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Managing Recreational Trail Environments for Mountain Bike User Preferences

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ABSTRACT / The carrying capacity model is an effective tool for the management of a wildland recreation resource. Within the model are four primary subcapacities, namely, physical capacity, biological capacity, social capacity, and facility capacity; combined, they are essential to the appropriate management of wildland recreation resource environments. This study focuses on environmental factors of recreational environments that are primarily used by mountain bikers. Little research has been conducted on the social carrying capacity of mountain biking environments, relative to the amount of physical and biological capacity research that has been conducted. The objective of this study was to further resource management knowledge of the mountain bike user in order to better incorporate social carrying capacity into the management of bike use environments. An email survey was used to identify such issues as mountain biker preference of soil erosion management techniques and to measure the effect on experience of resultant factors of soil erosion and trail design. Other issues, such as environmental concern, biker perception of other users, and biker commitment, were also measured. A 58% response rate was achieved. Data gathered from bikers in the United States, United Kingdom, Australia, and New Zealand ($N = 406$), highlight some important issues concerning the design and management of wildland recreation environments that are primarily used for mountain biking. For example, bikers were found to significantly prefer water bars above all other tested soil erosion management techniques; trail erosion factors, including the presence of rocks, roots, and gullies, all added to biking experiences on average; trail design factors, such as the presence of turns, bumps, jumps, and obstacles, all added to biking experiences in general. These findings were used to address questions that resource managers should consider when striving to effectively manage wildland recreation areas primarily used for mountain biking.

Knowledge of recreational user preferences facilitates the management of recreational areas. The provision of quality outdoor experiences while conserving the natural environment are the primary goals of resource management. One such management framework that incorporates these principles is recreational carrying capacity.

Recreational carrying capacity is defined as "the level of recreational use an area can withstand while providing a sustained quality of recreation" (Wagar 1964). Within this definition there are four subcapacities that must be identified by recreation resource managers to better manage recreation environments. These are physical capacity, ecological capacity, social capacity, and facility capacity (Shelby and Heberlein 1986).

KEY WORDS: Recreation resource management, Mountain bike, Trail design, Trail preferences

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Physical capacity is the amount of space available for recreation activity and is closely related to the design of an area and use levels. For example, there are a certain number of floaters that a 1-mile section of river can support at a given time.

Ecological or biological capacity is the ability of a resource to withstand recreational use without unacceptable damage to ecological components, such as soils, vegetation, wildlife, and water quality.

Facility capacity involves additions to the recreation environment intended to support visitor needs. For example, a parking lot might be constructed at a trailhead. Personnel are also included in facility capacity as they support visitor needs in some environments.

Social capacity is the number and distribution of visitors that provide minimal acceptable recreation experiences. Social carrying capacity is probably the most difficult capacity to define (Washburne 1982). What is an acceptable recreational experience to one individual may be viewed differently by another. For example, a hiker might term three wilderness contacts with other hikers as "unacceptable" because their primary motive for hiking is to be alone in the wilderness. Another hiker might consider 30 contacts as the point at which the presence of other hikers significantly detracts from the outdoor experience.

The task for recreation resource managers is to manage the recreation resource while considering all four capacities that constitute the above carrying capacity model. Much research has been done on the resource impacts of recreational user types (biological/ecological capacity), such as hikers (Bayfield 1973, Pounder 1985, Lance and others 1989), horseback riders (Summer 1980, 1986), all-terrain vehicle (ATV) users (Sparrow and others 1978), and all of the above together (Weaver and Dale 1978). There are also numerous studies on camping and its environmental impacts (Dotzenko and others 1967, de Vos and Bailey 1970, Legg and Schneider 1977, Cole 1981, Cole and Ranz 1983). Ecological carrying capacity has also been studied in depth.

Environmental impacts will occur as a result of any human use of a wildland recreation environment (Jacoby 1990). Therefore, studies have specifically documented the effects of visitor levels on vegetation damage or loss (Weaver and Dale 1978), soil compaction and bulk density change (Bryan 1977, Marshall and Holmes 1979, Vimmerstedt and others 1982), reduction of soil infiltration rates (Lutz 1945, Crawford and Liddle 1977, Marshall and Holmes 1979), depletion of soil organic matter (Frissell and Duncan 1965, Bryan 1977, Cole 1981), depletion of soil fauna (Duffey 1975), and the reduction of nutrient availability (Stohlgren and Parsons 1986). Thus, these types of study have served as useful aids in the management of physical and ecological carrying capacity of recreation environments.

Study Rationale

The rationale for this study is that there are few studies that have specifically focused on the social carrying capacity for mountain biking; however, there is a need to incorporate more social research into management decisions. For example, the study of mountain biker experiences and preferences warrants further inclusion in management decisions. At present, resource managers often face a difficult task of managing the physical environment, in addition to the diverse range of user groups that function in that space. Therefore, there remains a need for more research that focuses on the specific needs, preferences, and experiences of different user types. Studies need to focus on specific user groups and user group interaction to provide managers with data that can be applied in the field.

Relatively few researchers have focused on the needs, trail environment preferences, and experiences of the mountain biker. This study provides recreation resource managers with data that can instigate change in the way they perceive how trail environments should be managed. Questions are raised as to whether social capacity factors, such as preferences and experiences, should be given more weight in the wider carrying capacity model. At present, it is debatable whether social carrying capacity is effectively applied in mountain bike recreation environments.

Mountain Bike User Profile

In one of the few comprehensive studies of mountain biker preferences for recreational settings and experiences, Cessford (1995) in a study for the Department of Conservation, New Zealand, surveyed different users and their level of experience concerning preferred landscape factors, trail types, trail conditions, downhill and uphill preferences, and social encounters. Primary findings showed that there was a relationship between biker preference and level of experience. For example, novice bikers preferred smooth, open, or clear trails and had low preference for obstacles and carrying bikes on sections not feasible for biking. The same question posed to expert riders showed preference for rougher tracks and more tolerance for carrying bikes across terrain not suitable for biking. Cessford also concluded a number of other preferences for recreational settings. For example, novice bikers' reasons for recreational biking were exercise and personal fitness, whereas expert bikers sought "speed," "excitement," "technical challenge," and training for competition. All groups (novice, intermediate, and expert) stated that they preferred native forest settings to plantation pine forests, open farmland, or man-made surfaces. Novice bikers were also more tolerant of gravel roads and wide, smooth trails; more experienced riders preferred tight, narrow, rough, and uneven trails.

Sprung (1997) discussed attitudes of other trail users toward mountain bikers for the International Mountain Bike Association (IMBA). Other users perceived that mountain bikers did not have much concern for the environment. This perception was attributed to the speed at which bikes travel and the association of the term *mountain bike* with other forms of wheeled transport. However, a national study has shown that mountain bikers and their associations do stress substantial concern for the environment. Mountain bikers generally accepted the need for limits of acceptable change and organized much of their lives and recreation activity around environmental issues (Hollenhorst and others 1996). Hollenhorst and others (1996) also stated that bikers formed a ''tightly knit community'' of individuals. Trail preferences included single-track forest trials instead of gravel, physical and technically challenging trials, in addition to multiple-use trials that allowed hikers, equestrians, and other users to share the recreation environment. The study appeared to be orientated toward promoting the use of wildland recreation environments by mountain bikes. It seemed to ''dispel perceptions'' that bikers are anti-environment in order to attempt to shape future management policy. Hollenhorst and other's (1996) conclusions, surprisingly, were that bikers reported dissatisfaction with policy that designated trails solely for mountain bike use and that bikers formed a unique recreation community that needed to be managed accordingly. One major limitation of this study, which the authors stated as a unique benefit, was the study population. Bikers were only sampled from the IMBA. Membership in an active professional organization suggests some form of environmental and opinion orientation of an individual. Findings suggested that the sample did not adequately represent the more generic mountain biker population. For example, the reported average age of the typical biker was 38 years. The ''tightly knit community'' of environmentally aware individuals reported may just be due to the respondents' common interest of being a member of IMBA.

A survey of 393 bikers in southwestern Virginia studied the relationships between experience, commitment, and attitudes toward the management of mountain biking (Ramthun 1997). An initial hypothesis stated that bikers with more experience and commitment would have different trail preferences than beginners. This was supported, although no specific trail preferences were stated. It was also found that as bikers became more committed to the sport, there was a need for more trails to be opened for mountain bike use and more designated trails for bikers only.

Present literature on the user profile of mountain bikers is limited, relative to the amount and concentration of mountain bike use in many areas of the United States. The research that has been done appears to be narrow in scope or has not addressed some specific issues concerning recreation resource management.

Objectives

The objectives of this study are to focus on the trail and management preferences of mountain bikers. Trail environment conditions are affected by trail design, trail management, and natural processes, such as soil erosion, that are accelerated by use and result in the modification of the trail environment. Thus, these factors are studied in order to achieve better understanding of mountain bike users and their preferences for the trail environment.

Research Questions

This study seeks to add to social research concerning the user profile of a mountain biker. The purpose of this study is to answer the following four research questions based on four management issues:

1. *Trail Design:* How should a resource manager design trails to maximize mountain biker enjoyment while minimizing environmental damage?
2. *Trail Impacts:* When should a resource manager control or not control trail erosion in order to provide quality experiences while still managing the physical environment?
3. *Management Tools:* If erosion is to be controlled, how should a resource manager choose techniques that reduce soil erosion and protect the environment, but still cater for the preferences of the user at the same time?
4. *Management Strategies:* Is there evidence to suggest that resource managers should have different management strategies, in accordance with such variables as age, environmental concern, commitment, and timing of riding of mountain bikers that use such areas?

These questions will be addressed in the following sections.

Methods

To test the above research questions on how managers can effectively design and manage trails for mountain bike use, a pilot user survey was designed and tested. The primary objective was to gather data from mountain bikers concerning issues about the following four objectives:

1. to identify the mountain biker by age, sex, and location, and their commitment and use levels on the trails they ride;
2. to identify biker environmental concern and perception of other trail users;
3. to identify the influence of trail conditions on mountain biker experiences; and
4. to test whether any biker parameters could be used as predictors of trail preferences and environmental concern.

The survey was pilot tested in November 1997. Surveys were emailed to 32 mountain bikers from one email list in the United Kingdom to test wording, and selection of five- or seven-point Likert-type rating scales for some questions. A final survey was devised from the recommendations and results of the pilot survey.

The 17-question revised survey was then sent to 700 randomly selected mountain bikers on email discussion lists administered at www.cycling.org, on April 3, 1998. Bikers were selected randomly to achieve as much generalizability from the sample as possible. The sample thus represents bikers from all areas of the United States. It was assumed that bikers with email access adequately represent the overall biker population, although this hypothesis remains to be tested from future email studies of mountain bikers. The response rate from the initial mailing was 42%. A first reminder was sent on April 20, and the cumulative response rate increased to 51%. A final reminder was sent on April 27, and the final survey response rate totaled 58% ($N = 406$). Results were collated in Excel 97, and SAS v6.12 was used for statistical analysis. All reported significant differences were calculated at an alpha level of 0.05, unless otherwise stated, and least significant difference (LSD) was used as a method for means separation analysis. The selection of five- or seven-point Likert-type rating scales for specific variables was determined using the variance of each variable from the pilot test. For example, it was determined appropriate to use a seven-point scale to test the effect of design factors and resultant factors of erosion on experiences due to responses showing large variance whereas a five-point scale was used to test preference for management techniques due to the majority of respondents answering the same preference rating (lower variance) in the pilot test.

Results

The Mountain Biker and Use

It is primarily important that a resource manager identifies the type and profile of the user in the wildland recreation environment that is to be managed. For example, such parameters as biker age, skill, level of biking experience, and timing of use all affect the way that decisions concerning the management of the environment and biker experiences should be made. Bikers in this study represented 42 states of the United States, including California, Texas, and New York, in addition to areas of Australia, New Zealand, and the United Kingdom. The study found no significant differences in age, sex, and user preference and experiences due to location. Ninety percent (90%) of mountain bikers were male, 10% female. The average biker was 33.1 years old (median 32), indicating a normally distributed sample population, and two-thirds of all respondents were between 21 and 40 years of age.

More than one-third (36%) of bikers had been involved in mountain biking between 1 and 4 years, and another third (35%) between 5 and 8 years. In general, the majority of bikers were well experienced with the recreation activity (65% have biked for longer than 5 years), although more than a third of users (35%) were still relatively inexperienced.

In terms of self-rated skill level, only 8% of bikers rated themselves as low (≤ 2 on a five-point scale). In conjunction with the above data on experience, this indicates that mountain bike skill can be acquired in a short period of time (35% of bikers have only been involved in the activity between 1 and 4 years). Seventy-four percent (74%) of bikers rated their skill between 3 or 4 on a five-point scale. Therefore, these data suggest that resource managers are managing for a self-perceived relatively technical, skilled population of recreation bike users.

More than 60% of bikers frequently rode in each month from April to October. Peak use occurred in June (84% participation); however, the months of May, July, August, and September all exhibited participation greater than 78% of all bikers. Significantly more bikers rode in these months than any other month. Twenty-two percent (22%) of bikers frequently rode in the winter (December, January, February); however, significantly fewer people rode in these months than any other months. Although fewer mountain bikers rode in the winter, when soils have more potential to remain wet for prolonged periods, this small percentage use could have a dramatic impact on soil erosion. For example, in conjunction with the findings of Symmonds (1999), if 100% of people rode on dry soil conditions during the summer months, it would only take a 11% use level on wet conditions to instigate the same amount of soil erosion on the soil texture studied.

During the months that bikers most frequently participated, the majority of users rode between two and four times per week (57%). Nineteen percent (19%) of bikers rode more frequently than this. These data reflect the commitment of bikers to mountain biking and also the amount of available leisure time. In general, bikers are committed and/or have a significant amount of time available for recreation.

It might be hypothesized that bikers are often the best judge of use level on trails because they spend more time in the recreation environment than most other persons. If bias can be minimized (i.e., when asked to identify use level, some bikers might state low, because they fear that bike use will be restricted in the future if they state high), resource managers have a useful estimate of how much use is occurring in their resource area and at what time management should be instigated or intensified. This method of identifying use level is relatively easy and serves as a useful check to more empirical methods of measuring use level. In terms of amount of trail use, only 8% of bikers did not encounter any other bikers when riding. More than 83% averaged between one and ten encounters. This indicates that use levels on trails that bikers ride seem moderate to low; however, when asked to identify the level of use on trails (1 = low and 5 = high), only 10% of bikers stated a low use level (≤2). More than 60% of bikers rated the use level on the trails they rode as high (≥4). These data indicate that bikers perceived that use levels on trails, in general, were above moderate levels.

In addition to timing of use, it is beneficial for resource managers to identify the intensity of use at certain times of the year. Whether bikers ride alone or in social groups is therefore important to the management of recreational carrying capacity. More than three-quarters (76%) of mountain bikers rode with other people. Eighty-nine percent (89%) of these social riders recreated with between one and five other riders. Therefore, group size is relatively small from a management viewpoint. However, 11% of people who rode with others also rode with more than five people. This highlights a concern for resource managers when evaluating the impact of high-intensity use on trail erosion and widening. One respondent stated participation in the company of 50 others while social club riding. If mountain bike trails are to be managed to any degree on trails primarily used for biking, then high-intensity use and the timing of this use should be a primary consideration if soil erosion is to be minimized (Symmonds 1999).

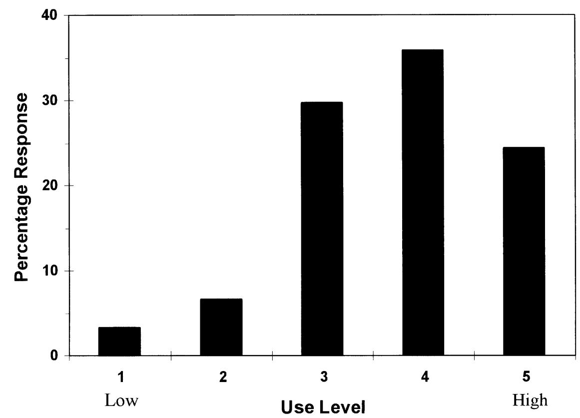

Figure 1. Perceived use level in the area bikers rode.

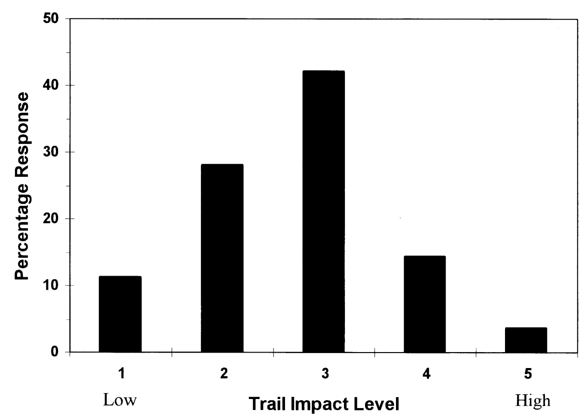

Figure 2. Perceived level of trail impact in the area bikers rode.

Trail Impact and Environmental Concern

Biker environmental concern is another important consideration for resource managers. When managing trail impacts of specific user types, such as mountain bikers, it is also important to know how much impact is perceived by the user and how much impact is actually occurring due to the user. Perceptions are often different from reality; therefore, resource managers can face a problem with the environmental education of user groups and perception of impacts of other user types.

The perceived level of trail impacts (depth of trail, width of trail, presence of trail erosion factors) were rated by users on a five-point scale (1 = low and 5 = high). Forty-two percent (42%) of bikers perceived a medium level of impacts (3); however, a majority of remaining bikers (39%) rated the level of impacts as low (≤2). Only 18% rated the level of impacts on the trails they rode was above medium (>3). Together with results on level of trail use (more than 60% of bikers rated the use level on the trails they rode as high), regression analysis indicates that bikers did not perceive that level of bike use was a strong predictor of level of impact ($R^2 = 0.05$, $P = 0.0001$). Figures 1 and 2 illustrate this relationship.

The relative trail impacts of mountain bikers, horseback riders, walkers/hikers, and motorized vehicles were rated on a scale of 1 (low impacts) to 4 (high impacts) in order to measure biker perception of themselves relative to other types of activity. Walkers/hikers were perceived as having the least impact ($\bar{x}$ = 1.6) and bikers rated themselves second ($\bar{x}$ = 2.2). Horse impacts averaged 2.8, and motorized vehicles were perceived as the most damaging ($\bar{x}$ = 3.4). These data show that bikers perceived themselves to be significantly less damaging than horse riders or motorized vehicle users, but significantly more damaging than walkers or hikers.

In addition to perceived impacts of bikers relative to other use types, a measure of erosion perceived to be caused by bikers was measured. If bikers underestimate their impacts, resource managers might consider a more intense environmental education program as part of managing carrying capacity. Ninety-one percent (91%) of bikers acknowledged that mountain biking caused some degree of trail erosion. However, only 10% stated that biking "greatly" accelerated trail erosion. The remaining 9% who stated that biking had "no effect" on soil erosion were perhaps unaware that "environmental impacts will occur as a result of any human use" of a wildland recreational area (Jacoby 1990, p. 28) or perhaps refused to admit that biking caused impacts because they feared that results would be used to limit bike use. Either way, this group of people need to be identified by resource managers to direct environmental education programs. Although this group represented only 9% of the study population, they could represent a greater percentage in specific locales.

General environmental concern is a further consideration, if environmental education is to be part of carrying capacity management. To compare perceived environmental concern with a measure of actual environmental concern, two measurement techniques were used. A single-item measure was used for perceived environmental concern. This consisted of a seven-point Likert-type scale (1 = low perceived environmental concern and 7 = high perceived environmental concern). An index measure was also used to calculate actual or measured environmental concern.

On the single-item measure (perceived environmental concern), 79% rated biker environmental concern above medium (≥4), and only 9% perceived concern for the environment as low (≤2) (Figure 3). The index measure of environmental concern (actual environmental concern) was calculated by asking bikers to check any of six environmental support activities in which they had participated in the past 12 months. Trail maintenance was the most popular support activity (58%). Other rates of participation ranged from 25% to 46% ("have been a member of a non-fee based biking organization" [25%], "have donated money to an environmental concern" [29%], and "have been a member of another environmental organization" [33%], "lobbying to keep trails open" [38%], "have been a member of a fee based biking organization" [46%]). Each respondent was assigned an environmental concern score from 0 to 6, according to the number of environmental support activities they had participated in. When the index measure of environmental concern (Figure 4) is compared to what bikers perceived as their level of environmental concern (Figure 3), opposing trends are revealed. Seventeen percent (17%) had not participated in any of the six environmental support activities, and more than 58% had participated in two or less of the support activities. These data highlight concern for resource managers. If a user perceives that their environmental concern is higher than it actually is, then environmental education and encouragement to participate in environmental support activities may be a more difficult task. In short, if users perceive they are already doing enough for the protection of the recreation resource, it might be more difficult to encourage them to volunteer more time or money than it would be if they perceived they were not already doing enough for the protection of the resource.

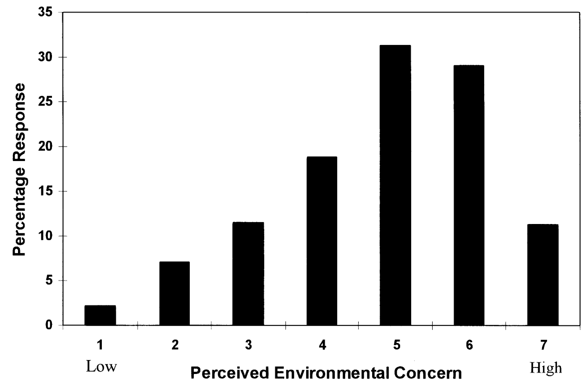

Figure 3. Percent of perceived concern for the environment by mountain bikers.

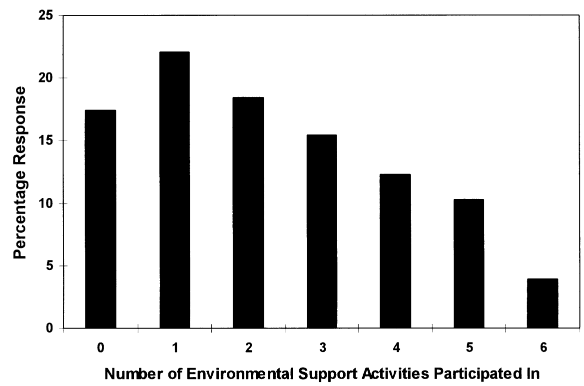

Figure 4. Percent of participation in six environmental support activities by mountain bikers.

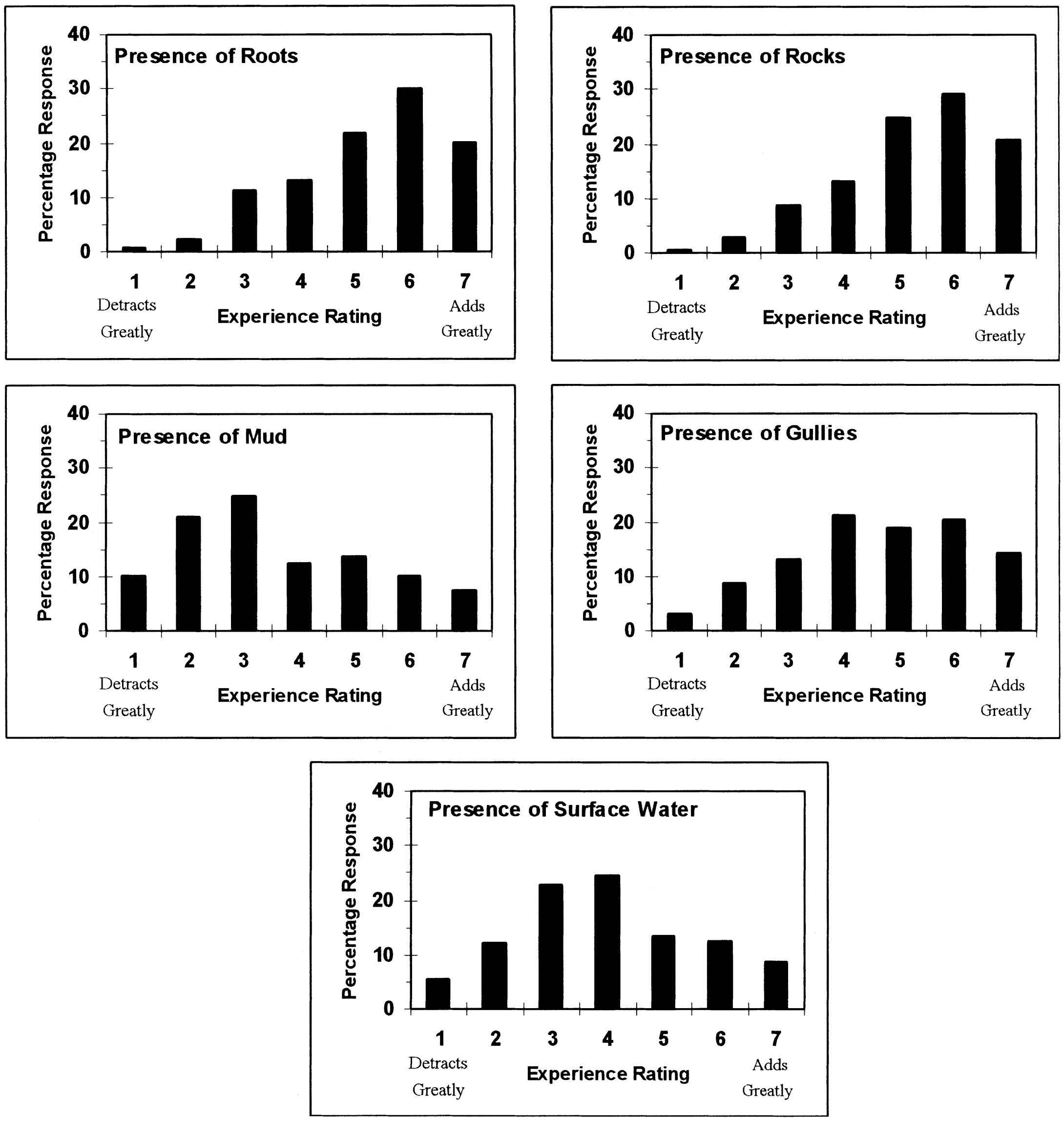

Figure 5. The effect of resultant trail erosion conditions on experiences of mountain bikers.

Influence of Trail Conditions on Mountain Biker Experiences

Different users have different motives for their selection, timing, and location of recreation. Therefore, it is important for recreation resource managers to identify the most influential trail environment conditions that add or detract from user experiences in general in order to effectively manage trail environments. In terms of mountain biking, these conditions are influenced by managers' selection of trail design and soil erosion management techniques.

Trail conditions resulting from a lack of erosion control were rated on a seven-point Likert-type scale according to their affect on quality of biking experiences (1 = detracts greatly from experience and 7 = adds greatly to experience). In general, the presence of roots, rocks, and gullies added to biking experience (Figure 5). Roots ($\bar{x} = 5.24$) and rocks ($\bar{x} = 5.29$) added to the biking experience significantly more than all other resultant factors of soil erosion. The presence of surface water did not affect experience positively nor negatively ($\bar{x} = 4.01$). The only erosion factor that detracted from biker experience was the presence of mud ($\bar{x} = 3.6$). The presence of mud had a significantly smaller effect on experience than all other resultant factors of erosion. Additional conditions written in as open-ended responses by bikers included "drops/drop offs" ($\bar{x} = 6.3$), sand ($\bar{x} = 2.2$), smooth

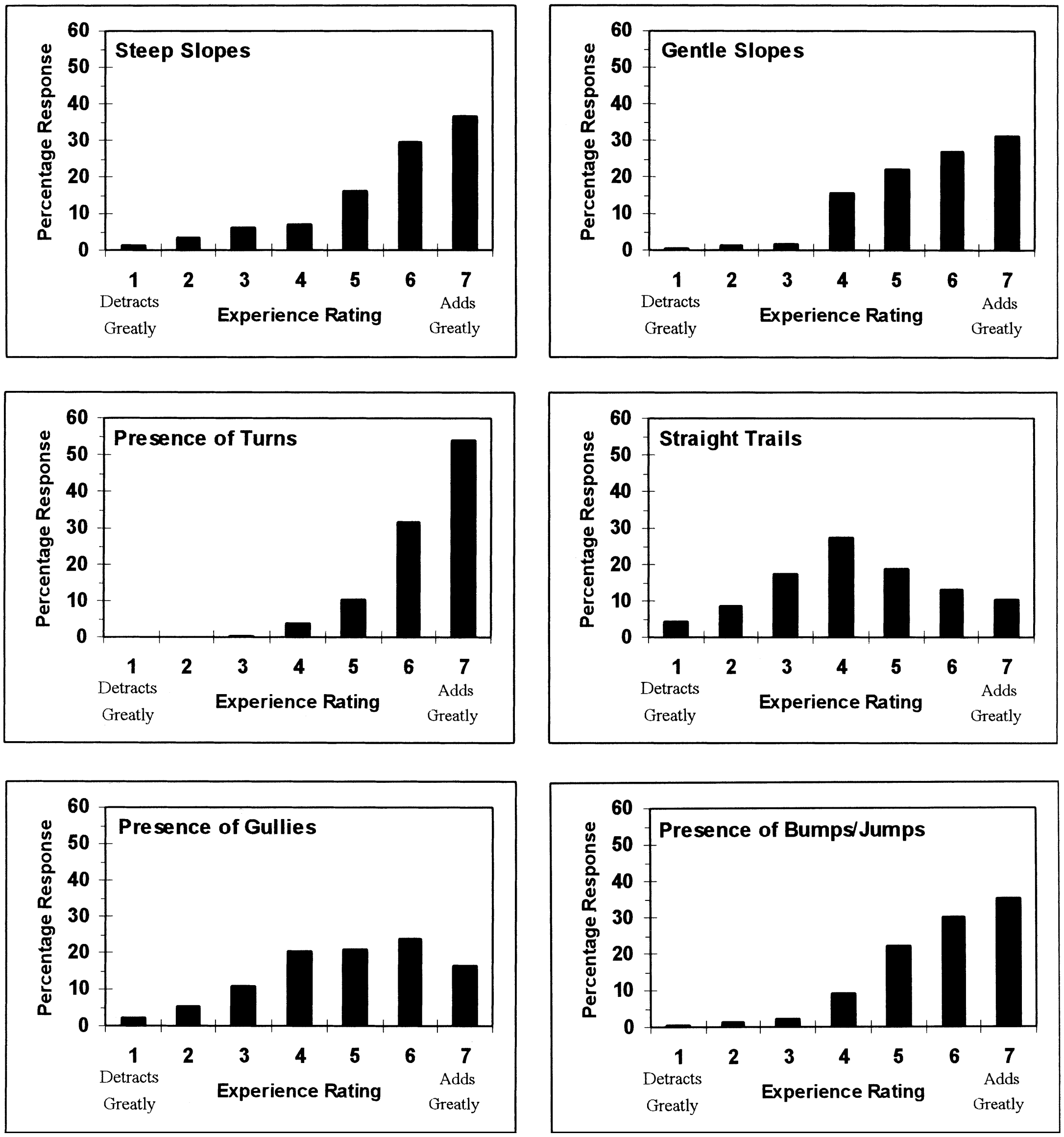

Figure 6. The effect of trail design factors on experiences of mountain bikers.

trails ($\bar{x} = 7.0$), dust or dry soil conditions ($\bar{x} = 6.0$), erosion holes ($\bar{x} = 2.0$), and ATV ruts ($\bar{x} = 1.0$).

Several trail design factors were also rated on a seven-point Likert-type scale (1 = detracts greatly from experience and 7 = adds greatly to experience). Mountain bikers preferred a mix of steep ($\bar{x} = 5.68$) and gentle slopes ($\bar{x} = 5.64$) and, in general, the presence of turns ($\bar{x} = 6.34$), bumps or jumps ($\bar{x} = 5.81$), and the presence of obstacles ($\bar{x} = 5.70$) added to experiences. No design factors detracted from the quality of biker experiences, with the exception of wide trails, which only detracted slightly ($\bar{x} = 3.76$). The presence of turns was the most important trail design factor, adding significantly more to the experience than any other design factor (Figure 6).

Some trail erosion and design conditions may even make mountain biking unfeasible and therefore need to be managed or avoided. Eighty percent (80%) of mountain bikers indicated that there were conditions that made biking unfeasible. The most common condition was mud or clay (30%), followed by wet trails (20%). Fifty percent (50%) of the conditions that made biking unfeasible related to improper or poor trail drainage. Other reasons expressed included concern for wildlife or habitats (8%); snow or ice (7%); steep gradients (6%); streams, flooding, or deep standing

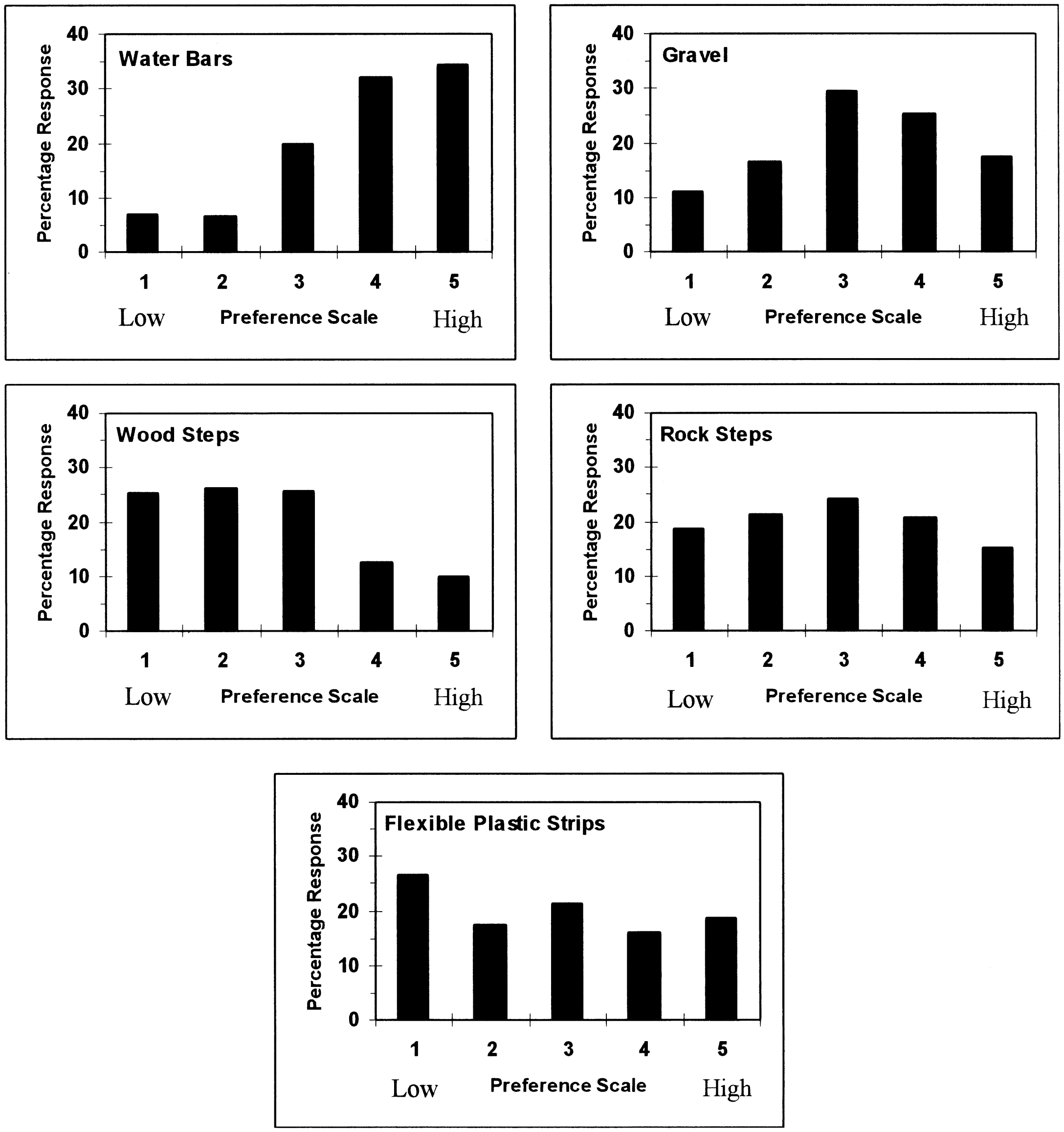

Figure 7. Preference for soil erosion management techniques.

water (5%); other users (5%); sand (4%); rocks or gravel (4%); erosion in general (4%); gullies or ruts (3%); and other conditions (4%). Unfortunately, some users misinterpreted the question as shown by some of the above factors. The question asked for specific "trail environmental conditions," however, some users included weather conditions or other users in this definition.

The remaining 20% of bikers that found no conditions that made biking unfeasible appeared to be "die-hard" or lesser experienced bikers. Conditions such as 2-feet-deep mud will make biking unfeasible. Those identifying no unfeasible conditions perhaps refused to admit that there were conditions in which they would not try to bike even though their experience would probably be very limited in those conditions, or perhaps those bikers were answering the question specific to their past experience. For example, some mountain bikers may not have experienced deep mud and therefore cannot judge whether deep mud makes biking unfeasible.

Many of the trail erosion and design conditions detracting from experiences of mountain bikers, particularly those making biking unfeasible, can be effectively reduced by recreation management techniques. Biker preference for several trail erosion management techniques was rated on a five-point Likert-type scale (1 = low preference and 5 = high preference). Mountain bikers

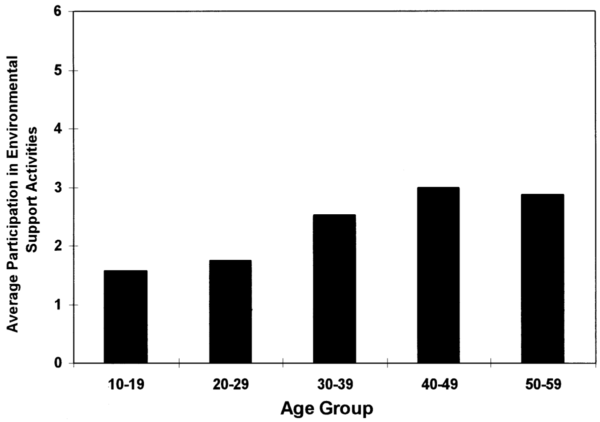

Figure 8. Age group and average participation in environmental support activities.

preferred water bars ($\bar{x} = 3.81$) significantly more than all other listed management techniques. Wooden steps ($\bar{x} = 2.55$) and flexible plastic water strips ($\bar{x} = 2.83$) were least preferred, of which wooden steps were significantly less preferred than all other management techniques. Gravel ($\bar{x} = 3.21$) and the use of rock steps ($\bar{x} = 2.92$) exhibited slightly more preference (Figure 7). Comments indicated that mountain bikers did not prefer plastic strips because they looked unnatural in the wildland environment. Few comments were acquired concerning the poor preference for wooden steps, however, this might be attributed to the difficulty in traversing such obstacles at speeds on a mountain bike as noted by Hain (1986).

The Effect of Age, Skill, and Commitment on Biker Preference for Trail Conditions and Biking Experiences, and Trail Management Techniques

Resource managers face a complex task in managing the recreation environment for a population with diverse parameters, such as mountain bikers. Therefore, any refinement of the population will enable managers to direct specific management decisions to specific resource areas and users. For example, if the age of a biker affects preference for a certain design of trail or erosion management technique, it would be useful for managers to be able to apply this knowledge to the recreation resource instead of attempting to manage for one homogenous population.

Age. An initial hypothesis stated that age would not be a significant predictor of biker skill level; use experience, environmental concern, and trail preferences. Age was not found to be a significant predictor of any of these variables (greatest $R^2 = 0.07$).

The amount of environmental support activities that a biker had participated in increased with age. However, this relationship was weak (but still significant) ($r = 0.27$, $p = 0.0001$). Suggestions for why this relationship was not well defined include the amount of time available to participate in environmental support activities. For example, in general bikers between the ages of 40 and 49 showed the most concern for the environment (Figure 8); however, some individuals within this group might have more time than others to participate. Therefore, correlation analysis did not show a significant relationship because the spread of participation scores within the age group was large ($N = 74$, $\bar{x} = 2.98$, $\rho = 1.70$).

The presence of gullies, mud, obstacles, and standing water were less important to biking experiences as age increased. This suggests that older bikers might be less physical or prepared to take risks in their biking activity and prefer to recreate in a more passive and appreciative mode. Different age groups exhibited a significant difference in how they rated the effect of erosion factors on their biking experiences (Table 1). A general decreasing trend across all resultant factors of erosion was observed as age increased, meaning that younger bikers significantly preferred resultant factors of erosion more than older bikers (Figure 9). For example, bikers aged 29 and younger stated that roots added to their experiences significantly more than roots added to the experiences of bikers aged 40 and older; the presence of rocks added significantly more to the experiences of bikers aged below age 40 than those above 40; bikers below age 20 stated that mud added to their experiences significantly more than the presence of mud did for older bikers; gullies added significantly more to the experiences of bikers below age 20 when compared to older bikers; surface water added significantly more to the experiences of bikers below age 20 than surface water did for older bikers. Table 1 summarizes the mean scores for each age category and highlights significant mean differences among the age subgroups for trail erosion factors.

The effect of trail design factors on experiences also decreased with age (Figure 10). The additive effect of steep gradients on experiences decreased as age increased, and the presence of steep gradients significantly added to the experiences of younger bikers aged 10–19. Gullies also significantly added to the experiences of younger bikers, aged 10–19, when compared to older age groups; and significantly detracted from the experiences of bikers older than age 40 when compared with younger bikers. The presence of bumps and jumps also added significantly more to the experiences of younger bikers (aged 10–19) than they did to older bikers. There was no significant difference between age group mean experience ratings for the presence of gentle slopes, turns, straight trails, or wide trails. This indicates that these trail factors were widely preferred

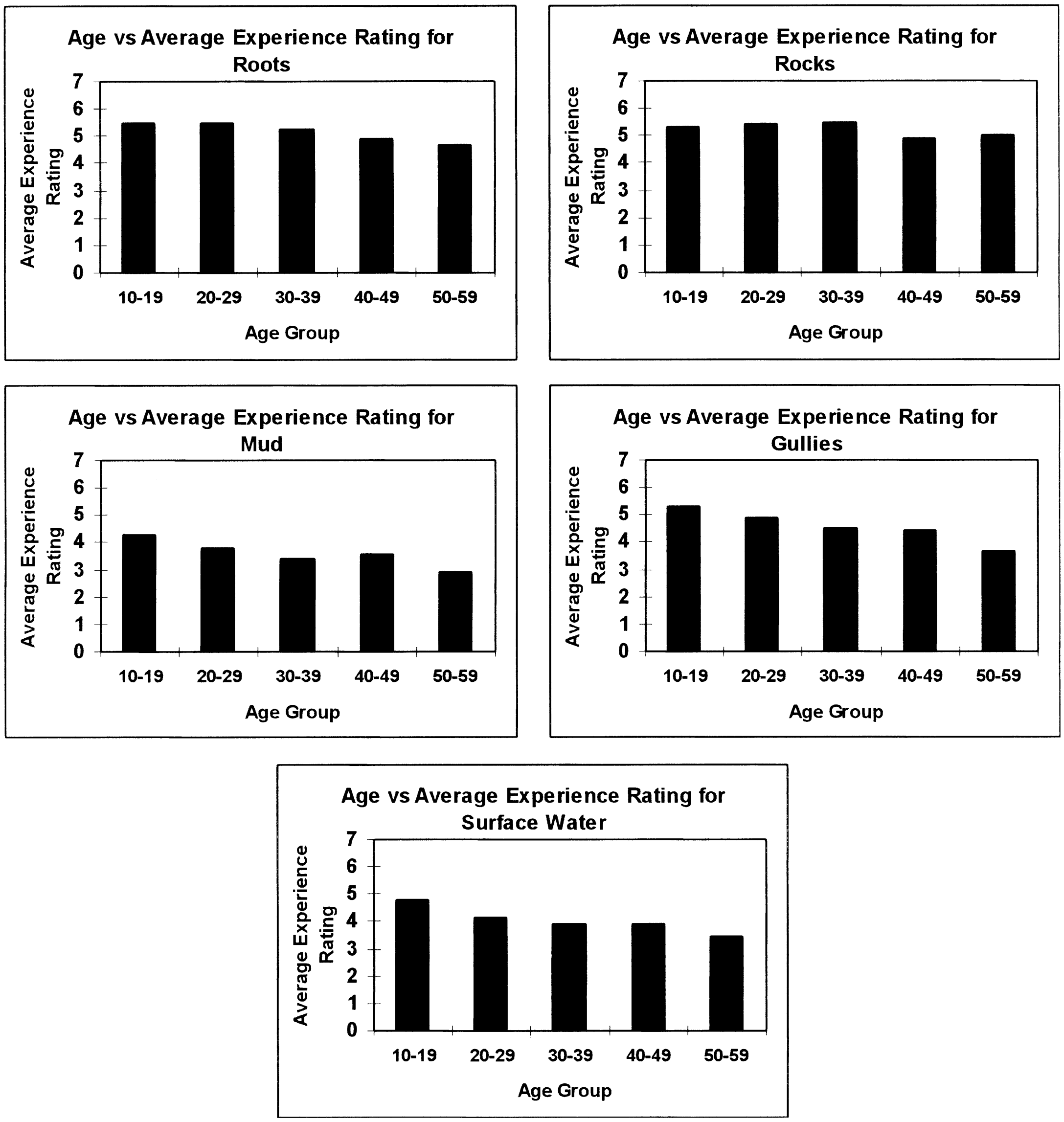

Figure 9. The effect of age on how resultant factors of erosion affect biking experiences.

(or not preferred in the case of wide trails) by all ages. Table 2 summarizes the mean scores for each age category and highlights significant means separation groupings for trail design factors.

Age was not found to affect the preference for management techniques, with the exception of gravel. Young bikers (age below 20) preferred gravel significantly less than older bikers with the exception of the 40–49 age group. Table 3 summarizes the mean scores for each age category and significant differences among the age sub-groupings for management preferences.

Skill Level. Biker skill influenced the way in which design factors added or detracted from biking experiences. Low-skilled bikers preferred steep trails and the presence of obstacles significantly less than more skilled individuals (Figure 11). The presence of turns, gentle trails, straight trails, wide trails, and bumps or jumps did not significantly influence the experiences of bikers with different skill levels (Table 2).

There was also a visible trend between skill level and the effect trail erosion conditions had on biking experiences. The presence of roots significantly detracted from biker experiences for those bikers with the lowest skill level. The presence of rocks exhibited a similar pattern. Low-skilled bikers felt that the presence of rocks significantly detracted from their experiences, more so than did more skilled bikers. In general, the more skilled the individual the more the presence of challenging obstacles, such a rocks and roots, added to

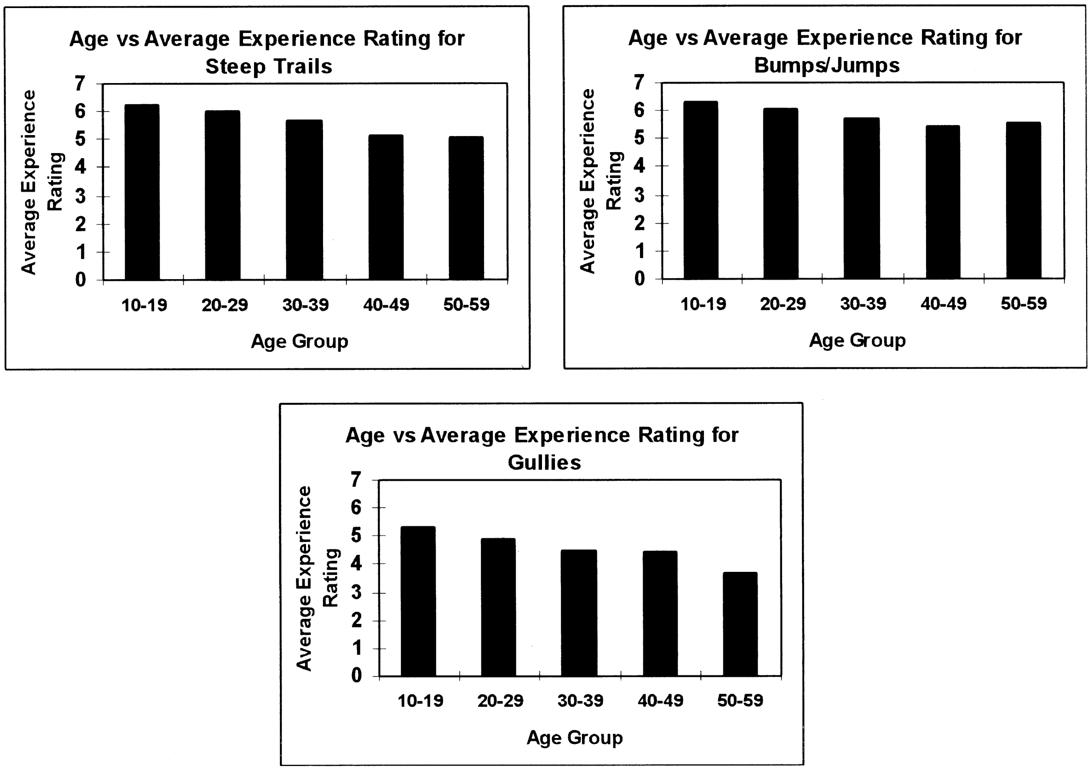

Figure 10. The effect of age on how design factors affect biker experience.

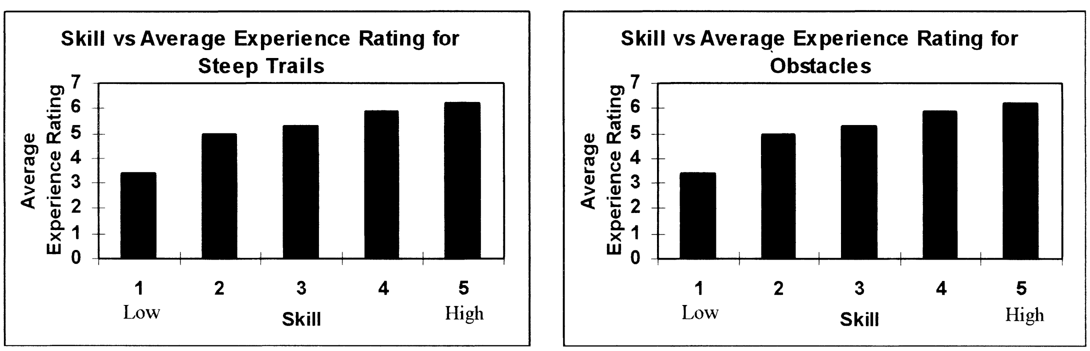

Figure 11. The effect of biker skill level on how trail design factors affect biking experiences.

experience (Figure 12). Skill was not found to affect preference for any management techniques (Table 3).

Commitment. It was hypothesized that riding commitment would have no effect on environmental concern. It was also hypothesized that age would not reflect the amount of years an individual had been riding. The frequency of riding (commitment) was not a useful predictor of skill ($R^2 = 0.08$, $P = 0.0001$), the amount of years an individual had been riding ($R^2 = 0.002$, $P = 0.37$), participation in environmental activities ($R^2 = 0.0003$, $P = 0.72$), or perception of mountain biker environmental concern ($R^2 = 0.015$, $P = 0.01$).

It is evident that such variables as age and skill can be used to segment the mountain biker population into smaller, more manageable subpopulations. However, it is also important to note that other variables, such as commitment, do not provide useful management predictions, such as which type of erosion management technique to use in a given area.

The mountain biker population is complex, as are some other user types using recreation resource environments. Refinement of this group by specification of preferences according to predictor variables (such as age) will aid resource managers in making decisions; however, it must be recognized that management cannot satisfy all people.

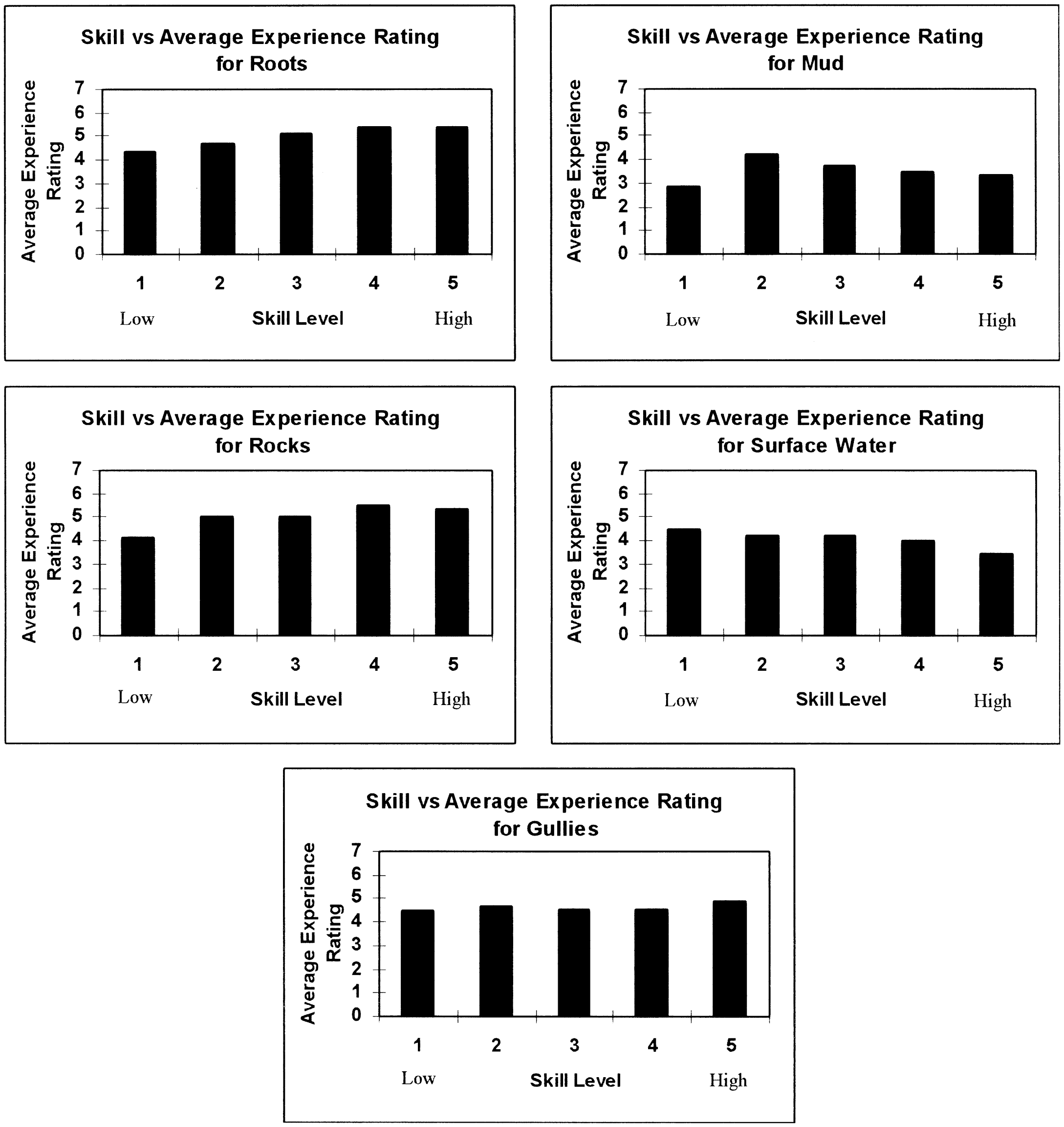

Figure 12. The effect of biker skill level on how trail erosion factors affect biking experiences.

Conclusion

The data presented in this study have highlighted some important issues for managers of recreation resources primarily used by mountain bikers. Relating to the four objectives of this study as detailed earlier, the following sections discuss how the findings of this study can be applied to the management of trail impacts, selection of management tools to control these impacts, trail design, and selection of management strategies.

Trail impact management is a major management consideration. Bikers in general enjoy the challenge of obstacles on the trail, such as bumps and jumps, gullies, roots, rocks, and surface water. Many of these obstacles are present due to erosion. Therefore, one must ask the question: Should resource managers minimize erosion when mountain bikers state that most trail erosion factors add to the biking experiences? Also, should erosion management be instigated at the inception of a new trail system, or should erosion management differ in its intensity over time? Once a trail system is designed and opened for mountain bike use, should managers allow some degree of erosion to occur until a point is reached where the trail conditions suit the biker and then instigate more intense erosion management? There appears to be an equilibrium point at which the social and ecological capacity for mountain biking meet. One cannot exist without a reduction in the other. One cannot minimize erosion and still provide favored biking experiences, and one cannot maximize biking experiences but reduce erosion to a minimum, because of the

Table 1. Significant differences (means separation) among subgroups for the effect of age and skill on the way in which resultant factors of erosion affect biking experiences

Independent variable	Roots present ($\bar{x}$)	Rocks present ($\bar{x}$)	Mud present ($\bar{x}$)	Gullies present ($\bar{x}$)	Water present ($\bar{x}$)
	Trail erosion condition affect on biking experiences				
Age (years)					
10–19	5.47[a]	5.28[ab]	4.24[a]	5.32[a]	4.76[a]
20–29	5.51[a]	5.42[a]	3.78[ab]	4.91[ab]	4.12[b]
30–39	5.23[ab]	5.46[a]	3.40[bc]	4.51[b]	3.89[b]
40–49	4.90[bc]	4.89[b]	3.55[bc]	4.41[b]	3.91[b]
50–59	4.69[c]	5.00[ab]	2.93[c]	3.69[c]	3.43[b]
Skill					
1 (low)	4.33[b]	4.17[b]	2.83	4.50	4.50[ab]
2	4.71[ab]	5.00[a]	4.20	4.72	4.24[a]
3	5.12[ab]	5.03[a]	3.72	4.55	4.20[ab]
4	5.38[a]	5.53[a]	3.50	4.55	4.01[b]
5 (high)	5.38[a]	5.40[a]	3.36	4.91	3.47[ab]

Means with different letter superscripts are significantly different (LSD, $\alpha = 0.05$).

erosion-related preferences of mountain bikers. This is not to say that allowing erosion is correct management or even desired from an environmental standpoint.

Trail location is another important design consideration for resource managers in accordance with the preference findings of this study and the conservation of the resource. A more logical solution to the above paradox is to locate and design mountain bike trails in areas resistant to trail erosion but that still provide the trail factors preferred by the majority of bikers. If within a resource area there are several soil types and textures, a resource manager might direct trail location to areas with textures that are more sandy and soil types that are shallow. This type of design would reduce erosion and pollution of the environment because of a more durable soil texture, and a shallow soil would create less potential for a large amount of soil loss than on a thicker soil. Shallow soils would also provide experience-enhancing obstacles, such as rocks, after a relatively small amount of soil erosion, compared to a large amount of soil having to erode on a deeper soil for unconsolidated rock material (saprolite) to be exposed.

The techniques that are used to control impacts are also a major consideration for resource managers. Preference ratings indicated that resource managers need to evaluate several aspects of different trail management techniques, instead of choosing the best at controlling erosion or the more readily available technique in a given area. Water bars were more preferred than wooden steps, rock steps, flexible plastic water strips, and gravel in terms of their effect on biker experiences and thus should be implemented wherever feasible. However, it is acknowledged that other factors, such as cost and time, also affect management decisions.

Management strategies were also suggested by the findings of this study. The mountain biker is another wildland recreation user with specific characteristics and trail environmental preferences. As a group, mountain bikers have well-defined parameters, such as age, skill, commitment, and trail preferences. Therefore, recreation resource managers should incorporate these parameters into the decisions they must make concerning the management of the recreation resource. However, it is sometimes not safe to assume or generalize about a population based on summary statistics. This study has shown that there is no single all-encompassing biker profile that resource managers can apply to the management of all mountain bike recreation environments. Within the mountain biker population there are subpopulations based on such variables as age and skill level. Thus, resource managers firstly need to identify user subgroup trail preferences within the area they manage. Once identified, a resource manager can incorporate an aspect of user preferences into wider management decisions. For example, the management of trails based in close proximity to a college town would require a different perspective on resource management than the management of trails close to a large metropolitan area. The primary predictor in this case might be age category. A resource area close to a college town would most likely attract a user with an average age of approximately 23 years, who, based on the data presented, would prefer mountain bike trails with steep slopes, bumps and jumps, gullies, and obstacles.

Another important finding was that there were no predictors of preference for trail management techniques, environmental concern, and biker experience. One might hypothesize that age would be a significant predictor of bikers' characteristics like environmental concern; however, this was not the case. There was no significant linear relationship between age and other variables tested. Therefore, resource managers should take care to not assume, for example, that the age of an individual in a specific area will directly predict their environmental concern for the resource. However, if users are grouped into age or skill categories, managers can segment the overall population into smaller management groups that have, for example, specific management preferences, environmental concern levels, and degrees of experience.

Additional findings, outside of the original objectives, showed that biker perception of other users revealed some important questions and recommendations for further research. Bikers perceived the following order of user impact from lowest impact on soil

Table 2. Significant differences (means separation) among subgroups for the effect of age and skill on the way in which trail design factors affect biking experiences

	Trail design factor affect on biking experiences							
	Steep slopes ($\bar{x}$)	Gentle slopes ($\bar{x}$)	Turns present ($\bar{x}$)	Straight trails ($\bar{x}$)	Gullies present ($\bar{x}$)	Bumps present ($\bar{x}$)	Wide trails ($\bar{x}$)	Obstacles present ($\bar{x}$)
Age (years)								
10–19	6.26[a]	5.18	6.38	3.97	5.56[a]	6.29[a]	3.74	5.91[a]
20–29	5.99[ab]	5.63	6.35	4.22	5.10[ab]	6.05[ab]	4.08	5.95[a]
30–39	5.64[bc]	5.59	6.34	4.38	4.89[b]	5.74[bc]	3.63	5.77[ab]
40–49	5.14[c]	5.81	6.32	4.35	4.58[c]	5.43[c]	3.49	5.41[b]
50–59	5.10[c]	6.00	6.34	4.46	4.28[c]	5.52[c]	3.67	4.86[c]
Skill								
1 (low)	3.40[c]	5.83	6.33	5.67	4.50[b]	5.50	4.33	4.33[b]
2	4.96[b]	5.79	6.29	4.29	5.00[ab]	5.56	4.21	5.64[a]
3	5.33[ab]	5.74	6.21	4.39	4.67[ab]	5.50	3.88	5.49[a]
4	5.92[a]	5.60	6.44	4.27	4.88[ab]	5.99	3.58	5.80[a]
5 (high)	6.21[a]	5.48	6.41	4.00	5.44[a]	6.11	3.79	6.02[a]

Means with different letter superscripts are significantly different (LSD, $\alpha = 0.05$).

Table 3. Significant differences (means separation) among subgroups for the effect of age and skill on the way in which soil erosion management techniques affect biking experiences

	Preference for soil erosion management techniques				
Independent variable	Water bars ($\bar{x}$)	Gravel ($\bar{x}$)	Wood steps ($\bar{x}$)	Rock steps ($\bar{x}$)	Plastic strips ($\bar{x}$)
Age (years)					
10–19	3.84	2.70[c]	2.66	3.09	2.54
20–29	3.86	3.22[ab]	2.62	2.89	2.72
30–39	3.80	3.34[ab]	2.63	2.99	2.84
40–49	3.80	3.10[bc]	2.22	2.86	3.02
50–59	3.62	3.63[a]	2.67	2.84	3.27
Skill					
1 (low)	4.25	2.25	3.00	2.50	3.00
2	3.80	2.90	2.70	2.55	2.69
3	3.85	3.18	2.53	2.85	2.65
4	3.73	3.30	2.53	2.94	2.83
5 (high)	3.91	3.23	2.57	3.16	3.13

Means with different letter superscripts are significantly different (LSD, $\alpha = 0.05$).

erosion to highest: 1: walkers/hikers; 2: mountain bikers; 3: horses; 4: ATVs. Whether this is a correct perception is not quantifiable using limited present research and the variability of impacts in different environments under different amounts and intensities of use. However, social psychological theory states that perception is an important issue in the study of recreational users; in particular, what is dubbed ‘‘fundamental attribution error’’ (Myers 1990). In this case, theory would suggest that bikers often underestimate their own impacts because they perceive that other user groups that share the same resource are causing more soil erosion than bikers. This was evident in the responses acquired from additional comments provided in the survey. Bold statements, such as ‘‘horses cause erosion more than bikers’’ and ‘‘the horses in our area tear up the soil, which makes the trails bad for us,’’ suggest that resource managers should attempt to dispel perceptions that are not based on scientific evidence. Any user does not have the right to erode the soil or impact the trail more than what is ‘‘acceptable’’ for a given area, just because someone else appears to be impacting the soil more than an acceptable level.

The findings of this study have discovered some interesting aspects concerning the mountain biker population and have reinforced other aspects that have already been studied. It is important to understand the user of a recreational environment as best as possible in order to direct resource management to safeguard the user experience as well as the physical environment itself. Providing quality outdoor recreation and sufficient user experiences and satisfaction can only be achieved through a better understanding of the user.

Future research needs to test the findings of this study and others that have been conducted. The mountain biker is a relatively recent addition to the recreation resource and future research needs to allocate as much study to this user group as it does to other recreational use types. It is still unclear how some recreation resource environments should ideally be managed for mountain bike use. A balanced information base will aid resource managers and allow them to make more informed decisions in our wildland areas concerning appropriate carrying capacities and levels of acceptable change. There are still many hypotheses and assumptions that remain to be tested, as suggested throughout this paper, that will aid recreation resource managers in providing quality outdoor recreation to the diverse populations that function in the resource.

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