Annals of Leisure Research Vol. 6, No. 4 

# *Managing Recreational Mountain Biking in Wellington Park, Tasmania, Australia*

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**Abstract**
The management of recreational mountain biking is examined in this paper, based on the findings of social and environmental research undertaken in Wellington Park, near Hobart, Tasmania. A review of existing research on the impacts of off-road mountain biking on the physical environment and on other recreational users is presented, followed by the findings of a questionnaire survey of mountain bikers and other park users and an environmental impact study of mountain biking. The questionnaire survey results (n = 255) revealed that conflicts between mountain bikers and other recreational users of Wellington Park were uncommon and there was considerable tolerance for mixed use of tracks. The concerns of non-bikers were mostly about bicycles travelling at excessive speed and not giving an approach warning. A physical impact study, which measured changes in track surface elevation under different conditions, revealed no significant difference between the level of impacts caused by mountain bikers and walkers under the conditions tested. Riding on wet sites and up steep hills and skidding were shown to have significantly greater levels of impacts than riding on flat, dry sites. User education and suitable track maintenance regimes are suggested as the favoured options for managing the main areas of concern relating to off-road mountain biking, namely environmental damage, safety issues and quality of experience.

## Introduction
The development of the mountain bike in the 1970s saw the merging of the road bicycle and the BMX (bicycle motocross) into a full-sized bicycle, with gears and wide tyres, suitable for riding off-road or on the road. The popularity of mountain biking has grown substantially over the last 25 years and continues to grow. Mountain bike sales are now reported to account for up to 80% of bicycle sales in New Zealand (Cessford, 1995b) and the United States (Widmer, 1997), with similar trends occurring in Australia. In 1983, 20,000 mountain bikes had been sold in the United States; by 1993 over 20,000,000 had been sold (Widmer, 1997). Most of these bikes may never see a bush track, much like the four-wheel drive motor vehicle phenomenon, however it is clear that many of them do. In fact, mountain biking has grown to be one of the most frequent forms of track

use (Hendricks, 1997) and riders even outnumber walkers in some areas (Osbaldeston, 1998).

This rapid surge in mountain bike use has left some land managers unprepared for their physical and social consequences, including environmental damage, safety problems and potential reductions in the quality of experience of other users. Indeed, land managers in both New Zealand (Cessford, 1995a) and the United States (Chavez, 1996) have identified mountain biking as the most significant new use issue facing outdoor recreation managers. In Australia similar trends seem to be occurring, but few studies of mountain bike management have been undertaken.

**Mountain bike research and management - background**

Mountain bikes were invented in the 1970s and, as indicated above, have grown rapidly in popularity since the 1980s. The challenge they pose to land management is therefore of recent origin and there is limited published information on mountain bike management issues. A number of studies have, however, been conducted, particularly in the United States and New Zealand, and these are summarised below under three headings: physical impacts and social impacts; and management options.

*Physical impacts of mountain bike riding*

The use of mountain bikes on bush tracks undoubtedly produces some physical impacts, including compaction of soils under the weight on their wheels, and erosion of soils with the shearing stresses of rotating wheels (Cessford, 1995a). One of the key impacts of mountain bikes, and other wheeled vehicles, is the formation of wheel ruts which channel water and increase erosion in the rut and elsewhere on the track (Cessford, 1995a; Chavez, 1997; Horn et al., 1994). Skidding, either deliberately for 'fun' or accidentally around a sharp corner, increases the rate of erosion. Erosion measurements taken at the 1997 National Mountain Bike Championships, held on Mount Majura in Canberra, found that soil loss at sharp corners was significantly greater than on straighter sections of track (Hawes, 1997). Steep slopes and corners were also found to be the most susceptible to the erosion impacts of mountain biking in the Western Australian study by Goeft and Alder (2001).

The question arises as to how mountain bike impacts compare with those of other recreational users. In a comparative study of the erosional impacts of hikers, horses, motorcycles and mountain bikes Wilson and Seney (1994) concluded that all of these users on wet trails increased erosion, but there were no significant differences in erosion rates between walkers and mountain bikes. Motorbikes travelling uphill and horses appeared to cause the greatest impacts.



Similarly, Thurston and Reader's (2001) comparative study of experimentally applied mountain biking and hiking impacts in a deciduous forest found biking and hiking to have similar effects on vegetation and soil.

In a 1987 United States study, referred to as the 'Kepner-Trego Analysis', it was concluded that the differences in erosion rates between walkers, horses riders and cyclists were insignificant when compared to the inherent erosion caused by the existence of the track (Cheshire, 1993; Grost, 1989). This conclusion did not apply to wet tracks however, and emphasis was given to the importance of track drainage (Cheshire, 1993).

Although more research needs to be undertaken on identifying and addressing the physical impacts of mountain biking, the present state of knowledge suggests that the physical impacts of recreational mountain biking are generally not significantly greater than those caused by walkers. It is even possible that in some situations the impacts caused by walkers, who transfer their weight from foot to foot and from heel to toe, may be greater than the impacts caused by mountain biking where the weight is evenly loaded over two wheels (Goeft and Alder, 2001). However, regardless of which recreational user is 'worse', there are clearly some physical impacts of mountain bike use that need to be managed. In many instances, however, it is the social impacts related to safety concerns or quality of recreational experience that cause mountain bike-related conflicts.

*Social impacts of mountain bike riding*

The social impacts of mountain bike use can generally be linked to perceptions that mountain bikes cause excessive environmental damage, to safety concerns or to impacts on other users' quality of experience. The present state of knowledge on the environmental impacts caused by mountain biking, summarised above, suggests that other user group's objections to mountain bike use, based on physical impacts alone, may not be justified if bush walking and/or horse riding is to be permitted. However, there are other conflicts that arise from mountain bike use, such as the safety concerns of other track users.

The design of mountain bikes allows travel both quietly and at high speeds. This combination sets up some potentially dangerous situations and is the basis of most safety concerns. Sections of track with poor sight distances, such as sharp corners, enhance the level of threat to user safety. Horses in particular can be 'spooked' by bicycles, which can cause safety concerns (Chavez, 1997). Sensible riding and giving an approach warning can undoubtedly reduce the safety risks of park users. Improving sight distances and leaving obstacles and rough surfaces on the tracks to reduce speeds can also reduce safety risks to other track users.

Mountain biking can also cause social impacts by reducing the quality of experience of other users. The term 'goal interference' has been used by several authors to describe conflict in recreation (Jacob and Schreyer, 1980; Moore, 1994; Moore and Barthlow, 1997). The term implies that dissatisfaction of some users with their experience can be attributed to other users interfering with their desired goal. Moore and Barthlow (1997) suggest that the *expectations* of the dissatisfied user can also be just as important as any actual encounter at all. Other factors that can influence a user's perception of a quality experience include: crowding (Jakus and Shaw, 1997); levels of tolerance (Moore, 1994); social values (Carohers et al., 2001); and violations of norms (Gramann and Vander Stoep, 1986). Moore (1994) suggests that violations of norms may be more useful as predictor of conflicts than goals, as conflict can still occur amongst users with the same goals.

*Management options*

Once site-specific information related to the physical and social impacts of mountain biking has been gathered, the options open to managers to mitigate those impacts generally fall under three categories: education and information; track design and maintenance; and regulations and enforcement. Ongoing monitoring and evaluation of the management approach is also important.

*Education and information provision* are, in principle, very good management tools for recreation management as they are not coercive techniques that may be deemed as incompatible with high quality recreational experiences (Moore and Barthlow, 1997). Education and information also have the scope to reduce many of the mountain bike-related conflicts. Resource damage can be reduced if riders are made aware of the impacts of irresponsible riding behaviour (e.g. skidding) and are informed of sensitive areas of tracks to be avoided. Safety risks may also be reduced by encouraging riders to give other users an approach warning and to travel at reasonable speeds. A mountain bike riders' code of conduct has been suggested by a number of authors to achieve these aims (Moore and Barthlow, 1997; Widmer, 1997). Research by Hendricks *et al.* (2001) suggests that a code of conduct can be particularly effective when promoted by other bike riders.

If mountain bikes are to be allowed on multi-use tracks then informing other users of their legitimate presence can further reduce safety risks, because users will be more prepared for an encounter. Furthermore, informing other users of the likely presence of bikes may change their expectations, and possibly reduce negative perceptions of having an encounter.

*Track design and maintenance* have the potential to mitigate negative impacts on the environment, reduce safety risks and improve the quality of user experiences. Some of the most effective track design procedures for reducing the physical impacts of mountain biking include: track hardening; constructing track drainage structures; re-routing the trail around sensitive areas; leaving obstacles and rough surfaces to slow users down; routing tracks on low slope angles across hills rather than straight up them; and avoiding sharp corners on steep descents (McCoy and Stoner, 1992).



Keeping water off the track is one of the most important measures for reducing the impacts of mountain biking (Cessford, 1995a; Cheshire, 1993; Grost, 1989). However, designers should ensure that track drainage structures are biker friendly or riders may elect to go around them, and cause extra erosion and track widening (Chavez et al., 1993). Grading dips instead of drainage ditches and modified water bars (such as rubber deflectors) have been suggested (McCoy and Stoner, 1992).

Leaving obstacles and rough surfaces on trails will slow down runoff and help reduce erosion as well as having the effect of reducing safety conflicts arising from excessive mountain bike speeds (as it will also slow down riders). Other trail design features that can help reduce safety issues include providing adequate sight distances and trail widths, and defining a direction of travel.

Providing separate trails for individual user groups is another option open to track managers (Hawes, 1997; Jacoby, 1990; Moore, 1994), and in some instances this may be desirable. However, single use trails can often lead to further conflict (Hasenauer, 1998; McCoy and Stoner, 1992; Moore, 1994). Separate trails can be expensive to produce and they can lead to excessive numbers of tracks in bush areas. Single-use trails also help engrain the idea that mountain biking is incompatible with other uses, which can reduce the chance of different user groups interacting positively with each other (Hasenauer, 1998). Some single-use trails may still be appropriate however, particularly in over-crowded areas or where competitive racing and training is to occur.

*Regulations and enforcement* tend to be the management options least favoured by mountain bikers (Cessford, 1995a). However, some sensitive areas are clearly unsuitable for mountain bike use (such as very wet and boggy areas and fragile soil types) and may require restrictions on mountain bike use. However, whilst regulations and enforcement may appear to be the simple solution, lessons learnt in the United States suggest that heavy-handed management approaches may, in fact, intensify user group conflicts (Baker, 1990). Furthermore, such regulations are inherently difficult and time-consuming to enforce.

On-going monitoring and evaluation of the effectiveness of any of the techniques used should also be included in any approach to managing mountain bike use. The management regime may need updating if the techniques employed are not working effectively. Ongoing evaluation is particularly important for managing recreational mountain biking as the activity is continuing to develop and evolve.

**Research needs**

The recent emergence and growth of mountain biking has provided only a decade or two for research on mountain bike impacts and management to be undertaken, so the literature on these topics is limited. A number of studies have been documented and reviewed here, however replication of these studies is needed in different environments to extend and confirm the findings. The conclusions drawn from the literature have been used to develop hypotheses on the physical impacts of mountain biking. However, these hypotheses were based on a limited number of sources, so the aim of the research reported here has been to further test and explore the validity of the assumptions and findings of the earlier studies.

Two separate studies were conducted on the same site, Wellington Park, Tasmania. The first was a questionnaire survey of park users to explore track preferences and inter-user attitudes. The second was a study of the physical impacts of mountain bike riding and walking on tracks. These two studies are described separately below, following a description of the study site.

**Wellington Park**

Wellington Park is located to the west of Hobart, Tasmania, , as shown in Figure 1. It covers an area of 18,250 hectares over the Wellington Range and is renowned for its natural beauty, bio-diversity and geo-diversity. The area also has a long history of human use and is valued for its historical and cultural significance. The close proximity of the park to Hobart, combined with its natural beauty, also ensures that recreation is ever-present in Wellington Park, with estimates of 250,000 visitors a year (Wellington Park Management Trust, 1997). The network of fire trails and other tracks in the park provide excellent opportunities for mountain biking, which has become increasingly popular in the park over recent years.

**User Survey**

*Method*

A questionnaire survey was designed to obtain the views of a cross-section of participants in all forms of recreation in Wellington Park. Two questionnaires were produced, one for mountain bike riders and another for walkers and other users. The questionnaire included questions on participants' characteristics,



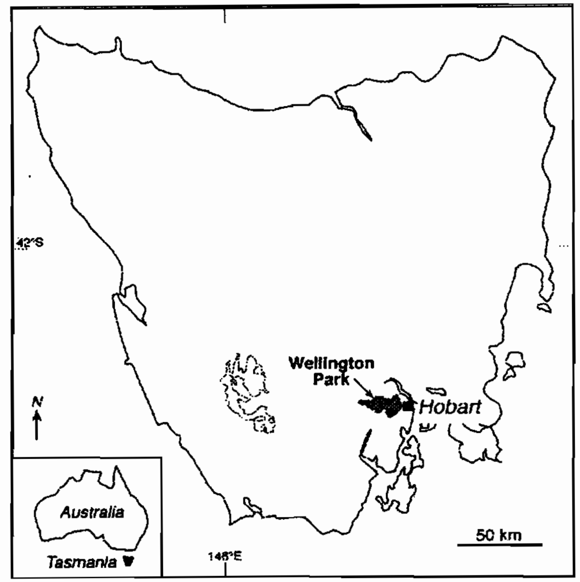



Figure 1. Location of Wellington Park, Tasmania, Australia

reasons for visiting the park, recreational setting and track preferences, perceived user-group conflicts and preferences for various management options.

The questionnaires were posted to 48 different recreational, community and management groups (Chiu, 1999). Collection points were also established in local outdoor and cycling shops over a period of five months in 1999. A total of 680 questionnaires were distributed, 360 for mountain bikers and 320 for 'other users'. Of these 255 were returned, 132 from mountain bikers (36.6% of the number distributed) and 123 from 'other users' (38.4%). The method of administration and the response rate raise questions as to the representativeness of the sample and the possibility that those who did not return the questionnaire may have had views significantly different from those who did (i.e. non-response bias), however this is a problem inherent with questionnaire surveying in such conditions and can be significant even with very high response rates (Crompton and Tian-Cole, 1990). While we have no way of directly checking the representativeness of the sample, every effort was made to contact a wide range of users and there is no obvious reason to believe that the sample is not a representative sample of all Wellington Park users.

*Results*

Demographic characteristics and other details of mountain bike riders and other users who responded to the survey are shown in Table 1. Males represented a clear majority (85%) of the mountain bike rider respondents. This reflects the findings of earlier studies (Cessford, 1995b; Horn *et al.*, 1994; Goeft and Alder, 2001), therefore it seems that mountain biking continues to be a male-dominated sport. In studies by Cessford (1995b) and Horn *et al.* (1994) the majority of respondents were in the younger age-groups, particularly 20-30 years. In this survey, however, riders were evenly spread between all the age- groups, from 16 to over 45.

Both mountain bikers and other users tended to visit the park for the same reasons, with exercise and 'appreciation of nature/scenery' being the two main reasons. However, a significant proportion of mountain bikers gave 'socialising' (42%) and 'excitement and risk' (34%) as reasons for their visit, while for 57% of other users 'relaxation' was mentioned as a reason. Such differences would seem likely to cause some conflict between bikers and other user-groups: it is easy to imagine how a bike rider aiming to have an 'exciting and risky' experience could interfere with the goals of a walker aiming to have a 'relaxing' experience.

Track preferences are indicated in Table 2. Mountain bikers were divided into 'expert/experienced' and 'novice/beginner' groups and, as might be expected, the latter preferred to ride on smooth surfaces and open, wide tracks and preferred the wider fire tracks to walking tracks. In contrast, the more experienced riders tended to prefer a mixture of walking tracks and fire trails and favoured rough surfaces, narrow/bending tracks and steep tracks. The majority of bikers had suspension on their bikes; this has implications for management, in that riders with suspension bikes are able to access more difficult areas and ride on more extreme terrain.

Table 3 indicates the perceived or experienced problems of relationships between user-groups and their attitudes towards various management options. The majority (70%) of other users reported no conflicts or bad encounters with mountain bikers. Of those that did, the largest concerns were for mountain bikes travelling at excessive speeds (20%) and for not giving an approach warning (9%). Similarly the majority (80%) of mountain bikers reported no conflicts with other users, although 9% reported walker abuse and 7% reported unleashed dogs as a problem. The apparent low level of conflict between users provides an opportunity for management to implement proactive measures now, rather than having to react to intensified conflicts that could occur later. Lessons learned in United States have shown that the reactive approach can prove difficult (Baker, 1990).



**Table 1. Respondent characteristics**

| | Mountain bikers | Other users |
|---|---|---|
| *Sample size* | | |
| Bikers | 132 | - |
| Bushwalkers | - | 93 |
| Dog-walkers | - | 13 |
| Runners | - | 9 |
| Horse-riders | - | 4 |
| Others | - | 4 |
| Total | 132 | 123 |
| Age | % | % |
| <16 years | 5 | 3 |
| 16-24 | 23 | 8 |
| 25-34 | 27 | 14 |
| 35-44 | 26 | 28 |
| 45+ years | 20 | 46 |
| *Sex* | % | % |
| Male | 85 | 45 |
| Female | 15 | 55 |
| *Experience* | % | % |
| Beginner/novice | 17 | 7 |
| Experienced | 62 | 59 |
| Expert | 21 | 34 |
| *Main type of riding* | % | N/A |
| Cross country | 64 | |
| Downhill | 5 | |
| Both | 23 | |
| Other | 8 | |
| *Type of bike* | % | N/A |
| No suspension | 43 | |
| Front suspension | 42 | |
| Dual suspension | 14 | |
| *Participation in other activities in W. Park* | % | % |
| Bushwalking | - | 33 |
| Mountain biking | 92 | - |
| *Mode of transport to W. Park* | % | % |
| Bike or walk | 64 | 36 |
| Car | 36 | 58 |
| Other | - | 6 |
| *Reasons for visiting W. Park* | % | % |
| Appreciation of nature/scenery | 72 | 82 |
| Exercise | 65 | 83 |
| Socialise | 42 | 18 |
| Excitement/risk | 34 | 3 |
| Relaxation | 30 | 57 |
| Proximity | 30 | 32 |

**Table 2. Track preferences**

| | Mountain bikers | | Walkers |
|---|---|---|---|
| | Beginners/ novice | Experienced/ expert | |
| *Track type* | Preferences | | |
| Mostly fire trails, some walking tracks | ✓ | - | - |
| Walking tracks and some fire trails | - | - | ✓ |
| Equal mix of fire trails and walking tracks | - | ✓ | - |
| Sealed roads | ✕ | ✕ | ✕ |
| *Track condition* | | | |
| Steep tracks, narrow/bending tracks/ rough surfaces. | - | ✓ | - |
| Smooth surfaces and open/wide tracks | ✓ | - | - |

**Table 3. Conflicts, access and management options**

| | Mountain bikers | Other users |
|---|---|---|
| *User group conflicts* | % | % |
| No conflicts | 80 | 70 |
| Abuse from walkers | 9 | - |
| Unleashed dogs | 7 | - |
| Excessive speed of bikes | - | 20 |
| Lack of approach warning | - | 9 |
| Rude riders | - | 8 |
| Track damage | - | 5 |
| *Fire trail access* | N/A | % |
| All/most of fire trails should be open to bikes | | 79 |
| No fire trails open to bikes | | 3 |
| *Walking track access for bikes* | % | % |
| None | 5 | 27 |
| A few | 27 | 40 |
| Half | 13 | 10 |
| Most | 28 | 14 |
| All | 27 | 10 |
| *Management options* | | |
| Bicycle education/information | ✓ | ✓ |
| Code of conduct | ✓ | ✓ |
| Pedestrian right of way | ✓ | ✓ |
| Permits for riding | ✕ | ✕ |
| Track closures | ✕ | ✕ |
| Speed limits | ✕ | ✓ |
| Separate use tracks | ✕ | ✕ |

Only 27% of other users believed that no walking tracks should be open to mountain bikes, although 40% indicated that only 'a few' should be open . This lack of objection suggests that most of the other users were prepared to compromise somewhat to accommodate mountain bikers. The majority of mountain bikers also seemed understanding of other users (or possibly environmental issues), as only 27% of riders believed that all walking tracks should be open for bikes, with the majority supporting most or a few being open.

Self-regulation management measures were identified by Cessford (1995b) as riders' most favoured approaches and indeed that was also the case here. Interestingly, they were also the most favoured options by the other users. Mountain bike education and information, a code of conduct and the principle that pedestrians should have right of way were the only three options that were strongly favoured by either group. In contrast, track closures and permit requirements were strongly rejected by both groups of participants.

*Conclusion*

This survey shows that, while the majority of bikers prefer to use walking tracks, conflicts between mountain bikers and other users of Wellington Park are relatively few and most walkers are tolerant of bikers using walking tracks. Further, there seems to be a willingness on the part of all user-groups to accept educative management measures if they are required to mitigate physical impacts, but a reluctance to accept more restrictive measures.

## Mountain biking and walking physical impacts on tracks

*Hypotheses*

Existing studies, as summarised earlier in the paper, allowed a number of hypotheses to be proposed concerning the levels of impacts caused by mountain bike use:

1. mountain biking and walking cause similar levels of impacts (Cessford, 1995a; Chavez et al., 1993; Grost, 1989; Wilson and Seney, 1994);
2. impacts increase when skidding (McGehee, 1998; NEMBA, 1999);
3. impacts increase at sharp corners (Hawes, 1997);
4. impacts increase on steep slopes (Bjorkman, 1998; NEMBA, 1999);
5. impacts increase on wet tracks (Cessford, 1995a; Chavez, 1997; Horn et al., 1994); and
6. impacts are cumulative - with a rapid initial change followed by a reduction in the amount of change as use levels increase (Bjorkman, 1998).

The paucity of detailed studies on the physical impacts of mountain biking on off-road tracks meant that the above hypotheses were drawn from a limited number of sources. It was therefore decided to test the hypotheses in a single study.

*Method*

In order to test the above hypotheses the surface profile of an off-road track was measured before and after use by mountain bikers and walkers, under a number of different conditions (Chiu, 1999). It was necessary to design a method that could monitor track conditions, whilst not inhibiting use by mountain bikers or walkers. It was therefore decided to use a linear elevation measuring instrument (LEMI) similar to that described by Toy (1983) and used by Hawes (1997). The instrument measures changes in surface elevation which, in this context, are mainly a function of compaction and erosion. Other methods that were considered for the study included erosion pins, sediment traps (Wilson and Seney, 1994), and quadrant observations (Thurston and Reader, 2001). However, erosion pins could be too easily dislodged, and sediment traps and quadrant observations lacked the level of detail that was wanted for this study.

The technique involved setting up site markers, which also supported the measuring instrument on either side of the track. The markers were made from 25mm heavy-duty electrical conduit and were chosen for their relatively low cost and strength. The measuring instrument consisted of a box section length of aluminium with vertical holes at 5cm intervals. Figure 2 shows an example of the instrument. The supports and the measuring instrument were adjusted until the instrument rested level with the ground. The height of each support was also recorded to check for any later disturbance. Measurements were then taken by inserting a 5mm (diameter) steel rod through the 5mm holes.

Measurements were taken just prior to the passes, immediately after half of the passes, immediately after all of the passes and then at 6 and 12 weeks after the passes. Five riders, four male and one female, with two front suspension bikes and three rigid framed mountain bikes completed the riding passes. The same five individuals completed the walking passes, four in running shoes, and one in walking boots. All were instructed to ride or walk as they normally would.

The site used was an abandoned fire trail known as Reids Track, which is situated on a private property in Fern Tree, adjacent to Wellington Park. The site was chosen because it was similar to trails in Wellington Park, but was on private property, which allowed it to be cordoned off from public use and possible disturbance. The site also had a relatively continuous geology (of mudstone) and a variety of slope angles, and was wide enough to run transects adjacent to each other.

In order to test each of the hypotheses outlined above, a number of different sites were set up for monitoring under a number of different conditions. The variables tested were: number of passes; slope angle; soil moisture; corner/straight and skidding. Site locations were carefully chosen in order to keep other factors, such as the soil type and track condition, the same as far as was practically possible, for all of the sites. A description of each site's slope angle, soil particle sizes, soil moisture content, bulk density and unconfined compressive strength was recorded. Control sites were set up for each of the variables. Sites referred to as 'flat' had slope angles of $3^0$ or less, while sites referred to as 'wet' had a soil moisture content of greater than 30%.



Figure 2. A linear elevation measuring instrument

*Results*

The first hypothesis was that mountain biking and walking would cause a similar level of impact, and indeed that was the case with this study. Mountain biking appeared to cause greater impacts than walking under the conditions tested, as shown in Figure 3. However, as Table 4 indicates, none of the measurements revealed a large enough difference between walker and rider impacts to be classified as significantly different. Walker and rider impacts were however identified as being different in nature, with riding tending to concentrate the damage in a relatively narrow groove towards the centre of the track, whereas walking often produced a more spread out and uneven type of impact, as shown in Figures 4 and 5.

**Table 4. Tests for difference in surface elevation changes: riders vs walkers**

| *No. of passes* | *t-value* | *Probability that difference is due to chance* |
|---|---|---|
| *Flat, Dry Sites* | | |
| 50 | -0.258 | > 50% |
| 100 | 0.097 | > 50% |
| 200 | -0.342 | > 50% |
| 400 | 0.655 | > 50% |
| *Flat, Wet Sites* | | |
| 50 | 0.167 | > 50% |
| 100 | -0.423 | > 50% |
| 200 | -0.929 | 30 – 40% |
| 400 | -1.052 | 30% |
| *Down 20° Slope, Wet Sites* | | |
| 50 | 0.585 | > 50% |
| 100 | 0.714 | 20-30% |
| *Up 20° Slope, Wet Sites* | | |
| 50 | 0.000 | > 50% |
| 100 | -0.600 | > 50% |
| *Riding vs Walking Impacts: Corner, Flat, Dry Sites* | | |
| 100 | -0.877 | 30 – 40% |
| 200 | -0.980 | 30 – 40% |

The second hypothesis, that impacts would increase when skidding, was certainly confirmed in this study. Measurements of the skid sites revealed considerably more soil loss than any of the other sites (Figure 3). The changes in surface elevation at these skid sites were also shown to be statistically significant, as shown in Table 5.

The third hypothesis, that the impacts of riding would increase at sharp corners, was not shown to be the case. The major finding of Hawes' (1997) study at the 1997 National Mountain Bike Championships in Canberra, was that soil loss at sharp corners was significantly greater than on straighter sections of track. It is likely that this anomaly relates to the fact that Hawes' measurements were taken in a race setting when more skidding through tight corners takes place than a recreational setting.

The fourth hypothesis stated that impacts would increase on steep slopes. This appeared to be the case, with riding the $20^0$ slope causing significantly more damage than on the flat sites, as shown in Table 5. It should be noted that due to unavoidable circumstances the $20^0$ slope trials were undertaken in wet conditions and so were only compared to other 'wet' sites. The impacts recorded on the $5^0$ slopes were not significantly different to the flat sites.



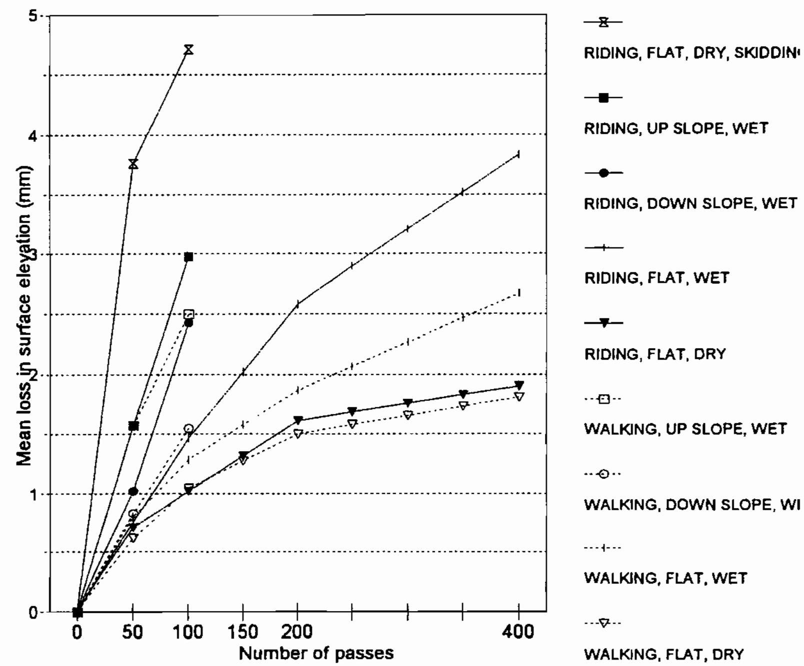



Figure 3. Comparison of walker and rider impacts under various conditions (All slopes $20^0$)

The fifth hypothesis, that impacts would increase on wet tracks, held true in this study, with a significantly greater impact detected at the wet sites as opposed to the dry sites (Figure 3 and Table 4).

The sixth and final hypothesis, that the impacts would be cumulative, but also curvilinear, was also revealed to be the case with this study. The impacts were certainly cumulative, in that they increased with increasing numbers of passes, however they were also curvilinear, with a rapid initial change followed by a reduction in the rate of change, as seen in Figure 3. It appears likely that this reduction in the rate of change reflects the hardening of the track as it is compressed, and eroded down to harder soils, following the passing of bicycles.

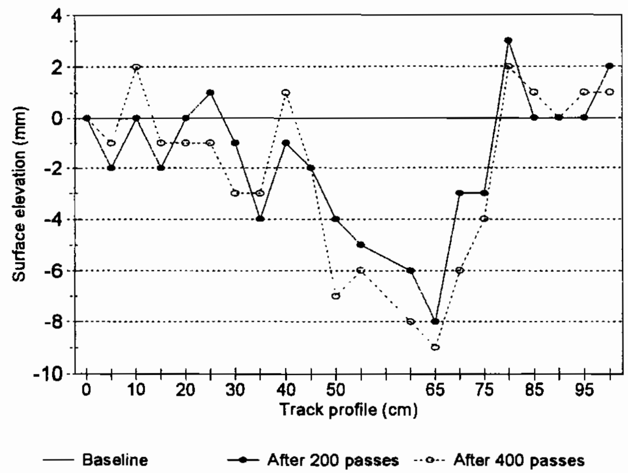



Figure 4. Track surface profile showing central groove following riding (Site 3A, Transect 1: riding: flat, dry)

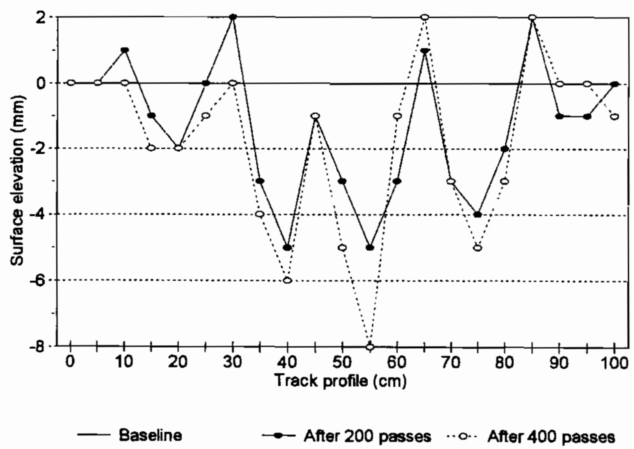



Figure 5. Track surface profile showing spread-out impacts following walking (Site 3B Transect 1: walking: dry, flat)



**Table 5. Tests for difference in surface elevation changes: riding under different conditions**

| No. of passes | t-value | Probability that difference is due to chance |
|---|---|---|
| *Wet Track vs Dry Track: Flat Sites* | | |
| 50 | -0.14051 | > 50% |
| 100 | -1.2943 | 10 – 20% |
| 200 | -1.55655 | 10 – 20% |
| 400 | -2.12485 | 2 – 5%* |
| *Down 5° Slope vs Flat: Dry Sites* | | |
| 100 | -0.17039 | > 50% |
| 200 | -0.01976 | > 50% |
| *Up 5° Slope vs Flat: Dry Sites* | | |
| 100 | -0.42987 | > 50% |
| 200 | -0.27076 | > 50% |
| *Down 20° Slope vs Flat: Dry Sites* | | |
| 50 | -0.59893 | > 50% |
| 100 | -1.51443 | 10 – 20% |
| *Up 20° Slope vs Flat: Wet Sites* | | |
| 50 | -1.76035 | 5 – 10% |
| 100 | -2.41963 | 2%* |
| *Skidding vs Normal Riding: Flat, Dry Sites* | | |
| 50 | -3.11105 | 0.1 – 1%* |
| 100 | -3.04769 | 0.1 - 1%* |
| Cornering vs Riding Straight: Flat, Dry Sites | | |
| 100 | 0.23191 | > 50% |
| 200 | 0.32393 | > 50% |

* statistically significant

## *Conclusion*

The first hypothesis, concerning the higher level of impact of mountain biking compared with walking, and the third, concerning the higher level of impact at corners, were not confirmed. All the other hypotheses were confirmed.

## Management implications

The three main areas of concern most relevant to the management of off-road mountain biking were identified in the opening discussion as: environmental damage (real or perceived); safety issues; and quality of experience issues. This section discusses the various options for managing each of these issues and proposes a framework for managing mountain bike-related conflict.

*Environmental damage*
The findings presented in this paper suggest that the environmental damage caused by off-road mountain biking is generally not significantly different in magnitude from that caused by walking. Therefore, conflicts based on this view alone may not be justified if walking or other recreational use is to be permitted on a track.

A number of findings related to the physical impacts of off-road mountain biking were identified. Impacts were shown to increase under a number of different conditions, including: skidding; steep slopes; and wet tracks. Hawes (1997) also identified sharp corners as being significantly more damaged by mountain bikes than straighter sections of track in a race situation. In the recreational situation however, this did not appear to be the case. Physical impacts on tracks were shown to be cumulative but also curvilinear.

These findings have a number of important implications for land managers. Understanding that track damage is likely to increase in wet conditions, on steep slopes, when skidding, and possibly at sharp corners, allows a manager to attempt to reduce the occurrence of these scenarios and hence reduce environmental damage. For example, managers can attempt to educate cyclists about the damage caused by skidding. Managers and planners can also attempt to reduce the occurrence of steep gradients and sharp corners in the future development or maintenance of tracks, and they can restrict use on fragile areas (such as very boggy areas). If it is understood that impacts are curvilinear and tend to taper off with increasing passes, then managers can seek to concentrate users on commonly used and already hardened tracks.

Appropriate track drainage is important for maintaining any recreational trail, but appears to be particularly important for maintaining trails used by mountain bikers. This is due to the tendency of mountain bikers to create a central groove in the trail (Figure 4), which could act as a water channel and increase erosion.

*Safety issues*
Mountain bikes allow riders to travel quietly and at high speeds, which can set up some potentially dangerous situations for both bike riders and other recreational users. It was not surprising that the greatest concern amongst questionnaire respondents in Wellington Park was about riders travelling at excessive speeds and not giving an approach warning when passing from behind.

This information is again useful for outdoor recreational managers, as there are numerous management techniques that can be employed to mitigate such problems. Educating riders (with trackside signs, information brochures, codes of conduct and public announcements) as to the need to travel at reasonable speeds and to give approach warnings on multiple use tracks may help. Leaving some obstacles and rough surfaces on the tracks to slow users down and providing good track widths and sight distances can also reduce safety problems related to off-road mountain bike use.



*Quality of experience*
Mountain bikers and other recreational users may have different goals for their recreational experiences, which in turn may lead to 'goal interference'. Whilst these conflicting goals often emanate from a mountain biker's increased desire for physical exercise (Cessford, 1995b; Horn et al., 1994), this did not appear to be the case in Wellington Park. Indeed, more of the 'other user' questionnaire respondents listed exercise as one of their three main reasons for visiting the park than did mountain bikers. However, and perhaps more significantly, 34% of riders listed excitement/risk as a main reason for visiting. This, combined with the 57% of 'other users' who visit for relaxation, sets up a potential scenario for goal interference, in that a rider aiming for an exciting/risky experience has the potential to interfere with a walker aiming to have a relaxing experience.

This is perhaps one of the hardest issues for managers to mitigate as there appears to be an inherent incompatibility between the two goals (i.e., excitement vs relaxation). Educating users (through publications and public announcements) as to the needs of other users and of appropriate behaviour in multiple use settings may improve their understanding of each other and hence reduce conflict. Attempting to provide a wide range of recreational opportunities can also help mitigate this potential conflict.

*Management framework*
The various management options that can be used to help mitigate mountain bike-related issues were identified as education, track design and maintenance, regulations and enforcement, and on-going monitoring and evaluation. The questionnaire responses suggest that the non-regulatory management options, such as education, information provision, and track design and maintenance, are the most favoured management techniques amongst recreationists. Whereas heavy-handed regulations, such as track closures and permit requirements, are the most disfavoured options. In the light of these findings, a framework for managing mountain bike related conflicts has been developed, as outlined in Figure 6.

*Mountain biking outcomes in Wellington Park*
The research presented in this paper has been utilised by the Wellington Park Management Trust in the development of a *Mountain Bike Strategy for*

*Wellington Park* (Wellington Park Management Trust, 2000). The strategy formally recognises that mountain biking is a permitted activity on the network of fire trails within Wellington Park, as well as on a few specific walking tracks.

The bike strategy is currently being implemented, with a strong focus on education as a management tool. Responsible riding in the park is promoted through a mountain bike riders' code of conduct. A bike map has been produced that details the permissible bike tracks within the park and includes information on the level of difficulty of each trail. The code of conduct appears on the map and is also being placed on trackside signs at key entry points to the park and is further promoted through the local newspaper and bike club newsletter notices.

Track drainage and signage is also being updated within Wellington Park to reflect the use by mountain bikers. Trails within the park are being monitored for adverse impacts and park users are regularly consulted regarding the effectiveness of management measures.

## Conclusion

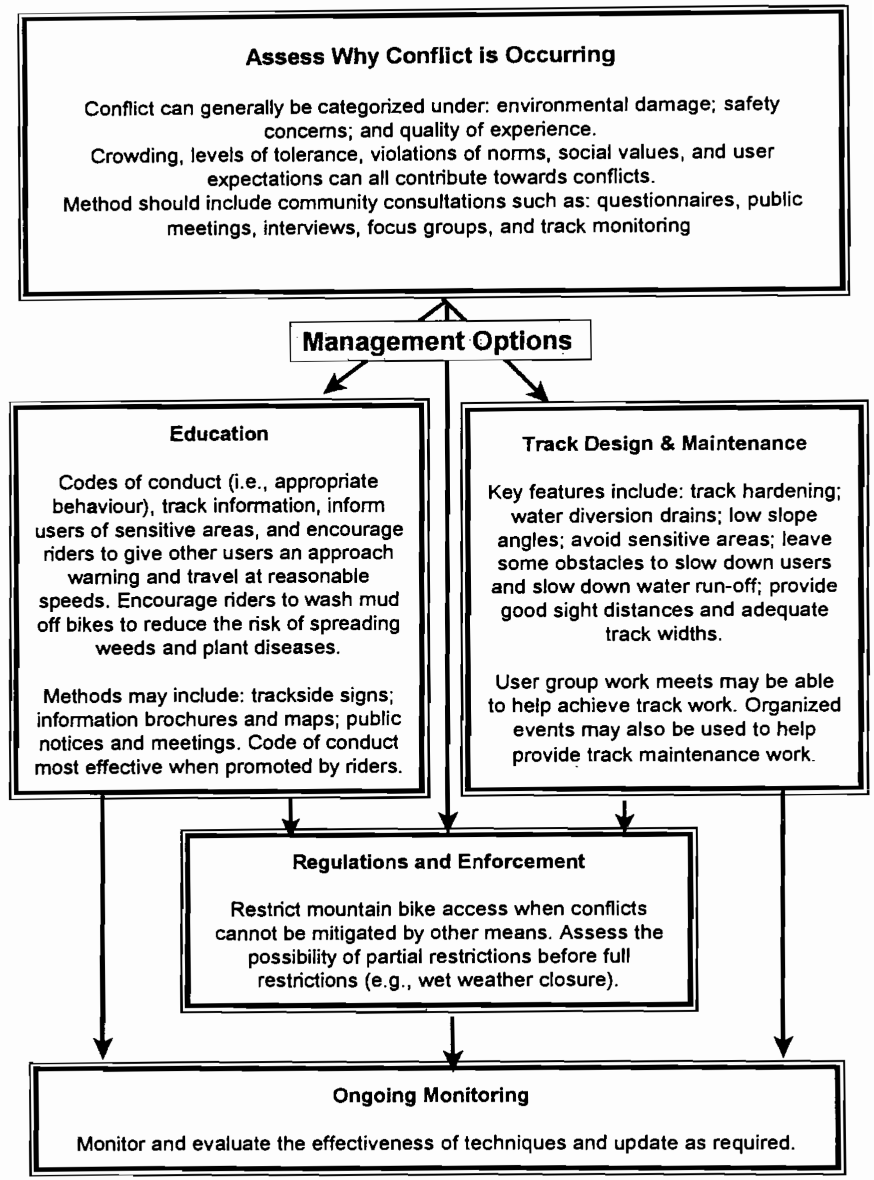
The international growth in mountain biking is likely to leave other land mangers in a similar position of needing information on park user opinions, possible impacts and options available to manage those impacts. The general conclusions on the types of impacts and concerns related to recreational mountain biking presented in this paper may prove useful to these managers. However, the variability of different environments means that mangers will invariably need to undertake site-specific research on the types and level of problems in their region. The process outlined in this paper, and summarised in Figure 6, provides an example of how this could be achieved.

## Acknowledgements

The authors would like to acknowledge the assistance provided by Michael Easton (Executive Officer, Wellington Park Management Trust), the Sustainable Tourism CRC, and the University of Tasmania.



Figure 6. Approach for managing mountain bike related conflicts



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