attribute indices used in the model were significant and effective measures of site attractiveness, and these findings add to our knowledge of recreation demand, specifically mountain-biking demand. The aggregation of variables into indices in this study allowed a more comprehensive description of the disparate sites. This contributes to the body of literature that successfully utilizes indices in recreation research (Ravenscraft & Dwyer, 1978).

Gimblett (1997) called for better methods to integrate social-science information with site biophysical data in recreation-management planning and decision making. This study explored an area of recreation management research that has been neglected, the methodological and analytical issues involved in incorporating social demographic information via focus-group input and on-site user surveys about site environmental attributes within a mountain-biking recreation-demand model.

The seminal work of Cole (1989) called for the development of methods for assessing, modeling, and incorporating the effects of recreational-site impacts and the better integration of geographers' analytical capabilities into recreation planning and management. Reed and Mroz (1997) identified the need for improved analysis methods and the incorporation of geospatial technologies in recreation-impact studies. Prior to this study, there have been few attempts to distinguish and study environmental impacts with geospatial technologies.

This research began with gathering and documenting recreation impacts and concluded by informing planners and managers about the recreation relationships between users and settings. This study provides methods for understanding the relationships between site environmental attributes and visitor use, which may be used to benefit both the environment and visitors. This study will add to the body of knowledge about human/environment relationships, specifically in mountain-biking settings. The routine collection of impact-monitoring data can bolster and enhance social-science analysis of recreation behavior, justifying the necessity of impact monitoring during lean budget periods.

5.5 Suggestions for Future Research

Further investigation is necessary to determine whether other environmental features, use-related variables, or management factors could be used within the site environmental attribute indices of this study or whether new, equally important indices might be created or identified. Future research should also investigate the use of these site environmental attribute indices in various climates and geographies. For example, variables important in desert geography may differ from those for temperate forests. This would validate the use of the indices themselves and would enable regional comparisons between sites.

Researchers should consider collecting systematic trail-use information, whether through trail counters or other count methods. Consideration should also be given to additional past-use experience questions, to distinguish skill groups, habitual users, and variety seekers. Westover (1989) indicated that visitors' expectations and goals about a location are adapted and changed by the range, rate of recurrence, and type of recreational settings that visitors were exposed to over time (Knopf, 1987; Schreyer & Lime, 1984).

Mountain-biking trails frequently have designated "beginner," "intermediate," and "advanced" loops or sections. Collecting more detailed information on usage of loops or sections will allow more specificity within the model, given that trail conditions, trail challenge, and trail development may vary greatly among individual loops at a given site.

Embedding a larger-scaled reference map in the survey will improve the accuracy of visitor-use locations in future surveys. Alternatively, with advances in GPS technology, data could be gathered by issuing a GPS unit to riders before they enter a trail system. This approach could accurately record information about site use and make available average speeds and distances ridden. In addition, mountain bikers could enter subjective data positions identifying perceived problems or points of interest (i.e., scenic vistas) along the trail.

As the demand for natural resources becomes more competitive and the supply increasingly meager, prospective research needs to address the importance of understanding appropriate site selection for sustainable trail development. Geospatial technologies can be used to explore each unique park setting to search for features that maximize user opportunities and enjoyment, while taking advantage of sites that are resistant to degradation. How to best do this and preserve the resource is the challenge. One possible way of achieving the goal of “use and preservation” is by conducting proper “suitability analyses” before building a new trail or updating existing trails. This method requires managers to view the most accurate and up-to-date resource data available with a GIS and overlay these layers to identify areas of concern (e.g., where erodible soils and high slopes overlap). By initiating this approach, resource managers can select a design that avoids negative trail conditions and can identify areas of existing trails that are highly susceptible to negative conditions.

5.6 Conclusion

All recreation activities influence the resources where they take place. This inevitable feature of recreation has direct costs to resource managers. Knowledge about the influence of site environmental attributes may help land managers plan for the best use of the resources managed. Information on the influence of site environmental attribute indices could help resource managers plan trail improvements and address significant impacts like those described in this research (trail erosion, widening, and root exposure).

Physical features such as trail mileage, elevation change, the physical state of the trail, and to what degree a trail is developed influence mountain-biking demand. Understanding the actual value of the benefits received by mountain bikers and what features influence mountain-biking demand could allow land managers to make better decisions when conducting cost-benefit analysis for trail improvements, trail maintenance, or new trail construction.

At the beginning of this study, it was not known what variables would be significant in determining demand. It became clear that many variables were significant and aided in the prediction of mountain-biker behavior. With many variables adding to the prediction potential of possible models, the consideration of a greater variety of site environmental attributes increases the possibility of a unifying theme, variable, or index that transcends site and situation.

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APPENDICES

APPENDIX A

Mountain Biking Trail Information

Study Site	Skill Levels	Contact	Location	Loops
Beaver Dam State Recreation Area	Beginner to Advanced	(919) 676-1027	Falls Lake NC 50, Creedmoor Road	2.6 mile outer loop 1.6 mile inner loop 2.4 mile west loop 6 mile south loop
Lake Crabtree County Park	Beginner	(919) 460-3390	South of the RDU airport, off Aviation Parkway	5 miles of trail 4 loops
Garner Recreation Park	Beginner to Intermediate	(919) 772-4688	Highway 70 east to Garner, exit at Vandora Springs Road exit, turn left	4.5 miles of trail
Harris Lake County Park: Hog Run Trail	Beginner to Advanced	(919) 387-4342	From Raleigh: Take 440 to US 1 South. Take US 1 12 miles from beltline to exit 89. Take a left, 2 miles on right.	Beginner Loop .67 miles Intermediate Loop 1.9 miles Advanced Loop 4.25 miles
Little River Trails	Beginner to Advanced	(919) 732-5505	From I-85 in Durham exit onto Guess Rd (Hwy 157) and go N. app 12 miles	7 miles 2 loops
Legend Park	Beginner to Advanced	(919) 553-1550	Clayton	8 miles 7 loops

APPENDIX B

Questioning Route for Focus Groups

Direct questions that will be used:

Opening: Please tell us your name and how long you have been mountain biking?

Introduction: How did you learn about mountain biking? How did you become involved with mountain biking?

Transition: Think back to when you were beginning to first mountain bike, what characteristics about mountain biking courses left a good impression on you, a bad impression on you?
What was the introductory process like for you? How did you choose trails to ride in this period?

Ranking exercises that will be used:

1) In the mountain biking community courses may be made up of many different types of challenges, obstacles, amenities, and designs. If your only limitation was choosing a Triangle N.C trail, what trail characteristics would you most concerned with when choosing a course to ride? (Please rank by importance and weight by their contribution to the whole (i.e., 80%, 18%, 2%, some items may receive no weight)).
    a. Distance to course (travel time)
    b. Course length
    c. Course challenge (topography, hills vs. flat land, tricks)
    d. Regulated vs. Unregulated
    e. Remoteness
    f. Naturalness
    g. Safety (no unknown dangers on trails, aggressive animals, washouts, fallen trees)
    h. Security (locking restrooms, lighting at parking lot, parking, no hiding places, criminals)
    i. Amenities available (restroom, parking, water, picnic tables)
    j. Site condition (erosion, litter, maintained vs. run down)
    k. Other?

2) If you were constrained (time, money, daylight, children, work, etc…) when choosing a mountain biking trail, what trail characteristics are you most concerned with when choosing a course to ride? (Please rank by importance and weight by their contribution to the whole (i.e., 80%, 18%, 2%, some items may receive no weight)).
    a. Distance to course (travel time)
    b. Course length
    c. Course challenge (topography, hills vs. flat land, tricks)
    d. Regulated vs. Unregulated
    e. Remoteness
    f. Naturalness

g. Safety (no unknown dangers on trails, aggressive animals, washouts, fallen trees)
h. Security (locking restrooms, lighting at parking lot, parking, no hiding places, criminals)
i. Amenities available (restroom, parking, water, picnic tables)
j. Site condition (erosion, litter, maintained vs. run down)
k. Other?

Key Questions:

Key?'s: What physical trail characteristics/conditions affect your choice of trails today?
What physical trail characteristics/conditions are particularly frustrating to you?
When you are planning to ride how do you base your choice of trail (design, maintenance, and trail conditions)?

Ending Questions:

Ending?'s: If you had a chance to give advice to triangle land managers of mountain bike courses, what advice would you give?
If you could change mountain bike opportunities within the Triangle what would they be?
We wanted you to help us evaluate mountain biking trail characteristics that count. We want to know how to improve the service and what a difference it would make to you and your families. Is there anything that we have missed? Is there anything you came here wanting to say or share that you didn't get a chance to say?

APPENDIX C

Long Table Approach

Analysis Rubric for Cutting and Pasting Transcription into Themes
Read and answer these questions:

Point 1. Did the participant answer the question that was asked?

- If YES go to point 3.
- DON'T KNOW set it aside and review it later.
- If NO go to Point 2.

(Undecided and unclear answers should be viewed with a conservative approach and saved and reviewed at a later time.)

Point 2. Does the comment answer a different question in the focus group?

- If YES move it to an appropriate question.
- If NO go to Point 3.

(Caution: Do not assume that answers will always follow the question asked. Participants will answer questions asked earlier and questions not asked throughout the focus group. If and when this occurs move the comment to the appropriate location.)

Point 3. Does the comment say something of importance to about the topic?

- If YES paste it to the appropriate question.
- If NO paste set it aside.

Point 4. Is it like something that has been said before?

- If YES start grouping like quotes together. Basically make a pile of like categories.
- If NO start a separate pile.

APPENDIX D

Triangle North Carolina Visitor Survey

Triangle, NC
Mountain Biking Recreation Study
2006

Parks, Recreation
and Tourism Management

North Carolina State University

Dear Mountain Biker

I am a PhD candidate at North Carolina State University, for partial fulfillment of my degree at NC State I am conducting a research study to further understand the adventure recreation experience and your level of development in mountain biking recreation. I would like to ask you to complete this questionnaire as a part of this study. The only identifying information on the questionnaire is your ID number, which you will assign yourself. Your ID number will not allow me to know your identity thus, your anonymity is assured. Completing this questionnaire is voluntary. You may decline or discontinue the questionnaire at any time with no consequences. Upon completing the questionnaire, please return it to the researcher. As a mountain biker, a benefit of this study is that you are helping to develop more fully the body of knowledge regarding the sport of mountain biking by your participation. If you have any questions about the study, you can call or talk to the researcher, Michael Naber (919) 515-2512. If you have questions about research in general at NC State, you can call Beth Wilson at (919) 515-3276.

By completing this questionnaire, you are giving me and NC State your informed consent to participate in this study.

Sincerely,
Michael David Naber
PhD Student
NCSU

Box 8004
Parks, Recreation and Tourism Management
Biltmore Hall
North Carolina State University
Raleigh, NC 27695-8004
mdnaber@ncsu.edu

YOUR RECREATIONAL MOUNTAIN BIKING TRIPS DURING THE PAST 12 MONTHS

Please consider only the outings that you made in the Triangle Area, NC. Use the map located in the center of the questionnaire. The map shows the locations of Triangle regulated mountain biking trails that people often use. The numbers on the map correspond to trails in the Triangle. Some of the questions below ask you to use this map.

Thinking back to how many mountain biking trips you made during the past twelve months. Using the locations on the map placed in the center of this questionnaire. I would like for you to give me some information on where you took your mountain biking outings. Brief instructions are provided below for answering Question 1.

A. Please write down the number of outings which involved mountain biking next to each name on the list on page 2. If you did not go to a trail on the list, leave the column "Total Trips" blank and skip to the next trail on the list.

B. The next column asks whether most of your mountain biking trips were during weekdays or weekends. Consider weekends as Saturdays, Sundays, or Holidays. Check whether most of your mountain biking outings were made during the week or weekends.

C. Write down the average one-way miles you traveled to each of the trails marked on the map that you visited during the past 12 months.

D. The last column asks whether most of your mountain biking outings started from your home or from your place of work. Place a check mark in the box for your home or place a check mark in the box for work.

1. Map #	A *Total Outings*	B *Most outings taken on:* Weekday/Weekend (Check One)		C *One-Way Miles*	D *Most Outings Start From:* Home	Work
1. Beaver Dam	______	☐	☐	______	☐	☐
2. Garner Park	______	☐	☐	______	☐	☐
3. Harris Lake	______	☐	☐	______	☐	☐
4. Lake Crabtree	______	☐	☐	______	☐	☐
5. Little River	______	☐	☐	______	☐	☐
6. Legend Park	______	☐	☐	______	☐	☐

2. Check below the two (2) most important decisions you make before a mountain biking outing?

First most important decision (Check only one box)

☐ Location of mountain biking trail (distance to)

☐ Degree of Difficulty (Skill level, Technical Challenge)

☐ Condition of Trail (Erosion, Management, Litter)

Second most important decision (**Check only 1 box different than above**)

☐ Location of mountain biking trail (distance to)

☐ Degree of Difficulty (Skill level, Technical Challenge)

☐ Condition of Trail (Erosion, Management, Litter)

Mountain Biking Trail Visit

The next series of questions refers to the trail you visited today.

1. What was the Triangle Trail that you visited today?

Beaver Dam ☐ Garner Park ☐ Harris Lake ☐

Lake Crabtree ☐ Little River ☐ Legend Park ☐

2. For the trail you visited today, CIRCLE the letter that best describes your feelings about each statement.

	Strongly Agree	Agree	Disagree	Strongly Disagree
I thoroughly enjoyed my mountain biking experience.	A	B	C	D
I did not ride some trails due to adverse trail conditions.	A	B	C	D

	Easy		Satisfactory		Hard
The level of trail difficulty was above or below my skill level.	A	B	C	D	E

3. What time did you arrive at the trail? ____________ AM PM

4. How many people (including yourself) were in your group

_____# of PEOPLE?

5. Were they: ☐Family, ☐ Friends, ☐ Both?

6. How much time did it take you to drive to the trail?

______Hours ________Minutes

7. How much time did you spend at the trail:

______Hours ________Minutes

8. How much did you spend on all estimated expenses related to mountain biking on this visit? (Gas, food, equipment, etc…)

___________________Dollars

9. On a scale of 1 to 10, with 10 being your perfect trip, how would you rate your mountain biking experience at the trail you visited today?
1 2 3 4 5 6 7 8 9 10 (Circle One)

Mountain Biking Experience Use History

1. How would you characterize your current stage of development as a mountain biker? *(Circle only one response.)*

Novice	Advanced Novice	Intermediate	Expert/ Professional	Post-expert
1	**2**	**3**	**4**	**5**
(Almost never ridden off-road)	(Done a little off-road riding)	(am getting into off-road riding)	(done lots of off-road riding)	(Advocacy / Lifestyle change)

2. Do you belong to any mountain biking clubs/organizations?
   ____Yes
   if yes what clubs or organizations?___________________________
   ____No

3. How many years during your *lifetime* have you been involved in mountain biking recreation?
   ____________________Years

4. On average how often do you normally ride your mountain bike for recreational purposes?________times per week

5. During the past 12 months, how many times did you mountain bike for recreation?________times (Include all rides in or outside the Triangle)

6. How long, in miles, is an average mountain bike ride for you (for recreational purposes)?_______miles

7. How long, in hours, is an average mountain bike ride for you (for recreational purposes)?_______hours

8. What is your primary means of transportation (e.g. car, bus, bike, etc…) to mountain biking recreation sites? _____________________

9. What is the average distance you travel by car for recreational mountain biking?_________miles

10. Do you consider mountain bike riding to be riding or training?

    Riding   Training   Seasonally Dependent

11. Which of the following activities have you participated in, in the last 12 months? (Circle all that apply)

    A. Trail Maintenance

    B. Lobbying to keep more trails open to bikers

    C. Have been a member of a fee based mountain biking organization.

    D. Have been a member of a non-fee based mountain biking organization.

    E. Have donated money to a mountain biking or environmental concern (beside membership fees).

    F. Have donated money, been a member of an environmental organization not associated with mountain biking.

The following questions are about you personally and will help me to know more about mountain bikers. Your responses will be confidential and grouped with others who have responded to this survey. I need your responses to the following questions to better explain who mountain bikers are in the Triangle N.C. so area land managers can better plan current and future developments for mountain biking in and around the Triangle, NC.

All of your answers are strictly confidential and anonymous.

1. Are you: ___Female ____Male

2. Age____years

3. Race: Asian/Pacific Islander American Indian Black Hispanic
   Caucasian Other_____________

4. Marital Status: Single Married

5. Children? (yes no)

6. Do you live in the Triangle Area (Wake, Johnston, Orange, Durham, Chatham, and Lee counties) of North Carolina? ___Yes ___No
    a. If yes, what is your zip code?__________
       and what is the nearest intersection to your residence?__________________________________
    b. If no, what is your zip code? ___________
       and what is the nearest intersection to your residence?__________________________________

7. What is the highest year of formal schooling you have completed so far? (Circle one number)

High School	College	Graduate	Post Graduate
9 10 11 12	13 14 15 16 17	18 19 20 21 22	22+

8. Which category best describes your **total household income in 2005**

    ___Under $10,000 ___$10,000 to $19,999 ___$20,000 to $29,999
    ___$30,000 to $39,999 ___$40,000 to $49,999 ___$50,000to $59,999
    ___$60,000 to $69,999 ___$70,000 to $79,999 ___$80,000to $89,999
    ___$90,000 to $99,999 ___$100,000 to $109,999___$110,000to $119,999
    ___$120,000 to $129,999___$130,000 to $139,999___$140,000to $149,999
    ___$150,000 to $159,999___$160,000 to $169,999___$170,000to $179,999
    ___$180,000 to $189,999___$190,000 to $199,999___$200,000to $209,999
    ___$210,000 to $219,999___$220,000 to $229,999___$230,000to $239,999
    ___$240,000 to $249,999___$250,000 or above

9. If you are not retired, how many vacation days do you take per year?
    _____Days

10. What is your occupation?

___Clerk ___Craftsman ___Driver

___Farmer ___Housewife ___Laborer

___Manager ___Professional ___Retired

___Sales ___Student ___Unemployed

___Other (Please explain) ______________________

I appreciate the time you have devoted to this questionnaire and your help in giving us accurate information.

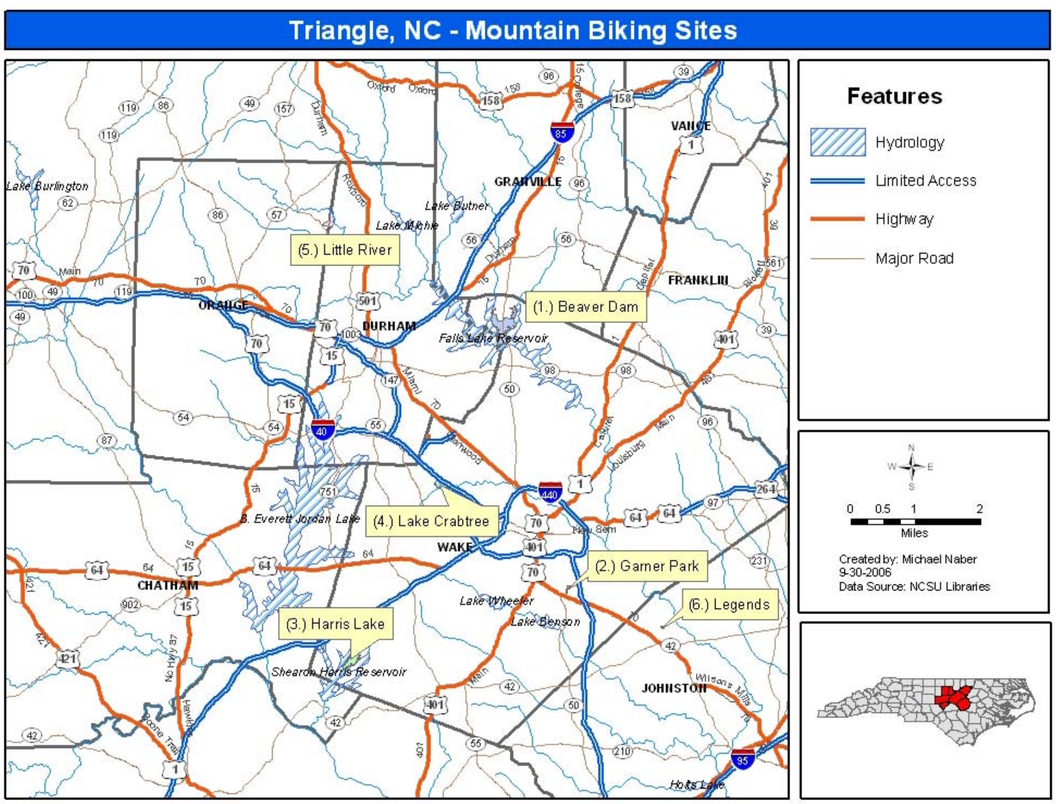
Any comments you wish to share will be greatly appreciated.

Thank you very much for your help

Comments:

____

____



APPENDIX E

Field Survey Procedures

Introduction

A point-measurement trail assessment procedure will be utilized in this study, with a focus on measuring maximum incision and trail width. The point sampling method has appeared in the literature as the most appropriate method for assessing trail impacts, such as incision and width, as these variables are continuous along the trail (Marion & Leung, 2001). For the point measurement method, Geographic Information System (GIS) and Global Positioning System (GPS) will be used to identify systematic sampling points at specific intervals located along the trail after a random start point near the trailhead or trail loop beginning. In their 1999 study, Leung and Marion examined the influence of sampling interval on the accuracy of trail impact assessments for frequency of occurrence and lineal extent for common trail impacts (tread incision, wet soil, exposed roots, multiple trailing) the authors established that intervals of less than 328 feet (100m) would provide the most accurate estimate of lineal extent. Understanding the inefficiency of such sampling intensity for most settings, however, Leung and Marion concluded that "sampling intervals between 328 feet and 1640 feet are therefore recommended to achieve an appropriate balance between estimate accuracy and efficiency of field work" (p. 178).

Systematic Point Measurement Field Survey Procedures

This manual describes standardized procedures for conducting an assessment of resource conditions on mountain biking trails. The objective of these procedures is to document mountain bike trail use conditions. The design relies on a sampling approach to characterize mountain bike trail conditions from systematic points that are calculated based on the loop or trail segments distance, to include at least 10 sample points for each trail segment or loop. Distances will be assessed with a Geographic Information System (GIS) pre-trip. Trail condition measurements will be applied at sample points to document the trail characteristics. Each trail was mapped prior to the systematic point survey with a GPS.

In order to accurately map sample points, survey locations will be entered as waypoints into a professional grade GPS unit that will be carried during the survey. Sampling intervals will vary between 27 feet and 1500 feet, these distances will vary so all trails, regardless of size (i.e., 300 feet and greater), will have a respective sample of at least 10 points. Trails shorter then 300 feet will not be included in the study. For trails less than 3000 ft (.57 miles) consult Table 1 for reduced sample point interval distances necessary to accurately characterize conditions on shorter trails. Trails longer then 16500 feet in length will have no more than 1500 feet between sample points.

Table 1. Example point intervals for mountain biking trails <15000 ft. (2.84 mi).

Interval (ft)	Trail Length (ft)
273	3000
227	2500-2999
163	1800-2499
91	1000-1799
68	750-999
45	500-749
27	300-499

Survey work should be conducted during the off-season, with leaf-off conditions for maximum GPS reception, and after a period where trail users have broken down leaf fall. Measuring during the off season is necessary because some determinations of trail complexity depend on the accuracy of GPS satellite reception which can be hindered or decreased by leaf-on conditions. Data will be summarized through statistical analyses to characterize resource conditions for each mountain bike trail loop.

Following is a list of materials that will be used in the field to collect and record data.

Materials
GPS receiver
Several batteries for the GPS
12 ft tape measure (25 ft for wide trails)
Metal stakes (3)
Clinometer
Compass
Survey procedures manual
Clipboard with compartment for forms
Pencils
Topographic and driving maps
Field form (waterproof paper if needed)

The following survey is adapted from Marion (1994), Leung (1998), and Cakir (2005).

Point Sampling Procedures

1. **Trail Loop Code:** Record a unique trail loop code (can be added later).

2. **Trail Name:** Record the trail loops name(s) and describe the loop beginning and end points.

3. **Surveyors:** Record initials for the names of the trail survey crew.

4. **Date:** Record the date (mm/dd/yr) the trail was surveyed.

5. **Use Level:** Record estimates for the types of use the trail receives, using percentages that sum to 100%. The most knowledgeable park staff member should provide these. Categories for use level include Hiking/Trail Running and Mountain Biking (specify).

6. **Weather:** Record basic daily weather, temperature, precipitation, and cloud cover.

7. **Parking Spaces:** Record number of parking spaces.

8. **Restrooms:** Record presence of restrooms, yes or no, and amount if present.

9. **Picnic Tables:** Record presence of picnic tables, yes or no, and amount if present.

10. **Shelter:** Record presence of overhead shelter, yes or no.

11. **Directional:** Record whether trail is uni-directional or bi-directional, yes or no.

12. **Starting/Ending Point:** Record a brief but accurate description of the starting and ending points of the survey. Choose identifiable and permanent locations that others can identify in the future, such as intersections with other trails, roads, or permanent trailhead signs. With the use of a GPS device, collect an accurate fix on these locations.
    Rejection of a sample point: Given the survey's objective, there will be rare occasions when you may need to reject a sampling point due to the presence of boulders, tree falls, trail intersections,

road-crossings, stream-crossings, bridges or other odd "uncharacteristic" situations. The data collected at sample points is intended to be roughly "representative" of the 150 ft sections of trail on either side of the sample point. Use your judgment but be conservative when deciding if a sample point should be relocated. Do not relocate a point to avoid longer or common sections of bog bridging, turnpiking, or other trail tread improvements or hardenings. The point should be relocated by moving forward along the trail an additional 30 ft, this removes the bias of subjectively selecting a point. If the new point is still problematic then add another 30 ft. Record the distance of the actual point and continue on to the next "correct" point (as though you did not need to move the last one).

13. **P# (GPS) – Point Number**: Record, starting from 1, consecutive numbers for each new survey location regardless of trail. Do not start again at 1, but continue from the last number on each new trail. Enter this figure in the survey field form and record the point in the GPS machine.

14. **Picture:** Take 1 or 2 representative photos of typical views of the point as follows: turn camera to take a vertical format photo and compose picture to get a closer view of trail tread in bottom foreground with a more distant view of trail corridor in background. Where possible, try to take these latter photos when the sun is behind clouds - the lighting will be much more even. For each photo, record the picture number and sampling point for labeling purposes in a photo log or on the trail forms

For the following data, in the field or office: If an indicator cannot be assessed, e.g., is "Not Applicable" code the data as -9, code missing data as -1.

15. **Trail Position (TP):** Use the descriptions below to determine the trail position of the sampling point. Record the corresponding letter code in the TP column.
    - **R** - Ridge: Ridge-top or high plateau position
    - **HB** - Hill base
    - **M** - Midslope or Sideslope position
    - **V** - Valley Bottom: Flatter valley bottom terrain

16. **Trail Grade (TG):** The two field staff should position themselves on the trail 5 ft either side of the transect. A clinometer is used to determine the grade (% slope) by sighting and aligning the horizontal line inside the clinometer with a spot on the opposite person at the same height as the first person's eyes. Note the percent grade (right-side scale in clinometer viewfinder) and record.

17. **Trail Alignment (TA):** Assess the trail's alignment angle to the prevailing land-form in the vicinity of the sample point. Sight a compass along the trail from a point about 5ft before the transect to about 5ft past the transect, record the compass azimuth (0-360, not corrected for declination) on the left side of the column (it doesn't matter which direction along the trail you sight). Next face directly downslope, take and record another compass azimuth - this is the aspect of the local landform. The trail's alignment angle ($<90^0$) can be computed by these two azimuths.

18. **Landform Grade (LG):** Assess an approximate measure of the landform slope in the vicinity of the sample point. Turn the clinometer perpendicular to the ground with the window facing your eye. Next orient the bottom of the clinometer in alignment with the prevailing landform slope (placing the clinometer on your clipboard and orienting the bottom of the clipboard may improve your accuracy). Record the percent off the scale in the window.

19. **<u>Secondary Treads (ST):</u>** Count the number of trails that parallel the main tread at the sample point. Count all treads regardless of their length, ***excluding** the main tread*.

20. **<u>Tread Condition Characteristics:</u>** Along the trail tread width transect, estimate to the nearest 10% (5% where necessary) the aggregate lineal length occupied by any of the mutually exclusive tread surface categories listed below. **Be sure that your estimates sum to 100%**. Record these on the form by labeling sections of the appropriate row with the relevant code separated by marked vertical lines indicating the appropriate percentage cover for each code.

S-Soil	All soil types including sand and organic soils, excluding organic litter unless highly pulverized and in a thin layer or smaller patches over bare soil.
L-Litter	Surface organic matter including intact or partially pulverized leaves, needles, or twigs that mostly or entirely cover the tread substrate.
V-Vegetation	Live vegetative cover including herbs, grasses, and mosses rooted within the tread boundaries. Ignore vegetation hanging in from the sides.
R-Rock	<u>Naturally-occurring</u> rock (bedrock, boulders, rocks, cobble, or natural gravel). If rock or native gravel is embedded in the tread soil estimate the percentage of each and record separately.
M-Mud	Seasonal or permanently wet and muddy soils that show imbedded foot or hoof prints from previous or current use (omit temporary mud created by a very recent rain). The objective is to include only transect segments that are frequently muddy enough to divert trail users around problem.
G-Gravel	<u>Human-placed</u> (imported) gravel.
RT-Roots	Exposed tree or shrub roots.
W-Water	Portions of mud-holes with water or water from intercepted seeps or springs.
WO-Wood	<u>Human-placed</u> wood (water bars, bog bridging, cribbing).
O-Other	Specify.

21. **<u>Tread Width (TW):</u>** From the sample point, extend a line transect in both directions perpendicular to the trail tread. Identify the endpoints of this trail tread transect as the most pronounced outer boundary of visually obvious human disturbance created by trail use (not trail maintenance like vegetation clearing). These boundaries are defined as pronounced changes in ground vegetation height (trampled vs. untrampled), cover, composition, or, when vegetation cover is reduced or absent, as pronounced changes in organic litter (intact vs. pulverized) (see photo illustrations in Figure 1, placed at the end of the manual). The objective is to define the trail tread that receives the majority (>95%) of traffic, selecting the most visually obvious outer boundary that can be most consistently identified by you and future trail surveyors. In places where the trail boundary is indistinct at the sample point project the boundary to the sample point from immediately adjacent areas. Include the widths of any secondary treads (see #8) crossed by the transect, excluding widths of any undisturbed areas between treads (as defined by the tread boundary definition). Measure and record the length of the transect (the tread width) to the nearest inch (don't record feet and inches).

22. **<u>Forest Type (F):</u>** Within the surrounding 100 feet, examine the general forest (H) – hardwood, (M) mixed deciduous, (E) Evergreen, (W) Wooded wetland.

23. **<u>Maximum Trail Incision (MIC):</u>** Measure the maximum depth of the trail tread (Hammitt and Cole 1998). At each sample point, trail boundaries will be defined to include the area where the vast majority of trail use (>90%) occurred by identifying visually obvious disturbance indicated by changes in ground vegetation height, cover and composition. Stakes will be placed at the trail boundaries to establish a transect perpendicular to the trail tread. Trail width is defined as the distance between the trail boundary points and measured to the nearest centimeter. A taut nylon cord is to be stretched between the base of the stakes and MIC will be measured as the maximum depth from the string to the trail surface to the nearest quarter inch. At each measurement point, technicians used digital camera to capture site images and recorded locations using GPS receiver.

NOTE: For this and all other options, if the line cannot be configured properly at the sample point due to rocks or obstructing materials that cannot be moved, then move the line forward along the trail in one-foot increments until you reach a location where the line can be properly configured.

Problem Assessment Field Survey Procedures

For each problem encountered, the following information about each problem is recorded. Record the beginning and ending point in the GPS and record on the assessment form number so that information collected can be related. Photograph with a digital camera each problem and name the photograph P(x) where x = point number. If there is more than one problem at a particular location, record the same point number for each problem and perform the systematic point survey procedure in the middle of the problem combination.

<u>Equipment List</u>
GPS receiver
Digital camera
Several batteries for the GPS and camera
Tape measure
Small ruler
Clinometer
Compass
Survey procedures manual
Clipboard
Pencils
Field form (some on waterproof paper)

The following survey is adapted from Marion (1994), Leung (1998), and Cakir (2005).

Problem Assessment Procedures

Problem sources will be documented using a Trimble GPS unit loaded with a data dictionary including the following parameters. Waypoints will be recorded where problem parameters exist along trail segments. Points should be taken at the beginning and end of each problem area and labeled accordingly.

Excessive Grade (EG): Sections of tread (≥40 ft) with a grade of ≥20%. Record beginning and ending in the GPS and record beginning and ending point on the Trail Assessment form.

Excessive Width (EW): Sections of tread (≥40 ft) when the trail exhibits a greater than 20% expansion in width that is clearly attributable to recreational uses, such as riding around tree falls, wet or muddy areas, eroded areas, multiple treads, etc. Record beginning and ending in the GPS and record beginning and ending point on the Trail Assessment form. In comment column record as follows: W3: 3-6 feet wider than normal or W6: > 6 feet wider than normal.

> ***Be alert:** this parameter will often be recorded in combination with the other resource problem parameters, i.e. excessive soil erosion, wet soils, and multiple treads often cause an excessive widening of the tread. Trail boundaries are indicated by pronounced changes in ground vegetation cover, composition, and height, or organic litter.

Muddy Soil (MS): Sections of tread (≥10ft) with seasonal or permanently wet and muddy soils that show imbedded foot or tread prints (≥1in). This should generally include any longer mud-holes or treads with running water. The objective is to include tread segments that are frequently wet or muddy enough to divert trail users around the problem, often leading to an expansion of trail width. Record beginning and ending in the GPS and record beginning and ending point on the Trail Assessment form.

Soil Erosion (SE): Sections of tread (≥10 ft) with soil erosion exceeding 4 in. depth within current tread boundaries. Record beginning and ending in the GPS and record beginning and ending point on the Trail Assessment form.

Root Exposure (RE): Root Exposure (begin/end): for trail sections exhibiting severe tree root exposure such that the tops and sides of many roots are exposed for sections of tread (≥30 ft). Record beginning and ending in the GPS and record beginning and ending point on the Trail Assessment form.

Rock Exposure (RK): Rock Exposure (bedrock, boulders, rocks, cobble, or natural gravel: begin/end): for trail sections exhibiting severe rock exposure such that the tops and sides of rocks are exposed for sections of tread (≥30 ft). Record beginning and ending in the GPS and record beginning and ending point on the Trail Assessment form.

Informal Trails (IT): Enter into the GPS informal or "visitor-created" trails that intersect the survey trail segment as you proceed to the next sample point. Do not count formal trails, roads of any type, extremely faint trails, trails <10 ft long, or trails that have been effectively blocked off by managers. Informal trails are trails that visitors have created to access streams, scenic attraction features, camping areas, or other features, to cut switchbacks, to avoid mud-holes, rutted treads, steep obstacles, or downed trees, or that simply parallel the main trail. Count both ends of any informal trails ≥10 feet long that loop out and return to or parallel the survey trail. Include any distinct animal or game trails as these are generally indistinguishable from human trails and their true origin is likely unknown.
At the end you will sum and record the total for each trail loop. This indicator is intended to provide an approximation of the extensiveness of unofficial, visitor-created trails associated with survey trail and afford an approximation of trail flow.

Puddle with standing water (P): If there is a puddle on the trail with a linear extent of more than 10 feet, record a “P” in the code column and measure the length, width, and depth of the puddle.

Multiple Trail Treads (M): If multiple trail treads are evident for more than 10 feet, record the linear extent of the multiple treads and total number of treads encountered.

Reference Point (REF): (Management Efforts and Other Points of Interest) Record the code and distance for this parameter periodically when you come across a permanent feature which can be used by future workers to compare and/or recalibrate their wheel readings to those you record. Under comments on the GPS describe reference points with sufficient detail that someone else could relocate the precise point with GPS or their wheel reading to coincide with your own.

Trail Intersections (TI): enter into the GPS all formal trail intersections along the survey trail segment as you proceed to the next sample point

Option Out Intersection (OI): enter into the GPS all trail obstacle option out intersections (beginning and ending along the survey trail segment as you proceed to the next sample point.

Option Out Intersection (OI): enter into the GPS all trail obstacle option out intersections (beginning and ending along the survey trail segment as you proceed to the next sample point.

Picture (Pic): Photos of "typical" trail features/conditions that might provide good illustrations of extreme" examples of trail impacts. Where possible, try to take these latter photos when the sun is behind clouds - the lighting will be much more even. For each photo, record the trail name and a description for labeling purposes in a photo log or on the trail forms.

Road Intersections (RI): enter into the GPS all road intersections (one point, center of the road) along the survey trail segment as you proceed to the next sample point

90° – Record > 90 degree turn AND < 10 ft in turning radius in the GPS.

Avoidable Trail Obstacle (ATO): If there is an avoidable (option out available) trail obstacle (down tree, rock, man-made obstacle, etc…) that can be categorized into three horizontal categories: 6-8 inches, 8-15 inches, and greater then 15 inches, enter the obstacle into the GPS and record a “ATO” in the code column and enter into the comment section what it is.

Unavoidable Trail Obstacle (TO): If there is an unavoidable (no option out available) trail obstacle (down tree, rock, man-made obstacle, etc…) that can be categorized into three horizontal categories: 6-8 inches, 8-15 inches, and greater then 15 inches, enter the obstacle into the GPS and record a “UTO” in the code column and enter into the comment section what it is.