

MOUNTAIN BIKE ACTIVITY IN NATURAL AREAS: IMPACTS, ASSESSMENT AND IMPLICATIONS FOR MANAGEMENT

A case study from John Forrest National Park, Western Australia



Claire Davies and David Newsome

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SUMMARY

An exploratory literature review was conducted into the biophysical and social impacts of mountain biking in Australia and around the world. This review provided the basis for an impact assessment method that could be applied to mountain biking in natural areas. Mountain biking is increasing in popularity in Australia and this is adding to the demand for more space in natural areas for recreational activities (Goeft & Alder, 2001, Faulks, Richtie & Fluker 2007, Standing Committee on Recreation and Sport 2006, CALM 2007). Mountain biking can have negative impacts on the natural environment but the extent and significance of impacts is not fully understood (Goeft & Alder 2001, Chiu & Kriwoken 2003, Hasenhauer 2003, Sprung 2004, White, Waskey, Brodehl & Foti 2006). This situation constitutes a problem for managers as they need impact information to ensure mountain biking in natural areas is sustainable.

This report addresses mountain biking as a recreational activity by examining styles of riding and the corresponding demands of riders. It also identifies the major impacts of mountain biking and explores potential management techniques for developing sustainable mountain biking activities in natural areas. A method of assessing mountain biking impacts has been field-tested. The study was conducted in John Forrest National Park (JFNP), a popular recreation area in the Perth metropolitan area, Western Australia. Park rangers have previously identified areas in the Park where mountain bikers have created informal trail networks and technical trail features. Such findings are recognised to be having a negative impact on the Park. A GPS and GIS assessment method was field tested in JFNP to quantify this impact and proved to be useful in quantifying areas impacted by mountain bike activities.

Objectives of Study

- To understand mountain biking as a recreational activity in terms of style and demand.
- To provide an initial determination main social and biophysical impacts of mountain biking in natural areas.
- To understand current methods for assessing and managing mountain biking in natural areas.
- To develop a trial assessment technique for quantifying the effects of the main biophysical impacts identified.
- To field test the assessment technique in John Forrest National Park, Perth, Western Australia.

Methodology

- An exploratory literature review was conducted to explore the styles of mountain bike riding, the attitudes that are typically attributed to each style and the impacts that these styles would have on a natural area. From this, important issues could be examined in order to determine the major effects of mountain biking in natural areas, the main management implications and what management strategies might be employed.
- A GPS was used to track a previously identified informal trail network in John Forrest National Park. The GPS data was transferred into a GIS and overlaid onto a map of the Park. The data was analysed on the GIS to quantify the impacts of informal trail networks. The methodology allowed the information to be displayed visually on maps.

Key Findings

- Four different categories of mountain biking were defined: cross country, downhill, free and dirt jumping. It is recognised that there are similarities and overlap between the categories with some bikers riding in more than one style. The biophysical and social impacts of these rider groups were found to vary and understanding rider demands is paramount to providing appropriate facilities and management strategies.
- Social conflict between hikers and mountain bikers is a potentially serious issue that needs to be addressed by natural area managers. Many research projects have focused on social aspects and the management implications and strategies are well understood.
- The biophysical impacts of mountain bikers are less well documented and therefore are not so clearly defined.

- Three biophysical impacts were defined as critical to understanding the effect of mountain bikes in natural areas:
 1. Trail erosion from skidding, breaking and formation of ruts
 2. Creation of informal trails
 3. Creation of informal technical trail features
- A GPS and GIS assessment method is appropriate for quantifying the impacts of informal trail networks and trail modifications in natural areas.

Future Action

- Conduct research into quantifying the impacts of more aggressive riding styles, skidding and breaking, on trails in natural areas.
- Use the GPS and GIS mapping assessment tool to determine the extent of the mountain bike impacts in natural and protected areas, such as JFNP, by tracking all known mountain bike impacted areas. All impacted sites can be plotted on a Park map to provide an overall baseline condition assessment of the Park that can then be monitored over time.
- Develop a management strategy and rehabilitation plan to ameliorate the most impacted areas of JFNP. Where mountain biking is a significant recreational activity a plan should be developed that considers closing off some trails for rehabilitation, instigates maintenance on other trails to make them suitable for the designated recreational use and examines alternative locations where facilities accommodating the more impacting activities, i.e. technical trail features, can be developed.
- Display an impact map and interpretive signage at Park information areas to inform mountain bikers about the consequences of their actions.

Chapter 1

INTRODUCTION

A literature review was conducted into the biophysical and social impacts of mountain biking in Australia and around the world. It provides the basis for an impact assessment method that could be applied to mountain biking in natural areas. Mountain biking is increasing in popularity in Australia and this is adding to the demand for more space in natural areas for recreational activities (Goefit & Alder, 2001, Faulks, Richtie & Fluker 2007, Standing Committee on Recreation and Sport 2006, CALM 2007). Mountain biking can impact on the environment but the extent of the activity is not fully understood (Goefit & Alder 2001, Chiu & Kriwoken 2003, Hasenhauer 2003, Sprung 2004, White, Waskey, Brodehl & Foti 2006). This situation constitutes a problem for natural area managers, as impact information is needed to ensure mountain biking in natural and protected areas is sustainable. This report addresses mountain biking as a recreational activity looking at the styles of riding and the corresponding demands of riders. It also identifies the major impacts of mountain biking and potential management techniques for developing sustainable mountain biking activities.

A rapid assessment tool, using GPS and GIS, was developed to quantify the effects of mountain biking in natural areas and tested in John Forrest National Park, where mountain bike created informal trails and modifications to existing trail systems is acknowledged as a problem by Park management. This assessment tool can effectively quantify the actual area impacted by the creation of mountain bike specific informal trails and associated trail modifications. It also provides management with informative and interpretive maps of the impacted area.

Mountain Biking as a Recreational Activity

Mountain biking is a rapidly growing activity in Australia (Goefit & Alder, 2001, Faulks et al. 2007, Standing Committee on Recreation and Sport 2006, CALM 2007), but there is little understanding of the size and scope of the market in Australia to date (Faulks et al. 2007, CALM 2007). In 2004, in Australia, 14% (19.6% in WA) of men and 7.1% (8% in WA) of women participated in cycling (Faulks et al. 2007). This represents a 15.3% increase from 2001 (Faulks et al. 2007). The survey, however, does not show what proportion of people are riding mountain bikes or riding in off-road situations. In 2006 cycling was reported to be the fourth biggest physical activity in Australia for people over 15 years. Of the 753,843 bikes sold in Australia in 2004, 69.8% were mountain bikes (Bradshaw 2006). What is interesting to note is that Western Australia has 10% of the national population yet 14% of bicycle sales (Bradshaw 2006). At the retail level one billion dollars is spent on cycling in Australia each year (Bradshaw 2006). Surveys in the US reveal that since 1998 about 50 million people have participated in mountain bike activities each year (Outdoor Industry Foundation 2006). In the US, the increase in the popularity of mountain biking has outpaced efforts to understand and therefore manage mountain biking in natural areas (White, Whaskey & Brodehl 2006).

Mountain biking has many benefits appealing to different markets. It can be a source of fitness, fun, mental activity, technical challenge, recreation and entertainment in the natural environment (Horn, Devlin, & Simmons 1994, Goefit & Alder 2001, CALM 2007, White et al. 2006, IMBA 2007). Cycling can provide a range of social and economic benefits to regional areas and the wider community by stimulating tourism and recreational spending (IMBA 2004, Faulks et al. 2007). The lack of research into cycle tourism in Australia may be inhibiting the development and marketing of cycle tourism (Faulks et al. 2007). Research in the US has shown that mountain biking contributes \$133 billion to the US economy, it supports nearly 1.1 million jobs and provides sustainable growth in rural communities (Outdoor Industry Foundation 2006).

Research for the South Australian State Mountain Bike Plan (Bicycle SA 2001) indicates that mountain bike riding will continue to increase in popularity, particularly in non-organised recreational mountain bike riding. Improvements in technology are making mountain biking in natural areas easier and therefore available to riders of all abilities (O'Donnell & Carroll 2003, White et al. 2006). An increase in the number of riders may lead to increased recreational pressures on peri-urban natural areas. In the US there is a popular belief that all mechanisation should be banned from wilderness areas (Scott 2003, O'Donnell & Carroll 2003). The International Mountain Bicycling Association (IMBA) encourage mountain biking in natural areas in the US. They aim to balance the social, recreational and environmental needs of various users so mountain biking can be sustainable.

Mountain Biking Styles

Mountain biking activities vary in terms of skills, exercise, motivation and equipment (Goefit & Alder 2001, CALM 2007, IMBA 2007). Mountain biking can be divided into several different categories; cross country, touring, downhill, free riding, dirt jumping (IMBA 2007). There are cross overs between the categories and riders may participate in more than one type of riding (IMBA 2007). Riders from the Southwest of Western Australia prefer to ride in natural settings and on trails with a variety of features such as slopes and curves (Goefit and Alder 2001). They also found that males, approximately 30 years old, are the most common participants in mountain biking in New Zealand, UK, the US and Germany. (Hollenhurst, Schuett and Olson 1995, Goefit and Alder 2001)

Cross Country Riding

Cross country riding varies from inexperienced gentle riders to avid riders (IMBA 2007). It covers a wide range of trails and most mountain bike riding can fit into this category (CALM 2007). Inexperienced riders tend to prefer riding on wide, smooth dirt roads or dedicated bike paths. These tracks are typically disused railway tracks (rail trails) or park access and management tracks (CALM 2007). The less experienced cross country riders tend to use standard mountain bikes, with little or no suspension, which limits them to riding on less technical trails (CALM 2007, IMBA 2007). These riders generally ride conservatively and will therefore have a relatively low environmental impact.

As riders become more experienced they may look for more remote, longer trails for solitude, exercise, nature or challenge (IMBA 2007). Experienced cross country riders are typically self sufficient, carry tools, food, water and first aid kits (IMBA 2007). Single track, a trail that is only wide enough for a single rider or groups in single file, is an important part of cross country riding beyond novice level (CALM 2007, IMBA 2007). The motivations behind single track may be solitude, being close to nature and the inaccessibility to motorized vehicles (CALM 2007). Single track are narrow and wind around obstacles, such as trees, so that riders experience a highly technical ride at relatively low speeds (IMBA 2007).

Cross country is included as a racing category in Perth Mountain Bike Club (2007). A racing trail would be based on single track or forest roads / fire tracks through natural vegetation for approximately 5km. The course will include sections of flat, uphill and downhill and obstacles, logs, rocks and jumps. The races are designed to test rider skill level and fitness, with a number of laps of the circuit.

Touring

These riders are generally concerned with longer trips including overnight stays (CALM 2007). They are often carrying camping equipment in panniers and are looking for wide, gently sloping trails through natural areas. Panniers alter the balance and increase the weight and width of the bike, so highly technical, steep, narrow trails are not appropriate (CALM 2007). These riders are otherwise similar to experienced cross country riders.

Downhill Riding

This group typically covers more experienced riders using highly sophisticated, full suspension bikes for descending technically challenging trails (IMBA 2007). Downhill bikes are usually heavy and so shuttle services and push up tracks to the trail head are often provided (IMBA 2007). Riders in the Southwest of Western Australia identified downhill as the most popular riding style with features such as long curves, tight curves, steep slopes, jumps, rocks, logs and short uphill sections (Goefit & Alder 2001). Downhill riding generally has greater potential for trail impacts than cross country riding, due to more aggressive riding styles, steep slopes, heavy bikes and high spectator numbers (pedestrian traffic on trail sides) (CALM 2007).

Downhill riding is also a competitive category in the Perth mountain bike club (PMBC 2007). The races are based on time trials on a sustained descent containing single track, wide track, rocky sections and jumps to test a riders' technical skills. The more difficult sections of the track often have alternative tracks around them to cater for all skill levels. Courses are usually 2 to 3 km in length (PMBC 2007).

Free Riding

These riders are seeking technical challenges such as rocks, logs and elevated bridges, dirt jumps, drop offs and see saws along with tough descents (IMBA 2007). They are seeking high-risk trails on unconventional or extreme (rough and unpredictable) terrain (CALM 2007).

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Free riding has often involved off-trail riding. This tends to have high environmental impacts except on extremely tough surfaces like bare rock or un-vegetated stony ground (CALM 2007).

Dirt Jumping

These riders are looking for dedicated jumping areas and a mix of jumping styles (IMBA 2007). Jumps can be provided as part of a skills area or part of a cross-country trail (IMBA 2007). Dirt jumpers use a variety of bikes, including some specialised models (IMBA 2007). These activities also have a high environmental impact if they are not suitable planned and designed.

Chapter 2

IMPACTS OF MOUNTAIN BIKING IN NATURAL AREAS

The impacts of mountain biking in natural areas can be arranged into four categories: social, biophysical, human safety, and political (Kerr 2003). In the US the political impacts are significant, as mountain biking is not permitted in wilderness areas. Therefore people who wish to ride bikes in these areas often lobby against the creation of new wilderness areas (Kerr 2003). In Australia this issue is not so relevant and will not be discussed further in this report.

Social Impacts

Conflict is a major social impact of mountain biking in natural areas (Schuett 1997, Carothers, Vaske & Donnelly 2001, Kerr 2003, CALM 2007). Table 1 describes the perceptions that can lead to conflict.

Table 1: Social conflict – perception and cause

Perception	Cause
Mountain biking causes unacceptable environmental impacts	Bad trail design Heavy trail usage Bad riding practices Low maintenance of trails Erosion caused by other user groups Erosion caused by water
Mountain bike riders and other visitors are at risk from falls and collisions	Potential collisions between different user groups High speeds High technology users and high risk riders Rider has a low skill level Blind corners and slopes Failure of cyclist to alert hikers of their presence
Mountain bikers have goals that are incompatible with the perceptions of other users	Disturbance of wildlife, Intrusion into solitude of other users Intimidation of 'lower technology' user Low standards of etiquette Multi use trails for incompatible user groups

Derived from Horn et al.1994, Moore 1994, Carothers 2001, CALM 2007, IMBA 2007

Conflict can be related to the mode of travel, the focus of the trip, user expectations, attitudes and perceptions of the environment and the level of user tolerance (Moore 1994). It is apparent that conflict is often asymmetrical, being greater on the side of the 'lower technology' user or the most vulnerable user, i.e. walkers feel conflict towards cyclists that cyclist do not reciprocate (Moore 1994, Horn et al. 1994, Beneficial Designs 1999, Carothers et al. 2001). As mountain biking is often perceived as the 'new user', more traditional users may be less tolerant of it (Schuett 1997, Mosedale 2003). Similarly mountain bikers in the southwest of Western Australia were found to be content to share trails with anyone except motorised vehicles (Goefit & Alder 2001). This is consistent with the theory that conflict is often perception based, with people being scared of being hit by a bike (Horn et al. 1994, Kelley 1998).

Single or multi use trails?

The presence of mountain bikes on multi use trails can be a major source of social conflict (Schuett 1997, Carothers et al. 2001, Kerr 2003, CALM 2007). Many mountain bikers are content to ride on rail trails, wide trails with relatively smooth surfaces (Goefit & Alder 2001, IMBA 2007), which are commonly designated multi use trails. Furthermore, multi use trails have many advantages to the natural area manager as there is less of a trail network to maintain and more visitors can be directed on to one trail. This potentially reduces the number of trails required and hence the amount of land impacted. However some more adventurous mountain bikers may prefer the challenges and solitude provided by single track (Goefit & Alder 2001, IMBA 2007, CALM 2007).

Single track does not necessarily mean single use but the nature of the trail and the rider style may make it incompatible with non-mountain bike users (CALM 2007). These trails often cover rough terrain and include natural technical trail features (TTFs), drop offs and jumps. Accommodating hikers and bikers on a single track

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without conflict requires clear information at the trail head and well designed trails with good sightlines (IMBA 2007).

Creating a network of trails that satisfies all users, avoids social conflict and has a low environmental impact is challenging for natural area managers. Multi use trails form the basis of many trail networks. These are more cost effective to maintain, manage and monitor and can accommodate the needs of most users. A network of single-track trails could be developed and integrated into the multi use trail network. Dedicated user trails can provide the added experiences required by specialist user groups and expert riders. Both trail types have advantages and some disadvantages in certain situations (Table 2). Development of a trail network is dependent on the funding and resources available (management capacity) and the ability for the natural area to support sustainable trails.

Table 2: Issues in the single use versus multi use trail debate

Single Track	Multi use
Reduces crowding	Accommodates the needs of most users but there is the potential problem of overcrowding and user conflict and inappropriate use of motorised vehicles
Narrow trails that are planned and managed are less impacting and blend in better with the environment	Sharing builds a trail community by encouraging interactions between user groups
Potential for specialised mountain bike tracks with obstacles, but this extends trail network that has to be managed	More cost effective for land managers to manage, monitor and maintain
Use single track as access to bike skills parks where only expert riders will go	Enables more visitors to access high demand features, e.g. viewing platforms, by fewer trails and hence less overall impact
Potentially reduces conflict where there are dedicated bike trails	Lower overall spatial impact as less trail network required
High speed trails on dedicated bike trails	Better use of available space
Conflict where there is inappropriate use of motorised vehicles	Empowers responsible, experienced users

Derived from Cessford 2003, CALM 2007, IMBA 2007, Kelley 1998

Human Safety Impacts

Many natural area users are concerned about the possibility of collisions with fast moving mountain bikes suddenly appearing along trails where visibility is low (Horn et al. 1994, Kerr 2003). Another risk of mountain biking is the potential of injury from falls when tackling more technical trails or TTFs. Informal trails and TTFs that are not built to an acceptable standard can be a danger to the unsuspecting rider (CALM 2007). There are many examples of lawsuits in the US where riders who have suffered injuries on trails have attempted to prove that the natural area management was at fault (IMBA 2007).

Biophysical Impacts

The biophysical impacts of mountain biking in natural areas have not been clearly understood until very recently (see Newsome and Davies in press). Comprehensive reviews of the literature by Sprung (2004) and Marion and Wimpey (2007) concluded that mountain biking is no more damaging than hiking, although at the same time, it is agreed that bikers, and hikers, would cause some environmental damage from their presence in natural areas. Such impacts can be general trail erosion, reduction in water quality, disruption of wildlife and changes to vegetation. Hikers and bikers have similar impacts on vegetation, preventing vegetation growth close to the trail

centreline (Thurston & Reader 2001). Horses, by comparison, cause more damage than bikers as they dislodge more material and use wider trails (Wilson & Seney 1994, White et al. 2006).

Mountain bikes can cause different types of erosion to other users (Figure 1), (Horn et al. 1994, Cessford 1995, Foreman 2003, IMBA 2007). Breaking and sliding activities loosen track surfaces, displace soil down slopes and create ruts, berms or cupped trails. Tyre tracks are continuous and can therefore form ruts and long rills through which it is easier for water to flow exacerbating erosional losses (Horn et al. 1994, Foreman 2003). Impacts have been found to be more severe when bikers or hikers travelled on slopes or wet ground or when bikers were cornering, skidding or breaking (Leung & Marion 1999, Goeft & Alder 2001, Chiu & Kriwoken 2003). Mountain bikers are also capable of travelling much further per trip than hikers. Therefore they may have a higher spatial capacity for impact, increasing their relative impact when compared to hikers.

Research to date has used general trail assessment methods, systematic point sampling or continuous census assessments to measure these impacts (Sprung 2004, Marion & Wimpey 2007). These studies typically measured the corresponding impacts of mountain bikers and hikers passing over a stretch of trail under experimental conditions. Understanding the nature of trail degradation is important, as it is expensive to rehabilitate or to mitigate impacts on trails. There are also safety issues associated with users on degraded and muddy trails with degraded trails reducing visitor satisfaction (e.g. Newsome, Moore & Dowling 2002). In the Tasmanian Wilderness, for example, more money is spent on maintaining and rehabilitating degraded trails than on any other user impact (Hill & Pickering 2009). Some 15 years ago there was the perception that mountain biking was a substantial contributor to trail degradation (Chavez, Winter and Baas's 1993).

Nonetheless, in natural areas, it can be difficult to attribute erosion to a particular user group. Use levels are often unknown and vary between user groups. Bikers also ride in a variety of styles, each style having different impacts. An inexperienced cross country rider on a wide, clear multi use path is likely to have less impact than a more aggressive rider cutting off trail through native vegetation. The impacts of informal trails and the creation of TTFs along paths have been identified as problematic but have rarely been documented (Marion and Wimpey 2007).



Figure 1: Examples of mountain bike specific erosion, muddy trail tracks and bike skid marks

Impacts of informal trail development

In this study informal trails are considered to be those that have been created by mountain bikers and are not managed or approved by the land manager (e.g. Figures 2, 3 and 4). In some cases the increase in demand for mountain biking facilities and the slow response from natural area managers has lead riders to create their own informal trails or to ride on trails designated for hikers only (CALM 2007). Informal trails may develop because riders want more challenging trails to those provided, as a short cut, to reach specific destinations or to connect existing tracks (Marion 2007, pers. comm., 30th August, IMBA 2007). They can also develop as users attempt to circumnavigate worn or excessively muddy conditions on the main track (Leung & Marion 1999). Significant damage to natural areas can occur when bikers, or other users, go cross-country off track (Foreman 2003). The creation of informal trails increases the amount of land, fauna and flora subject to impact by adding new trails or widening existing trails (Cessford 2003, Marion 2007, pers. comm., 30th August). Informal trails are neither planned nor approved before construction. Therefore, they may inadvertently impact on heritage areas, rare and or priority flora populations, threatened plant communities, spread weeds or encroach on water catchments (Annear 2007, pers. comm. 30th October, Marion & Wimpey 2007). Informal trails can be created very quickly with a substantial amount of vegetation and soil impacted occurring in the first year of their development (IMBA 2007).



Figure 2: Mountain bikers in John Forrest National Park traversing granite outcrops in order to access user created (informal trails)



Figure 3: Mountain biker created trail (informal trail) traversing granite outcrops in John Forrest National Park, Western Australia



Figure 4: Paint markings on a tree indicating the directions to access mountain biker created trail (informal trails) in John Forrest National Park, Western Australia: such activity indicates organised activity and a commitment to create informal trails

Impacts of construction and modification to existing (approved) and informal trails

Technical trail features (TTFs) are trail elements that enhance the character and difficulty of a trail. They can come in the form of ladders, drop offs, ‘skinnies’ (narrow items that can be traversed) and see saws. They are important to the free riding style adding technical skill and challenge to a trail (e.g. Figures 5–7) (CALM 2007, IMBA 2007).

Informal trails and TTFs are often badly located, poorly built and represent a significant hazard to riders (CALM 2007). Some of the TTFs found in JFNP have been considered structurally unsound and comprise significant areas of impact (Annear 2007, pers. comm. 30th October).



Figure 5: Trail surface modified to create a TTF in John Forrest National Park, Western Australia: note the end of the feature has been reinforced by cement



Figure 6: Trail surface modified to create a skidding area in John Forrest National Park, Western Australia



Figure 7: Examples of off-trail constructed TTFs, bridge structure and see saw

Chapter 3

MANAGING MOUNTAIN BIKING

Social Management Issues

Education is often cited as a management tool that can reduce conflict (Horn et al. 1994, Moore 1994, Hollenhurst et al. 1995, Beneficial Designs 1999, Carothers et al. 2001, Goeft & Alder 2001, Bicycle SA 2001). Education can take the form of informative trail signage, promotion of user etiquette and law enforcement activities (Moore 1994, Carothers et al. 2001). Trail rules can be developed to educate users about etiquette and low impact usage (IMBA 1998, Naturebase 2007). Clear and informative signage at the trail head can provide information on the suitability of trails for user groups.

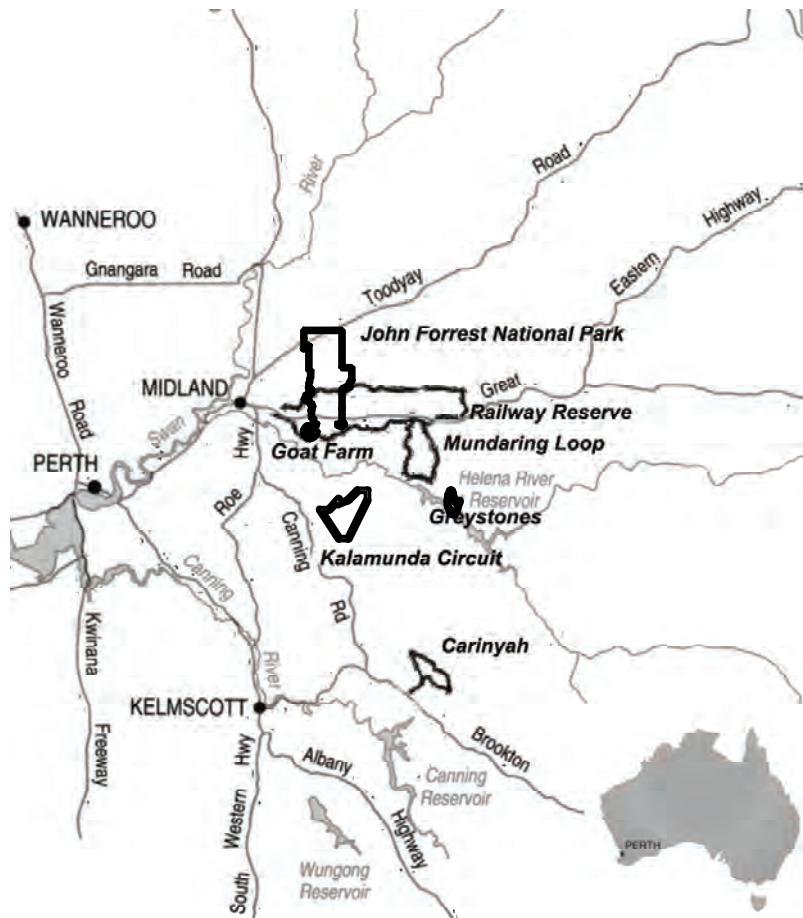
Different user groups need to be educated to understand each others' needs in order to remove suspicions and misguided perceptions. Managers need to be educated so that they know what various users want, while users need to appreciate that the core function of protected areas is conservation of flora, fauna and landscape and the promotion of natural values and experiences (Newsome, 2007; Newsome and Davies, in press). Communication between user groups and managers therefore needs to be encouraged (Hollenhurst et al. 1995, Beneficial designs 1999, Bicycle SA 2001).

Zoning is another option to minimise conflict by reducing the number of interactions between different user groups (Carothers et al. 2001, Moore 1994). This can be managed by diverting 'expert' high-speed riders onto dedicated single use tracks if space allows. If not then temporal closures, such as bikers and hikers using the trail on alternate days, can reduce use and give hikers and mountain bikers some space. Temporal closures also facilitate trail maintenance (Horn et al. 1994, Goeft & Alder 2001).

Multi use trails may be the only option when space is limited, at high volume visitation sites, when funds are a constraint or where environmental impact must be minimised. Conflict can be minimised by restricting user groups to touring or trail activity to that of recreational bikers and hikers. Informative trail-head signage can advise users about manager expectations and trail etiquette (CALM 2007). In some situations where demand is high expert riders could be diverted to designated bike trails. Such strategies can also reduce trailhead congestion by moving some users to a different area and minimising interactions between different level user groups (Cessford 1995, CALM 2007). The perception of a threat from injury from bikes can vary from reality (Cessford 2003). There are very few documented examples of biker / hiker accidents on multi use trails (Cessford 2003). Hikers on the Queen Charlotte track in New Zealand that had not had encounters with bikes held the strongest negative perceptions of bikes and bikers (Cessford 2003). They were generally older people. For multi use tracks to be successful, these perceptions of conflict need to be addressed. Conflict can also be reduced by understanding user needs and providing trail experiences that meet various user demand (Moore 1994). Sources of conflict can be identified by employing surveys. Analysis of such data by managers can lead to appropriate management actions (Moore 1994, Borrie, Freimund, Davenport & Manning 2001).

In the Perth metropolitan area the Department of Environment and Conservation (DEC) has developed several trails that have been designated for mountain bike use (Annear 2007, pers. comm., 30th October). These trails include technical downhill trails, touring trails and cross country trails providing recreation activities for a wide spectrum of users. By providing these facilities, DEC aim to meet the demands of users and take the pressure off areas presently subjected to illegal riding. Some examples of the mountain bike trails in the peri-urban area of Perth, Western Australia (see Figure 8) are as follows:

- Mundaring Loop Trail – 15.5km easy to moderate cross country loop trail, mostly old firebreaks
- Railway reserve trail, Mundaring – 41km easy to moderate cross country loop trail on old rail trails
- Carinyah trail – 15.7km easy to moderate cross country loop trail (one way)
- Lake Leschenaultia – 5.25km easy to moderate cross country loop trail
- Kalamunda circuit – cross country loop trails, developed from disused walking trails
- Lane Pool, Dwellingup – cross country trail upgrade of informal trail
- Langford Park, Jarrahdale – 6km challenging cross country race trail
- Turner Hill, South Dandalup – 9km challenging cross country race trail
- Grey stones, Mundaring – 5.5km challenging cross country race trail
- Goat farm, Greenmount – challenging cross country and downhill trails
- Nanup – challenging downhill race trail
- Munda Biddi – 900km touring trail from Mundaring to Albany



Derived from Trailswest, Ministry of Sport and Recreation

Figure 8: Indicative location of peri-urban mountain bike trails in South west, Western Australia

A locally based collaborative approach including a variety of stakeholders can provide a good start for collective management, successful funding applications and a source of volunteer workers (IMBA 2007). The stakeholders can include mountain bike clubs and associations and community members. Working with these stakeholders can provide managers with knowledge of what the users want (Bicycle SA 2001, IMBA 2007). Maintenance and management of bike trails can be successful as a community effort (IMBA 2007). Using volunteers to help maintain trails can reduce expenditure from public resources (Hollenhurst et al. 1995).

In the peri urban area of Perth, Western Australia, DEC have identified partners such as the International Mountain Bicycling Association (IMBA), Western Australian Mountain Biking Association (WAMBA) and Mountain Biking Australia (MBA) to help develop their strategic plan (CALM 2007). They aim to support mountain biking on their estates by promoting the development of suitable trails (CALM 2007). The Goat Farm (a C class reserve next to Greenmount National Park) in Perth, Western Australia, is a purpose built downhill and cross country trail network. It is a good example of using community groups to build, continually improve and manage a mountain biking area (IMBA 2007). This collaboration involved the Department of Sport and Recreation, the WAMBA and the Perth Mountain Bike Club (IMBA 2007). From this experience Annear (2007, pers. comm., 30th October) advises that training mountain bikers in sustainable trail design and developing a system where only trained trail builders can assist with trail construction on public land would be an ideal situation for the continued success of the Goat Farm.

The Munda Biddi trail, Western Australia, is another example of a successful community project (Naturebase 2007). DEC worked together with the Munda Biddi Trail Foundation to create this trail (Naturebase 2007). The foundation organised volunteers to help with construction, organised community events and provided information and resources to enhance the trail experience. Other partners in this project included the Department of Sport and Recreation and the Western Australian Mountain Bike Association (Naturebase 2007).

The issues of social conflict between mountain bikers and hikers are currently being studied at Monash University by Tumes (2007, pers. comm., 21st November). The STCRC, Department of Conservation (DEC) and Parks Victoria are sponsoring research to explore the nature and extent of recreational conflict within project areas. The study identified mountain bikers and hikers as user groups who consistently experienced conflict. A qualitative methodology involving unstructured in-depth interviews with mountain bikers and hikers was used to investigate this conflict. Preliminary results show that inappropriate riding, not adhering to rules and perceived concern for safety are the main sources of recreational conflict that bushwalkers reported. Inappropriate riding includes riding on designated walking tracks because they perceive there are not enough mountain bike trails.

Human Safety Impact Management

The possibility of mountain bikers having falls and bringing lawsuits is a concern for landowners and government agencies that build mountain bike specific trails (IMBA 2007). Managers can minimise this risk by performing a risk assessment on their facilities (IMBA 2007). Volunteer or professional mountain bike patrols can reduce conflict and trail erosion and promote safety. Their presence on the trails can be as a guide, educator, emergency responder or role model (IMBA 2007).

Biophysical Impact Management Issues

Informal trail management issues

Informal trails can impact greatly on a natural area as they are formed without environmental consideration or design (CALM 2007). Once an informal trail has been identified management have to decide whether to close and rehabilitate the trail, modify it to be sustainable or to maintain the trail as it has been developed (Marion 2007, pers. comm., 30th August). As well as dealing with the environmental effects managers must also consider why the trail was developed. Understanding rider preferences and providing a range of riding activities can prevent riders creating informal trails (Goefit & Alder 2001, Foreman 2003, CALM 2007). Educating riders about the environmental and social impacts of creating informal trails may reduce the number of trails created. Peer related bike patrols can also be used to encourage responsible behaviour (IMBA 2007, Marion 2007, pers. comm., 30th August).

Many riders, however, do not join clubs but use the Internet or SMS (mobile phone text messaging) as tools to organise social events (Annear 2007, pers. comm., 30th October). One example of this is the WA Freeride Forum, which currently has 648 members (WA Freeride 2007). The website hosts discussion forums for organising rides, technical information, buying and selling and other mountain biking topics. The forum is free to join and provides a detailed knowledge base for anyone interested in mountain biking and group rides. Another person stated that he uses SMS to organise informal mountain bike skills classes. He sends an SMS, detailing when and where he will be giving a class, to everyone in his address book, that is, his client base. The speed of these methods and their informal structure make it hard for Park managers to address the problem of informal use (Annear 2007, pers. comm., 30th October).

Informal TTF development as a management issue

Informal TTFs can be structurally unsound and degrade the environment (CALM 2007, IMBA 2007). Unsafe structures are a hazard to other users and should be removed for rider safety and land manager liability concerns (CALM 2007, IMBA 2007). Providing well built and maintained jumps in a safe environment can reduce the liability of land managers, reduce the danger to users and any consequent biophysical impacts (IMBA 2007). This can be done as a skills park concept in an area nearby or adjacent to a trail or at the trail head. TTFs can also be incorporated into a downhill course (IMBA 2007). The level of mountain bike targeted development should relate to the demands of all users but if deemed appropriate the facilities should offer opportunities for all mountain bike skill levels (IMBA 2007).

Design of mountain bike or multi use trails intended for mountain biking

Many of the factors influencing mountain bike related trail degradation are dependent on the physical attributes of the trails themselves. Environmental damage can be avoided or at least minimised with appropriate trail siting, design and management (Goefit & Alder 2001, Lathrop 2003, Marion & Leung 2004, CALM 2007). A rolling contour trail, characterised by gentle grades, grade reversals and an outslowing tread, can be built to resist erosion (see Appendix A). Water will tend to drain off such a trail in a non-erosive manner (IMBA 2004). Erosion is strongly affected by natural water run off, which is dependent on climate, slope and surface soil conditions, and in some cases the tendency towards natural erosion may be more significant than that caused by human use (Horn et al. 1994, Chiu and Kriwoken 2003, Leung & Marion 1999, Goefit & Alder 2001, Kelley 1998). Water movement and pooling on trails is considered a major trail degradation problem. Efforts to mitigate water based erosion should be considered during the trail design (IMBA 2004). In order to prevent erosion

MOUNTAIN BIKE ACTIVITY IN NATURAL AREAS: IMPACTS, ASSESSMENT AND IMPLICATIONS FOR MANAGEMENT

through excessive water movement, trails should be constructed away from areas which are seasonally wet and drain poorly (Blue Ridge Parkway et al. 2004, Marion & Leung 2004). Two critical design specifications are (1) to avoid flat areas where water can pool and (2) to avoid the fall line, the shortest route down a slope (IMBA 2004). Water removal from trails should be a top maintenance priority (Marion & Leung 2004). Water bars can be a good method for removing water from tracks (Beneficial Designs 1999, Symmonds, Hammit & Quisenberry 2000, Goeft & Alder 2001). Where possible creating grade reversals on the trail is preferable as water bars require more maintenance, clog quickly and can be circumvented by riders and heavy rain/runoff which can flow over the top of the bars carrying soil away (IMBA 2004).

The physical aspects of a trail are also important to designing a sustainable trail and cross slope, soil types, aspect, exposure, climate, use and maintenance effort should be incorporated into trail design (Beneficial Designs 1999, IMBA 2004, Marion & Leung 2004). Erosion is greater on steeply sloping trails and if the soil surface is loose and easily detached (Goeft & Alder 2001, Meyer 2002, Lathrop 2003, IMBA 2007). Sandy soils have a high drainage rate and are not easily compacted and thus less susceptible to water erosion. Silty soils, on the other hand, have a much lower drainage rate and more compactable rendering them more susceptible to water erosion. Clay soils have an even lower drainage rate, susceptible to compaction and thus very susceptible to water erosion. The ideal trail soil is a loamy soil, which is a mixture of particles where neither sand, clay nor silt predominates (IMBA 2007). Techniques such as tread hardening and geosynthetic materials are available for areas where trails are susceptible to erosion and can't be re-routed (Meyer 2002, Marion & Leung 2004).

To avoid user disappointment and potential conflict situations with other users a trail must be designed to deliver expectations which will differ according to skill level and user desire (Cessford 1995). Incorporating user needs and requirements at the design stage can lessen or prevent conflict issues and more importantly help to mitigate informal trail development (Moore 1994). If a trail is not sited in a place where riders want to go then informal trails will be formed by off-roading (Goeft & Alder 2001). Mountain bikers actually like trail features such as bare rocks, roots, gullies, as they add to their experience but such features are also aspects of erosion that may impact on the expectations and experience of hikers if they are also using the same trail. Moreover, jumping over and skidding round these obstacles can exacerbate erosion providing a social / biophysical conundrum for management (Cessford 1995, Symonds et al. 2000). Providing jumps, steep sections and obstacles within the design of the trail, however, may reduce the probability of users creating them informally (Goeft & Alder (2001). But such approaches modify the natural features of a trail and can pose difficulties if used by hikers or horse riders.

Informative signage at the trail head can detail the trails intended use. Managers must then ensure that the design is consistent, for example, if intended for free riding and dirt jumping mountain bikers, there are no obstacles on a trail intended for more general and inexperienced riders (Beneficial Designs 1999). Standardised information detailing track difficulty should be available at the trail head so the user can judge its suitability for use.

Chapter 4

MEASURING THE EXTENT OF INFORMAL TRAIL AND TECHNICAL TRAIL FEATURE DEVELOPMENT

Introduction

Research to date has used general trail assessment methods, systematic point sampling or continuous census assessments to measure biophysical impacts (Sprung 2004, Marion & Wimpey 2007). These approaches have generally assessed physical degradation in terms of soil erosion, trail widening, muddiness and damage to vegetation. Mountain bike specific impacts have recently been defined and catalogued by Newsome and Davies (in press), with informal trails and user created TTFs, recognised as specific and significant problems arising out of the use of natural areas by mountain bikers. Moreover, these latter impacts have been identified as an important management issue in JFNP and other national parks in Western Australia.

Accordingly rangers have identified areas in JFNP where mountain bikers have created informal trails and TTFs. The impact of these activities may not be adequately quantified using the general trail assessment techniques indicated above. Therefore a method using GPS and GIS was developed and field-tested to assess the impact of a mountain biker user created informal trail network in JFNP, Perth, Western Australia.

John Forrest National Park

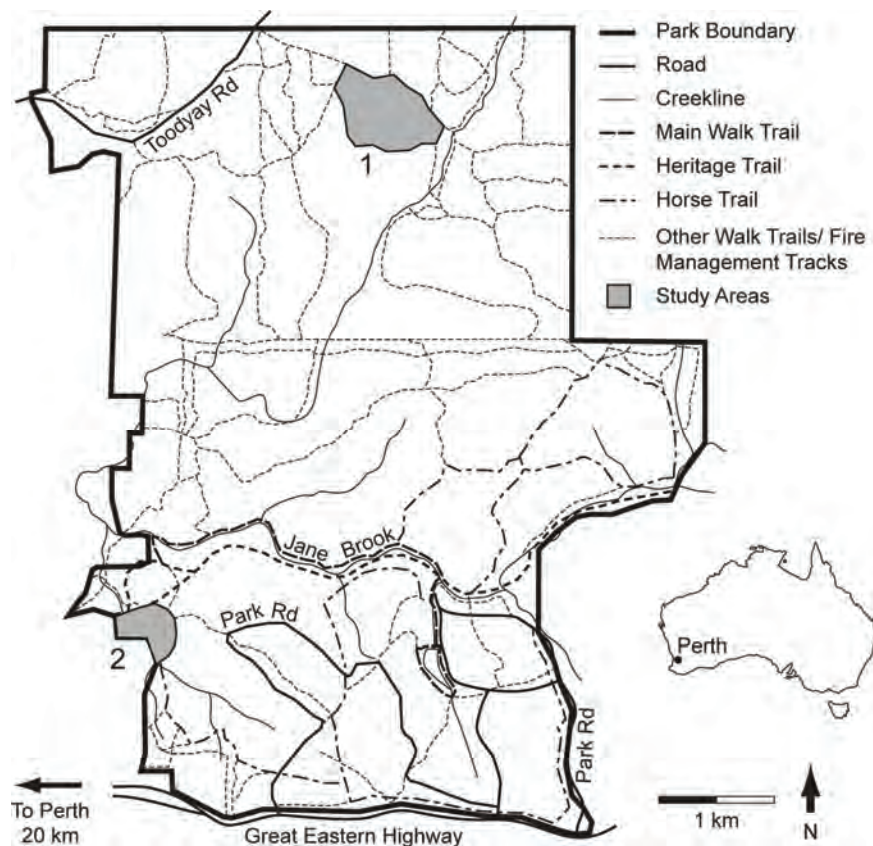
Location and Characteristics

John Forrest National Park (JFNP) is an 'A' class reserve covering approximately 2676 hectares (CALM 1994). It is located on the edge of the Darling Scarp, adjacent to the Great Eastern Highway allowing easy access from the Perth metropolitan area (Figure 9). Its accessibility to the general population and the growing number of recreational mountain bikers in Perth provide an opportunity but also an impact containment problem for Park management (CALM 1994). Moreover, JFNP is environmentally important as a natural area providing a refuge for fauna and flora. It contains species of significance, threatened species and examples of different ecosystems (CALM 1994). The park is recreationally important as it is easily accessible, has Aboriginal historic value and many natural geological features (CALM 1994). The main management concerns of the park are overcrowding, conflict between users, wildfires, introduction of alien species and degradation arising from recreational activities (CALM 1994). One of the management aims for JFNP is to conserve its environmental and cultural significance whilst providing for the recreational needs of and educating the community (CALM 1994). To achieve this aim management recognise the need to understand the impacts of various recreational activities on the park (CALM 2007).

Mountain Biking History

The park developed in the late 1800s as a weekend barbeque area and passive recreation area. In more recent times active recreation opportunities such as hiking and biking have become more popular. When the JFNP Management Plan was developed in 1994 there were comparatively few bikers using the park, but this number has increased significantly since then. Park management are concerned about the environmental impact of bicycles, cyclist safety on unstable tracks and user conflict issues (CALM 1994) (Annear 2007, pers. comm., 30th October).

JFNP has a network of multi use trails that have arisen from management needs and fire control operations. The trail network includes fire management tracks and an old railway line. There is also a designated single track walk trail (Eagle View Trail), developed to provide hikers with a dedicated long distance walk trail. Bushwalking has traditionally been the most popular trail use in the Park although there are a small number of horse riders on designated multi use trails (CALM 1994). Cycling is permitted on the scenic drive, the old rail track line and on the fire management tracks. The network of fire management tracks is shown in Figure 9.



Source: CALM 2007

Figure 9: John Forrest National Park track network and location of mountain bike study sites

The Eagle View walk trail is the only formal single track in the Park and rangers are aware that bikers have been using this trail. Park users have reported conflict issues when meeting bikers on this trail. Rangers are also aware of a number of informal trails that bikers have made to access the Park and to create more exhilarating riding experiences. These trails have had informal TTFs built on them that the rangers have removed for the safety of other users (Annear 2007, pers. comm., 30th October).

Methodology

The first stage in quantifying mountain bike impacts in a natural area is to identify where the informal trails and trail modifications are. Ranger knowledge may be the quickest way of collecting this information. In circumstances where this is not applicable the assessor may have to complete a trail inventory (Leung & Marion 1999, Marion 2006, CALM 2007). This can be done using a continuous census assessment methodology. The location of any informal trails and trail modifications can be marked on a GPS.

An informal trail network previously identified by Park rangers was used to field test the methodology. The position of the informal trail network was located on a map of the Park. A study area (encompassing informal trails) was defined by using fire management tracks that form a boundary to the informal trail network (Figure 9, site 1). The field test commenced at point B (Figure 10) where the informal trail left the fire management track. A GPS was mounted on the bike and was set to 'tracking'. The trail was cycled and each TTF passed was marked in the GPS as a waypoint, with a corresponding description recorded in a pocket notebook and a digital photo taken. Intersections were also marked on the GPS and recorded in the notepad along the travelled direction. Whenever a fire management track was reached (the study boundary), the recorder returned to a previous intersection and tracked off the different route. In this way the whole trail network within the boundary was tracked. Some of the TTFs had a bypass trail around them or were built on a bypass trail. The distances of these bypasses were measured using a measuring tape along the trail centre line to prevent numerous back tracks on the GPS.

An image of JFNP was downloaded from Google Earth, imported into a GIS and geo referenced. The GPS data was downloaded into the GIS and the tracked map overlayed onto the JFNP image (Figure 10). The informal trail length was calculated by digitising the trail track on GIS at high resolution. The locations of the

A case study from John Forrest National Park, Western Australia

TTFs were displayed as waypoints on a separate layer. A map of the informal trails and the TTFs was produced to give a visual indication of the impacted area (Figure 10).

Results and Discussion

The main informal trail was 2.34 km long with 199 m of bypass trail (Table 3) making an informal trail network of 2.54 km (Figure 10). Using an approximate trail width of 1m it can be shown that 2540 m² of forest area had been impacted by the informal trail network. The informal trail network included 18 TTFs (Table 3). Riders had created 1 TTF every 140 m or 7 TTFs every kilometre of informal trail.

Table 3: TTFs on the Point B informal trail network

TTF	Description	Dimensions	Height off ground	Bypass Trail
1	Log ride – ride length of fallen tree, ramps for mount and dismount built	7 m x 0.5 m	2 m	5 m long x 2 m wide
2	Rock jump – natural rocky landing	1 m x 1 m	1 m	3 m long x 0.5 m
3	Ramp – log / rock / stump	3 m x 1 m	0.5 m	5 m long x 1 m wide
4	Log ride -	12 m long	1 m	5 m long x 1 m
5	Log / dirt ramp across path	8 m x 0.5 m	1 m	
6	Log ride – ride length of fallen tree, ramps for mount and dismount built	11m x 0.5 m	1 m	3 trails each 10 m long x 1 m wide
7	Log ramp	2 m x 2 m	1 m	5 m long x 1.5 m wide
8	Log ride – ride length of curved bark of fallen tree	9 m x 0.5 m	1.5 m	40 m x 1 m
9	Log ramp	2 m x 1 m	0.3 m	
10	Log / dirt ramp	3 m x 2 m	0.3 m	10 m long x 1 m wide
11	Log / dirt ramp	2 m x 2 m	1.5 m	15 m long x 1 m wide
12	Log / stone / dirt ramp	3 m x 3 m		9 m long x 1 m wide
13	Stone / log ride	4 m long	1 m	15 m long x 1 m wide
14	Fallen log with 3 jumps across it – a) dirt take off and landing ramps built up across log b) log ramp through split in fallen tree c) dirt ramp up to fallen log jump	a) 8 m x 2 m b) 3 m x 2 m c) 3 m x 1m	a) 2 m b) 1 m c) 2 m	27 m long x 1 m wide a) 10 m long x 1m wide b) 20 m long x 1m wide c) 30 m long x 1m wide
15	Log ramp	1 m x 1 m	1 m	12 m long x 1 m wide
16	Dirt ramp	16 m x 2 m	2 m	

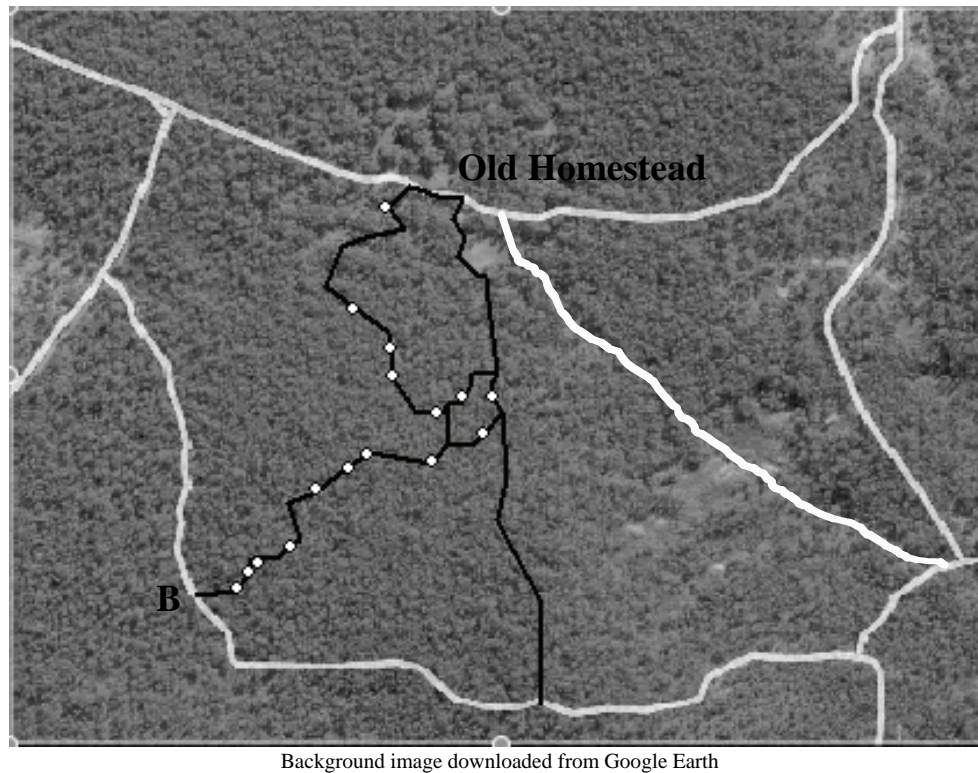


Figure 10: Informal trail network (dark lines) and TTFs (circles) from Point B at Study area 1

The TTFs had all been created from natural materials found close by in the forest, such as fallen trees, rocks and dirt and blended into the environment (Figure 11). In this instance no material had been brought in nor was there any evidence of any tools being used in the construction of the TTFs as has been the case in other areas of the Park.



Figure 11: Examples of TTFs in John Forrest National Park using natural materials

The GPS and GIS assessment method can provide an accurate and informative assessment of the impact of mountain bikers in JFNP and similar protected areas. The method can quantify the impact on a natural area by calculating the amount of land cleared. This information can then be displayed on an informative map. This process should be repeated to assess each informal trail identified by trail inventory or from ranger knowledge. The total area impacted can then be calculated by summing the individual areas from each assessment. This will give a total area impacted for the natural area. Each assessment can be displayed on a map of the natural area to give visual representation of the impact.

General Conclusion

This study explored the research on mountain biking and its impacts on natural areas. Past research has indicated that the relative impacts of bikers and hikers in natural areas are similar. However, previous research has used controlled passes of hikers and bikers along with general trail assessment methods to determine mountain biking impacts. Furthermore, previous research has not adequately catalogued the impacts of mountain biking in natural areas. Following on from Newsome (2008) and Newsome and Davies (in press) the environmental impacts of mountain biking can be summarised as follows:

On trail impacts:

- Erosion as a result of skidding
- Linear ruts/trail incision
- User conflict
- Addition of technical trail features to existing trails

Off-trail:

- Creation of informal trails
- Creation of technical trail features
- Reduced amenity/conservation value
- Cost of management response

In relation to social issues many of the causes of user conflict are perception based and relate to environmental impact issues, physical safety and differences in user expectations. Methods of managing conflict have already been documented. It is important to note, however, education and interpretation are important for managing conflict. Understanding the potential users is also key to providing the appropriate facilities and preventing conflict. Further research into attitudes and reasons for the social conflict between bikers and hikers will increase understanding of this issue (Tumes 2007).

In order to understand the impact that mountain bikes are having on JFNP and other natural areas the motivation and demands of different styles of mountain biker need to be considered. The major biophysical impacts of riding in JFNP appear to be due to riders creating illegal trails and TTFs. The GPS and GIS assessment method can be used to determine the impacts of creating informal trails and TTFs. This method is appropriate for use in any natural area where informal trails and TTFs are a problem.

It is also important to understand why mountain bikers have created informal trails and TTFs in JFNP. The Park is a confusing network of fire management tracks that were not created for recreational use (Figure 9). Many tracks, especially fire management tracks, are eroding under natural conditions and have not been designed to withstand erosion even in situations of no recreational use. Unfortunately, it appears that fire management tracks are still not being adequately designed or maintained. For example, a new fire management track was created, through native vegetation, in the Throssell Road area (see Study Area 2, Figure 9) over the period of this study. This track has some steep sections that already show signs of erosion. In one area a second, parallel fire management track had been created to a length of about 30 m. Cutting a fire management track through native vegetation, wide enough for a car, removes more vegetation than a informal mountain bike single track trail of equal length. Whilst the requirement to manage fire in the Park is understood it leads to a major problem for Park managers trying to manage recreation in the park who use the fire management tracks and, because they are eroding, for users to appreciate the negative impacts of their own activities.

The informal trail network at Point B (Figure 10) leads northwards to the old homestead area in the Park. Around the old homestead is an area that is covered in weeds and rubbish (scrap metal, 44 gallon drum, scraps of wood, old cart, concrete slab) (Figure 12a). Some of the rubbish has been used to create jumps and TTFs. This area appears degraded and therefore it would again be difficult to impress upon people that they are causing environmental damage by creating TTFs in this area. One of the biggest issues observed was the prevalence of weed species in this area, e.g. Patterson's Curse (*Echium plantaginium*) (Figure 12b). One of the main reasons that Park management wants to control the recreational activities in the Park is that bike tyres may spread weeds between areas. It is clear that the Park management should make every effort to help this by reducing the extent of weeds already in the Park and in this area.

Following the trail south from Point B leads to the only formal single track in the park, the Eagle View dedicated walk trail. Rangers are aware that mountain bikers have been using this trail. The rationale of the mountain bikers may have been to connect up two areas of interest, the homestead and the single track trail, with an informal trail.



Figure 12: Junk and weeds at the Homestead area in John Forrest National Park

At the same time, conversation with three separate riders in the Park demonstrated that there is some confusion over where mountain bikers are allowed to ride. Rangers are aware that someone from a bicycle shop is telling people to ride the Eagle View trail (Annear 2007, pers. comm., 30th October). These people may therefore believe that it is acceptable to ride this dedicated walk trail. There was also little understanding that the TTF area close to Point B was an informal trail network unapproved by Park management. Park management have made efforts to inform users by signage (Figure 13), but report that these signs get vandalised or removed regularly. It is believed that better communication between the two parties could reduce inappropriate behaviour.

A recurring theme in these observations is the perceived degradation of the Park by the user and their response to that. Many of the fire management tracks are severely degraded. There are large water channels running along the tracks and the surface is unstable in many areas. If Parks are to be managed in a sustainable manner and want to support recreation then they need to be given the resources to do so. Park management needs to demonstrate to the users that it is doing all it can to maintain the Park, such as to rehabilitate degraded areas and badly eroded or unused fire management tracks. Effort is also required to educate users about environmental issues and management strategies. Without these measures users may continue to be unaware of the damage they are causing and will have no incentive to change their behaviour.



Figure 13: Signage at John Forrest National Park, present and removed

Recommendations

1. Employ the GPS and GIS mapping assessment tool to determine the extent of the mountain bike impacts in JFNP and other protected areas by tracking all known mountain bike impact areas. All impact sites can be quantified and plotted on a Park map to provide an overall impact assessment of the activity in a protected area.
2. Develop a management strategy and rehabilitation plan to ameliorate the most impacted areas of JFNP. This plan should consider closing off some trails for rehabilitation, maintenance of other trails to make them suitable for the designated recreational use and consideration of alternative locations where facilities accommodating more impacting activities, such as technical trail features on designated mountain bike trails, can be developed. Relevant literature and additional details on trail planning and management are included in the Appendix (pp. 21–27) of this report.
3. Display an impact map and an interpretive notice at Park information areas to inform mountain bikers about facilities, trail use and the consequences of their actions in non-designated areas.
4. Future research could include experiments targeting less conservative riding styles in order to measure the effects of skidding and breaking on trail stability under different environmental conditions and management scenarios. This would provide a better understanding of impacts of mountain biking on trails in natural areas.

APPENDIX A: Planning for Mountain Bike Activities in Natural Areas

To manage visitor use of natural areas and resulting impacts planning is essential (Newsome et al. 2002). As a result a number of planning frameworks have been developed (Newsome et al. 2002, Castley et al. 2007). The Recreation Opportunity Spectrum (ROS), Limits of Acceptable Change (LAC), Visitor Impact Management (VIM), Benefits Based Management (BBM) and more recently the Tourism Optimisation Management Model (TOMM) are examples of frequently used frameworks (Newsome et al. 2002, McCool, Clark & Stankey 2007). They all involve setting objectives, determining threats and impacts, developing a monitoring program including which indicators to use, data collecting, collating and analysis, analysing alternatives, formulating a final plan and implementation actions (Newsome et al. 2002, Castley et al. 2007). Management actions are identified from the framework and a program of continual monitoring and assessment ensues (McCool 1996). In choosing a planning framework managers should consider the strengths and weaknesses of each and the situation to which it is applied (Newsome et al. 2002).

The Forest Management Plan 2004–2013 is the overarching management plan for the forested area of the Southwest of Western Australia (Figure 1). It includes the commercial, heritage, environmental and socio-economic aspects of forest management in the Southwest, Swan and Warren districts in Western Australia. It uses a modified Montreal Criteria as its framework to identify management actions and key performance indicators in line with the principles of biophysically sustainable forest management (CCWA 2004). An objective of this plan was to sustain and enhance socio economic benefits from the forest. As a result a major key performance indicator was to determine the number, range and type of recreation/tourism activities available in the plan area (CCWA 2004).

In Western Australia the national park network is governed according to specific management plans, such as the John Forrest Management Plan (CALM 1994). Such plans can use the specified planning framework to identify recreational opportunities that are available within this specific area, such as walking trails, mountain bike trails, horse riding, camping and recreation facilities. Once the recreational activity has been identified the capacity to create a specific activity management plan arises. It is at this stage that a mountain bike trails plan for John Forrest National Park could be applied. A planning framework could thus be used to create an activity specific plan, a trails master plan dealing with all types of trail or a specific trail plan. An example of an activity specific plan is the South Coast Trails Management Plan and a trail specific plan could be the Munda Biddi operational guidelines. Marion and Leung (2004) consider that a specific trail plan should include the following elements:

1. Management goals and objectives
2. Evaluation and specification of recreational opportunities
3. Incorporation of a decision making framework identification of indicators, standards and monitoring protocols
4. Trail inventory
5. Evaluation of proposed trail use
6. Trail standards

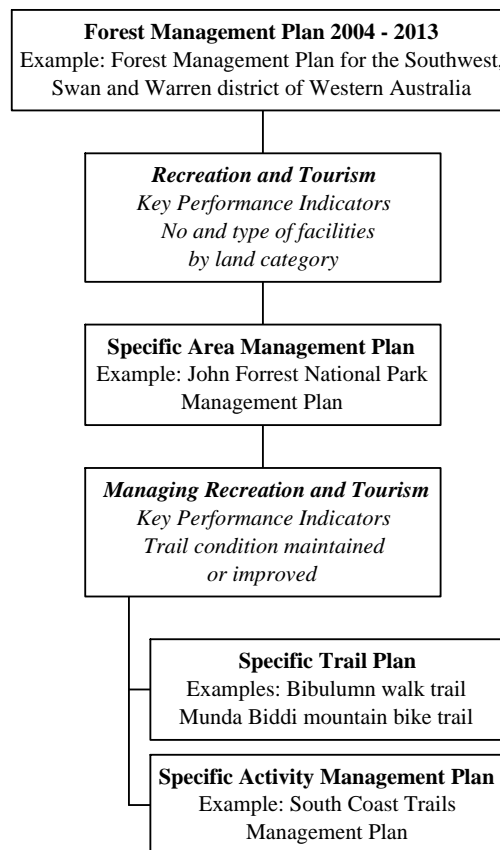


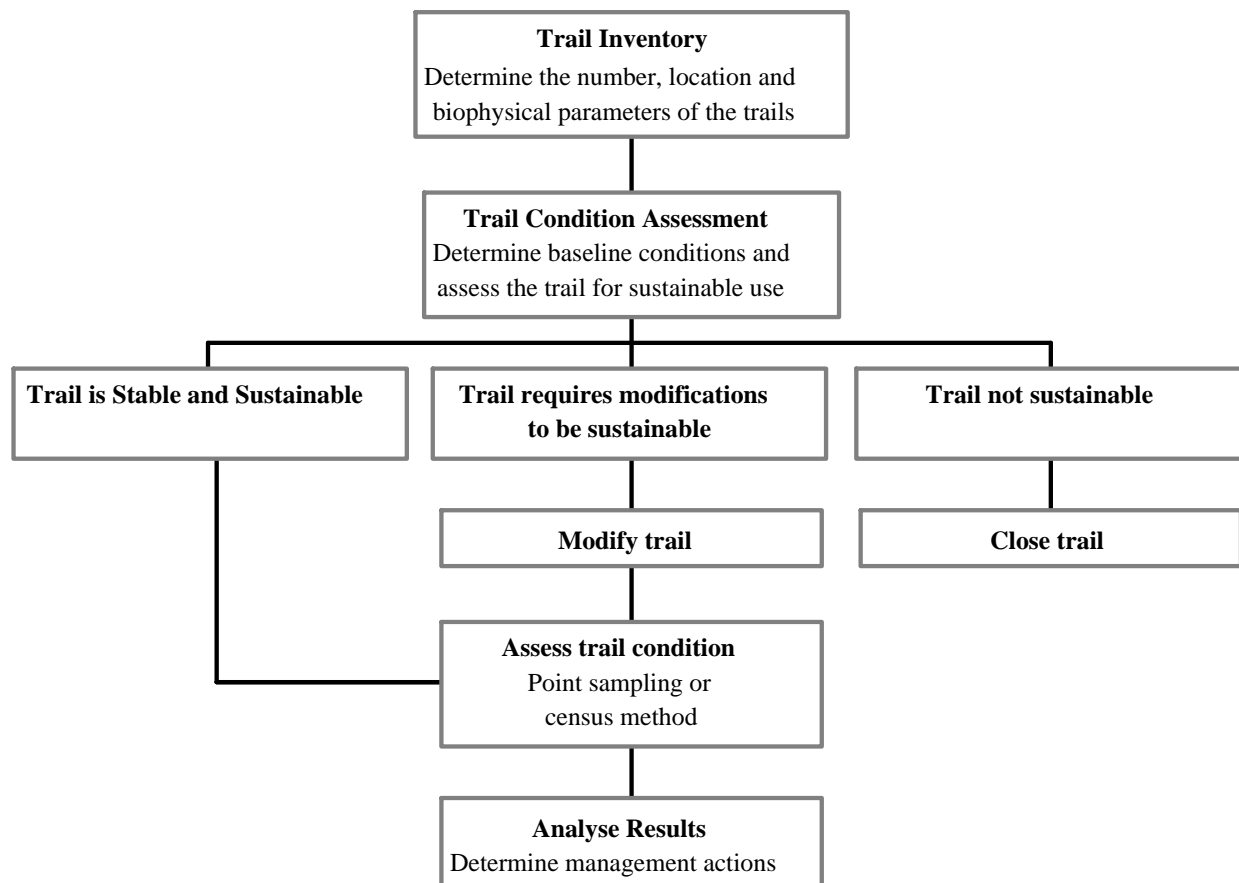
Figure A1: Planning for trail systems and management in the forests of the Southwest of Western Australia

Biophysical Impact Assessment

The aim of the biophysical impact assessment is to assess trail degradation and the impacts associated with mountain biking in a natural area. To determine the impacts of mountain biking preliminary baseline assessments need to be carried out and then the trails must be assessed and monitored for damage (Figure 2) (Moore 1994). A trail inventory describes the distribution and condition of a trail network at a specific point in time (Hill & Pickering in 2009b). A trail inventory can be used as the first step in the assessment of a natural area for sustainable trail use to provide a picture of the trail network in question and baseline for monitoring (Hill & Pickering 2009b).

General information about the trail should be recorded along with environmental and maintenance information (Leung & Marion 1999, Hill & Pickering 2009a)

General information:	Trail ID, date, name, time, type of trail, use of trail
Environmental information:	Soil type, vegetation type, outslope, grade
Maintenance and design features:	Trail hardening, bridges, water bars, TTFs



Derived from IMBA 2007, Hill & Pickering 2009 b

Figure A2: Proposed plan for the biophysical assessment methodology of mountain bike trails

Assessing the Sustainability of Mountain Bike Trails

Many managers of natural areas inherit a trail network created by people informally accessing scenic areas on fire management tracks, logging roads or access to remote locations and which were not originally designed for recreational access and use (Marion & Leung 2004). It is often the case that managers have more trails than they have resources to maintain (Marion & Leung 2004). Marion and Leung (2004) suggest that a trail assessment process should be conducted to evaluate trails for suitability and sustainability. Based on the information derived from trail assessment a manager may decide to close a trail to all recreational users if it is unsustainable or deemed unsuitable for a particular use, or decide to rehabilitate certain areas of the trails to make it sustainable or to keep the trail open and maintain it for users (Marion & Leung 2004).

The physical parameters of a trail, soil type, outslope, grade, can also affect the susceptibility of a trail to erosion (IMBA 2004). Trail erosion is caused by a combination of gravity, water and trail users (IMBA 2007). IMBA (2007) claim that inadequate or poor trail design is often the primary factor in a trails susceptibility to erosion. This can be demonstrated by the fact that a well designed trail may be erosion free if the grade and outslope allow water to flow gently off the trail.

IMBA (2004) suggest there are five main elements to assessing the sustainability of a trail, these are summarised here:

1. The half rule – a trails grade should not exceed half the grade of the hillside or slope it traverses.
2. The 10% average guideline – generally an average trail grade of less than 10% is most sustainable.
3. Maximum sustainable grade – This would typically be about 15–20% but fluctuates according to various physical, user and climatic factors. Wet conditions can lead to water caused erosion but too dry conditions can lead to dry and loose tread surfaces. Rocks can generally sustain higher grades than unconsolidated soils. The grade of a soil based trail will depend on the physical properties of the soil. The level and type of use must also be considered, for heavier use and for the higher impacting users the grade must be shallower.

4. Grade reversal – grade reversals should be present where water collects to force water to exit the trail (see Figure A3).
5. Outslope – the outer edge of the tread should slope down and away from the high side of the trail (Figure A3).

Using these guiding principles in assessing trail sustainability a manager can then decide whether to close an unsustainable trail, to modify section of a trail to make it sustainable or to continue to make a trail available to mountain bikes if it is sustainable.

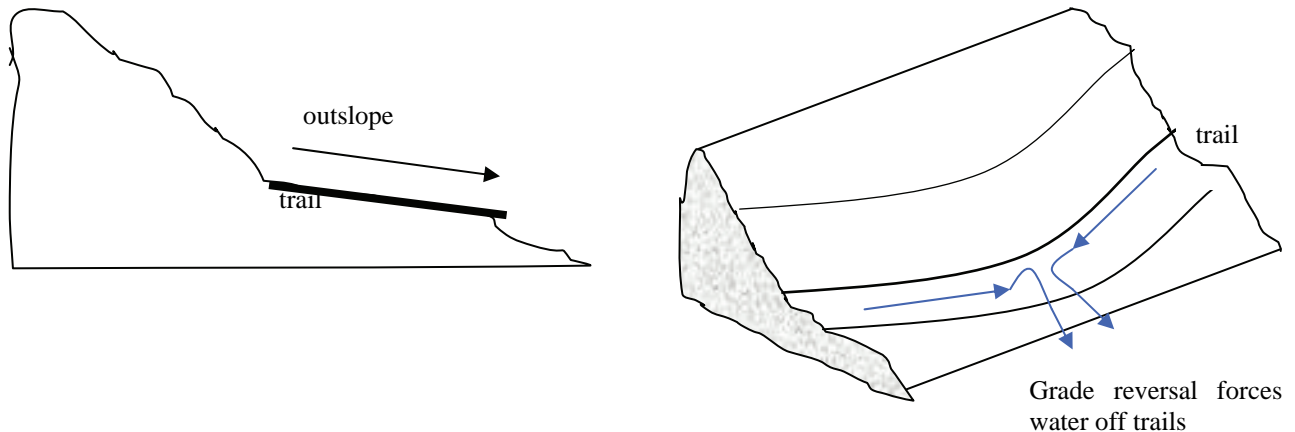


Figure A3: Outslope and grade reversal

Approaches to the Assessment of Trail Condition

If a trail is to be kept open to users the conditions of the trail should next be assessed for mountain bike specific impacts. The literature shows that the methods used to assess the conditions of walking trails are usually based on point sampling methods or census methods but there is no accepted standardised assessment method for mountain bike specific impacts (Leung & Marion 1999, Newsome et al. 2002, Mende & Newsome 2006, Hill & Pickering in progress a & b).

Point sampling involves the measuring of parameters or the application of condition classes at systematically located, permanently or non-permanently marked points along the trail (Table A1) (Leung & Marion 1999, Newsome et al. 2002, Hill & Pickering in progress a & b). Non permanent point sampling allows a general indication of trail condition, is a rapid, common approach but it may require a large number of points to accurately define a trail problem and it does not give information on the location or severity of trail problems (Leung & Marion 1998, Newsome et al. 2002, Hill & Pickering in progress a). The use of permanent sampling points can provide a more accurate assessment but is more time consuming (Newsome et al. 2002). A point sampling based approach, compared to a census based approach, will be less time consuming or allow greater detail to be collected (Leung & Marion 1998). In Australia this method has been used to systematically assess and predict trail conditions and degradation in the Tasmanian Wilderness World Heritage Area and to assess trails in the Stirling Range National Park Western Australia (Mende & Newsome 2006, Hill & Pickering 2009b).

Census methods provide a comprehensive trail condition assessment by recording all trail features; trail problems, grade and soil texture along with their location, severity and extent (Leung & Marion 1999, Hill & Pickering in progress a). This method permits rapid assessment of general trail conditions but does not provide information on average conditions, i.e. no statement can be provided giving the average muddiness of a trail (Leung & Marion 1999, Newsome et al. 2002). These methods can be split into two classes, sectional evaluation using condition classes or continuous assessment using track problem assessment.

In the condition class census approach the track is divided into sections, see Table A1, with similar environmental and physical conditions, and assessments made for each using predefined condition classes (Hill & Pickering in progress b). This is a very rapid assessment method that will identify major changes and is suitable for a track inventory covering long distances (Hill & Pickering in progress b). Its major disadvantage is that the condition classes are subjective on where impact problems begin and end and the assessment is based on the judgement of each assessor how to record the problem (Newsome et al. 2000, Hill & Pickering in progress b).

The continuous trail assessment method (see Table A), provides management with quantitative information for use in trail planning, maintenance and management that employs a continuous search for indicators of pre-defined tread problems and yields census data documenting the location and occurrence of impact problems

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(Leung & Marion 1999). This method has the same problem of the assessor deciding when the trail problem observed meet the criteria for assessment and deciding where the erosion problem begins and ends (Leung & Marion 1999). White et al. (2006) have used a problem assessment method to measure tread incision and tread width to determine the effects of mountain bikes on bike trails. The track problem assessment method has also been used to provide a comprehensive trail inventory of 1000 km of the Tasmanian Wilderness World Heritage Area (Hill & Pickering in progress b). In the Stirling Range National Park in Western Australia this method was used to provide comprehensive information on the location, extent and severity of walk trail conditions and to determine the effectiveness of trail maintenance (Mende & Newsome 2006). It was used in conjunction with a point sampling approach, as it was determined that some variables are more suited to point sampling, e.g. trail width, slope, rockiness, than to problem assessment, e.g. erosion, excessive trail width, exposed roots, informal trails, constructed features (Mende & Newsome 2006).

Table A1: Summary of trail assessment methods.

Method	Application	Advantages	Disadvantages
Census – Condition classes Evaluator searches for and documents the extent and location of trail problems by assigning them to a predefined condition class	Qualitative trail inventory over large areas	Cheap, quick	Subjective, does not identify small changes
Census – Continuous trail problem assessment As above but uses pre determined trail conditions and maintenance parameters instead of condition classes	To record every occurrence of pre-determined track conditions and maintenance parameters, 1–5 km of track.	Frequency, extent and location of problems	Subjective on where problem begins and ends, does not provide average conditions
Point – Non permanent Evaluator records conditions at systematically located points along trail	Rapid assessment of average trail conditions, spatial variation in track condition	Accurate and precise information on average and general conditions, sensitive to change,	No location information, no frequency information, not good at identifying infrequent conditions i.e. informal trails.
Point – Permanent As above but points are marked	Accurate and precise data on changing trail conditions	Permits subtle changes to be detected	Time consuming in documentation, does not document overall trail condition or infrequent condition.

Derived from Leung & Marion 1999, Newsome et al. 2002, Mende & Newsome 2006, Hill & Pickering in progress 2009 a and b.

The Universal Trail Assessment Process (UTAP) is an example of a track problem assessment method as an on-the-ground data collection trail assessment exercise in which trails are walked and features (natural and man made) and characteristics (grade, slope, width and surface type) recorded in the field (Axelson & Longmuir 2002). This data can then be used by land managers to manage maintenance efficiently, to provide trail information to users and the trail experience that users expect (Axelson & Longmuir 2002). It has been used extensively in the US for a variety of trail types by IMBA (2007) and the US Department of Transportation (1999).

Regular and repeated monitoring of parameters will show erosion over time (Royce 1983, Goeft & Alder 2001). The measurements and sampling intervals should be determined by what is required for the intended statistical analysis (Leung & Marion 1998, Goeft & Alder 2001). Leung and Marion (1998) found that a point sample interval of <100 m is usually adequate for estimating the lineal extent of trail impact problems.

An important consideration in assessing trail condition is the choice of parameters to measure. It is critical that managers understand the specific role that indicators have within management frameworks and the criteria they should satisfy to provide suitable information (Castley et al. 2007). Biophysical indicators are qualitative or quantitative variables that provide useful information about changes in the natural environment (Castley et al.

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2007). They are physically measurable parameters that provide a method of evaluating trends in conditions and are an efficient way of collecting relevant data (Marion 2007). Indicators must be easy to measure, locally relevant, represent the effect that we are trying to understand and reflect the impacts of recreational use (McCool 1996, Bicycle SA 2001).

A criticism of previous studies assessing mountain biking impacts, summarised in Sprung (2004), is that mountain bike specific impacts have not been considered in depth, like ruts and grooves caused by skidding and breaking and increased distance of travel (Vandeman 2000). A comprehensive study should measure these impacts and must include sections of uphill, downhill and flat stretches combined with straights and curves (Beneficial Designs 1999, Goft & Alder 2001). A suggested approach to investigating mountain bike specific impacts has been developed by Newsome and Davies (in press) with specified impacts and indicators summarised in Table 2.

Table A2: Summary of potential indicators from multiple user trail usage and use of trails by mountain bikes

Impact	General Indicator	Mountain Bike Specific Indicator
Soil erosion	Trail cross sectional area (m ²) Maximum incision (mm) Depth x length x width	Tyre incision depth (mm) and lineal extent (m)
Soil compaction	kg/ cm ² Penetrometer or bulk density	Tyre marks in dry compacted areas (number and length)
Trail muddiness	Muddiness (% of tread width)	Tyre marks in muddy areas (number and length)
Trail widening	Max width of trail as identified by tread marks (m)	Maximum width of trail as identified by tyre marks (m)
Tread width	Tread width (m)	
Trail surface	Loose/displaced soil, compacted Subsoil exposure	Loose/displaced soil due to sudden application of brakes and skidding
Informal Trails	No of trails, condition, length, width, area, proximity to sensitive areas, erosion measurements as per formal trails.	As general indicator but determine user group from trail markings/other indicative evidence
Multiple trails	Parallel trails or diversions around obstacle (number of)	Parallel trails or diversions around obstacle made by tyre imprints (number of)
Trail modifications		Technical Trail Features (number and description)
Maintenance features	Water bars, crossings, grade reversals (number and condition rating)	Designated mountain bike trail with relevant interpretive signage
Directional signage and interpretation	Functional/non-functional	Functional/non-functional on multiple use/mountain bike designated trails
Vegetation (trail edge and on trail)	Identification and number of weeds or bare ground (% of quadrant)	

Derived from Leung & Marion 1998, Goft & Alder 2001, Meyer 2002, Newsome et al. 2002, Marion per comm. 2007, White et al. 2006, Castley et al. 2007.

REFERENCES

- Axelson, P., Longmuir, P., 2002. The universal trail assessment process training guide, PAX Press, Beneficial Designs, Inc. Minden, Nevada, USA.
- Beneficial designs, 1999. Designing sidewalks and trails for access, US Department of Transportation, Federal Highway Administration.
- Bicycle SA, 2001. State mountain bike plan for South Australia, Office for Sport, Recreation and Racing, www.recsport.sa.gov.au.
- Blue Ridge Parkway Raonoke Valley Greenway Commission National Park Service, Rivers and Trails Program, The Roanoke valley Blue Ridge Parkway Planning Team, 2004. Roanoke Valley, Blue Ridge Parkway Trail Plan Final Draft,
- Borrie, W., Freimund, W., Davenport, M., Manning, R., 2001. Crossing methodological boundaries, *Managing recreational Use*, George Wright Forum, 18 (3) pp.72-84.
- Bradshaw, G., 2006, The Australian bicycle industry report 2006, Bicycle Industries Australia, Graphyte Media Pty Ltd, Melbourne, Australia.
- CALM, 1994. John Forrest National Park Management Plan 1994 – 2004, Department of Conservation and Land Management and National Parks and Nature Conservation Authority, Australia.
- CALM, 2007. Mountain Bike Management Guidelines DRAFT, Department of Conservation and Land Management, Perth, Australia.
- Carothers, P., Vaske, J.J., Donnelly, M.P., 2001. Social values versus interpersonal conflict among hikers and mountain bikers, *Leisure Sciences*, 23 pp.47-61.
- Castley, J.G., Hill, W., Pickering, C.M., 2007. Frameworks and biophysical indicators for sustainable management of visitor use of protected areas, Development of terrestrial ecosystem indicators and methods for the sustainable management of visitor use of protected areas. CRC for Sustainable Tourism, Queensland, Australia.
- Cessford, G.R., 1995. Off-road mountain biking: A profile of riders and their recreation setting and experience preferences, *Science & Research Series no 93*, Department of Conservation, Wellington.
- Cessford, G.R., 2003. Perception and reality of conflict: Walkers and mountain bikes on the Queen Charlotte track in New Zealand, *Journal for Nature Conservation*, 11 (4) pp.310-316.
- Chavez, D., Winter, P., Baas, J., 1993. Recreational mountain biking: A management perspective, *Journal of Park and Recreation Administration*, 11 (1) pp.7.
- Chiu, L., Kriwoken, L.K., 2003. Managing recreational mountain biking in Wellington Park, Tasmania, Australia, *Annals of Leisure Research*, 6 (4) pp.339-361.
- Conservation Commission of Western Australia (CCWA), 2004. Forest Management Plan 2004–2013, Government of Western Australia.
- Faulks, P., Ritchie, B., Fluker, M., 2007. Cycle tourism in Australia : an investigation into its size and scope, CRC for Sustainable Tourism, Queensland, Australia.
- Foreman, D., 2003. A Modest Proposal, *Wild Earth*, 13 (1) pp.34-35
- Goeft, U., Alder, J., 2001. Sustainable mountain biking: A case study from the Southwest of Western Australia, *Journal of Sustainable Tourism*, 9 (3) pp. 193-210.
- Hasenauer, J., 2003. A Niche for Bicycles, *Wild Earth*, 13 (1) pp.21-22.
- Hill, W., Pickering, C., (2009)a. Walking track assessment manual, Development of terrestrial ecosystem indicators and methods for the sustainable management of visitor use of protected areas. CRC for Sustainable Tourism, Queensland, Australia.
- Hill, W., Pickering, C., (2009)b, Review of impacts and assessment of walking tracks in protected areas, Development of terrestrial ecosystem indicators and methods for the sustainable management of visitor use of protected areas. CRC for Sustainable Tourism, Queensland, Australia.

- Hollenhurst, S.J., Schuett, M.A., Olson, D., 1995. Conflicts and issues related to mountain biking in the National forests: A multimethodological approach, USDA Forest Service Gen. Tech. Rep. PSW-156.
- Horn, C., Devlin, P., Simmons, D., 1994. Conflict in recreation: the case of mountain-bikers and trampers, Department of Conservation, New Zealand.
- IMBA, 2004. Trail solutions, IMBA's guide to building sweet single track, IMBA, Boulder, Colorado, United States.
- IMBA, 2007. Managing mounting biking, IMBA's guide to providing great riding, IMBA, Boulder, Colorado, United States.
- Kelley, M., 1998. Bikes and horses: A case for sharing, International Mountain Bicycling Association, http://www.imba.com/resources/bike_management/clemson_horses.html, accessed 23rd March 2007.
- Kerr, A., 2003. Which Way? *Wild Earth*, 13 (1) pp.26-30
- Lathrop, J., 2003. Biophysical impacts of mountain biking: A critical literature review, Wildlands CPR, <http://www.wildlandscpr.org/biophysical-impacts-mountain-biking-critical-literature-review>, accessed 10th October 2007.
- Leung, Y-F., Marion, J., 1999. Assessing trail conditions in protected areas: application of a problem assessment method in great Smoky Mountains National Park, USA, *Environmental Conservation*, 26 (4) pp. 270-279.
- Marion, J.L., Leung, Y-F., 2004. Environmentally sustainable trail management, *Environmental Impacts of Ecotourism*, CAB International.
- Marion, J.L. 2006. Assessing and understanding trail degradation: Results from Big South Fork National River and recreation area. USDI, National Park Service.
- Marion, J.L. Wimpey, J. 2007. Environmental Impacts of Mountain Biking: Science Review and Best Practices, Pages 94-111 in Webber, P. (eds.), Managing mounting biking, IMBA's guide to providing great riding, International Mountain Bicycling Association (IMBA), Boulder, Colorado, United States.
- Marion, J., 2007. Determining physical carrying capacity: Identifying indicators and setting standards, Virginia Tech Field Unit, USGS, Patuxent, WRC http://www.wilderness.net/toolboxes/documents/VUM/Indicators_Standards-Marion_files/frame.htm, accessed 15th October 2007.
- McCool, S.F., 1996. Limits of acceptable change: a framework for managing national protected areas: experiences from the United States, Workshop on impact management in Marine parks, Kuala Lumpur, Malaysia.
- McCool, S.F., Clark, R.N., Stankey, G.H., 2007, An assessment of frameworks useful for public land recreation planning, Recreation and Tourism Initiative, General Technical Report, PNW-GTR-705.
- Mende, P., Newsome, D., 2006. The assessment, monitoring and management of hiking trails: A case study from the Stirling Range National Park, Western Australia, *Conservation Science*, 5 (3) pp.285-295.
- Meyer, K.G. 2002. Managing degraded off highway vehicle trails in wet, unstable and sensitive environments, USDA Forest Service, Technology and development program, 2E22A68 – NPS ONV management.
- Moore, R.L., 1994. Conflicts on multiple-use trails, International Mountain Bicycling Association, http://www.imba.com/resources/bike_managment/conflictsfull.html, accessed 23rd March 2007.
- Mosedale, J., 2003. Planning for appropriate recreation activities in mountain environments: Mountain biking in the Canadian Rocky Mountains, FES Outstanding Graduate Student Paper Series, 7 (5), Faculty of Environmental Studies, York University, Toronto, Ontario.
- Naturebase, 2007. Creating the trail together. <http://www.naturebase.net/content/view/431/895/>, accessed 22nd October 2007.
- Newsome, D. and Davies, C. (in press) A case study in estimating the area of informal trail development and associated impacts caused by mountain bike activity in John Forrest National Park, Western Australia. *Journal of Ecotourism*.
- Newsome, D., Moore, S.A., Dowling, R., 2002. Natural Area Tourism: Ecology, Impacts and Management, Aspects of Tourism, Channel View Publications.
- Newsome, D. (2008) The issue of mountain bike activity in natural areas: assessing impacts in John Forrest National Park in Western Australia. *Australian Protected areas Congress*, Sunshine Coast, Australia.

MOUNTAIN BIKE ACTIVITY IN NATURAL AREAS: IMPACTS, ASSESSMENT AND IMPLICATIONS FOR MANAGEMENT

- Outdoor Industry Foundation, 2006. The active outdoor recreation economy: A \$730 billion contribution to the U.S. economy, www.outdoorindustryfoundation.org, accessed 14th November 2007.
- O'Donnell, B., Carroll, M., 2003. Don't tread here, *Wild Earth*, 13 (1) pp.31-33.
- Perth Mountain Bike Club (PMBC), 2007. <http://www.perthmtb.com>, accessed 17th October 2007.
- Royce, P., 1983. Horse riding trails in John Forrest National Park: An Environmental impact assessment, National Parks Authority of Western Australia.
- Schuett, M., 1997. State park directors perceptions of mountain biking, *Environmental Management*, 21 (2) pp.239-246.
- Scott, D.W., 2003. Some History, *Wild Earth*, 13 (1) pp.23-25.
- Sprung, G. 2004. Natural resource impacts of mountain biking, Pages 249-254 in Webber, P. (eds.), Trail solutions, IMBA's guide to building sweet singletrack, IMBA, Boulder, Colorado, United States.
- Standing Committee on Recreation and Sport, 2006. Annual report 2005: Participation in exercise, recreation and sport, Department of Communications, Information Technology and the Arts, Australian Sports Commission, Australian Government.
- Symmonds, M.C., Hammitt, W.E., Quisenberry, V.L., 2000. Mountain recreational trail environments for mountain bike user preferences, *Environmental Management*, 25 (5) pp.549-564.
- Thurston, E., Reader, R.J., 2001. Impacts of experimentally applied mountain biking and hiking on vegetation and soil of a deciduous forest, *Environmental Management*, 27 (3) pp.397-409.
- Tumes, K., 2007. Out of my way: Using qualitative methods to understand recreation conflict between bushwalkers and mountain bike riders, *Anthropological Notebooks* 13(1) pp.45-55.
- United States department of the Interior (US Dep Int), 2002. National Mountain Bicycling strategic action plan, Bureau of land management, Washington, D.C.
- WA Freeride, 2007. WA freeride forum index, <http://wafreeride.com/index.php>, accessed 14th November 2007.
- White, D.D., Waskey, M.T., Brodehl, G.P., Foti, P.E., 2006. A comparative study on impacts to mountain bike trails in five common biophysical regions of the south western U.S., *Journal of Park and Recreation Administration*, 24 (2) pp.21-41.
- Wilson, J.P., Seney, J. 1994. Erosional impacts of hikers, horses, motorcycles and off-road bicycles on mountain trails in Montana, *Mountain Research and Development*, 47(1) pp.77-88.

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