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Managing mountain bike impacts in the South West of Western Australia : Combining biophysical impact studies with rider preferences for better trail design

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Managing Mountain Bike Impacts in the South West of Western Australia:

Combining Biophysical Impact Studies with Rider Preferences for Better Trail Design

by Ute Goeft

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USE OF THESIS

Abstract

This thesis examines the environmental impacts of mountain bikes on trails in the southwest of Western Australia and the preferences, perceptions, trail use and demographics of mountain bike riders in that region. This information is important for resource managers and trail developers to ensure that the trails that are provided and planned for mountain bike use in the region are environmentally appropriate and acceptable to users.

The environmental impacts were examined through biophysical studies, which investigated soil loss, soil compaction and vegetation damage on and adjacent to mountain bike trails over a period of six months. A mountain bike racing trail (Lowden, WA) and a trail designed for recreational mountain biking (Marrinup, WA) were monitored. A self-administered questionnaire was used to obtain information about user preferences, user perceptions, trail use and demographics. The results of these studies were integrated and the implications for trail design, conclusions and recommendations were derived.

Overall, the biophysical studies found limited trail impacts, in particular there was little soil loss on the trails, few impacts on areas adjacent to the trails and no trail widening. Racing impacts differed from those of recreational riding. Occasional loosening of the trail surface and minor temporary damage to the adjacent vegetation were observed after racing and not on the recreation trail. Trail features (curves and straight stretches), slope and soil characteristics should be taken into consideration when designing a trail to ensure low erosion and maintenance.

The main findings of the user survey indicated that mountain bike riders prefer natural settings and trails with a firm surface. They support a code of conduct and are aware of environmental and management issues associated with trail use. Differences have emerged between racing riders and recreational riders. Racing riders prefer technically demanding and challenging trails with downhill sections, curves and jumps, whereas recreation riders prefer trails that are less challenging, but are well marked and have drinking water provided. All riders agreed that more mountain bike trails are needed in the study area.

This study concluded that mountain bike trails in the southwest of Western Australia can be environmentally sustainable and acceptable to trail users. Slope and soil characteristics must be major considerations in the siting and design of trails. Environmental impact can be minimised if trails are designed specifically for racing or recreational purposes.

Declaration

I certify that this thesis does not, to the best of my knowledge and belief:

(i) incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education;

(ii) contain any material previously published or written by another person except where due reference is made in the text; or

(iii) contain any defamatory material.

Signature...[redacted]..

Date...7 November 1999...

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1 Introduction

Increasing leisure time has led to an increase in the range of outdoor recreation pursuits within the natural environment. Outdoor recreation has many benefits for society, such as increased health and awareness of the environment. It is also an important use of natural resources and the recent increase in the popularity of outdoor pursuits has raised concerns for the natural environment. Recreation impacts on the natural environment and appropriate resource allocation need to be considered if outdoor recreation is to be sustainable.

Mountain biking is a relatively new and increasingly popular addition to outdoor recreation. Like all human endeavours in the natural environment, mountain biking creates impacts. Managers need to be aware of these impacts so as to be able to manage resources in an environmentally appropriate manner. In addition, they need to know what the recreation needs of mountain bikers are in order to meet them while minimising degradation to the environment. Environmental impacts of mountain biking are associated with trails, trail heads and the vicinity of trails. In addition to the environmental impacts, social impacts have emerged which are related to conflicts between mountain bikers and other trail users on multiple use trails as well as to trail access and trail safety.

Research into the environmental and social issues of mountain biking has been primarily conducted in the United States (for example Chavez, 1993; Blahna, Vilter and Von Koch, 1994; Bjorkman, 1996; Carrothers, Vaske and Donnelly, 1998). Some studies were carried out in the United Kingdom (Ruff and Mellors, 1993), in New Zealand (Cessford, 1995a) and in Germany (Wöhrstein, 1998). In Western Australia, one study examined the need for a long-distance mountain bike trail (Brindal and CALM, 1995). However, up to now, research into the environmental and social aspects of trail use has not been conducted in Western Australia although managers have identified a need for information in these areas. Management authorities such as CALM and Trailswest, as well as the Western Australian mountain bike clubs, require baseline information and monitoring programs concerning the issues identified earlier for the appropriate environmental management of the sport and the resources that support it.

This study has provided some information to enable these managers to better plan for and manage mountain biking in the southwest of Western Australia.

The aims of this research were threefold. Firstly to determine the physical impacts of mountain bikes on designated trails in the natural environment under recreational use as well as in cross-country racing conditions in the southwest of Western Australia. Secondly to ascertain how mountain bike riders use trails, their perceptions concerning various management issues and the types of experiences and settings they seek. Thirdly, to make recommendations for appropriate trail design, trail management and rider behaviour management by combining the results of these two studies with current trail design principles.

This thesis is composed of five chapters. The background places the research into context with the literature. The methods for both projects, the biophysical impact study and the mountain biker survey, are then described, which is followed by an outline of the results respectively. Subsequently the results are discussed and the implications for the design of mountain bike trails derived. Recommendations for various issues relating to mountain bike management that arose from this study are also made. Some of the results of the biophysical study, the survey forms and all comments were placed in Appendices.

2 Background

2.1 Bicycling

Austroads (1999) in 'Australia Cycling 1999-2004 - The National Strategy' promotes the bicycle as an environmentally friendly mode of transport and recommends that its use be encouraged. The strategy refers to the economic and health benefits that bicycling can provide, its contribution to social equity, the benefits of bicycle use to the environment by not adding to greenhouse gas emissions, and its contribution to the sustainable use of resources. It envisions: "Increased cycling for transport and recreation to enhance the well-being of all Australians" with the goal to: "Double bicycle use by the year 2004" (Austroads, 1999, p.6) and spells out six objectives on how to achieve this. These objectives refer to a coordinated approach that integrates bicycling into policy and planning, to ensure adequate facilities and improved safety for cyclists, to educate decision-makers and the community about the benefits of cycling and to ensure that cycling is incorporated in appropriate areas of education. Strategies, responsibilities and performance measures are outlined. The strategy does not differentiate between various forms of cycling and therefore encourages all forms, including mountain biking.

Bicycle use in Western Australia has increased in recent years (CALM, 1997; 1999b), with part of this increase being due to growing interest in mountain biking as a sport and recreational activity. Overall the pursuit of recreational activities, especially in natural settings, has become more popular over recent years. Factors that might be affecting this growth include an increase in leisure time and the recognition of the health benefits of outdoor pursuits such as cycling. Often people seek to combine bicycling and enjoying scenery or thrill seeking. Mountain biking in natural areas enables people to satisfy all these desires. As a consequence, trails are specifically developed for mountain biking or existing trails and tracks are shared with various users.

The increase in popularity of mountain biking has raised concerns amongst the community on the environmental impacts of the sport in the State's natural areas (Wayne Schmidt, pers. comm. 1998; CALM, 1999b). It is therefore necessary to know if and how mountain bikes affect the environment and what trail features and settings mountain bike riders actually want if the use of mountain bikes is to continue to grow in an environmentally sustainable manner. Previous work on this subject can provide a basis for the future design of environmentally appropriate mountain bike trails that meet rider demands.

2.2 Mountain Biking

The mountain bike, an off-road or all terrain version of the bicycle, originated in California where the first "clunkers" were one gear bicycles with balloon tyres used for downhill riding. The first commercial mountain bikes became available in 1979 (Kelly, 1990). Since then mountain biking has increased in popularity (CALM, 1997; 1999b) with mountain bikes accounting for over 80% of all bicycles sold in the USA in 1997 (Widmer, 1997). Mountain bike sales figures for Australia were not available, but will be compiled this year (G. Bradshaw, pers. comm., Sept. 1998). According to CALM (1999b, p. 105), "over 90% of all bikes currently sold in this state are mountain bikes." Import figures for all bicycles into Australia have stabilised in the first quarter of 1998-1999 (304 000 bicycles) after a slight downturn in the 1997-1998 period due to a weak Australian dollar (Bicycling Trade Magazine, 1998).

The popularity of the mountain bike can be ascribed to various factors. Widmer (1997) refers to the comfort of the ride due to the fat tyres and the advances in suspension, which soften the ride allowing travel across rough terrain, as well as the relatively upright posture a rider assumes on a mountain bike. In addition, mountain bikes have up to 27 gears, allowing for easy hill climbs as well as fast down hill rides (Barrie Thomas, pers. comm., 1998). The gears which are easily changed with the modern indexed shifting technology, as well as the powerful cantilever (or even disc) brakes, allow the negotiation of technically demanding as well as steep downhill sections. All these features allow mountain bike riders to enjoy a ride with an appropriate challenge at nearly every skill level (Widmer, 1997). These advances in technology also allow bicycles into areas where they could not go before (Chavez, Winter and Baas, 1993).

Western Australia's first mountain bike club, the Perth Mountain Bike Club, was formed in 1989. Membership increased rapidly until other clubs were formed and membership now totals over 200 (Peter Gaull, pers. comm., 1998). In 1995 the Western

Australian Mountain Bike Association (WAMBA) was founded, which incorporates 10 Western Australian mountain bike clubs. In the last two years membership has stabilised at about 400 members (Mick Ahrens, pers. comm., 2[illegible] Aug. 1998), with not all mountain bike club members being WAMBA members and vice versa (Peter Gaull, pers. comm., 14 Dec. 1998). Most clubs are racing orientated, catering mainly for the racing community. Many mountain bike riders who pursue the sport only recreationally do not appear to be affiliated with any clubs, making it hard to estimate the total number of mountain bikers.

In addition to its growth as a popular recreational pursuit, mountain biking has become a highly competitive sport internationally and an Olympic discipline (CALM, 1997). In 1990 the sport was recognised by the UCI (Union Cycliste Internationale- International Cycling Union). The UCI, the international bicycling body, regulates bicycle competitions and has devoted a 55 page section in the UCI cycling regulations to mountain bike races. The different forms of mountain bike racing that are recognised are cross country ("XC", with four different categories) where an undulating course with obstacles is ridden repeatedly, downhill ("DH") which entails racing a downhill course with obstacles, dual slalom "DS", where two riders race down a hill on parallel tracks, and hill climb ("HC") where riders race uphill. Trials (or observed trials ("OT") are another recognised form of competition, involving the negotiation of a natural or constructed obstacle course without setting a foot on the ground or leaving the course. Stage races ("SR") are held over two or more days (two categories) (UCI, 1998-1999). Besides a description of the different forms of racing, the regulations outline guidelines pertaining to the classification of riders, clothing, the venue, official duties and identification of riders during racing amongst others. The guidelines for observed trials are dealt with in a different section. The UCI guidelines are generally followed for mountain bike racing in Western Australia (Les Machin, pers. comm., 1999). All forms of mountain bike racing, except for observed trials, always take place in the natural environment. Depending on locations and the nature of the race, existing trails may be used or modified or new trails are constructed.

In Western Australia, most mountain bike racing trails are being used for recreational riding as well and are cordoned off for racing events. There are few 'mountain bikes only' trails in Western Australia yet, and most of the mountain bike trails can be used by other types of recreationists. Very few of the trails that are used by mountain bikers are marked as such. At John Forrest National Park the staff have published a leaflet aimed at mountain bikers describing the appropriate use of mountain bikes in the park (CALM, no date).

2.3 Impacts of mountain biking

Any outdoor activity pursued by humans has an impact on the natural environment. Mountain biking is no exception and, therefore, has the potential to impact on soils, water, vegetation and wildlife (Cessford, 1995b). As the name implies, and as outlined above, the mountain bike can be ridden in off-road conditions, which raises a number of issues concerning trail and resource management. CALM (1999b, p. 1) outline that "the impacts of cycling on the natural environment are generally minimal, provided this activity is confined to roads and trails which are appropriately located, designed, managed for disease control and maintained." However, they also state that conflicts are a potential problem associated with mountain biking that are likely to increase with advances in technology and an anticipated rise in popularity of the sport. The three main areas of concern have been identified by Cessford (1995a) as physical impacts of mountain biking on trails and the environment, social impacts of mountain biking on other users of trails, and preferences of mountain bikers concerning settings and experiences. These different aspects of mountain bike impacts will be referred to in turn below.

2.3.1 Trail impacts

Mountain biking, by its very nature, is an activity mainly pursued on trails and similar features, i.e. roads and fire tracks, therefore most impacts will be related to these features. In some conditions, for instance in Europe, the mountain bike can be ridden cross country, not utilising trails, resulting in impacts differing from those on trails (Wöhrstein, 1998). However, these conditions are not readily encountered in Western Australia and these impacts will therefore not be considered in this context.

An important finding by Seney and Wilson (no date) is that only approximately 35% of all erosion impacts on trails are caused by trail users, the other two thirds are ascribable to a complex interaction of natural influences such as rainfall and water runoff, terrain and soil texture and vegetation cover. This suggests that most impacts on a trail can be attributed to its very existence and any kind of trail use only adds to these effects. This highlights the need for proper placement of trails from the very beginning (Cole, 1993). Another point that should be kept in mind is that according to Bjorkman (1996, p. 72) "Impacts of narrow maintained recreation trails may be of less concern than wider impacts of landscape changes beyond the forest boundary." He refers thereby to the "...effects from large scale land fragmentation by roads, power lines, logging, mining, and agriculture." (Bjorkman, 1996, p. 70). The evaluation of this statement and its implications was not the intention of this study and efforts were concentrated on impacts on trails and their immediate vicinity.

Although environmental concerns relating to trail damage by mountain bikes have been raised by resource managers (Chavez et al., 1993), little information in respect to mountain bike-specific impacts is available. One of the main difficulties appears to be the lack of trails that are exclusively used by mountain bikes (Thomas Wöhrstein, pers. comm., 17 Feb. 1999), Indeed, only two studies were found that examined the effects of mountain bikes on trails (for details see below). Most trail impact studies were conducted on trails used for walking, horse riding and/or motorcycling. Many of these studies are outlined below and although the findings may not always be directly applicable to mountain biking, some findings are relevant or they serve as a comparison to show where mountain bike impacts differ.

Walking

Cessford (1995b) in his review of research on impacts associated with walking trails pointed out that a distinction is necessary between purposely formed trails and unformed trails resulting from trampling. Purposely formed trails are those constructed by agencies for users, whereas unformed trails are those which are formed by the visitors to an area by trampling or repeatedly using a corridor until a trail or track has formed. Although this study is mainly concerned with purposely built trails, research into trampling effects can be applicable. Trampling can occur next to purposely formed trails, for instance by spectators of mountain bike races or by riders who have to walk a mountain bike on a narrow trail because the trail is too steep or goes uphill for too long (or the riders are not fit enough). In the case of multiple-use trails, trampling can occur if users have to make room to pass each other.

Various studies into the effects of trampling of previously undisturbed vegetation observed the greatest loss of vegetation in the early stages of use (100-300 passes) (Leonard, McMahon and Kehoe, 1985; Kuss and Hall, 1991). Resistance to trampling was found to vary between vegetation types (Cole, 1985; Calais and Kirkpatrick, 1986; Cole, 1993; Sun and Liddle, 1993, Cole, 1995) and recovery times varied with plant species (Leonard et al., 1985). Grasses were found to be more resistant to trampling than woody plants, whereas the latter were more resilient (Sun and Liddle, 1993; Leonard et al., 1985; Cole 1993). Some vegetation types were found to be able to tolerate certain amounts of trampling below a threshold whereas others were very sensitive and recovery was very low even at low trampling intensities (Cole, 1995).

Soil disturbance, such as compaction and associated reduction in water infiltration capacity, rose with increasing damage to vegetation and its removal (Cessford, 1995b) and increased use (Kuss and Hall, 1991). Again the greatest impacts were also observed with initial use (Cole 1985). Another effect was mineral soil exposure which depended on vegetation type, trampling intensity and type of user (Cole and Spildie, 1998), as well as on the thickness of the organic horizon (Cole, 1985). The resulting increase in runoff on slopes led to greater erosion, whereas on poorly drained and highly organic soils unconsolidated muddy areas developed (Cessford, 1995b).

De Gouvenain (1996) identified compaction as the primary effect on soil by trampling. A compacted soil is reduced in volume, but has an increased bulk density. An increase in small soil pores and a decrease of large ones increases the soil water potential therefore allowing it to store more moisture in the dry season than a non-compacted comparable soil. At the same time this can lead to inadequate soil and root aeration. Higher thermal conductivity is generally also a result of compaction as is a reduction in mobility of inorganic ions. This and a decrease in mineralisation of nutrients by soil organisms can affect plants, whereas the changes in water and nutrient uptake can increase pathogen invasion of plants. These effects depend on the intensity and extent of the trampling impact, and plant communities can take up to several hundred years to recover. However, as Bjorkman (1996) points out, for a narrow trail the described effects would be limited and unlikely to affect forest plant communities substantially, unless they are very sensitive.

For purposely formed walking trails the first, and major, impact is the formation of the trail itself (Cole, 1987, quoted in Cessford, 1995b). This stage is comparable with the early stages of unformed trail formation. Once trails have been formed, purposely or not, Cessford (1995b) has identified four main management problems associated with ongoing use of trails. These are:

erosion due to increased water flow, on slopes and drainage points
muddy areas in saturated soil, often leading to track widening
multiple track development around damaged/altered areas
informal track development, e.g. shortcuts or around huts/attractions

Bratton, Hickler and Graves (1979) surveyed trails in Tennessee (USA) for width, depth and erosion and came to the conclusion that vegetation type, elevation and slope have an influence, with slope being the most important parameter. In addition Bratton et al. (1979, p. 438) remark that "trails that are constructed perpendicular to the slope of the surrounding terrain (trail angle 80°-90°) show the least erosion" in comparison to those at steep angles (0°-20°). Cole (1983) studied walking trail conditions in Montana (USA) in relation to habitat type, slope and amount of use, and found that all these parameters were related to trail condition. Certain habitat types were eroded easier than others. The maximum trail depth was positively correlated with slope and trail width, whereas trail depth increased with greater use. A study by Calais and Kirkpatrick (1986) of damage on Tasmanian mountain tracks found correlations between annual user numbers, vegetation type, geological substratum and altitude. They have suggested threshold levels below which impact on tracks is acceptable.

In Scotland, Lance, Baugh and Love (1989) found increasing footpath widening and erosion with increased use. A consequence of erosion was multiple trail development, which was also referred to by Cessford (1995b) citing various authors, where users circumvented areas on trails that were hard to negotiate due to erosion, muddiness or other obstacles. Erosion problems and multiple trailing were associated by various authors with poor location and trail design (Cole, 1983; Bratton et al., 1979; Weaver and Dale, 1978).

Burde and Renfro (1986) measured cross-sectional area loss on the Appalachian Trail (USA) and found that soil type, vegetation type, elevation, precipitation, slope and amount of use influenced trail depth, whereas trail width was related to soil type and vegetation type. Despite these relationships, the predictive value of these parameters for erosion changes on the trail was low. Garland (1990) found rainfall, soil type and slope to be the main parameters in determining the erosion potential of a trail. These findings were confirmed by Seney and Wilson (no date), who identified rainfall intensity and slope gradient to be the main factors for soil loss, whereas soil properties such as structure, texture and moisture content, which determine resistance to erosion, were less important.

In another study Cole (1991) compared trails over an 11-year period and found that although the trails had changed, deterioration was mainly localised and occurred more on the lesser used trails. Fish and Brothers (1981) in their study also found changes on trails and roads. In this case they consisted mainly of deposition, indicating the importance of these structures in impeding natural drainage. Bright (1986) examined hiker impacts on vegetation along trails and found that vegetation density as well as amount of use was influential on trail width, with the latter relationship being well documented by other authors (as listed in Bright, 1986).

Weaver and Dale (1978) compared the effects of hikers, motorcycles and horses on trails in meadows and forests. They studied vegetation cover, trail width, trail depth and soil compaction and found that generally impacts were greater on slopes than on flats and more rapid in shrubby vegetation compared to grassed areas. Wilson and Seney (1994) in their comparative study of the effects of horse riding, motorcycling, walking and mountain biking on trail erosion concluded that soil texture, slope and user type were most important in determining trail erosion. In addition, they found that wet trails were more susceptible to erosion than dry trails.

The relationship of the various parameters studied in respect to trail erosion is very complex (Wilson and Seney, 1994) and will vary according to local conditions. Therefore the best way of minimising erosion problems on trails appears to be, according to Simmons and Cessford (1989; quoted in Cessford, 1995b) and Cole (1983), to properly site trails during construction, ensuring that susceptible soil and vegetation types as well as steep slope angles are avoided.

Horse riding, motorcycling and other uses

Some research into trail use impacts other than walking is available, albeit to a very limited extent. Various researchers have studied the effects of horses and motorcycles and one research team has investigated the impacts of a new addition to outdoor recreation, the llama.

Summer (1980) studied the geomorphologic changes on horse trails in the Rocky Mountains (USA). She found that horse use was not the dominant factor in trail changes but was only interacting to varying degrees with parent material, slope and side slope of trail, soil texture and organic content, rockiness and stoniness, vegetation and drainage. When Whinam and Comfort (1996) looked at the impacts of commercial horse riding on Tasmanian sub-alpine tracks they found that the level of use was not sustainable and trail hardening would be necessary to counteract the severe soil loss and track deterioration caused by the horses.

Weaver and Dale (1978) found in their comparative study that overall horses had the greatest impacts on trails in the Rocky Mountains (USA) followed by motorcycles and that walkers did the least damage. When uphill and downhill effects were compared, motorcycling did the greatest damage uphill whereas walking and horse riding was more damaging downhill. Wilson and Seney (1994) found that horses and walkers (hooves and feet) were more damaging to wet trails than motorcycles and mountain bikes (wheels) in terms of sediment yield, and that horses also caused higher sediment yields than the other users in dry conditions.

Deluca, Patterson, Freimund and Cole (1998) compared the soil erosion potential of llamas, horses and hikers on Montana (USA) trails. The parameters measured were sediment yield and runoff, change in soil bulk density and change in soil surface roughness. It was found that horses consistently made the most sediment available and that sediment yield from llamas and walkers was comparable. Unaffected by user, runoff was increased on wet trails whereas sediment yield was increased on dry trails in conjunction with decreased bulk density and increased soil roughness. These findings were in part opposite to those of Wilson and Seney (1994) mentioned above, which could be due to differences in soil texture, which was relatively coarse in the study by Deluca et al. (1998).

According to all studies available on other users of trails, by far the most damaging appears to be the horse, with all other users, except the motor bike, not showing any significant differences in trail damage potential.

Recreational mountain biking

Mountain biking is in most cases a trail related activity and therefore mountain bikes will have impacts on trails. Many of these impacts will be in addition to the impacts caused by other users such as walkers, horses and motorcycles. Few trails are used exclusively by mountain bikes and therefore it is difficult to distinguish mountain bike impacts from those of other users (Chavez, 1993). Up to now, research into impacts of mountain bikes on trails has been very scant and little is known about the actual physical impacts of mountain bikes on trails overall and even less so in Western Australia.

In a field experiment, Wilson and Seney (1994) compared the physical impacts of mountain biking, hiking, horse riding and motorcycling. They found that mountain biking impacts were comparable with those of walking. In fact horse riding proved to be the most damaging and motorcycling was considered intermediate. Weaver and Dale (1978) found in their experimental study on meadow and forest trails that motorcycles had the least impact on downhill sections of trails, if skidding did not occur, compared to walkers and horses. The effects of mountain bikes would be expected to be much less than those of motorcycles due to the lower wheel loadings of mountain bikes (Cessford, 1995b). Keller (1990; cited in Cessford, 1995a) nevertheless concedes that mountain bikes can potentially damage trails severely while travelling down hill if they skid and employ poor braking technique. Cessford (1995a) also has associated mountain bikes with specific damage to trails, with some impacts being due to poor riding technique (e.g. skidding). Therefore trail erosion, according to Chavez et al. (1993), is dependent on site conditions and rider behaviour.

Chavez et al. (1993) point out that the added effects of mountain bike use on trails, be they mountain bike specific or indirect through increased use, are important to trail managers in respect to potential increases in trail maintenance. They refer to a finding by Hain (1986; cited in Chavez et al. (1993) on p. 30) in Deschutes National Forest (USA) where mountain bike riders had gone around log-style water bars, thereby creating additional erosion and trail widening. In Germany, Wöhrstein (1998) found only rare evidence of erosion attributable to mountain bikes. The erosion he saw was in its early stages and only occurred on trails that were very highly frequented and then only in areas that received exceptional mechanical wear/stress. In these cases erosional lesions were mainly of a linear nature which was explained by the linear tracks mountain bikes produce. Keller (1990, cited in Cessford, 1995a) also referred to these influences.

Wöhrstein (1998) goes on to say that in conditions (viscous surface) where linear tracks do form, these are often deformed by other users, for instance walkers or other riders, and often only remain for very short periods of time. This implies that shared use trails might be advantageous by reducing erosion potential and hence the need for maintenance. The greatest erosion potential in Germany was seen in saturated soils on steep slopes and high water runoff conditions. These conditions are atypical for the southwest of Western Australia.

Bjorkman (1996) compared the amounts of soil in the runoff from two comparable steep slopes on a newly opened highly used mountain bike trail in Wisconsin. One slope had been treated with geotextile matting, a material made from woven strips of car tyre, to reduce runoff. After six rain events in two months the amount of soil washed from the untreated site was approximately 100 times that of the treated slope. He conceded that the Revised Universal Soil Loss Equation (as used by the USDA Natural Resource Conservation Service) predicted a high runoff on a bare surface at the incline and length of slope examined and that any kind of use only accelerates soil loss. In the given context, his main concern was the potential of mountain biking to reach very high levels near urban centres.

Soil texture is one of the most important factors influencing the erodibility of a compacted trail surface. Fine sand particles (0.2 - 0.06 mm) are most prone to dislodgement by water, whereas larger particles need greater force to be moved and smaller ones have greater adherence (Wöhrstein, 1998; Lal and Elliot, 1994; Marsh, 1991). The most easily eroded soils are fine sands and silts (Liddle, 1997; Marsh, 1991; Cole, 1983). In these soils, particles are easily detached and transported (Lal and Elliot, 1994). Bjorkman (1996) found that in Wisconsin sandy soils and soils with a high organic content were most easily eroded, although a higher clay content in any soil reduced their erosion potential. Sandy soils were also found to encourage trail widening as did steep slopes.

Particle composition also determines the infiltration rate of water into a surface, which declines with declining particle size. This means that a soil with fine texture can absorb less water resulting in more runoff and, therefore, more erosion. In addition, a rougher soil surface, for example on soils with a mix of grain sizes including pebbles or rocks, reduces water velocity thereby decreasing its capacity to transport soil (Wöhrstein, 1998; Liddle, 1997; Lal and Elliot, 1994). Infiltration rate is also influenced by surface compaction. The denser a soil is packed the fewer pores are available and the longer it will take for water to infiltrate. This will increase runoff especially on slopes (Liddle, 1997; Lal and Elliot, 1994). Trails will often have a compacted surface depending on the underlying soils, the moisture content of the soil and the amount of use. The velocity of runoff is dependent on the incline of a slope whereas the length of a slope influences the amount of runoff, hence long steep slopes generate the most erosion (Marsh, 1991).

The type of user may also play a role in determining the extent of compaction. Wöhrstein (1998) points out that a mountain bike with high profile tyres will reach a maximum contact area pressure of 14 kg/cm^2 in a steep uphill situation. This value is much smaller than the maximum pressure of 56 kg/cm^2 reached by a walker in a steep downhill situation. Horses and cattle reach values up to three or four times higher than that. Even in 'normal' situations, that is on level ground, walkers reach comparable and often higher pressures than bicycles, although the contact area of a foot is larger than that of a bicycle tyre. An additional negative effect is the inelasticity of the sole of a shoe in comparison with a soft air-filled tyre. Overall, mountain bikes exert slightly greater pressure in steep uphill situations whereas walkers exert greater pressure downhill.

Another mechanism contributing to the erosion of a trail surface is the dislodgement of material in dry conditions. Wilson and Seney (1994) found that the sediment yield of the trails they examined was mainly due to soil detachment. This was reduced when a trail was wet due to increased soil cohesiveness (Deluca et al. 1998; Parker, Michel and Smith, 1995). Dislodgement of soil will happen to an extent through normal trail use but can be exacerbated, in the case of mountain bikes, by locking up the wheels through hard braking which leads to skidding (Cessford, 1995a).

A factor which reduces soil erosion is its cover. Litter cover reduces raindrop velocity as well as water runoff velocity thereby reducing its erosion potential. In addition, vegetation like trees that grow beside trails can also reduce the energy with which rain drops hit the ground effecting reduced erosion (Wöhrstein, 1998; Marsh, 1991). Plant roots also bind the soil and therefore increase the soil's resistance to erosion (Marsh, 1991). A forest canopy can reduce surface runoff to 10 percent of the incoming rain (Ammer, 1983, cited in Wöhrstein, 1998). Admittedly, a typical Western Australian forest is not comparable to a typical German or central European forest and these figures would probably be higher in local conditions.

Overall, the erosion problems arising from mountain biking on trails in Germany have been considered to be minimal and in comparison to hiking impacts insignificant (Winterling, 1997, cited in Wöhrstein, 1998). In Wisconsin (USA), Bjorkman (1996) found that mountain biking on high use trails led to erosion in some areas but that these impacts could be controlled by appropriate siting and management. Wöhrstein (1998) points out that the main ecological impact on a landscape is the trail itself because it can be the starting point for extensive erosion. It is also a starting point for intrusion of the natural environment by visitors and it dissects animal habitats.

Although recreational mountain biking accounts for most of the trail use by mountain bikes it is not the only form of mountain bike use. Cross country, down hill and dual slalom racing are other forms of mountain biking that utilise trails. Due to the more sophisticated and high-tech equipment used, as well as the competitive nature of these forms of mountain biking, the impacts on trails may not be the same as for recreational riding.

Cross country (XC) mountain bike racing

The impacts on the trails and their immediate vicinity are expected to be more pronounced under racing conditions than under recreational use. This is due to a greater number of riders per time period, higher intensity of riding (faster, harder, skidding around corners) and the presence of spectators. Anecdotal evidence claims that impacts can be quite severe, but that the recovery of vegetation along a trail can be remarkable (E. MacGregor, Trailswest, pers. comm., 18 August 1998).

Evidence of cross country racing-specific research was only found in the German literature, where Wöhrstein (1998) examined soil compaction after a World Championship XC race with 870 participants riding the course altogether 6,000 times while being cheered on by 80,000 spectators. He found that compaction by mountain bikes was higher to a depth of 7 cm compared to that of the spectators on foot. Then the trend reversed and the compaction by mountain bikes reached pre-existing levels at a depth of 10.5 cm whereas compaction levels by spectators reached those levels only at a depth of 21 cm. A field experiment involving 50 passes, by a mountain bike and a walker respectively, resulted in comparable levels of compaction. In all cases the ensuing damage to vegetation was no longer visible after ten months and compaction levels in the first 3.5 cm had reverted to pre-existing levels.

However, these results, although very impressive, cannot be applied directly to Western Australian conditions due to differences in soils and vegetation. In addition, in Western Australia XC races, including State Championships, are held on race courses which are in use all year round for club races as well as for recreational riding (personal observation; Les Machin, pers. comm., 1998). Therefore recovery of the race courses to original conditions is not possible nor intended. No research into the effects of XC racing on racing trails has been undertaken to date. The same is true in regard to spectator damage to vegetation adjacent to XC trails and its recovery, highlighting the need for research as undertaken in this study.

Down hill and dual slalom racing

These forms of mountain biking are mainly racing orientated and intense in terms of riding. The nature of these forms of mountain biking requires special trails that slope downhill at various angles and contain jumps and ramps. The impacts of these races from riding fast, jumping and skidding can be quite pronounced, however trails are normally well maintained by the riders. It is in their own interest to have good quality trails and to maintain them since getting access to land for their exclusive use is difficult (Les Machin, pers. comm., 1998). The literature search has not uncovered any down hill or dual slalom specific research.

Other environmental impacts

Impacts on wildlife

Miller (1994) points out that trails cause an edge effect in the natural environment thereby fragmenting habitats. Therefore, care should be taken to reduce impacts on sensitive environments by proper trail location and the avoidance of sensitive habitats. Visitor education through signs and trail etiquette can also be used to reduce impacts on wildlife. In some cases permit systems might be appropriate, whereas in others periodical closures might be warranted, for example to protect ground-nesting birds in the breeding season.

Gander and Ingold (1997) investigated the effects of single hikers, joggers and mountain bikers on alpine Chamois and found that the habitat used by the animals was affected by all three activities. The alert distance (distance when the first animal raised its head and looked towards the person) as well as the escape distance (distance between person and animal at the moment the animal moved away) were the same for all three types of use. The distance fled was slightly higher for animals confronted with a jogger or mountain biker than when encountering a walker. Overall fewer animals were found in the studied area after the experiments than before.

Although Bjorkman (1996) did not examine trail effects on wildlife in Wisconsin he sought the opinion of various experts. Most did not think that there were any problems associated with narrow trails in relation to wildlife if sensitive areas with fragile and rare habitats were avoided.

Little research has been undertaken to determine the influences of recreational activities on wildlife. Most of the studies that were done have looked at the immediate effects (behavioural changes, death) of these influences, and the long-term effects on an individual, population or community level have received little attention (Knight and Cole, 1995b). Nevertheless, it seems to be understood that the effects on wildlife differ with the type and magnitude of a recreation activity and that synergistic effects of different activities have to be taken into account. Mountain biking was classed as an extensive activity comparable with its impacts to hiking. Knight and Cole (1995b) cite many examples of the effects of these extensive activities, some of which found an increased heart rate and flight in mountain sheep when seeing hikers. Other effects were short-lived behavioural changes in birds as well as longer-term effects resulting in a reduction of breeding populations although breeding success was not reduced.

Knight and Cole (1995a) point out the factors that influence the response of wildlife to recreationists fall into the two categories of recreation influences and wildlife characteristics. They cite a variety of studies into wildlife responses towards recreationists some of which found that slow moving activities are less disturbing and that predictable and non-threatening activities evoke little overt response. Others discovered that frequency and magnitude of disturbance can influence breeding success in visited nests and a threshold level of disturbance was suggested. Timing of disturbance was found to have different effects, where in the breeding season the productivity of individuals could be reduced and in the rest of the year an individual's energy balance could be influenced possibly affecting survival, especially in winter. The wildlife characteristics influencing responses to recreationists were cited as type of animal, group size, age and sex.

Although the results of these studies cannot be transferred directly to Australian conditions, any trail will have some impacts on the local wildlife. This should be considered when choosing a site for a trail and when designing the trail course.

Dieback disease

In Western Australia, the Department of Conservation and Land Management recognises the importance of the water mould *Phytophthora cinnamomi*, which is the best known of a number of pathogens that cause "dieback". Management procedures are in place to control the disease and its spread (CALM, 1999a).

Phytophthora cinnamomi attacks many plant species in the Southwest with some of them being killed by it and others functioning as hosts. The organism is not native to Australia and has a widespread but discontinuous distribution in areas with rainfall above 400mm per year. Attacked plants often die a sudden death after the mould has attached itself to the root or basal stem tissue, preventing the uptake of water and nutrients (CALM, 1999a; Shearer and Tippett, 1989).

The pathogen is parasitic and can spread via mycelium (its microscopic threadlike body) or two forms of spores, zoospores and chlamydospores. The zoospores are produced in large numbers under favourable conditions (warm and moist). They are very small and short-lived, and can actively swim to a new host or can be transported in water for long distances, thereby spreading the infection. The chlamydospores are produced under unfavourable conditions and are long-lived, persisting in dead plants or soil until they encounter favourable conditions to grow and produce mycelium. Sexual reproduction is possible but does not occur in Western Australia (CALM, 1999a; Shearer and Tippett, 1989).

Plant families most susceptible to *Phytophthora cinnamomi* attack are:

- Proteacea

- Epacridaceae
- Papillionaceae/Fabaceae and
- Myrtaceae.

Within these families not all genera or species are susceptible in the same way. For example some Eucalypts, like Karri and Marri, are resistant and others, like Jarrah, are susceptible, although they can resist in certain conditions (CALM, 1999a; Shearer and Tippett, 1989).

Disease Risk Areas (DRA) have been declared to control the disease. A DRA "is an area of public land where the Executive Director considers that the earth, soil or trees may be, or may become infected with forest disease" (CALM, 1999a, p. 36). Access to these areas is controlled through the erection of signs and barriers at the sites and written permission has to be obtained before accessing a DRA with a carrier, that is a vehicle of any description or a hoofed animal. The permit has to be carried and produced upon request. The procedures of authorisation are outlined in the Management Guidelines and entail briefing of the applicant as to why a permit is required (CALM, 1999a). A strategy has been adopted to identify uninfected 'significant protectable areas' to protect them through controlling human access and effecting hygiene procedures on entry. Mapping of diseased and uninfected areas as well as monitoring and review are part of the program (CALM, 1999a).

Little is known about the spread of dieback via vehicles. Inferences have been made from the occurrence of dieback along roads (Batini, 1984, cited in Shearer and Tippett, 1989) and spores have been found in soil obtained from vehicle tyres implying that the disease can be spread by vehicles (Batini, 1973). It is assumed that spores can also be carried on bicycle tyres as well as on the soles of shoes or on the feet of animals (Kevin Vear, pers. comm., Feb. 1999). No research was available to that effect and clearly this needs further investigation in Western Australia.

In some cases mountain bike race tracks in Western Australia are located in Disease Risk Areas. Since mountain bikes are classed as vehicles, the required permits are given out to riders on the day at race registration and they are advised if any hygiene procedures are needed before entering the DRA (Peter Gaull, pers. comm. and personal observation on race day, 23 Aug. 1998). In the case of the Mundaring DRA no such measures are needed because the area is dieback affected. Walkers, who are not classed as vehicles or carriers, can use these trails at any time without a permit.

Other problems associated with mountain biking

Illegal trail building has occurred and was ongoing in 1997 in the Marin Watershed in California. All efforts to discourage this practice and the use of the trails have failed so far, but it is hoped that legally built trails on private land will help to reduce the pressure on the Watershed (Edger, 1997). In Western Australia this practice does not appear to be a problem in the forest nor in any of the municipalities in Western Australia (Chris Thompson, pers. comm., 1999).

2.3.2 Shared use impacts and user conflicts

Mountain bikes are often ridden on trails that have traditionally been used by walkers, horse riders, motorbikes and four wheel drive vehicles. From this shared use of trails and tracks a series of concerns, mainly of a perceptual and subjective nature, have been raised. Mountain bikes are seen as a safety hazard, damaging to trails and as inappropriate technology in natural settings. Mountain bike riders are perceived to be less appreciative of the environment than other users, are seen to compete for resources (trails) with other users, consequently reducing their access to trails, and are often just disliked (Cessford, 1995b). These perceptions have resulted in conflicts over the most appropriate use of trails (Horn, Devlin and Simmons, 1994). Conflicts can be observed on the trail, ranging from discontent to confrontation, but also off the trail, due to insufficient cooperation among user groups, which can result in lost trail opportunities (Moore and Barthlow, 1997).

Trail conflicts are a type of recreational conflict, which has been defined by Jacob and Schreyer (1980, p.369) as "goal interference attributed to another's behaviour". These conflicts can occur between different user groups, within user groups and due to factors unrelated to the trail activity. At its most extreme, contact between users is not even necessary. Moore and Barthlow (1997, p. 11) summarise: "Conflict is thought to be influenced by activity style (mode of travel, level of technology, environmental dominance, etc.), focus of trip, expectations, attitudes toward and perceptions of the environment, level of tolerance for others, and different norms and social values held by different users". Conflict is often asymmetric, or one-sided, which means that one user group resents another group, which in turn does not reciprocate these sentiments (Moore and Barthlow, 1997; Watson, Williams and Daigle, 1991). Jacob and Schreyer (1980, p. 378) point out that: "...conflict is a dynamic social interaction which can go through several stages." It is therefore important that potential conflicts and their sources are recognised early so that appropriate preventative measures can be taken.

Horn et al. (1994) in their study on conflict between mountain bikers and trampers (hikers) in New Zealand mention that most conflict between these groups occurs close to urban areas where most of these activities are practised. They add that recreational mountain biking, as opposed to racing, has the greatest impact on walkers. Sixty five per cent of walkers who participated in the study disliked mountain bikers.

Carothers et al. (1998) examined the conflicts between hikers and mountain bikers in terms of type of conflict. They distinguished between 'interpersonal conflict', which depends on the physical presence of users, and 'social-value conflicts', which stem from perceptions independent of the physical presence of users. Three groups were surveyed: hikers, mountain bikers and dual sport participants, the latter participating in both hiking and mountain biking. They found that hikers had very little conflict with other hikers, whereas there was much conflict with mountain bikers which was of a mainly interpersonal nature. Mountain bikers and dual sport participants on the other hand experienced more conflicts with bikers than with hikers, although at somewhat lower levels than the hikers, with both an interpersonal and a social-value component.

Bjorkman (1996) explored the potential sources of conflict between hikers and mountain bikers on multiple-use trails in Wisconsin (USA). The sources of conflict he identified were in regard to trail displacement, right of way and speed, differences in motivation and values, changed trail experience and environmental impact. An aspect raised by Ruff and Mellors (1993) in the United Kingdom was that walkers might feel that mountain bikers pose a threat to their own values and lifestyle and that they even might be jealous at the ease with which mountain bikes can access the country compared with walking.

Forest managers in the US stated that most conflicts observed or reported were between mountain bikers and hikers and mountain bikers and horse riders although some conflicts also existed between mountain bikers and motorised users as well as pack animal groups. In some cases the mountain bike riders were reported to be the problem whereas in others the other users were the problem. A small number of conflicts were between mountain bikers and wildlife or vegetation (Chavez, 1996a;1996b).

Although there is little literature available on the specific conflicts between mountain bikers and other trail users, the main trail conflict issues associated with mountain biking are outlined below.

Safety

The silence and speed of mountain bikes has raised concerns for the safety of other users (e.g. walkers and horse riders) of multiple-use trails. This was investigated by Pettit and Pontes (1987) and Ford (1989) (both cited in: Chavez et al., 1993), but they concluded that the risk of accidents was considered small. One study mentioned an accident involving walkers and mountain bike riders (Chavez et al., 1993), but occurrences of that kind were found to be rare (Cessford, 1995b).

A problem commonly referred to in various studies undertaken on user conflict is that (some) mountain bikers approach walkers or horse riders too fast for the trail conditions and are not prepared to slow down (Horn et al., 1994; Watson, et al. 1991). As Widmer (1997, p. 24) put it so aptly: "Riding under control is essential for the safety of all trail users". On the other hand, a study by Jacoby (1990) in the United Kingdom found that only few walkers perceived mountain bikes as hazardous and a source of dissatisfaction.

Chavez (1996b) found that 59% of surveyed US forests reported safety problems associated with mountain bikes. Over half of these were related to high speeds and some to bicycles being too quiet. Few were associated with mountain bikers being too careless around vehicles or pack animals. In addition, 48% of respondents reported mountain bike accidents, although it was not specified if other users were involved. Even though few accidents between mountain bikers and hikers have occurred in the Marin Watershed in California, bicycle accidents as such were the largest category of medical attention given by rangers (Edger, 1997). This indicates that mountain bikers are more a danger to themselves than to other users.

This seems to be confirmed by a study on traumatic injuries sustained by mountain bikers undertaken by Kronisch and Rubin (1994). They found that of the 265 participants questioned, 85.7% had injured themselves in the previous year. Most injuries were not classed as significant and included abrasions, contusions and lacerations, but 22.6% of injuries were 'significant' and mainly traumatic in nature. These injuries were clearly related to loss of control, high-speed descent and racing, with a competitive rider having an over four times higher risk of getting injured than a non-competitor. Uphill riding reduced the likelihood of injury by 76% compared to downhill or level riding.

Overall there is insufficient research to date to determine to what extent concerns about safety in relation to mountain bikes on multiple-use trails are real or related to feelings of discomfort by other users (Cessford, 1995b).

Perceptions of Environmental Damage

Other concerns relate to the perceptions by other trail users that mountain bikes cause environmental damage (Cessford, 1995a). Keller (1990; cited in Cessford, 1995a) cites various examples and Horn et al. (1994) found that most of the walkers that were surveyed indicated "track damage" when asked why mountain bikes were a problem on trails. Also of concern was the flora and fauna in the vicinity of the trails, and that the utilised areas were too fragile to be used by uncaring bikers.

To land managers the issue of trail damage is important because it is related to costly trail maintenance. The perception that mountain bikes are damaging trails can also be found amongst managers of public lands in the United States, as a survey by Chavez et al. (1993) showed. In this study, 35% of managers indicated that some trail damage was due to mountain bike use although it was hard to discern from damage done by other users or by increased use. The damage was usually limited to susceptible stretches of tracks or a small number of trails. In another survey involving US National Forests by Chavez (1996a; 1996b), 58% of all respondents reported resource damage due to mountain bikes with only 2% being unsure which user group was causing the damage. The types of resource degradation most commonly reported were trail impacts such as widening, rutting, braiding and short cuts, soil impacts such as erosion and compaction and water-related impacts such as damage to draining structures and tread, to name only a few examples. A possible explanation of the difference in the answers might be due to an increase in mountain bike use during these years.

Interestingly, when mountain bikers were asked to comment on trail damage in Wisconsin they explained that horses do a lot more damage to trails or that there were not enough trails provided for mountain bikes (Bjorkman, 1996). Hikers, on the other hand, accused mountain bikes to be responsible for trail damage. One hiker even refused to visit damaged trails because he or she was so taken aback by the changes.

As outlined above, current research focused on trail impacts so far indicates that mountain bikes contribute little to trail damage, or at least little more than walkers, except perhaps in very high use areas. Furthermore, as Chavez et al. (1993) point out, it is difficult to discern on a multi-use trail how much trail damage is due to a certain group of users.

Other issues

The perceptions relating to mountain bikes being a safety hazard and being environmentally damaging are only partially responsible for the social conflict relating to mountain biking. Petit and Pondes (1987, in Chavez et al. 1993) found that traditional users in Los Padres National Forest (USA) did not like mountain bike riders because they were so new.

Watson et al. (1991) discovered that only about 20% of hikers who perceived that mountain bikers diminished their experience in Rattlesnake National Recreation Area (USA) could link this perception to mountain biker behaviour. They also found that walkers perceived themselves to be different from mountain bikers in terms of lifestyle, occupation, income and education levels as well as in their attitudes towards the recreation area and the environment in general. Mountain bikers on the other hand were more accurate in their estimates that there was very little difference between the groups in those respects.

The picture was different when the motivations of trail use in Wisconsin (USA) were investigated. There Bjorkman (1996) found that hikers and bikers, although they both placed the same emphasis on a natural setting, differed most in two categories. Nature study was relatively most important to hikers and intense exercise was most important to bikers. This difference between the two groups was identified as a potential source of conflict, because a hiker is interrupted in his observations by a rider who has to slow down.

In the study by Horn et al. (1994, p. 2), meeting mountain bikers reduced their "sense of enjoyment and relaxation" and "the feeling of freedom or wilderness that many get from walking through quiet areas" for the walkers in New Zealand. Many walkers had been shocked by a bike suddenly appearing around a blind corner. Altogether, the mere possibility of meeting a mountain biker can diminish a walker's experience. In Wisconsin (USA), close to half of all hikers who had been passed by mountain bikes reported that their enjoyment had been decreased by the experience (Bjorkman, 1996). In a study on the behaviour of mountain bike riders when passing walkers, Bjorkman (1996) observed that over 70 per cent of riders did not announce themselves. Although that behaviour did not result in any problems (being touched or hit by a bike or harsh language) he concedes that it could "be a source of surprise, especially when bikers are coming up from behind" (p. 26). He also describes a study by Ramthun (1992) who investigated compliance of mountain bikers with trail etiquette and found that only 6.6% of the mountain bikers encountered yielded the trail (i.e. gave the right of way) to the walker. Bjorkman (1996, p. 26) came to the conclusion that: "On high-use trails, both right of way and speed differences are sources of conflict."

On the other hand, the irresponsible behaviour of a few mainly young and less experienced riders has led to mountain bikers being labeled 'hoons' or 'hooligans', meaning "people who ride at high speed with little regard for other users or for the environment" (Horn et al., 1994, p. 3). Many mountain bikers felt that this bad image was the main problem in regard to the conflict between walkers and mountain bike riders.

Another potential source of conflict described by Bjorkman (1996) was the displacement of hikers from shared-use trails. Hikers did not like to share trails with bikers in the high use situations described and shifted to hiking-only trails. This was especially true in the case when they had encountered mountain bikes before. Another aspect was that walkers who had put time and effort into building tracks were annoyed that mountain bikers ride and damage trails without contributing to their maintenance.

Despite these conflicts, many walkers actually conceded that mountain biking is a legitimate form of recreation and a healthy sport and should be catered for (Horn et al., 1994). Bjorkman (1996) also found that all users (hikers and riders) of some Wisconsin multiple-use trails were satisfied overall with their trail experiences, which in part was a result of active trail management.

2.4 Management of mountain bike impacts

To control and minimise the environmental as well as social impacts of mountain bikes on trails, various management approaches have been tried and utilised. They range from direct (limiting trail use, law enforcement) and indirect management approaches (education, information) to visitor management, resource hardening (trail maintenance) and bridge building (cooperation, volunteerism) (Chavez, 1996a; 1996b). These management tools will vary in their effectiveness in dealing with the different problems encountered in conjunction with mountain bike use on trails. Although little information concerning the success of these management tools is available (Chavez, 1996a), various examples have been described in the literature and are outlined below.

2.4.1 Shared use conflict management

Guidance on effective conflict management is available from the literature. For example a report to the US Federal Highway Administration by Moore (1994) lists 12 "principles for minimising trail conflicts on multiple-use trails". They are:

1. Recognise conflict as goal interference;
2. Provide adequate trail opportunities;
3. Minimise number of contacts in problem areas;
4. Involve users as early as possible;
5. Understand user needs;
6. Identify the actual sources of conflict;
7. Work with affected users;
8. Promote trail etiquette;
9. Encourage positive interaction among different users;
10. Favour "light-handed management";
11. Plan and act locally;
12. Monitor progress.

Briefly these principles suggest that the presence of conflict does not imply that different trail activities are incompatible but that they might interfere with experiences that other users seek. By offering a range of settings and adequate resources the potential for interference can be reduced, especially in congested areas and at trailheads. By involving all prospective users and potentially affected parties in the planning and design of a trail as early as possible potential sources of conflict can be anticipated and minimised from the outset. For existing trails, the involvement of all parties in conflict resolution should occur as soon as a problem is recognised (Moore, 1994).

User involvement also provides an opportunity to understand the motivations and preferences of the different users as well as the actual sources of conflicts. In addition, solutions can be found that can be agreed to by all parties, therefore reducing the potential for future conflict. This will be enhanced further by promoting responsible trail behaviour through the dissemination of educational material as well as by providing opportunities for positive interaction between different trail user groups. The latter could, for instance, be achieved through the formation of a Trail Advisory Council or by organising trail maintenance projects or "user swaps", where the respective users try out each other's activities (Moore, 1994).

In order to preserve freedom of choice it is important to use the least intrusive management approach possible to achieve the desired objectives. All issues should be addressed at a local level involving local users to ensure that local needs are met. And last but not least, ongoing monitoring ensures that conflicts are being addressed successfully and that necessary changes can be accommodated effectively (Moore, 1994).

An approach designed to reduce conflict and trail damage adopted by the International Mountain Bike Association (IMBA), and promoted by various mountain bike organisations, was the formulation of a code of conduct.
These 'Rules of the Trail' are:

1. Ride on open trails only;
2. Leave no trace;
3. Control your bicycle;
4. Always yield the trail;
5. Never spook animals; and
6. Plan ahead.

Rule number 4, however, has been identified as being problematic by Ruddell and Hendricks (1997). Although it suggests that cyclists always stop and move out of the way for other users, in practice walkers are the ones stepping to the side or off the trail if it is narrow. It is also unlikely that all mountain bikers will always follow this rule, so that, in effect, hikers are always left wondering if the next cyclist will stop or not, hardly reducing any unease concerning the approach of bikes.
User education is nevertheless an important tool in reducing trail use conflicts and can be achieved by various means such as signs, posters and brochures as well as interpretive rides/walks. Presentations and videos provided by management staff, volunteer trail patrols, public meetings or media articles are just a few more of the many possible avenues to reduce trail conflicts (for an extensive list see Moore, 1994). The

last resort to reduce trail conflict should be regulations. Users can be separated either physically, for example through provision of separate trails, or temporally, for example by allowing different users on the same trails on different days. Right of way regulations can be used to specify who must give way to whom (Moore, 1994).

Chavez (1996a; 1996b) found that forest managers in the US, basically in keeping with Moore's recommendations, used a combination of approaches to prevent user conflict but mainly relied on indirect management (signs, poster, etiquette). This was followed by direct (law enforcement, separation of trails) and bridge building (personal contacts, volunteer patrols) approaches whereas resource hardening was used only in a few cases. A quarter of managers of participating forests did not report a management strategy to address conflicts.

The management options available to address trail conflicts, according to Moore and Barthlow, (1997) are "trail design, information and education, user involvement and regulations and enforcement". Kulla (1995) grouped the available management options into five categories. These are: elimination of activities (prohibit use, restrict by time of day or day of week); segregation (e.g. single use trails, recreation use zoning), regulation and enforçement (including one-way trails, volunteer patrols); education (such as signs, self-policing, training programs), and manipulation of the environment (widening trails for multiple-use, speed barriers, speed limits).

Kulla (1995) also found that hikers and bikers agreed that education was the most acceptable management option followed by regulation and enforcement, segregation of activities and manipulation of the environment. Elimination of activities was the least acceptable option. On the other hand, in high-use areas in Wisconsin the allocation of separate trails for hikers and bikers was agreed to by both user groups as being the best way of reducing trail conflict, because all users will have a "more predictable trail experience" (Bjorkman, 1996, p. 33).

In some instances, trails will have to be restricted to exclude mechanised use to ensure certain experiences, but in many cases multiple use can be accommodated and is an economical and efficient way of allowing many people to access a scarce resource. Often trail use conflicts are very emotional and therefore hard to eliminate, however, progress can be achieved over time with patience, good planning and attentive management (Moore and Barthlow, 1997). As is often the case, there is no one best approach and the local situation and resource availability need to be considered to determine the best possible solution.

2.4.2 Safety

A foremost and basic requirement to ensure the safety of trail users is proper trail design and maintenance. This can include a trail design with many turns to slow down riders (Moore, 1994) Another approach has been to separate trails for different users. Other management tools to control the speed of mountain bikes has included barriers, speed limits and even radar guns in conjunction with heavy fines although, as with all direct management tools, their effectiveness lies in policing, which is time consuming and expensive (Edger, 1997). As mentioned before restrictions and regulations should also be the last resort when trying to increase trail safety (Moore, 1994).

Widmer (1997), on the other hand, stresses that proper education of mountain bike riders increases their awareness and skill levels, thereby enhancing safety as well as rider enjoyment. The IMBA Rules of the Trail (see above) should be adhered to and cyclists could reduce the potential to startle other trail users by announcing themselves well in advance. Moore (1994) also points to education as being instrumental in increasing safety on trails including volunteer trail patrols which can be used to spread the message.

United States Forest Service managers mainly used indirect approaches such as signs, brochures and maps to manage safety issues, although bridge building (e.g. workshops and personal contact), direct approaches (e.g. law enforcement, trail separation) and resource hardening (wider curves, waterbars) were also reported (Chavez, 1996a).

2.4.3 Environmental damage

Chavez (1996a) in her survey of National Forests in the United States found that 25 of the 90 respondents did not use any management tools to address resource damage. The strategies employed most often were resource hardening (e.g. trail surface, water bars and good trail design) and indirect management approaches (e.g. signs, brochures and newspaper articles). Direct management approaches (e.g. trail closures and law enforcement) and bridge building (personal contacts, bike club meetings) were used to a lesser extent.

Widmer (1997) points to the importance of rider education in reducing environmental damage. According to him a skilled rider employs good riding technique and an aware rider rides at an appropriate level, therefore skidding is avoided and trail erosion reduced. Trail damage and erosion could be diminished if IMBA rules 1,2 and 3 (see above) were followed by cyclists. Education of mountain bikers can also raise awareness of managers' concerns in relation to resource management. This can lead to better cooperation and understanding between riders and managers, resulting in reduced environmental damage.

According to Wöhrstein (1998), using low or no profile tyres (semislicks or slicks) can reduce the amount of soil material loosened on trails by mountain bikes. Most of the force exerted by a bicycle is conducted through the hind wheel whereas all of the steering and up to 80% of the braking power is conducted through the front wheel. Wöhrstein (1998) therefore suggests a high profile tyre on the front wheel to retain control for braking and steering whereas a slick or semi-slick tyre is considered sufficient for the hind wheel in most conditions. This tyre profile combination reduces erosional impacts on surfaces and generally provides enough traction, but forces riders to dismount in very wet conditions thereby protecting the soil when it is most vulnerable to damage.

As Cole (1983) points out trail maintenance, rebuilding or relocation is expensive so it is paramount that these costs be minimised. This can be achieved through anticipation of likely trouble spots and appropriate trail design and location that avoids these areas. Monitoring should be used to alert managers to areas that need attention which can then be repaired or realigned before they deteriorate and expensive remedial measures are needed, thereby keeping down maintenance costs.

Bjorkman (1996) also suggests that the best way to reduce trail damage and keep maintenance levels down is to avoid sensitive areas when routing a trail. These are very sandy and highly organic soils as well as slopes greater than 15%. If that is not possible then trail protection measures can be employed in susceptible areas. These can take the form of trail hardening where the soil surface is covered and/or strengthened with artificial materials or soil binders such as concrete. Water bars which effectively reduce the length of a slope thereby reducing water velocity and erosive potential, runoff and trail damage can also be utilised (for a detailed description of materials and techniques see Bjorkman, 1996).

To avoid damage to the 'greater' environment beyond the trail itself, care should be taken to avoid certain habitats with rare species or ones that are sensitive to this kind of disturbance (Bjorkman, 1996). For this it is important to undertake a biological inventory before siting the trail. A narrow trail corridor should be maintained to reduce impacts. Bjorkman (1996) also points to the lack of knowledge in regard to the impacts of narrow trails beyond the immediate trail corridor and the need for more research in the area.

Proactive management is a very effective way of maintaining good trail condition and should entail the formulation of a plan with clear goals and objectives and the setting of trail standards. Adequate funding and resources as well as regular monitoring are essential to provide quality trails and keep environmental damage in check (Bjorkman, 1996).

2.4.4 Other issues related to management

Chavez (1996a) concluded that a variety of management techniques were used by forest managers to address the various problems associated with mountain biking but that research is needed to evaluate the effectiveness of these different approaches. She also pointed out that provisions for mountain bikes should be made in forest management plans and policies developed to deal specifically with mountain bike related issues. Chavez et al. (1993) stressed that an important aspect of good management is ongoing communication between managers and users.

When Chavez (1996b) asked National Forest managers if forest plans provided for mountain bikes 53% of respondents answered with 'yes'. In contrast, when Schuett (1997) surveyed all State Parks in the USA only three of them did not allow mountain biking and of the others only five had an existing management plan. In ten States a statewide policy on mountain biking was in existence whereas in the other States policies were park specific. Provisions for mountain bikes were made in nine state trail management plans. The levels of cooperation between park managers and mountain bike clubs was high (78%) and was mainly in the areas of trail maintenance and development. Rider education and public information, volunteer patrols, adopt-a-trail and special events and races were other areas of cooperation.

Schuett (1997) also found that in most State Parks mountain biking was allowed on designated trails and only few allowed mountain bikes on all trails. Mountain bike use was permitted to varying degrees on paved roads, on gravel roads and on abandoned roads. Trails open to mountain biking varied between less than 1% to 100% with a median of 21% and from less than 1 mile to 1600 miles. Half of the managers estimated use levels to be low, the other half as moderate.

Various examples of the problems associated with mountain biking and the different approaches to management in various settings have been published and are informative and sometimes entertaining to read (for example Baker, 1990; Jacoby, 1990; Grost, 1989).

In the Marin Municipal Water District Watershed (California,USA), where the first "clunkers" were ridden down Mt. Malpais, mountain bikes have been perceived to be a problem on the trails from the mid nineteen seventies, shortly after the first mountain bikes began to appear. In 1977 the first citations were issued to cyclists, and in 1984 a speed limit of 15 mph was set for bicycles on fire tracks and paved roads. Bicycles were completely banned from trails, and that eventually included possession of a bicycle on the trails, even if carried on the shoulder (Edger, 1997).

These regulations were enforced, with rangers devoting considerable time to trail patrols. Various methods of speed measurements were used culminating in the introduction of radar guns in October of 1989. In that year 122 citations were issued, increasing to 216 in 1990 and since then varying between 140 and 204 per year. The fine for possession of a bicycle on a trail is $125.00 and for speeding $250.00 (Edger, 1997). The message that the District was serious about enforcing its mountain biking regulations has apparently been received, with many cyclists telling rangers that "it's just not worth the hassle" to ride in the watershed (Edger, 1997).

Another approach utilised in the District Watershed was that of education. Signs were posted, a map was produced and a brochure of bicycle etiquette distributed. In 1986 a bicycle advocacy group was formed, which produced a bicycle regulation sign and conducted information outposts in cooperation with rangers and a little later with a hikers and equestrian advocacy group. Outcomes included increased public awareness and the promotion of responsible bicycling. Also the various interest groups came to know each other better as well as their respective positions (Edger, 1997).

On a positive note the International Mountain Bike Association (no date) has put together a booklet of 'Mountain bike success stories' which contains case studies to that effect.

2.5 Rider preferences

To enable appropriate design and management of mountain bike trails information is needed on how mountain bike riders actually use trails and what they expect in terms of experiences and settings (Cessford, 1995a). Research to explore various aspects of mountain bike rider behaviour, preferences, perceptions and demography was undertaken in the United Kingdom by Ruff and Mellors (1993) and in New Zealand by Cessford (1995c). In the United States of America Watson et al. (1991), Chavez (1993), Blahna et al. (1994), Blahna, Van Patten, Dawson, Reiter and Van Koch (no date), and Hollenhorst, Schuett, Olson and Chavez. (1995) investigated the same aspects. In Germany Wöhrstein (1998) did an extensive survey of mountain bikers through a bike magazine.

All researchers found that males around the age of 30 years dominated mountain biking, although participants were slightly younger in New Zealand and Germany compared to the US and the UK. This finding is consistent with mountain biking being regarded as a form of adventure recreation (Priest and Dixon, 1990) where participants look for a certain element of risk, excitement and peak experiences (Ewert, 1989). Hollenhorst et al. (1995) have confirmed that mountain bikers are looking for these elements in their sport. Cessford (1995b) points out that trail design, in regards to surroundings, incline, and length of a trail, as well as difficulty and variation of a course, plays an integral part in satisfying these user expectations.

Watson et al. (1991) explored hiker and mountain biker perceptions in regard to conflict and found that few mountain bikers disliked hikers. Interestingly, a very high proportion of bikers came to the Rattlesnake Natural Recreation Area (USA) because of the wilderness experience and many of them came alone.

Ruff and Mellors (1991) found that two thirds of respondents had ridden a mountain bike for more than two years and 86% went cycling more than once a week. The same high percentage of riders used their bikes for training for competition or fitness, which becomes understandable when considering that only mountain bike club members were sampled. Another 30% used their bikes for recreation purposes and 8% rode to work. Riders preferred a forest setting to mountains and moorland, with only few riders preferring country parks and farmland. Bridle trails were preferred over footpaths.

Although Cessford (1995c) also found a low percentage of women in the sport in New Zealand, a high component (42%) of beginner riders were women. This was taken as an indication that rider characteristics are in flux. He also found a variety of preferences and settings that were important to riders of all levels, such as exploration of new areas, scenery and nature, speed and excitement, and socialising as well as native forest and undulating terrain. Preferences for other features depended on the level of experience where technical challenges, speed, racing, single track, fast technical downhills and long steep uphills with rough hard surfaces became more important to more experienced riders. Obstacles and difficulties on the tracks were also more preferred by these riders. Altogether, racing was not very important to riders but many experienced riders had done overnight tours. Overall riders did not like to meet motorised vehicles and had a somewhat negative attitude towards meeting walkers. More experienced riders were more accepting of other mountain bikers than less experienced riders and were more tolerant of pine forest and farmland. When the attitudes of riders toward management issues were explored, riders believed that most walking trails should be available for riding and that damage done by mountain biking is overrated. Voluntary codes of conduct were seen as a preferred management option.

Chavez (1993) found that most respondents to her survey of mountain bike riders on the San Jacinto region were riding with friends and fewer rode alone or with family. On average, mountain bikers had been riding a mountain bike for 4.6 years; had ridden 42 times in the previous year, and their rides averaged 14.2 miles. Membership with various mountain bike organisations was low. Opinions on trails and trail use were also explored with most riders agreeing with the need for trail etiquette and environmentally responsible behaviour. When asked about the desirability of various items at the trailhead, riders indicated a map of the trail with mileage, signs showing permitted and prohibited trail users and drinking water were the most desired items. Toilets and parking were of medium importance.

Hollenhorst et al. (1995) also found that most mountain bikers in his survey of five US National Forests rode with friends and that they preferred trails to roads. Average riding experience in years was 3.75 and in the previous 12 months they rode a mountain bike on average 67 times for about 15 miles per ride. Reasons for riding a mountain bike were given as enjoyment/fun (30.5%), exercise (23%) and being in nature (10.8%).

In his survey of the readership of a German mountain bike magazine, Wöhrstein (1998) utilised only 1,600 of the 3,100 forms received because after 400 forms had been analysed values only changed on the decimal places. The unusually high respondent rate was attributed to the great interest of mountain bikers in the environment and associated issues. Wöhrstein (1998) found that most mountain bikers rode a sport or racing bike but that only 15% of them were club members. The bikers rode their bikes on average about four times a week and close to 3,500 km a year. The average ride length was calculated as 16.5km. 43% of riders indicated that they did tours and close to 37% used their bikes to ride around the city or to work. 96% used their mountain bike for rides in the countryside. Gravel roads were most frequented, followed by trails between 1m and

2m wide sealed roads and footpaths below 1m width followed this. Only very few mountain bikers did not ride on trails. Overall, riders experienced few problems with walkers, although women had slightly more problems than men did and young riders had more problems than older ones. When asked to compare the impacts of mountain bikes with those of hiking, mountain bikers estimated the impacts to be the same.

To date, research on mountain bike trail impacts and design has been of limited relevance to Western Australia because of differences in the environments used. The same may be true for user expectations, preferences and perceptions and urgent investigation is needed (E. MacGregor, Trailswest, pers. comm., 13 August 1998). Nevertheless, the overseas studies provide a useful framework for designing mountain bike research programs in Western Australia and can be used to make interesting comparisons.

2.6 Mountain bike trails in Western Australia

Trails currently used for recreational mountain biking in Western Australia are vehicle tracks, walking trails, equestrian tracks and some mountain bike specific trails (CALM, 1997; M. Ahrens, WAMBA, pers. comm., 20 August 1998). Some of the trails that have been approved for mountain bike use have not been designed specifically for use by mountain bikes and other trails are being used illegally by mountain bikers (E. MacGregor, Trailswest, pers. comm., 18 August 1998). Therefore, these trails may be susceptible and subject to specific environmental impacts caused by mountain bikes and subject to user conflicts associated with mountain biking.

The Western Australian Mountain Bike Association (WAMBA) and the Department of Conservation and Land Management (CALM) plan to increase the number of trails for mountain bike specific use as well as multiple-use (M. Ahrens, WAMBA, pers. comm., 20 August 1998; B. Cuthbert, CALM, pers. comm., 21 August 1998). In the long term a comprehensive recreation trail network throughout the South West of Western Australia is envisaged, which will include walking, horse riding and mountain bike trails (Trailswest, 1998). WAMBA in conjunction with Bikewest, CALM, Trailswest and the regional development councils concerned (Southwest, Great Southern and Peel) are planning to initiate a mountain bike trail network in the Southwest. Existing and planned mountain bike loops will be connected with a 'Bibbulmun Track' style long-distance trail (Les Machin, Ewen MacGregor, Jim Krynen, pers. comm., 1999). Consequently, there is a need for reliable information on environmental management requirements and user expectations for the development, operation and management of mountain bike facilities by the managers of forests and trails in Western Australia (e.g. CALM, Trailswest, Water Authority, mountain bike clubs). A draft report by Brindal and CALM (1995) has addressed many of the issues outlined above but has not been published.

In Western Australia a process is in place to ensure that trails are sited and built in an appropriate manner. The initiator of a mountain bike trail is usually a mountain bike club. The first step is to contact the authority responsible for the land in question. In the case of trails on CALM controlled land, CALM conducts an environmental inventory to assess the suitability of the area for a mountain bike trail. The club then sites the trail in cooperation with CALM and applies for funding assistance if needed. Trailswest, for example, has a process in place to allocate funds from the trails funding program of the Lotteries Commission of Western Australia to community groups that want to build trails. The last step is to build and/or mark out the trail, which will be the responsibility of the club, although CALM will ensure that their trail building standards are met. CALM also plays an advisory role and ensure that the trails are managed and maintained to their standards. In the case of trails on other public lands the trail development process would be similar but would entail a different authority. (Bill Cuthbert, CALM and Ewen MacGregor, Trailswest, pers. comm. on various occasions in 1998 and 1999). Besides the allocation of funds, the role of Trailswest is to coordinate the trail planning and building efforts in Western Australia, develop policies, provide guidelines for trail development and information, education and advise on trail related matters. Trailswest also advocates trail development and use and peak user groups (walkers, mountain bikers and horse riders) (Trailswest, 1998)

The current approach to trail design is founded in landscape architecture and design principles and these principles are adapted as needed (Mike Bodsworth, pers. comm., 6 April 1999). The Tasmanian Walk Track Manual (Department of Lands, Parks and Wildlife, 1987) is used for basic specifications of trails and a basic trail classification system is applied. There is no specific Western Australian trail building manual available at the present time.

At Manjimup, kangaroo tracks were utilised in the design of a racetrack (Richard Robinson, pers. comm., February 1999). It was found that these tracks follow good gradients along slopes and, because they are well worn in by the animals, little effort is needed to actually 'build' the trail. The track formed in this way has shown minimal deterioration even though it has been used for racing periodically over the last year. Les Machin (pers. comm., 1998, 1999) pointed out that the approach taken in the construction of mountain bike trails by the Peel District Mountain Bike Club is designed to cause the least amount of environmental impact possible. Hence major obstacles are circumvented or utilised wherever possible and the removal of vegetation, especially of larger plants, is avoided. Curves are built not too tight for ease of manoeuvering and care is taken to reduce the risk of injury for riders by avoiding or removing branches at eye height, rocks in the curves and debris from the trail.

The paucity of studies specific to Western Australia highlights the urgency of investigating both the environmental and social aspects of mountain biking which are important to trail design. This study aims to provide some recommendations for landscape and mountain bike trail designers to assist them with the planning of future trails, either multiple-use or mountain bike specific.

2.7 Summary

Mountain biking is a popular sport and recreational activity, but concerns have been raised in regard to its impacts. Three areas of mountain bike management have been identified by Cessford (1995a). These are: the physical impacts of mountain biking on trails and the environment; the social impacts of mountain biking on other trail users, and the preferences of mountain bikers in regard to settings and experiences.

Little literature is available on mountain bike specific impacts on trails. Nevertheless, some principles can be derived from the literature on the impacts of trails on the environment and the effects of trail use on trails. The few studies that are available equate the damage done by mountain bikes with that of walkers. Environmental parameters were found to be the main source of trail erosion (Seney and Wilson, no date). From the literature on trail damage, irrespective of user, soil characteristics (for example soil texture and grading), steepness and length of slope, rainfall and vegetation cover, as well as amount of use determine trail erosion potential. Soil compaction is another parameter that can influence trail erosion through an increase in runoff. All these factors should be taken into consideration when building a low maintenance trail.

More literature was available on trail use conflicts and shared use impacts. Conflicts between walkers, horse riders and mountain bikers have been described but in some cases the conflict potential was considered small. Issues such as the perceptions that mountain bikes pose a safety hazard to other users or that they are a threat to the environment could not be substantiated and most conflict seems to be of a more intangible nature.

Various management options have been suggested for the impacts of mountain biking. Most importantly, the careful location and design of trails can avoid resource damage. In the case of existing trails, trail hardening, rider education and trail closures are some of the options available to resource managers. In the case of user conflict, management options ranged from user education to prohibition and user separation.

Rider preferences were assessed by a variety of researchers, most of whom found that mountain bikers prefer natural settings to ride in and that they ride fairly long distances. In addition, riders prefer trails with a variety of features. Some of the studies also found that riders prefer to ride with friends and that an important reason for riding a mountain bike is for fitness. All of these studies were conducted overseas.

In Western Australia, few mountain bike specific trails are available and most trails have been built for other users and are also still used by them. These trails may be susceptible to damage by mountain bikes and shared use conflicts. Plans are under way to increase the number of mountain bike trails in Western Australia, therefore information in regard to trail damage by mountain bikes and preferences of mountain bike riders in Western Australia is critical to ensure that the trails are environmentally appropriate and wanted by mountain bikers. To date, virtually no research on mountain bike related impacts is available in Western Australia and the approach to trail design has been based on general landscape architecture principles and walking trail design.

3 Methodology

The study considered two major aspects of mountain bike management. Physical impacts of mountain biking were studied under recreational use and cross-country racing conditions, and user needs and perceptions were investigated, specifically the trail features and settings mountain bike riders seek, the kinds of trails they use and how they use them. In addition, rider demographics as well as awareness and perceptions in regard to mountain biking, mountain bike trails and the environment, especially dieback, were explored.

The two aspects of the study required two independent approaches as described below. In section 3.1 the physical impact study is outlined. A site description is followed by the respective research designs for the racecourse and the recreation trail. Methods and data analyses are then described. Section 3.2 outlines the user preferences and perception study and corresponding analysis.

3.1 Assessing Environmental Impacts

Firstly, relevant government departments and mountain bike associations were contacted to determine appropriate trails for the project. Time and resource constraints have limited the detailed trail studies to two sites, one cross-country racing trail and one recreational trail.

3.1.1 The sites

Lowden cross country (XC) race trail

A suitable cross country racecourse was located on a private property in Lowden in the Preston Valley, approximately 50km inland from Bunbury (Figure 3.1). The track is used almost exclusively by mountain bikes and access is controlled. This is important because on all other potentially suitable trails trail bikes (motorcycles) are known to also use the tracks. Parts of the Lowden course have been used for mountain bike racing before, whereas other sections were established just before the start of this study and had never been used for racing prior to this study (see Figure 3.2). This provided an opportunity to investigate the initial as well as ongoing and accumulative impacts of cross-country racing. The track is 3.7km long and traverses through jarrah and marri forest with an understorey of banksia and balga, which was selectively logged in the 1950s.

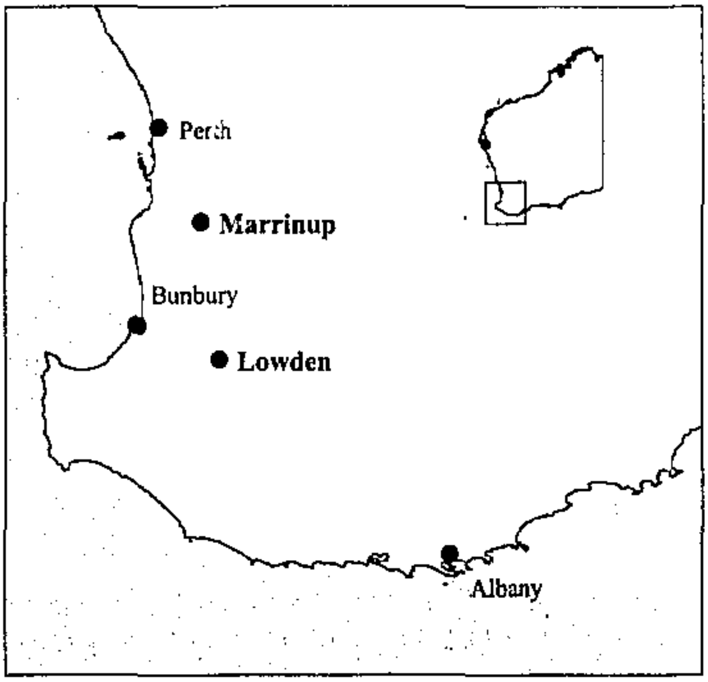


Figure 3.1: Map of Western Australia with the approximate location of Lowden and Marrinup

Racetrack preparation of the new track consisted of removal of litter and unwanted debris. Obstacles such as logs were incorporated into the trail and adapted for mountain biking whereas living plants or other 'unrideable' objects were avoided. Some small woody plants were removed at ground level. No other work was undertaken to prepare the track for racing. Hardening of the track was not considered necessary for preparation, nor was this desirable for its purpose as a XC track.

For the races the entire track was marked with tape and small signs, which were removed after the race. The racetrack was marked for racing at two different levels of difficulty. At cadet, sub-junior and fun levels a shorter version (2km) of the trail was used whereas at junior, sport and expert levels the full length of the track was ridden. In the intervening time between the races the track was used for fun and for training purposes. Not all parts of the track received the same use but use levels at different sections was impossible to discern with only one counter in place.

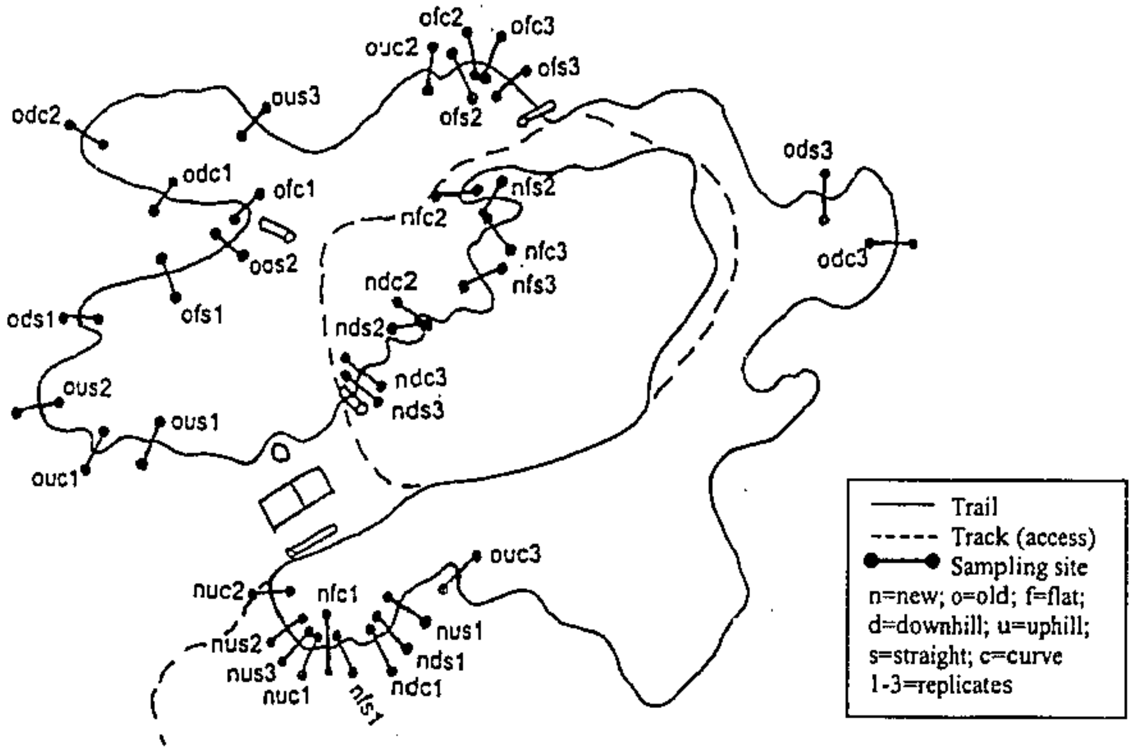


Figure 3.2: The Lowden cross-country racetrack with sampling sites
(Adapted from a map supplied by Barrie Thomas)

Marrinup recreation trail

A suitable recreational trail was located at the former Marrinup Townsite, which is now a recreation area. The site is situated about 6km northwest from Dwellingup and approximately 100km from Lowden (see Figure 3.1). The area was mined for bauxite from 1974 to the mid 1980s and has been rehabilitated since then. The town burned down in the 'big fire' in 1961 and was never rebuilt. Most of the trail runs through a minesite rehabilitation area with mixed regrowth forest and some marri/jarrah and sheoak stands.

The track was constructed in 1997 as a recreational mountain bike trail but is used for racing occasionally. The track is approximately 10.5km long. Many obstacles were retained on the trail and this it was believed would deter motorcycle use of the trail. Funding has been approved by Trailswest to mark the trail with permanent trail markers and trailhead signage. A preliminary map is available from the Peel District Mountain Bike Club (Figure 3.3). At the time of the study the trail could be followed with the help of some markers left along the trail from the racing events. The trail follows stretches of single track interspersed with fire tracks and a service track for a golf course.

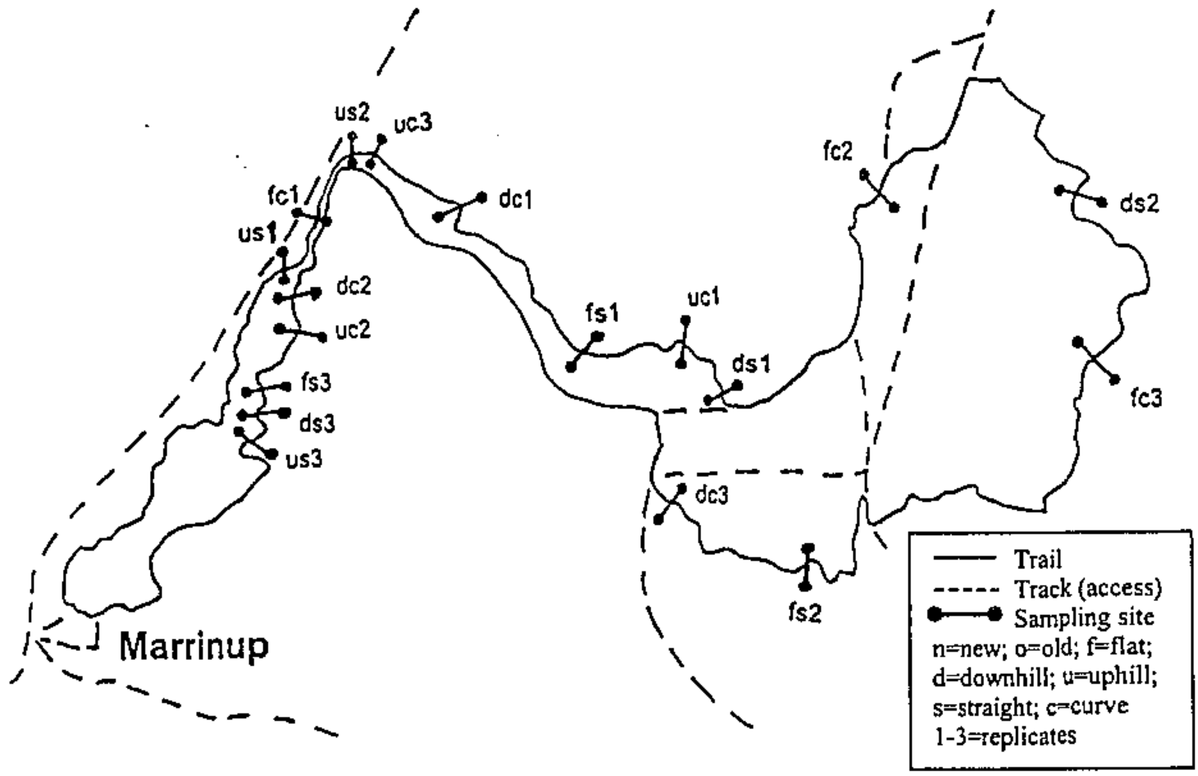


Figure 3.3: The Marrinup recreation trail with sampling sites
(Adapted from a map supplied by Peel District Mountain Bike Club)

Both trails fulfil the requirements for mountain biking, that is, they provide a variety of experiences and features to make them interesting to ride, such as logs, uphill stretches, downhill stretches and a variety of combinations of curves and straight stretches.

3.1.2 Research design

Racing use

The racing trail was divided into sections based on age and slope (Figure 3.4). Within these sections straight stretches and curves were distinguished as trail features (Table 3.1). It was deemed necessary to distinguish between these attributes because different impacts were expected in curves as opposed to straight stretches and on uphill, downhill or flat stretches of trail. In each category three randomly placed samples were taken before the race, immediately after the race and subsequently at approximately monthly intervals for four months (Table 3.2). A race on Sunday, 7 February 1999 was taken as an opportunity for an additional sampling event. Sampling was carried out at a high frequency to obtain a detailed picture of the changes to the trails and adjacent areas.

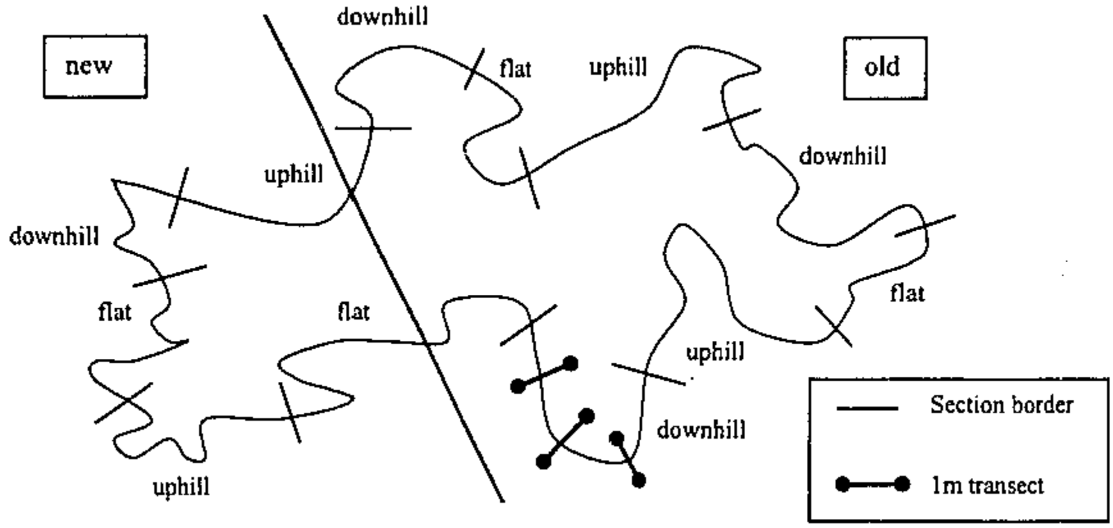


Figure 3.4: Illustration of division of trail into sections according to age and slope

Table 3.1: Experimental design for trail transects (cross-county racing)

Age (x2)	old						new					
Incline (x3)	uphill		downhill		flat		uphill		downhill		flat	
Feature (x2) (straight/curve)	s	c	s	c	s	c	s	c	s	c	s	c
Replicates (x3)	3	3	3	3	3	3	3	3	3	3	3	3
Samples over time	6	6	6	6	6	6	6	6	6	6	6	6

Table 3.2: Sampling times and dates for Lowden race course

Sampling time	**Sampling dates**
Time 1	18 – 20/9/1998 (before race)
Time 2	20 – 21/9/1998 (after race)
Time 3	30/10 – 01/11/1998
Time 4	23 –25/11/1998
Time 5	18 – 21/12/1998
Time 6	08 - 10/02/1999 (after summer race)

At each sampling time a number of environmental parameters were measured and recorded (see section 3.1.3). The data were then analysed as described in section 3.1.4.

Recreational use

The recreational trail at Marrinup Townsite was sampled using a similar research design as that for the racetrack. The entire track was divided into sections in regard to slope as at Lowden (Figure 3.4), but since the entire trail was used before the beginning of the study no differentiation between new and old sections was possible (Table 3.3). Sampling took place at approximately monthly intervals (see Table 3.4 for dates) to investigate changes in the trail over time and with sustained use. The parameters sampled and the methods used are described in section 3.1.3. After compilation, the data were compared and analysed as outlined in section 3.1.4

Table 3.3: Experimental design for trail transects (recreational use)

Incline (x3)	uphill		downhill		flat	
Feature (x2) (straight/curve)	s	c	s	c	s	c
Replicates (x3)	3	3	3	3	3	3
Samples over time	5	5	5	5	5	5

Table 3.4: Sampling times and dates at Marrinup trail

Sampling time	**Sampling dates**
Time 1	24 – 25/10/1998
Time 2	22 – 23/11/1998
Time 3	16 – 17/12/1998
Time 4	14 – 15/01/1999
Time 5	11 - 12/02/1999

3.1.3 Methods

Micro profiles

Micro profiles are used to measure soil loss on trails and short and long-term changes in the trail profile over time (Whinam and Comfort, 1996). A method very similar to the one used in this study is described in Coleman (1977), where it is classed as a medium-term measurement method. Cole (1983) described the method in detail, also explaining how the cross sectional area under the line can be calculated. He stresses that the line must be absolutely taut, that the height of the line must be exactly the same in every measuring event and that the measurements must commence from the same side of the trail. In this study it was endeavoured to follow these premises.

Whinam, Cannell, Kirkpatrick and Comfort (1994) described a similar methodology, but with a more sophisticated (square aluminium tubing) apparatus. In a similar study by Whinam and Comfort (1996), they observed an accuracy of about 1cm. The advantages of the method are its simplicity and inexpensiveness, while the lack of precision may be outweighed by the greater number and larger variety of sites that can be sampled and monitored. It is argued that if path erosion is too small to be measured by this technique, then it may not be a problem (Coleman, 1977).

Sampling in this study consisted of 1m wide micro profiles to measure soil displacement (Figure 3.5). Short pieces (30cm) of PVC pipe were hammered into the ground in an upright position and as deep as possible (in some cases the ground was hard and only minimum depth could be achieved) with at least the upper 3 cm of pipe showing. These permanent markers served as bases for the measuring apparatus. This apparatus consisted of two upright pieces of PVC pipe that held a horizontal taut line from which the relief measurements were taken at intervals of 5cm. Uprights and line were marked and levelled to ensure accurate and repeatable measurements (Figure 3.6). To ensure vertical measurement accuracy a soft measuring tape was weighted and used as a bob line. Vertical measurements were read to the closest 0.5cm. These measurements were taken at each site at every sampling event.

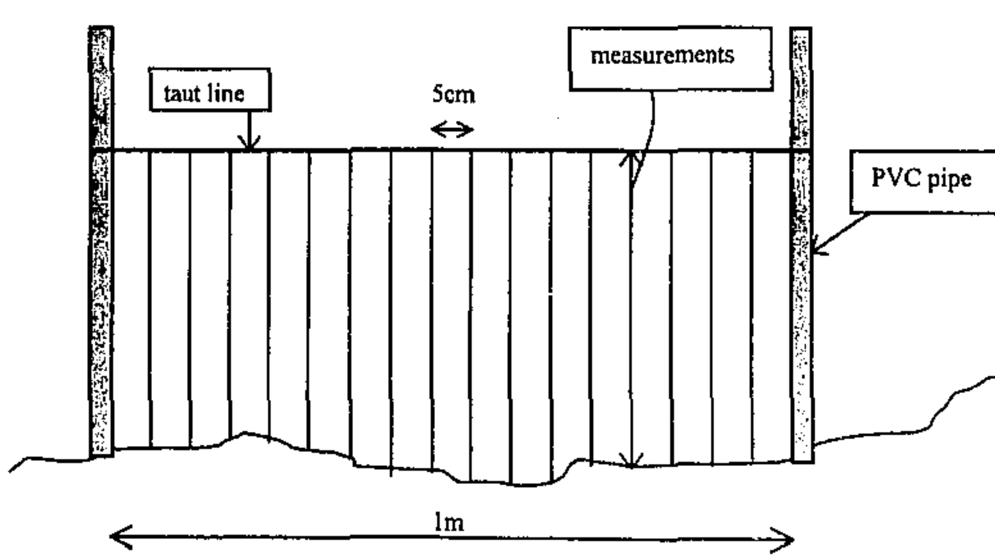


Figure 3.5: Set up for micro relief measurements

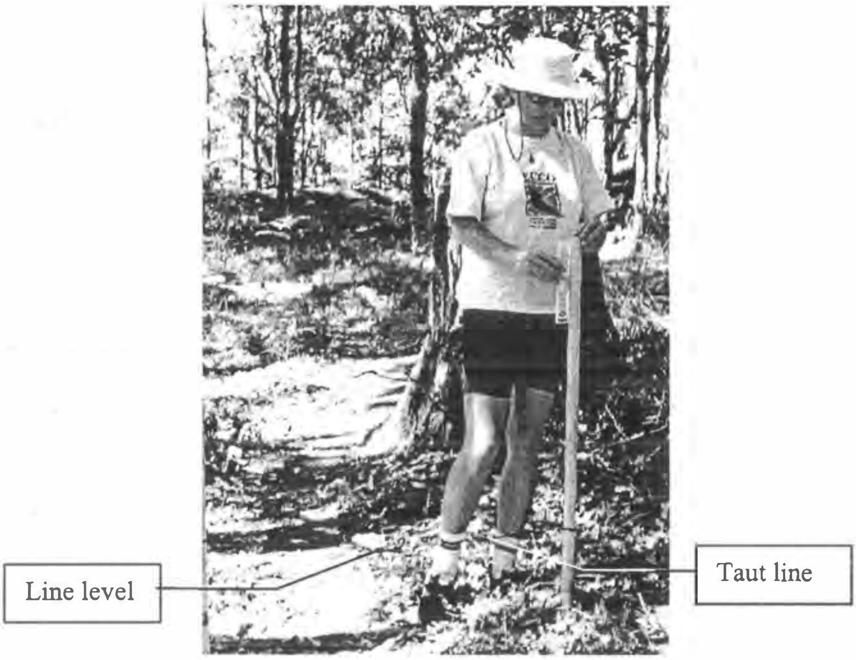


Figure 3.6: Setting up the apparatus in the field

Vegetation Damage

The micro relief transect was flanked on both sides by two 1 m quadrats (Figure 3.7). The quadrats were sampled using a $1m^2$ collapsible frame in which percentage vegetation cover was estimated in each quadrat. Damage to plants, e.g. broken branches, bruised leaves, was noted in the quadrats as well as tyre tracks, footprints and other notable occurrences. These measurements were taken at each sampling event at all sites.

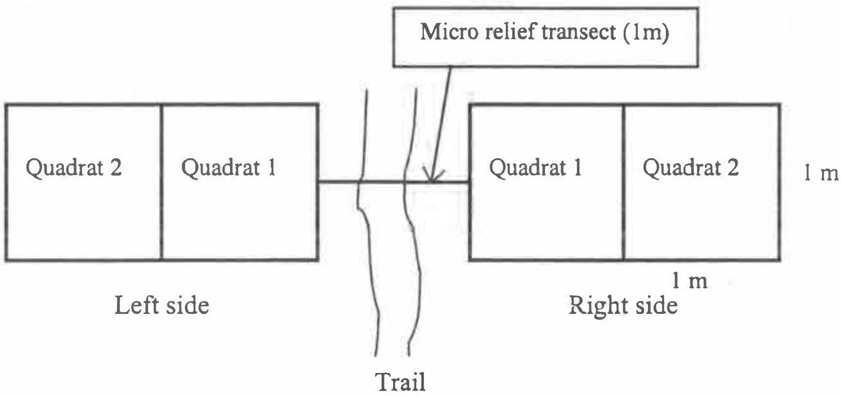


Figure 3.7: Set up for vegetation transects

Trail width

Trail width was determined by measuring the width of ground that was obviously used by mountain bikes. Although this visual determination was necessarily somewhat subjective it was deemed a better measure than width of exposed ground because the trail was at times partially covered with litter, or the exposed ground was clearly wider than the area actually used by the mountain bikes. This measurement was taken to determine if the track was widening as an indication of erosion and was repeated at each sampling occasion.

Soil compaction

Along the 1m micro relief line penetrometer readings were taken with a pocket penetrometer (Humboldt) after it was lowered to the ground (Figure 3.8) and recorded at 5 cm intervals to determine soil compaction in kilograms per square centimetre (kg/cm^2). In the 2m quadrat zones the intervals were increased to 20 cm. This was repeated at every sampling event. Soil compaction was measured because it gives an indication of soil permeability and increased compaction indicates increased runoff potential.

Figure 3.8: Set up for trail soil compaction measurements

Other measurements

Incline and aspect

A clinometer (Suunto PM-5/360 PC) was used to determine slope, which was noted as degree incline, and a Silva compass was used to ascertain the aspect of the trail in degrees from North.

Soil characteristics

Soil samples were taken immediately next to the trail to determine various soil parameters. Only small holes to a depth of about 20cm were dug to study the surface layers of the soil while keeping the environmental impact as low as possible. The depth of 20cm was considered sufficient since Wöhrstein (1998) found that soil compaction through mountain bike related activities occurred to about that depth. In addition, the maximum depth of trail erosion encountered in Tasmania was 15cm per year in fragile high rainfall environments (Ann Wessing, State Trails Conference, October 1998). Such conditions are not present at the study sites therefore erosion depth was anticipated to be below 15cm and well within the depth of soil analysis.

The depth of the O_2 horizon (organic layer), where present, and of the A horizon were determined. The O_1 horizon (litter) depth was not measured because this layer is removed during trail construction. Soil samples of the A horizon and, if encountered, the next horizon underneath, were bagged and analysed later. The difficulty of determining the horizons due to the shallow digging depth was considered to be acceptable because in most cases the differences in colour and/or texture between the layers were large enough to warrant the assumption that the horizon was a B horizon.

Field texture was determined according to: "A guide to field assessment of texture for mineral soils" by S. Northcliff, Reading University and J.R. Landon, Booker Agricultural International. Soil texture is deemed important for the erosive potential of a soil (Wöhrstein, 1998; Lal and Elliot, 1994; Marsh, 1991). Soil colour was determined with the help of a Munsell® colour chart (1994) as an aid to determine the horizon.

Fragment size and percentage of coarse fragments (>1mm) was determined visually. This rather subjective way of obtaining these measurements was chosen due to time constraints. Nevertheless, these parameters were considered to provide an additional indication as to the erodibility of the examined soils (Wöhrstein, 1998; Lal and Elliot, 1994; Marsh, 1991).

The property of some dry soils to repel water could have implications in terms of increased runoff and transport of loosened surface particles in the first good rains after a dry period. Therefore this property was noted at the same time that the soils were analysed for field texture and colour.

Trail use

A traffic counter consisting of a Pressure Mat (a series of metal strips, which act as contacts, sealed in plastic) was installed on a plywood base and connected to a Trail Count 1 electronic counter (by Ballinger Technology, Victoria). It was then buried 5-10cm deep in a suitable location on each trail to give an indication of the number of users over the time of the study and between visits.

Visual recordings

Repeated photographs have captured the visual impressions and change over time of the trail and its vicinity in the area of the quadrats. In addition, photos were taken during the summer race in Lowden to illustrate impacts of mountain bike cross- country racing at strategic locations.

Rainfall records

Rainfall records were obtained for the period of the study because rainfall is an important influence on trail erosion (Seney and Wilson, no date) The rainfall records for Lowden were provided by a Lowden resident and the records for Dwellingup were obtained from the CALM office there. Average annual rainfall figures were obtained from the Bureau of Meteorology web site.

3.1.4 Data analysis

The variables micro relief (% change in total measured area; for explanation see below and Figure 3.2 in the methods section), soil compaction and trail width were analysed by Analysis of Variance (ANOVA) and Analysis of Covariance (ANOCOVA). The quadrat data were compared visually.

In preparation for the analyses, the data were calculated as follows. Due to the nature of the measuring apparatus, the micro relief areas under the line were not directly comparable with each other. To achieve comparability the percentage area change in respect to time 1 were calculated for all subsequent sampling events at each site. For the relief soil compaction the means for each transect were calculated and the trail width data was used unchanged. Data was entered into a Microsoft Excel (Windows platform) spreadsheet for initial storage, verification and editing. Data were then analysed using SPSS version 7.5 for Windows.

The above data were analysed as a repeated measures general factorial ANOVA crossing features with incline and age (see research design). Before commencing with this analysis the data were checked for homogeneity of variance by calculating the coefficient of variation (CV). In addition the Levene's test of equality of error variances was performed as contained in SPSS. The micro relief data was arcsine transformed and the soil compaction as well as the trail width data was log transformed to control variability. The ANOVA's were then performed on the raw (non-transformed) as well as the transformed data. Various soil parameters (depth of O_2 and A horizon, % fragments of horizon A and B, fragments size of horizon A and B) as well as slope and aspect were recorded, transformed as appropriate (arcsine for % fragments) and used as covariates in the ANOCOVA's for the variables mentioned above.

The data generated in the quadrats to the left and right of the trail were analysed as follows. The averages of the percent vegetation cover data from the two quadrats on each side of the trail were checked for variability by calculating their CVs respectively. The 95% confidence intervals were calculated for the means and the means were then graphed over time and compared visually. Quadrat soil compaction was averaged for each side and also checked for variability by calculating the CVs. The 95% confidence intervals were calculated for the means and the data were then graphed over time and compared to the mean soil compaction of the trail itself (including the 95% confidence intervals).

3.2 Survey

3.2.1 The questionnaire

A short (four page) questionnaire (see Appendix 2B) was designed to generate information in the following four areas of user management:

1. preferences of mountain bikers in regard to trail features, settings and trail locations;
2. how and why mountain bike riders use trails;
3. perceptions of mountain bikers in regard to impacts of the sport on the environment and in respect to aspects of management; and
4. demographics.

The questionnaire was designed for easy and quick completion (8 to10 minutes) and focused on the above areas. A mix of open, closed and Likert scale questions was used as outlined in section 3.2.2 below.

After the questionnaire was developed, it was reviewed by various experts in the fields of mountain biking and survey design and then tested on 15 individuals to identify any problems with design, delivery, question clarity and response clarity. After the appropriate adjustments had been made and deemed satisfactory and ethical approval obtained, the questionnaire was distributed. In all, 980 questionnaires were printed and distributed.

Questionnaires were mailed out to all individual members of the Western Australian Mountain Bike Association (WAMBA) whose address was available (200). Packages of survey forms were sent or delivered to bicycle shops as well as to most regional CALM offices in the south west corner of Western Australia including the Perth metropolitan area for distribution to their customers and visitors. In addition, various mountain bike riders who were encountered either on the road or at sampling events were asked to fill in questionnaires. All questionnaires that were sent out were accompanied by a letter, which explained the research project and how to return the form(s) (Appendix 2A).

The respondents either returned the completed form to the researcher in person or posted it in a reply paid envelope, as in the case of WAMBA members. The shops and offices were asked to collate the questionnaires and either send them back in the reply paid envelopes provided or to await collection by the researcher.

All shops and offices were contacted by the researcher towards the end of January, inquiring about the progress made, and reminded to send the forms back by early February. Participating shops that had not returned the surveys by February 15 were contacted again and asked to return the forms immediately.

3.2.2 The questions

The first question asked if the respondent was a member of a mountain bike club (tick 'yes' or 'no'). The next six questions explored basic areas of interest in relation to management. Question 2 explored what motivation respondents had to ride a mountain bike. The question allowed multiple answers therefore the total of all answers is greater than 100%. Question 3 asked how often respondents ride a mountain bike (tick one choice) and Question 4 determined when they started to ride (complete year). Length of average ride was explored in Question 5 where respondents were asked to tick one of six ranges. Question 6 asked if riders had done tours that included overnight stays. In the case of a positive answer they were asked to specify number of tours done and number of nights stayed away on the last tour. If the answer was negative the interest in doing tours was explored (yes/no). In Question 7 riders were asked to list their three favourite riding areas or trails according to preference. All these answers were then collated and ranked according to how often they were chosen.

Questions 8 to 10 were Likert type questions aimed to examine rider preferences. Question 8 explored the extent to which riders like to encounter other trail and track users. The Likert scale ranged from 1 (love it) to 5 (hate it). Questions 9 and 10 both used the same Likert scale (from 1='essential' to 5='don't want at all'). They were designed to investigate how important various trail features were to mountain bike riders (in terms of surface, slopes, length of uphills and downhills, curves, other trail features, facilities and information) and which settings riders prefer (native bush, plantation forest, farmland, suburbs, sealed or unsealed roads, wide trails or single track).

Rider opinions were ascertained in Question 11 by giving short statements, which were to be answered with the help of a Likert scale ranging from 1-'strongly agree' to 5-'strongly disagree' and 6-'don't know'. Thirteen statements were provided relating to mountain bike management and environmental awareness. The statement "Trail damage by mountain bikes is overrated" was used to verify the statement " mountain bike riding damages trails".

Question 12 asked if riders were prepared to accept a voluntary code of conduct. The choice was 'yes' or 'no' with request for information about which aspects would be important or why a code of conduct would not be followed respectively.

The question "What type of mountain bike do you ride?" (Question 13) was asked to explore the level of riding in comparison to equipment. It was hypothesised that riders who were club members and partook in races had better equipment.

The next two questions were asked to explore aspects of dieback awareness and management. Question 14 explored how often riders clean their bikes and was asked in order to assess the potential of dieback being spread by mountain bikes. The subsequent question (Question 15) ascertained the level of awareness in regard to dieback risk areas. In the case of a positive answer, respondents were asked for details of what dieback risk areas are and where they are found.

The last three questions explored basic demographics in terms of age (tick a range; for reasons of comparability the same scale was used as CALM use on their survey forms) and sex. This information was sought to enable comparison of these parameters with studies conducted elsewhere. Post-code information was sought to enable comparison of place of residence and favourite riding area.

Space for additional comments was provided at the end of the questionnaire and respondents were encouraged to use it (Question 19).

3.2.3 Data analysis

The data was compiled and then analysed using SPSS for non-parametric statistics appropriate to the style of question. Percentages were used for closed questions, means and modes for Likert scales and counts for the open questions. In some cases, cross tabulations with Chi squared tests (SPSS 7.5 for Windows) made in the appropriate areas were typed out in full and collated.

Some adjustments in the data analysis were made when respondents did not answer a question or when they answered single-answer questions twice. A few respondents ticked two boxes in both Question 3 and Question 5. These multiple answers were explored separately from the single answers and excluded from further analysis. The multiple answers received for Question 14 were also analysed separately and did not enter the cross tabulations.

In Questions 8 to 10 the means and modes for the answers were derived from all answers received. If the question was not answered it did not enter the analysis. In Question 11 the same principles applied. In addition, the answers in the 'don't know' category were analysed for percentage of answers but did not enter the means and modes. The comments of Question 12 and Question 15 were sorted into categories and ranked according to frequency. The comments that were received at Question 19 were tallied and then separated as far as possible to allow sorting into categories and ranking according to frequency.

The cross tabulations for rider motivation were based on the categories 'recreation only' and 'racing and recreation', the 'racing only' category was omitted due to low numbers.

4 Results

4.1 Biophysical Impact Study

4.1.1 The trail: Micro relief, soil compaction and trail width

Overall, the trail data for micro relief, soil compaction and trail width showed high variability at both sites, as shown by the coefficients of variation (Tables 4.1 to 4.6) as well as by the Levene's (equality of error variances) tests carried out in conjunction with the analyses of variance (ANOVA's) (Table 4.7). Nevertheless, ANOVA's were calculated because standard non-parametric methods appropriate for the experimental design (repeated measures general factorial ANOVA) of this project could not be found (Zar, 1984). In addition, Chapman, Underwood and Skilleter (1995, p. 108) point out that: "Analysis of variance is relatively robust to heterogeneous variances..." Analyses of covariance (ANOCOVA's) were also carried out to investigate the relationship between the covariates aspect, incline and various soil parameters with the variables micro relief (% change), soil compaction and trail width. In addition, the intention was to take advantage of the potential of ANOCOVA to adjust the means and thus reduce variability of the parameters tested (Steel and Torrie, 1960). The results of these tests are outlined below contrasting the locations for each variable. The significance level in all cases is 5% unless stated otherwise. Throughout, the ANOVA and ANOCOVA interactions (2-way and 3-way) were often significant. Hence, interpretation of the effect of significant single factors (age, feature or slope) are constrained.

Table 4.1: Lowden, means, standard deviations and coefficients of variation for micro relief (% area change in relation to time 1)

	time1-time2				time1-time3				time1-time4				time1-time5				time1-time6			
Site	%change	mean	stdev	CV (%)	%change	mean	stdev	CV (%)	%change	mean	stdev	CV (%)	%change	mean	stdev	CV (%)	%change	mean	stdev	CV (%)
ndc1	-11.00				-10.05				-9.00				-10.34				1.54			
ndc2	-20.25				-82.79				-18.63				-21.14				-1.51			
ndc3	-9.62				-12.29				-14.85				-12.97				-6.28			
ndc		-13.62	5.78	-42.44		-35.05	41.37	-118.04		-14.16	4.85	-34.27		14.82	5.63	-37.99		-2.08	3.94	-189.11
nds1	0.03				-0.03				4.11				2.27				-0.23			
nds2	-14.41				-16.31				-6.68				-11.79				7.90			
nds3	-8.13				-6.01				-4.88				-5.14				4.16			
nds		-7.50	7.24	-96.55		-7.45	8.23	-110.52		-2.48	5.78	-232.59		-4.89	7.03	-143.87		3.94	4.07	103.19
nfc1	-13.33				-8.52				-8.62				-11.86				2.18			
nfc2	-1.76				-1.42				0.40				-1.62				2.67			
nfc3	-2.87				0.38				0.20				1.01				3.88			
nfc		-5.98	6.39	-106.72		-3.19	4.71	-147.47		-2.67	5.15	-192.69		-4.16	6.80	-163.59		2.91	0.88	30.17
nfs1	-14.80				0.35				-7.79				-6.59				8.23			
nfs2	-2.03				-3.25				-2.20				-2.06				-1.16			
nfs3	-2.84				0.89				-7.40				0.68				2.13			
nfs		-6.56	7.15	-109.08		-0.67	2.25	-335.63		-4.13	3.17	-76.85		-2.66	3.67	-138.32		3.07	4.76	155.36
nuc1	-1.69				-0.96				0.76				-2.17				3.07			
nuc2	M				M				M				M				M			
nuc3	-3.88				-2.47				-2.30				-9.78				1.84			
nuc		-2.78	1.55	-55.60		-1.72	1.07	-62.62		-0.77	2.16	-282.65		-5.97	5.38	-90.13		2.45	0.87	35.54
nus1	1.08				4.14				14.43				5.78				4.15			
nus2	1.09				1.59				2.12				1.93				2.96			
nus3	-10.01				-9.48				-6.75				-6.27				4.26			
nus		-2.61	6.41	-245.13		-1.25	7.24	-578.22		3.27	10.63	325.47		0.48	6.16	1285.98		3.79	0.72	18.99
odc1	2.99				2.32				1.83				27.35				-6.28			
odc2	-2.54				1.32				3.02				-0.45				-1.50			
odc3	-1.90				-1.65				-1.97				-1.94				0.78			
ndc		-0.48	3.03	-626.51		0.66	2.06	311.97		0.96	2.60	270.97		8.32	16.50	198.22		-2.33	3.60	-154.27
ods1	-6.34				-4.21				-10.17				-0.72				-5.12			
ods2	4.52				0.83				-3.24				13.19				-0.78			
ods3	6.31				0.31				1.14				4.89				0.83			
nds		1.50	6.85	4.57.50		-1.02	2.77	-270.76		-4.09	5.70	-139.44		5.78	7.00	121.02		-1.69	3.08	-181.88
ofc1	0.92				2.74				2.71				-2.10				0.52			
ofc2	-2.89				-4.07				2.62				-3.98				1.96			
ofc3	-0.83				1.72				0.14				-2.48				-1.54			
nfc		-0.93	1.90	-204.17		[illegible]	3.67	2789.16		1.83	1.46	80.11		-2.85	0.99	-34.86		0.31	1.76	561.59
ofs1	1.39				2.22				0.74				-4.05				-4.28			
ofs2	-3.08				2.21				2.38				-1.81				4.78			
ofs3	0.12				-0.87				-3.08				-2.35				-1.87			
nfs		[illegible]	2.31	-441.27		1.19	1.78	150.50		0.01	2.80	20054.1		-2.74	1.17	-42.70		-0.46	4.69	-1020.83
ouc1	-7.86				-8.04				-12.05				-10.89				-2.08			
ouc2	-0.64				-1.04				-2.93				-15.67				-1.35			
ouc3	-1.78				-0.47				-0.96				-1.87				-0.49			
nuc		-3.43	3.88	-113.11		-3.18	4.22	-132.56		-5.31	5.91	-111.24		-9.47	7.00	-73.93		-1.31	0.80	-61.02
ous1	7.78				8.46				7.71				1.58				-7.19			
ous2	-0.74				1.16				-0.03				1.88				-3.67			
ous3	0.00				-1.27				-2.22				-4.42				-3.42			
nus		2.34	4.72	201.3[illegible]		2.78	5.06	181.93		1.82	5.22	287.02		-0.32	3.55	-1101.38		-4.76	2.11	-44.36

site: n=new; o=old; d=downhill; f=flat; u=uphill; c=curve; s=straight; number refers to replicate; M=missing data CV = Coefficient of variation; M = missing data; stdev= standard deviation

Table 4.2: Marrinup, means, standard deviations and coefficients of variation for micro relief (% area change in relation to time 1)

	time1-time2				time1-time3				time1-time4				time1-time5			
Site	**%change**	**mean**	**stdev**	**CV (%)**	**%change**	**mean**	**stdev**	**CV (%)**	**%change**	**mean**	**stdev**	**CV (%)**	**%change**	**mean**	**stdev**	**CV (%)**
dc1	8.43				0.33				1.98				0.79			
dc2	0.21				1.36				0.62				0.51			
dc3	1.28				2.25				2.28				-0.18			
dc		**3.31**	**4.47**	**135.28**		**1.31**	**0.97**	**73.50**		**1.63**	**0.89**	**54.62**		**0.37**	**0.50**	**134.22**
ds1	0.83				1.72			-	2.55				0.62			
ds2	3.96				-12.08				-11.83				-11.32			
ds3	0.43				2.42				1.87				1.11			
ds		**1.74**	**1.94**	**111.26**		**-2.64**	**8.18**	**-309.23**		**-2.47**	**8.11**	**-328.53**		**-3.19**	**7.04**	**-220.44**
fc1	2.36				-1.43				3.48				16.82			
fc2	1.65				1.68				1.77				4.25			
fc3	0.29				0.13				-1.54				0.80			
fc		**1.43**	**1.05**	**73.58**		**0.12**	**1.55**	**1246.68**		**1.24**	**2.55**	**206.06**		**7.29**	**8.43**	**115.67**
fs1	-1.93				-1.32				-0.12				2.95			
fs2	-0.12				1.86				2.64				4.92			
fs3	0.82				0.38				4.72				3.96			
fs		**-0.41**	**1.40**	**-339.85**		**0.31**	**1.59**	**517.55**		**2.41**	**2.43**	**100.47**		**3.95**	**0.98**	**24.92**
uc1	0.11				-3.21				-4.06				-1.15			
uc2	1.10				0.28				-1.78				-1.75			
uc3	0.95				1.68				0.76				-0.39			
uc		**0.72**	**0.53**	**73.85**		**-0.42**	**2.52**	**-600.52**		**-1.69**	**2.41**	**-142.18**		**-1.10**	**0.68**	**-61.88**
us1	0.24				2.60				1.69				2.81			
us2	0.39				4.04				4.51				-1.97			
us3	0.69				-1.74				0.98				-1.51			
us		**0.44**	**0.23**	**51.55**		**1.63**	**3.01**	**184.08**		**2.39**	**1.86**	**77.90**		**-0.22**	**2.64**	**-1186.43**

site: d=downhill; f=flat; u=uphill; c=curve; s=straight; numbers refer to replicates

CV=coefficient of variation; stdev= standard deviation

Table 4.3: Lowden, means, standard deviations and coefficients of variation (%) for micro relief soil compaction (kg/cm^2)

	time1				time2				time3				time4				time5				time6			
site	msc	mean	stdev	CV	msc	mean	stdev	CV	msc	mean	stdev	CV	msc	mean	stdev	CV	msc	mean	stdev	CV	msc	mean	stdev	CV
ndc1	1.12				1.13				2.53				2.07				1.67				0.54			
ndc2	1.22				0.83				2.43				1.89				1.58				0.87			
ndc3	1.74				1.63				3.08				3.45				2.70				0.82			
ndc		1.36	0.33	24.34		1.20	0.41	33.85		2.68	0.35	13.01		2.47	0.85	34.48		1.98	0.62	31.32		0.74	0.18	23.84
nds1	0.50				0.95				2.37				2.18				1.50				2.00			
nds2	0.51				0.75				1.39				1.63				1.22				0.30			
nds3	1.17				0.99				2.67				3.34				1.96				0.29			
nds		0.73	0.38	52.70		0.89	0.13	14.18		2.14	0.67	31.10		2.39	0.87	36.59		1.56	0.37	23.84		0.86	0.98	113.36
nfc1	1.43				1.78				3.26				2.72				2.50				2.95			
nfc2	1.61				1.89				3.45				3.08				2.47				1.68			
nfc3	2.49				2.32				3.32				3.76				3.49				2.76			
nfc		1.84	0.56	30.66		2.00	0.28	14.21		3.34	0.09	2.84		3.19	0.53	16.57		2.82	0.58	20.48		2.46	0.68	27.68
nfs1	1.32				0.93				2.79				2.53				1.58				1.58			
nfs2	0.97				0.99				2.87				2.21				2.22				1.20			
nfs3	1.29				1.37				3.51				3.04				2.62				1.82			
nfs		1.19	0.19	15.96		1.10	0.24	21.61		3.06	0.40	12.99		2.59	0.42	16.14		2.14	0.52	24.52		1.53	0.31	20.38
nuc1	0.67				0.79				2.25				1.95				1.43				1.11			
nuc2	M				M				M				M				M				M			
nuc3	2.26				2.36				3.78				3.25				3.36				2.45			
nuc		2.26	1.13	49.74		2.36	1.11	47.01		3.78	1.08	28.58		3.25	0.92	28.34		3.36	1.36	40.49		2.45	0.95	38.78
nus1	0.30				0.67				1.08				1.74				0.86				1.91			
nus2	0.79				1.42				2.09				1.72				1.43				1.07			
nus3	1.26				1.72				2.74				2.68				2.13				2.30			
nus		0.79	0.48	61.18		1.27	0.54	42.61		1.97	0.84	42.44		1.88	0.74	39.14		1.47	0.64	43.37		1.76	0.63	35.92
odc1	1.74				1.14				2.92				2.75				2.09				1.39			
odc2	1.33				1.17				2.22				2.05				1.92				0.66			
odc3	2.74				2.33				3.72				3.16				3.11				2.21			
odc		1.93	0.72	37.45		1.55	0.68	43.68		2.96	0.75	25.39		2.65	0.56	21.06		2.37	0.64	26.98		1.42	0.78	54.65
ods1	2.49				3.11				4.13				4.08				3.76				3.72			
ods2	2.55				2.66				3.43				3.38				3.08				2.92			
ods3	1.32				1.33				2.17				2.40				2.02				2.23			
ods		2.12	0.70	32.85		2.36	0.92	39.08		3.25	0.99	30.62		3.29	0.84	25.66		2.95	0.88	29.82		2.96	0.75	25.25
ofc1	1.24				1.29				2.41				2.75				2.07				0.92			
ofc2	2.86				3.09				3.11				3.97				3.75				3.26			
ofc3	3.05				2.47				3.76				3.75				3.66				3.43			
ofc		2.38	1.00	41.83		2.29	0.92	40.09		3.09	0.68	21.92		3.49	0.65	18.66		3.16	0.95	29.99		2.54	1.40	55.29
ofs1	1.78				1.86				2.46				2.82				2.00				2.47			
ofs2	2.01				1.96				3.32				3.14				3.04				3.03			
ofs3	1.91				1.59				3.29				2.93				2.84				2.32			
ofs		1.90	0.12	6.25		1.80	0.19	10.53		3.02	0.49	16.14		2.96	0.17	5.62		2.63	0.55	21.01		2.61	0.37	14.32
ouc1	2.70				2.70				3.92				3.57				2.76				1.62			
ouc2	3.07				2.71				4.14				4.17				4.01				3.04			
ouc3	1.18				1.14				3.64				3.71				3.43				3.17			
ouc		2.32	1.00	43.06		2.18	0.90	41.22		3.90	0.25	6.42		3.82	0.32	8.28		3.40	0.63	18.38		2.61	0.86	32.99
ous1	2.49				2.46				3.61				3.50				3.13				1.67			
ous2	3.11				3.18				4.14				3.59				3.49				1.83			
ous3	2.92				2.64				3.58				4.05				3.67				2.45			
ous		2.84	0.32	11.19		2.76	0.38	13.59		3.78	0.32	8.46		3.71	0.30	7.97		3.43	0.27	8.00		1.98	0.41	20.70

site: n=new; o=old; d=downhill; f=flat; u=uphill; c=curve; s=straight; number refers to replicate CV = Coefficient of variation; M = missing data; stdev= standard deviation

Table 4.4: Marrinup, means, standard deviations and coefficients of variation (%) for trail soil compaction (kg/cm^2)

	time 1				time 2				time 3				time 4				time 5			
Site	msc	mean	stdev	CV	msc	mean	stdev	CV	msc	mean	stdev	CV	msc	mean	stdev	CV	msc	mean	stdev	CV
dc1	2.61				2.51				2.75				2.39				3.55			
dc2	2.51				2.38				2.18				3.36				3.20			
dc3	2.32				1.84				2.79				3.14				3.45			
dc		2.48	0.15	6.0		2.25	0.36	15.8		2.57	0.34	13.2		2.96	0.50	17.0		3.40	0.18	5.4
ds1	2.03				1.97				2.38				3.46				3.26			
ds2	1.58				1.86				2.51				3.26				3.00			
ds3	2.89				1.74				2.62				3.54				3.20			
ds		2.17	0.67	30.9		1.86	0.12	6.4		2.50	0.12	4.7		3.42	0.14	4.2		3.15	0.14	4.3
fc1	2.78				1.50				2.72				2.38				3.11			
fc2	2.80				2.84				2.41				2.14				2.84			
fc3	3.50				2.42				2.37				2.25				2.51			
fc		3.03	0.41	13.6		2.25	0.69	30.4		2.50	0.19	7.8		2.26	0.12	5.3		2.82	0.30	10.5
fs1	3.28				2.00				3.20				2.21				2.95			
fs2	3.36				1.08				2.84				2.17				2.58			
fs3	3.04				1.04				2.79				1.97				2.97			
fs		3.22	0.16	5.1		1.37	0.54	39.6		2.94	0.22	7.5		2.12	0.13	6.0		2.83	0.22	7.8
uc1	3.17				3.29				2.54				1.67				3.14			
uc2	2.58				3.20				2.70				1.49				2.45			
uc3	2.71				2.96				3.01				1.51				2.47			
uc		2.82	0.31	11.0		3.15	0.17	5.4		2.75	0.24	8.8		1.56	0.10	6.4		2.69	0.40	14.7
us1	2.66				2.87				2.84				1.11				2.38			
us2	2.63				2.86				2.59				3.50				2.09			
us3	2.43				3.08				2.83				3.28				1.45			
us		2.57	0.12	4.7		2.93	0.13	4.3		2.75	0.14	5.1		2.63	1.32	50.3		1.97	0.48	24.2

site: d=downhill; f=flat; u=uphill; c=curve; s=straight; numbers refer to replicates CV=coefficient of variation; stdev= standard deviation

Table 4.5: Lowden, means, standard deviations and coefficients of variation (%) for trailwidth (cm)

	time1				time2				time3				time4				time5				time6			
Site	trailwidth	mean	stdev	CV	trailwidth	mean	stdev	CV	trailwidth	mean	stdev	CV	trailwidth	mean	stdev	CV	trailwidth	mean	stdev	CV	trailwidth	mean	stdev	CV
ndc1	55				65				60				50				60				65			
ndc2	70				M				50				50				50				50			
ndc3	65				100				60				55				50				65			
ndc		63.33	7.64	12.06		82.50	24.75	30.00		56.67	5.77	10.19		51.67	2.89	5.59		53.33	5.77	10.83		60.00	8.66	14.43
nds1	55				45				50				50				55				55			
nds2	40				40				50				45				50				40			
nds3	100				100				80				65				75				50			
nds		65.00	31.22	48.04		61.67	33.29	53.99		60.00	17.32	28.87		53.33	10.41	19.52		60.00	13.23	22.05		48.33	7.64	15.80
nfc1	50				55				50				50				45				45			
nfc2	55				70				65				50				60				55			
nfc3	65				75				70				50				45				50			
nfc		56.67	7.64	13.48		66.67	10.41	15.61		61.67	10.41	16.88		50.00	0.00	0.00		50.00	8.66	17.32		50.00	5.00	10.00
nfs1	40				45				55				50				55				45			
nfs2	40				M				50				50				45				55			
nfs3	70				70				55				55				60				40			
nfs		50.00	17.32	34.64		57.50	17.68	30.74		53.33	2.89	5.41		51.67	2.89	5.59		53.33	7.64	14.32		46.67	7.64	16.37
nuc1	40				45				45				45				45				40			
nuc2	M				M				M				M				M				M			
nuc3	65				70				70				60				60				60			
nuc		52.50	17.68	33.67		57.50	17.68	30.74		57.50	17.68	30.74		52.50	10.61	20.20		52.50	10.61	20.20		50.00	14.14	28.28
nus1	50				45				50				40				50				40			
nus2	40				50				40				45				50				35			
nus3	60				60				60				60				55				50			
nus		50.00	10.00	20.00		51.67	7.64	14.78		50.00	10.00	20.00		48.33	10.41	21.53		51.67	2.89	5.59		41.67	7.64	18.33
odc1	85				85				80				80				60				60			
odc2	70				70				60				55				60				50			
odc3	55				100				55				55				55				55			
odc		70.00	15.00	21.43		85.00	15.00	17.65		65.00	13.23	20.35		63.33	14.43	22.79		58.33	2.89	4.95		55.00	5.00	9.09
ods1	90				90				90				60				65				65			
ods2	50				65				40				40				40				35			
ods3	50				50				40				40				40				35			
ods		63.33	23.09	36.46		68.33	20.21	29.57		56.67	28.87	50.94		46.67	11.55	24.74		48.33	14.43	29.86		45.00	17.32	38.49
ofc1	55				60				60				60				60				70			
ofc2	50				50				50				50				45				45			
ofc3	100				100				60				50				45				50			
ofc		68.33	27.54	40.30		70.00	26.46	37.80		56.67	5.77	10.19		53.33	5.77	10.83		50.00	8.66	17.32		55.00	13.23	24.05
ofs1	55				55				50				45				55				55			
ofs2	25				25				50				30				30				40			
ofs3	40				45				40				45				50				45			
ofs		40.00	15.00	37.50		41.67	15.28	36.66		46.67	5.77	12.37		40.00	8.66	21.65		45.00	13.23	29.40		46.67	7.64	16.37
ouc1	100				M				60				50				55				55			
ouc2	50				50				50				55				60				55			
ouc3	60				70				60				60				55				55			
ouc		70.00	26.46	37.80		60.00	14.14	23.57		56.67	5.77	10.19		55.00	5.00	9.09		56.67	2.89	5.09		55.00	0.00	0.00
ous1	80				55				60				60				60				70			
ous2	M				40				40				30				45				50			
ous3	100				100				80				75				65				70			
ous		90.00	14.14	15.71		65.00	31.22	48.04		60.00	20.00	33.33		55.00	22.91	41.66		56.67	10.41	18.37		63.33	11.55	18.23

site: n=new; o=old; d=downhill; f=flat; u=uphill; c=curve; s=straight; CV = Coefficient of variation; M = missing data; stdev= standard

Table 4.6: Marrinup, means, standard deviations and coefficients of variation (%) for trail width (cm)

	time 1				time 2				time 3				time 4				time 5			
Site	trailwidth	mean	stdev	CV	trailwidth	mean	stdev	CV	trailwidth	mean	stdev	CV	trailwidth	mean	stdev	CV	trailwidth	mean	stdev	CV
dc1	70				75				80				45				55			
dc2	60				55				60				55				55			
dc3	65				55				55				50				35			
dc		65.00	5.00	7.69		61.67	11.55	18.72		65.00	13.23	20.35		50.00	5.00	10.00		48.33	11.55	23.89
ds1	50				40				40				30				40			
ds2	40				45				50				40				40			
ds3	50				45				50				50				50			
ds		46.67	5.77	12.37		43.33	2.89	6.66		46.67	5.77	12.37		40.00	10.00	25.00		43.33	5.77	13.32
fc1	80				70				70				65				50			
fc2	45				40				50				40				50			
fc3	65				70				70				60				60			
fc		63.33	17.56	27.73		60.00	17.32	28.87		63.33	11.55	18.23		55.00	13.23	24.05		53.33	5.77	10.83
fs1	50				45				55				40				40			
fs2	50				50				45				35				40			
fs3	45				45				50				40				45			
fs		48.33	2.89	5.97		46.67	2.89	6.19		50.00	5.00	10.00		38.33	2.89	7.53		41.67	2.89	6.93
uc1	50				45				50				35				40			
uc2	50				35				45				50				50			
uc3	40				40				55				40				55			
uc		46.67	5.77	12.37		40.00	5.00	12.50		50.00	5.00	10.00		41.67	7.64	18.33		48.33	7.64	15.80
us1	60				55				50				45				40			
us2	50				30				40				30				40			
us3	60				55				60				50				50			
us		56.67	5.77	10.19		46.67	14.43	30.93		50.00	10.00	20.00		41.67	10.41	24.98		43.33	5.77	13.32

site: d=downhill; f=flat; u=uphill; c=curve; s=straight; numbers refer to replicates

CV=coefficient of variation; stdev= standard deviation

Table 4.7: Results of Levene's test of equality of error variances for % change in micro relief, soil compaction and trail width at Lowden and Marrinup

Micro relief				
	Whole relief		Trail only	
Lowden	F(11,23)	sig.	F(11,23)	sig.
t1-2	1.813	0.111	4.821	0.001
t1-3	10.887	0.000	5.627	0.000
t1-4	8.799	0.000	2.677	0.022
t1-5	5.450	0.000	4.688	0.001
t1-6	9.067	0.000	7.539	0.000
Marrinup	F(5,12)	sig.	F(5,12)	sig.
t1-2	8.263	0.001	9.594	0.001
t1-3	3.597	0.032	2.232	0.118
t1-4	4.862	0.012	1.263	0.341
t1-5	6.381	0.004	2.011	0.149

sig.=significance n (sample size) =3 (for all)

Soil compaction		
Lowden	F(11,23)	sig.
t1	3.366	0.007
t2	2.971	0.013
t3	1.656	0.148
t4	3.163	0.010
t5	3.143	0.010
t6	2.347	0.041
Marrinup	F(5,12)	sig.
t1	1.683	0.213
t2	2.721	0.072
t3	0.191	0.960
t4	2.888	0.061
t5	0.888	0.518

Trail width		
Lowden	F(11,19)	sig.
t1	2.043	0.083
t2	2.033	0.084
t3	4.548	0.002
t4	3.259	0.012
t5	3.228	0.012
t6	3.980	0.004
Marrinup	F(5,12)	sig.
t1	4.135	0.020
t2	3.130	0.049
t3	1.694	0.210
t4	1.780	0.191
t5	0.937	0.492

Micro relief

Appendices 1A and 1B illustrate the micro relief profiles sampled at each sampling site over the study period at Lowden and Marrinup respectively. At Lowden the variability of most of the data is clearly illustrated. The high peaks visible in the profiles (for example Figures 3 and 5 in Appendix 1A) are due to plants and plant parts encountered within the profiles. Some profiles indicate potential sampling errors and the limited accuracy of the measuring apparatus (e.g. Appendix 1A, Figures 1, 14 and 18). By contrast, other profiles (such as Figures 12 and 20 in Appendix 1A) show little variability over time and, indeed, if sampling errors and plant 'peaks' are discounted for all profiles the change within the profiles over the sampling period was below 2 to 3 cm. This recorded change in micro relief would probably be considered large in another context, however, the inaccuracy of the measuring apparatus has probably exaggerated the differences considerably.

For Marrinup a similar picture has emerged. Here the main sources of variability of the data were also plants and plant parts (for example Figures 7 and 10 in Appendix 1B) and to a lesser extent sampling error (e.g. Figures 14 and 18, Appendix 1B). As in the case of Lowden, if these sources of variability are discounted the changes in micro profile over time were under 3 cm. As at Lowden, these changes were probably exaggerated.

As outlined in the methods section, the change in micro relief area over time in relation to time 1 was used to test the effects of time, slope, trail width and a variety of covariates (aspect, incline and various soil parameters, see section 4.1.3). The ANOVA's on this raw data for Lowden revealed close to significant differences of the factors feature (p=0.072) and slope (p=0.057) (Table 4.8). The within-subject effects showed a close to significant interaction between time*age*slope (p=0.059) which is in keeping with the significant interactions of time*age (p=0.039) and time*slope (p=0.026). ANOCOVA revealed a significant relationship of the covariate texture A (soil texture of the A horizon) with micro relief (% change). The adjusted data showed a feature effect (p=0.53) and a slope effect (p=0.73). A time*texture A interaction (p=0.083), a significant time*age interaction (p=0.033) and a time*slope interaction (p=0.058) were also observed. In addition a time*age*slope interaction (p=0.084) revealed that all these factors interacted with each other. When the Lowden micro relief data were compared visually (Figures 4.1a to d) the interactions of age and slope over time are clearly visible.

The ANOVA's for the transformed (arcsine) data showed fewer significant effects and interactions, indicating that the transformation has reduced the variability (Table 4.8). The effect of slope was close to significant (p=0.067) and the interaction of time*age increased in significance (p=0.009). ANOCOVA also revealed an interaction of texture A with micro relief but with increased significance (p=0.019). A slope*age interaction (p=0.083) was seen and the within-subjects analysis produced a significant time effect (p=0.018), a significant time*texture interaction (p=0.032) and a highly significant time*age interaction (p=0.006).

In an attempt to reduce data variability, ANOVA's and ANOCOVA's were calculated for the % area change in micro relief of the trail only. The distance of the trail edge from the left pole was measured at time 6 and the average trail width was determined for consistent area calculations. The variability of the data was somewhat reduced (Table 4.7), however, an age*slope interaction (p=0.042), a time effect (p=0.073) and a time*age interaction (p=0.019) were still observed for the untransformed data (Table 4.8). The untransformed data also revealed an interaction of the covariate thickness O_2 (thickness of the O_2 horizon) with change in the micro relief area of the trail was also found which showed an age*slope interaction (p=0.035) and a time*slope interaction (p=0.059). The arcsine transformed data showed the same interactions and effects as the untransformed data (age*slope, p=0.042; time, p=0.085; time*age, p=0.021) but no relationship with any of the covariates.

Table 4.8: Significant results of ANOVA's and ANOCOVA's for Lowden micro relief (% area change in relation to time 1)

		Between-subject effects							Within-subject effects							
	β=0	Age	Feature	Slope	A*F	A*S	F*S	A*F*S	Time	T*A	T*F	T*S	T*A*F	T*A*S	T*F*S	T*A*F*S
Data not transformed (whole micro relief)	-	ns	0.072	0.057	ns	ns	ns	ns	ns	0.039	ns	0.026	ns	0.059	ns	ns
Data transformed (whole micro relief)	-	0.009	ns	0.067	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Data not transformed (trail only)	-	ns	ns	ns	ns	0.042	ns	ns	0.073	0.019	ns	ns	ns	ns	ns	ns
Data transformed (trail only)	-	ns	ns	ns	ns	0.042	ns	ns	0.085	0.021	ns	ns	ns	ns	ns	ns
Covariates*																
Texture A (not transformed)	0.083	ns	0.051	0.036	ns	ns	ns	ns	ns	0.000	ns	0.018	ns	0.084	ns	ns
Texture A (transformed)	0.019	ns	ns	0.083	ns	ns	ns	ns	0.000	0.000	ns	ns	ns	ns	ns	ns
Thickness O2 horizon (trail only, not transf.)	0.074	ns	ns	ns	ns	0.035	ns	ns	ns	0.059	ns	ns	ns	ns	ns	ns

ns = not significant; - = not applicable; *only significant (p<0.1) covariates are listed

The results of the ANOVA's for % area change for Marrinup (Table 4.9) indicated fewer significant effects and interactions than for Lowden. Analysis of the untransformed data revealed a slope effect (p=0.053) and after transformation a time effect was detected (p=0.066). None of the covariates showed any significant relationships with % change in micro relief. The visual depiction of the Marrinup micro relief data clearly reveals the slope effects (Figure 4.2a and b).

As for the Lowden data, the % area change in micro relief for the trail only was tested. The ANOVA's for both the untransformed and the transformed data sets revealed a slope effect (p=0.088) and no interaction with any of the covariates (Table 4.9).

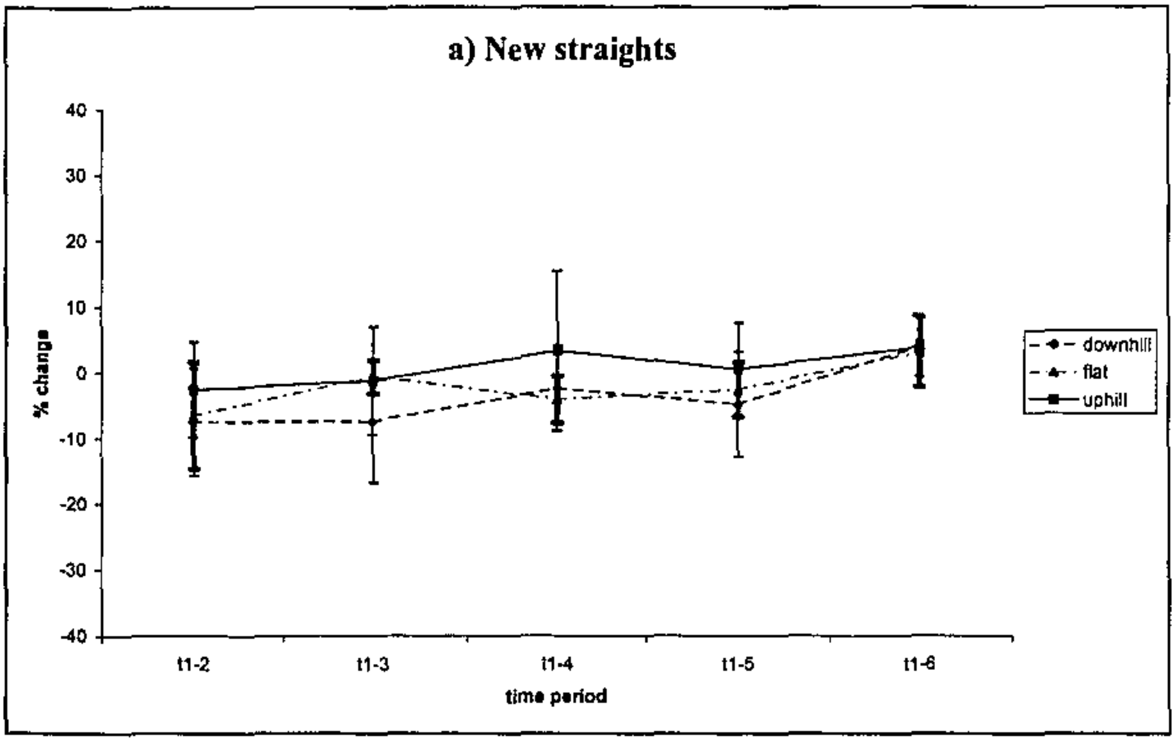
Table 4.9: Significance of results of ANOVA's and ANOCOVA's* for Marrinup micro relief (% area change relative to time 1)

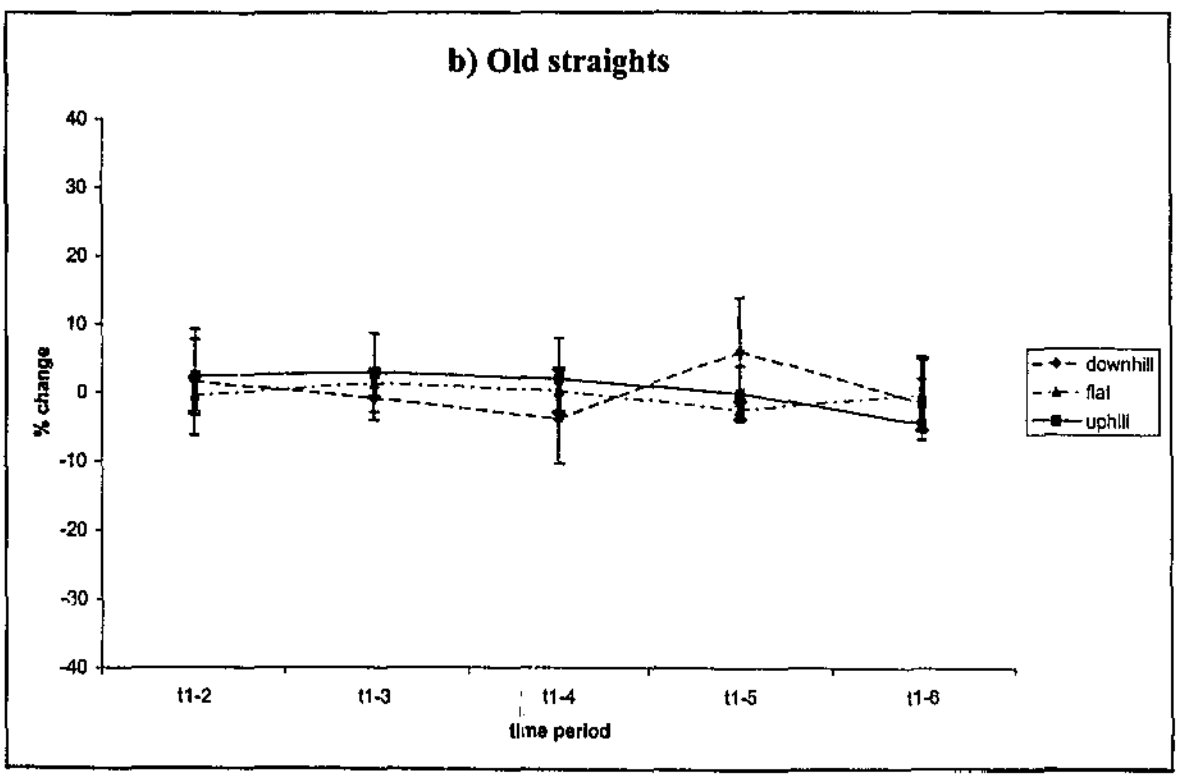
		Within-subject effects			Between-subject effects			
	β=0	Feature	Slope	S*F	Time	T*F	T*S	T*F*S
Whole micro relief								
Data not transformed	-	ns	0.043	ns	ns	ns	ns	ns
Data transformed	-	ns	ns	ns	ns	ns	ns	ns
Trail only								
Data not transformed	-	ns	0.088	ns	ns	ns	ns	ns
Data transformed	-	ns	0.088	ns	ns	ns	ns	ns

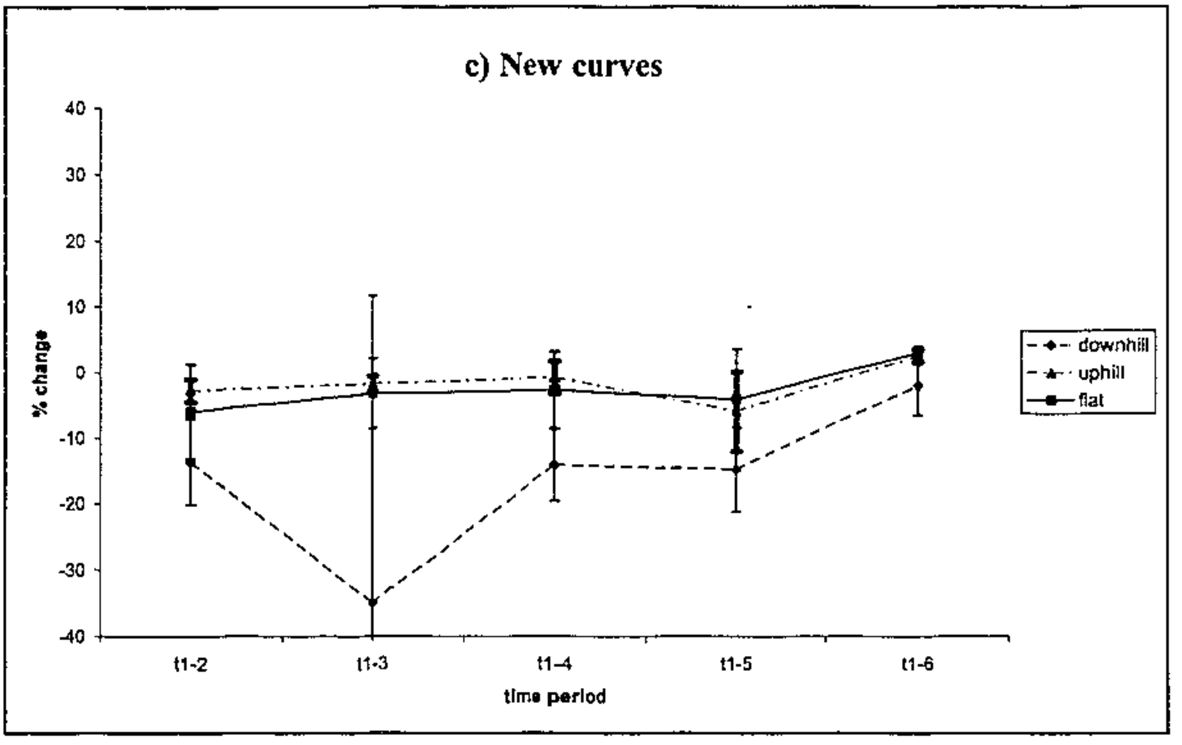
ns= not significant; - =not applicable; *all covariates were not significant at p<0.1

Figure 4.1a-d: Lowden, micro relief (% area change in relation to time 1) for features

(Error bars represent the 95% confidence intervals)






c) New curves
40
30
20
10
0
-10
-20
-30
-40
% change
t1-2
t1-3
t1-4
t1-5
t1-6
time period
downhill
uphill
flat

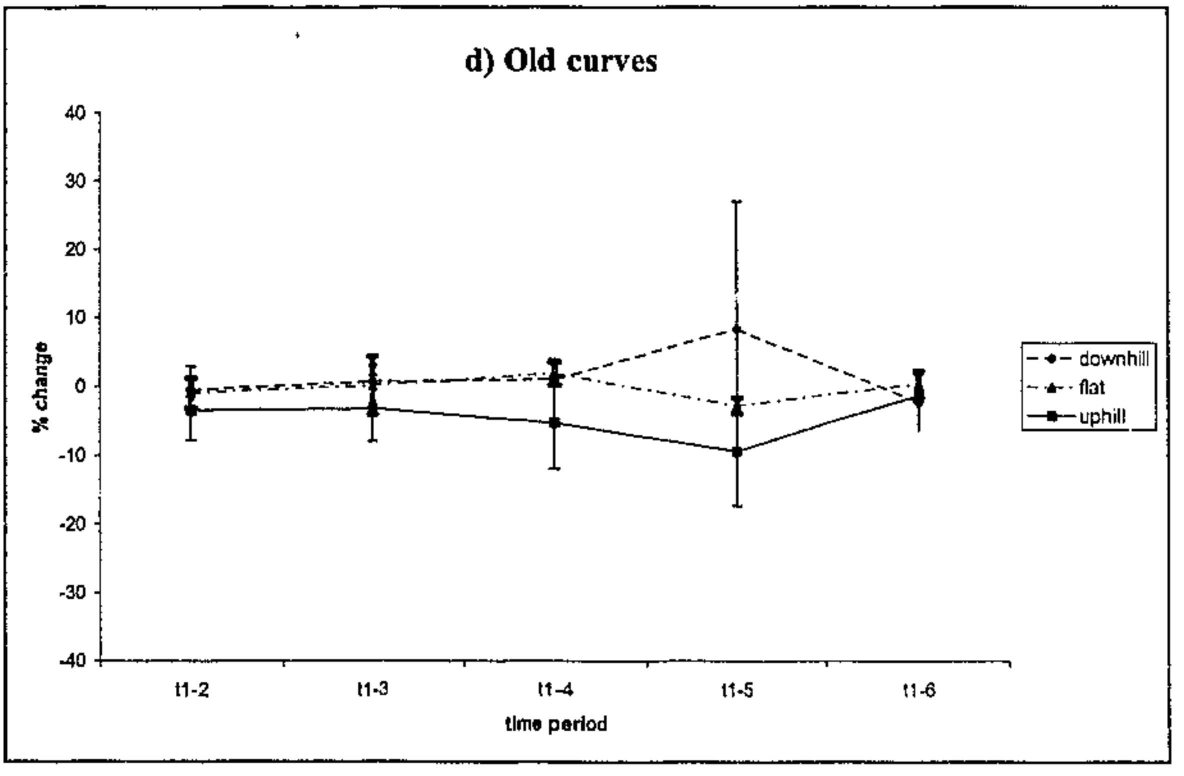
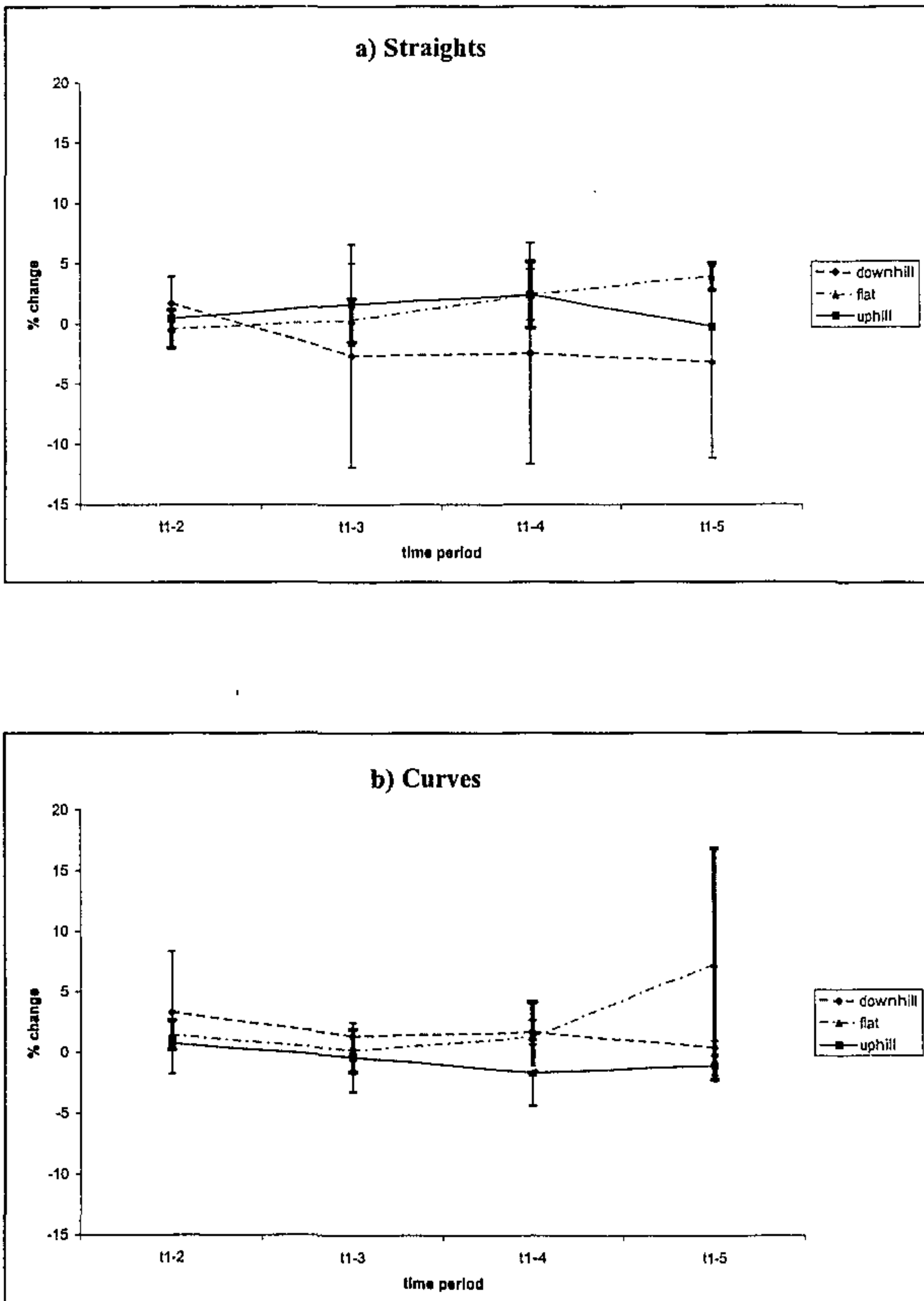

d) Old curves
40
30
20
10
0
-10
-20
-30
-40
% change
t1-2
t1-3
t1-4
t1-5
t1-6
time period
downhill
flat
uphill

Figure 4.2a-b: Marrinup m, micro relief (%area change in relation to time 1) for features

(Error bars represent the 95% confidence intervals)



Soil compaction

Appendices 1C (Lowden) and 1D (Marrinup) illustrate the soil compaction measured throughout the sampling period. These results illustrate the high variability of the measurements within the profiles as well as over time. At Lowden this variability was more pronounced for the data from the 'new' trail sections (Appendix 1C, Figures 1-17) whereas some of the 'old' sites showed relatively stable compaction, at least for parts of the trail (for example Appendix 1C, Figures 20 and 22). These stable sites showed no association with a specific feature or slope. At some of the Lowden sites an increase of soil compaction over time was observed (e.g. Appendix 1C, Figures 15 and 32) whereas at others, after an initial increase in compaction, a loosening of the soil over time was apparent (see Figures 13 and 14, Appendix 1C). On some of the figures in Appendix 1C a loosening of the soil at time 6 (after the summer race) is clearly visible (for example Figures 3, 16 and 19, Appendix 1C). At Marrinup, overall the data was less variable and the sites were more compacted than at Lowden with some of the sites (for example Appendix 1D, Figures 7 and 15) showing consistent results over the time of the study.

To facilitate the analysis of variance and covariance, the mean soil compaction values of each of the sites were calculated. The ANOVA of the non-transformed data of the Lowden racetrack revealed an age effect (p=0.001) as well as a time effect (p=0.000) and a time*age*slope interaction (Table 4.10). In addition the covariates fragment size B (fragment size of coarse particles in the B horizon of the soil) (p=0.063) and texture B (soil texture of the B horizon) (p=0.057) showed a relationship with soil compaction. The ANOCOVA for fragment size B also indicated an age effect (p=0.001), a feature effect (p=0.099) and a slope effect (p=0.036). A time*age*slope interaction (p=0.003) was also found. The ANOCOVA for texture B also showed a highly significant age effect (p=0.000) and a significant slope effect (p=0.017). In this case an age*feature interaction was revealed (p=0.050) in addition to a time*age*slope interaction (p=0.011). Figures 4.3a–f show these effects and interactions clearly. It should, nevertheless, be noted that the 'old' features were consistently (with the exception of three data points) more compacted than the 'new' features. In addition, on most of the curves a peak in soil compaction at time 3 is visible.

After transformation (log+1) the ANOVA resulted in even more interactions and effects indicating that variance was not reduced (Table 4.10). In addition to an unchanged significance for age (p=0.001), slope was now also close to significant (p=0.068). In the within-subject effects, time remained unchanged (p=0.000) whereas the interaction of time*age*slope increased in significance (p=0.004). Furthermore, the interactions time*age (p=0.069), time*slope (p=0.056) and time*feature*slope (p=0.075) were close to significant. On the other only one relationship with a covariate (texture B; p=0.078) was detected. Texture B also revealed a highly significant age effect (p=0.000), a significant slope effect (p=0.014) and an age*feature interaction (p=0.086). A time*slope interaction (p=0.077) and a highly significant time*age*slope interaction (p=0.002) were also seen.

Table 4.10: Significance of results of ANOVA's and ANOCOVA's for Lowden soil compaction

		Between-subject effects							Within-subject effects							
	β=0	Age	Feature	Slope	A*F	A*S	F*S	A*F*S	Time	T*A	T*F	T*S	T*A*F	T*A*S	T*F*S	T*A*F*S
Data not transformed	-	0.001	ns	ns	ns	ns	ns	ns	0.000	ns	ns	ns	ns	0.020	ns	ns
Data transformed	-	0.001	ns	0.068	ns	ns	ns	ns	0.000	0.069	ns	0.056	ns	0.004	0.075	ns
Covariats*																
Fragment size B (not transformed)	0.063	0.001	0.099	0.036	ns	ns	ns	ns	ns	ns	ns	ns	ns	0.003	ns	ns
Texture B (transformed)	0.078	0.001	ns	0.014	0.086	ns	ns	ns	ns	ns	ns	0.077	ns	0.002	ns	ns

ns = not significant; - = not applicable; *only significant (p<0.1) covariates are listed

For Marrinup, the untransformed data produced the within-subject effect of feature (p=0.048) and a feature*slope interaction (p=0.009) as well as the between-subject effect of time (p=0.000) and the time*feature*slope (0.012) interaction (Table 4.11). A relationship with the covariate texture B (p=0.053) was detected for this data set in regard to soil compaction. It showed a significant feature effect (p=0.10) and a significant feature*slope interaction (p=0.024) in addition to a significant time*feature*slope interaction (p=0.042). The interactions of feature and slope over time are clearly visible on Figure 4.4.

The transformed (log+1) data only produced a time effect (p=0.002) (Table 4.11), but in addition a significant relationship of the covariate fragment size B (p=0.001) as well as of texture A (p=0.048) with soil compaction were found. The adjusted data for fragment size B also showed a slope effect (p=0.096) and a significant feature*slope interaction (p=0.018), whereas the texture A data only revealed a significant feature*slope interaction (p=0.033).

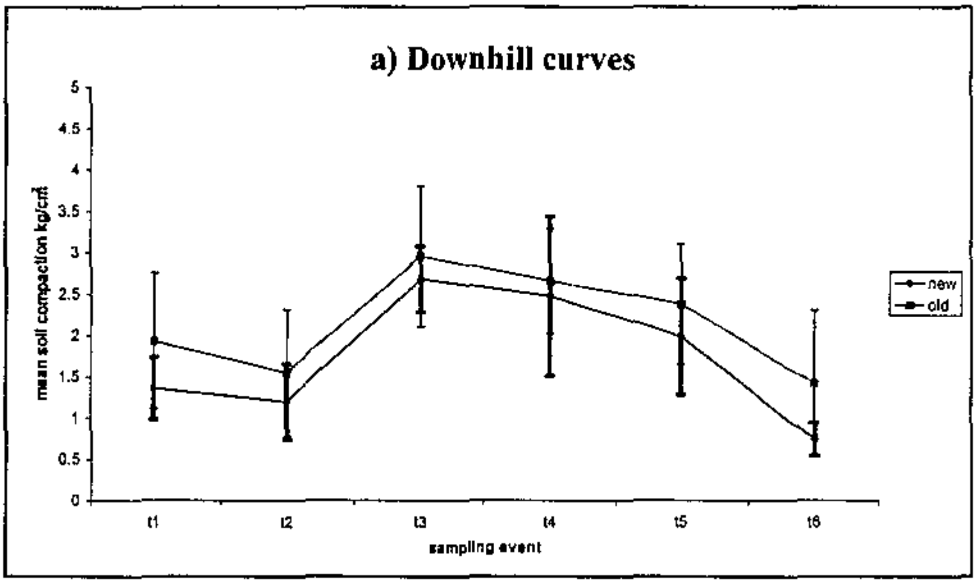
Table 4.11: Significance of results of ANOVAs and ANOCOVAs for Marrinup soil compaction

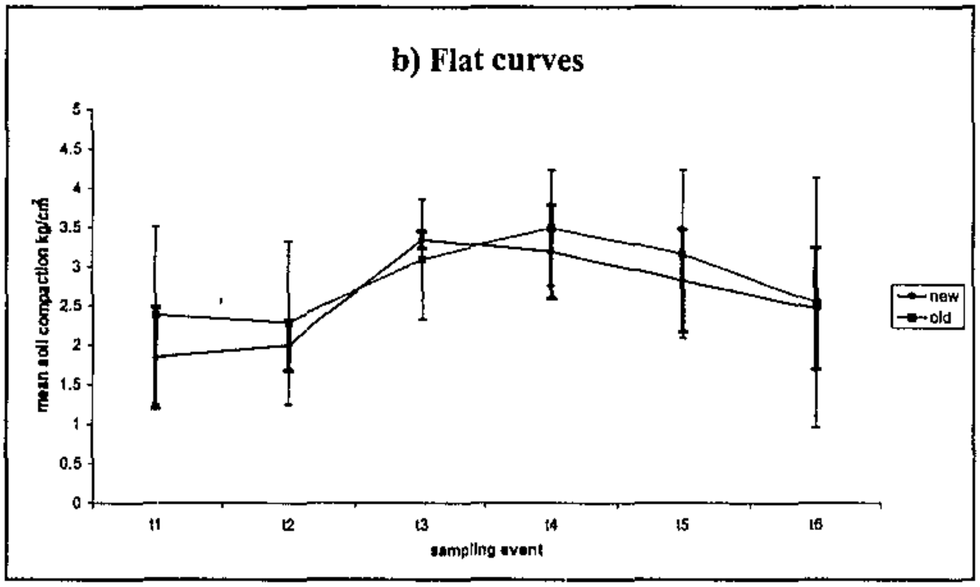
		Within-subject effects			Between-subject effects			
	β=0	Feature	Slope	F*S	Time	T*F	T*S	T*F*S
Data not transformed	-	0.048	ns	0.009	0.000	ns	ns	0.012
Data transformed	-	ns	ns	ns	0.002	ns	ns	ns
Covariates*								
Texture B (not transformed)	0.053	0.01	ns	0.024	ns	ns	ns	0.042
Texture A (transformed)	0.048	ns	ns	0.033	ns	ns	ns	ns
% fragments B (transformed)	0.001	ns	0.096	0.018	ns	ns	ns	ns

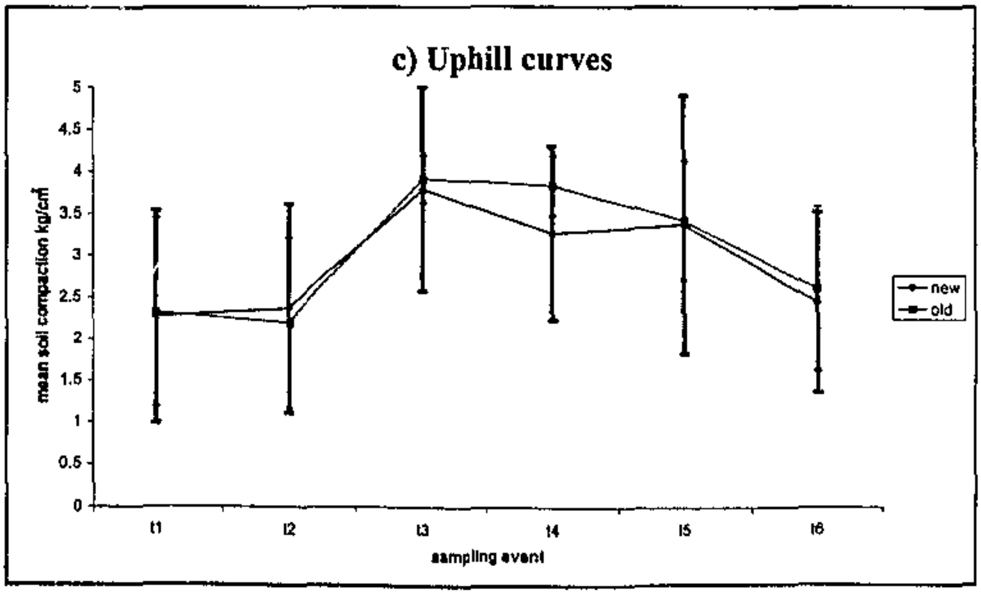
ns= not significant; -'=not applicable; *only significant (p<0.1) covariates are listed

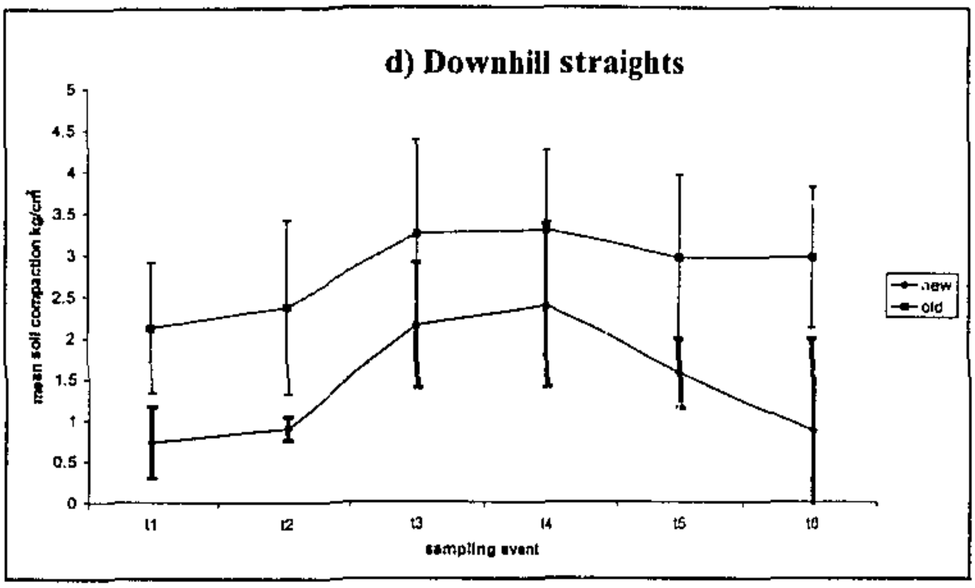
Figure 4.3a-f: Lowden, comparison of trail soil compaction between ages for features

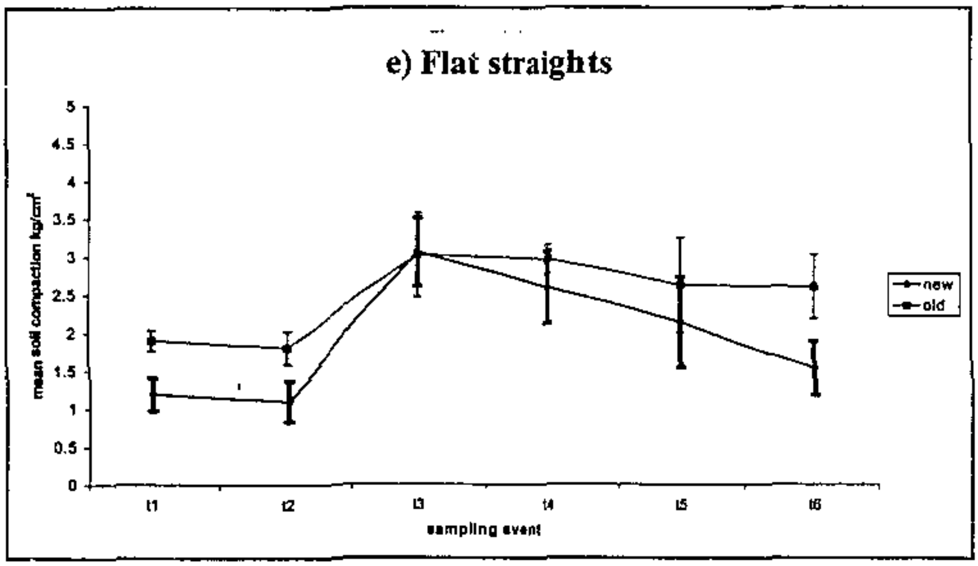
(Error bars represent 95% confidence intervals)

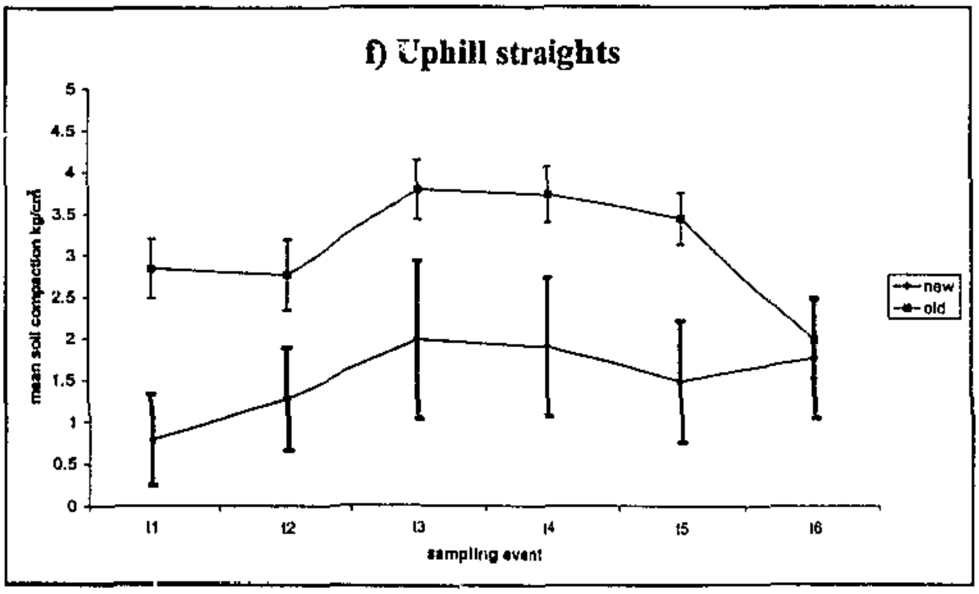







d) Downhill straights
mean soil compaction kg/cm²
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
t1
t2
t3
t4
t5
t6
sampling event
new
old


e) Flat straights
mean soil compaction kg/cm²
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
t1
t2
t3
t4
t5
t6
sampling event
new
old


f) Uphill straights
mean soil compaction kg/cm²
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
t1
t2
t3
t4
t5
t6
sampling event
new
old

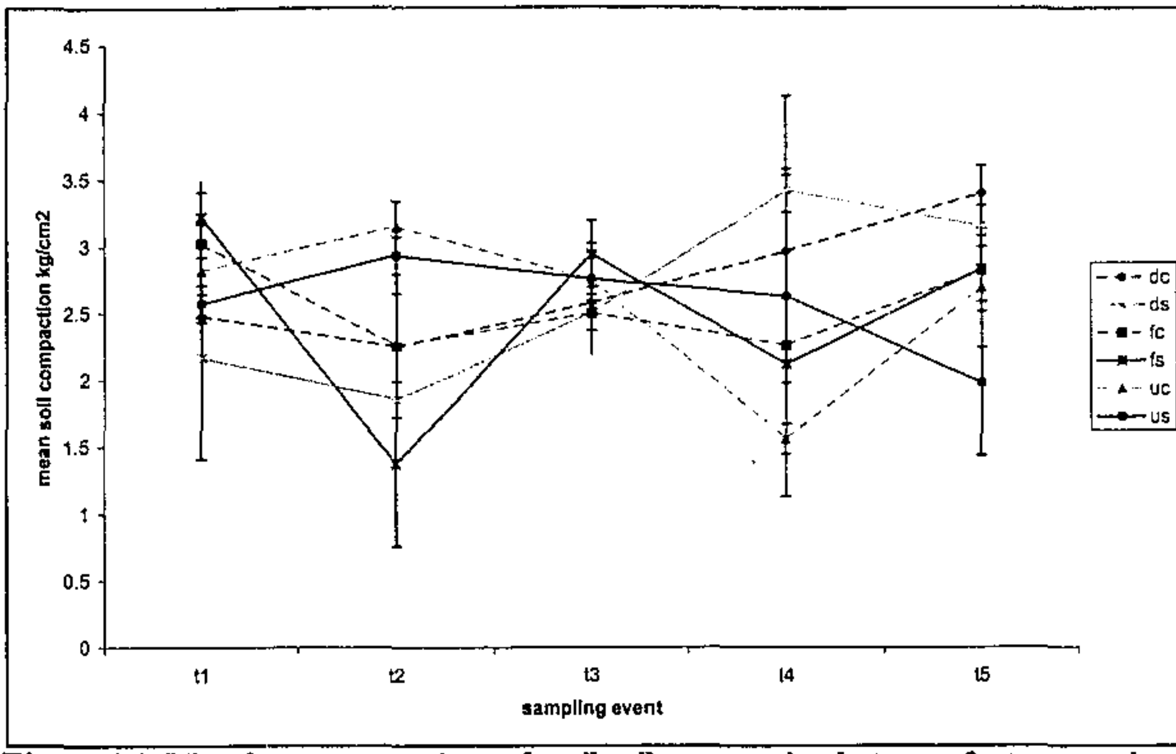


Figure 4.4: Marrinup, comparison of trail soil compaction between features and slopes (Error bars represent 95% confidence intervals)

Trail width

The untransformed data as well as the transformed (log+1) data for Lowden indicated a time effect (both p=0.000) for trail width (Table 4.12). A relationship with any of the covariates was not detected.

Table 4.12: Significant results of ANOVA's and ANOCOVA's* for Lowden trail width

		Between-subject effects							Within-subject effects							
	β=0	Age	Feature	Slope	A*F	A*S	F*S	A*F*S	Time	T*A	T*F	T*S	T*A*F	T*A*S	T*F*S	T*A*F*S
Data not transformed	-	ns	ns	ns	ns	ns	ns	ns	0.000	ns	ns	ns	ns	ns	ns	ns
Data transformed	-	ns	ns	ns	ns	ns	ns	ns	0.000	ns	ns	ns	ns	ns	ns	ns

ns = not significant; - = not applicable; *all covariates were not significant (p<0.1)

The ANOVA for Marrinup showed a highly significant time effect for the untransformed as well as the transformed (log+1) data (p=0.000 and p=0.002 respectively) (Table 4.13). In addition, a relationship of the covariate fragment size A with trail width (p=0.086) was detected although this analysis did not show any further effects and interactions.

Table 4.13: Significance of results of ANOVA's and ANOCOVA's for Marrinup trail width

		Within-subject effects			Between-subject effects			
	β=0	Feature	Slope	S*F	Time	T*F	T*S	T*F*S
Data not transformed	-	ns	ns	ns	0.000	ns	ns	ns
Data transformed	-	ns	ns	ns	0.002	ns	ns	ns
Covariates*								
% fragments A (transformed)	0.086	ns	ns	ns	ns	ns	ns	ns

ns= not significant; -= not applicable; *only significant covariates (p<0.1) are listed

An inspection of Figure 4.5 shows a widening of the trail at Lowden for time 2, after the race, and a subsequent reduction of trail width to time 5 inclusive. At time 6 a slight increase in trail width can be seen, also illustrating the impacts of a race.

Trail width for Marrinup (Figure 4.6) shows the same trends as Lowden but the reduction of trail width over time is less pronounced. Times 4 and 5 showed the narrowest trail width.

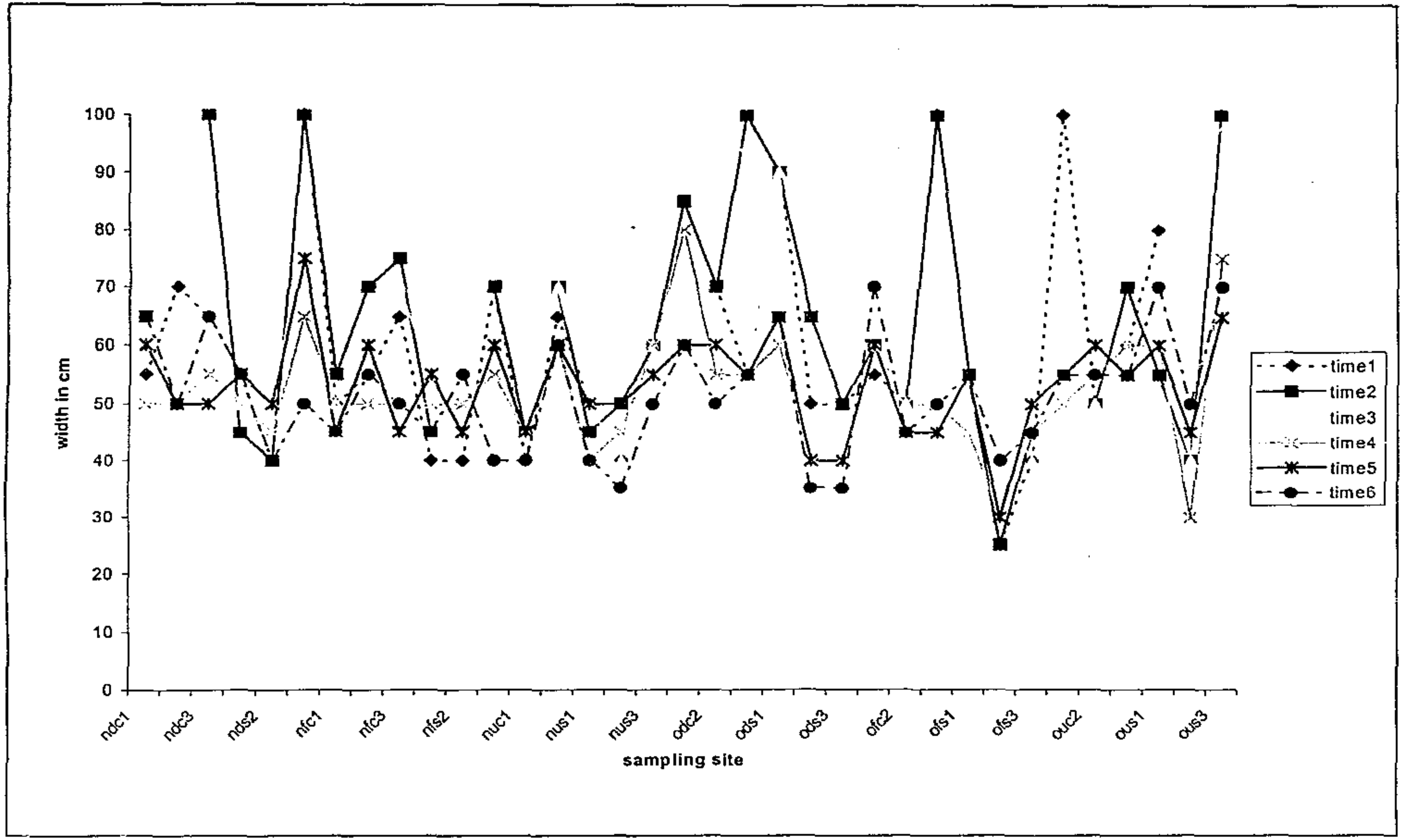


Figure 4.5: Lowden, comparison of trail width over time for all sampling sites

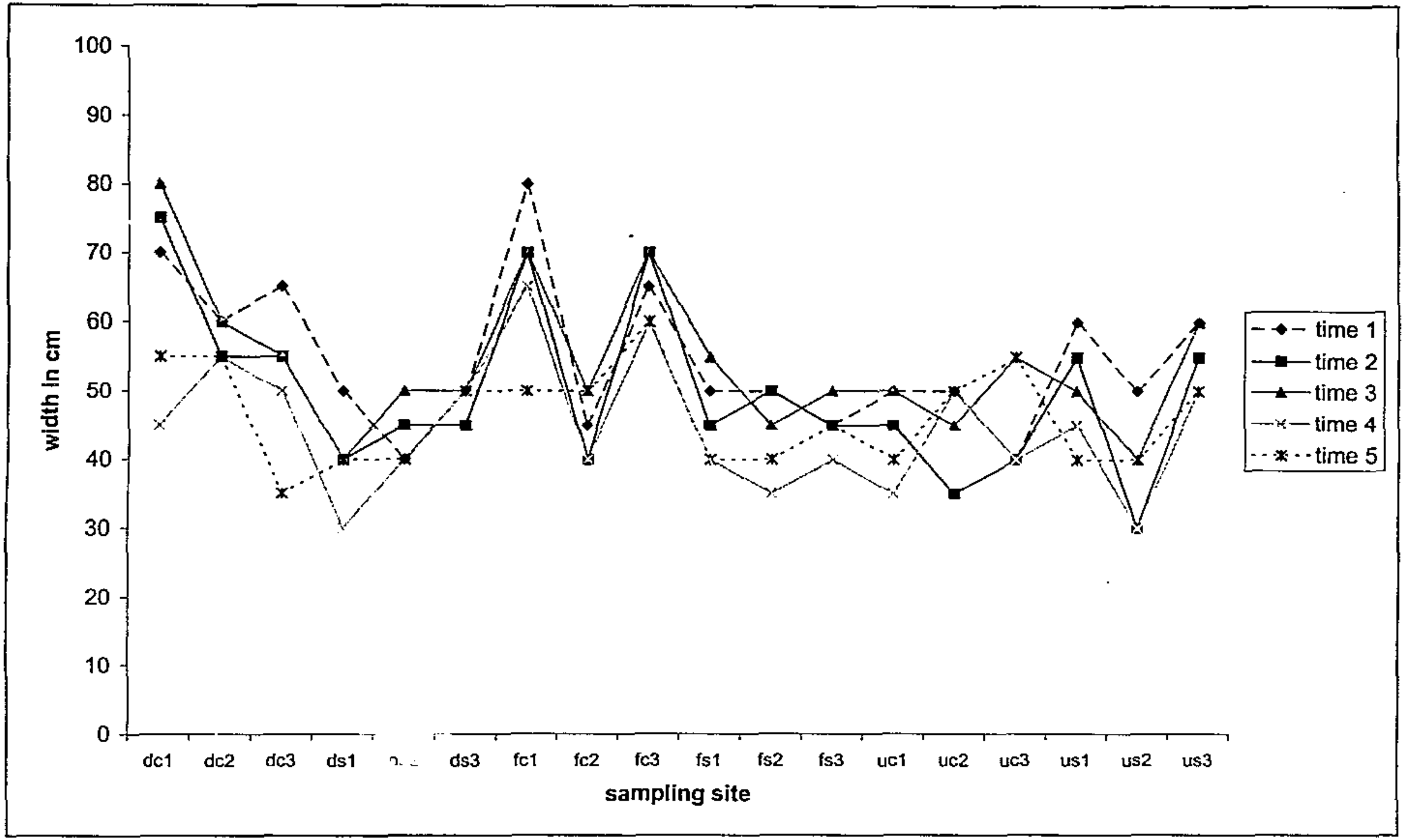


Figure 4.6: Marrinup, comparison of trail width over time for all sampling sites

4.1.2 The quadrats

Percent vegetation cover

The percent vegetation cover within the two $1m^2$ quadrats on both sides of the trails proved to be highly variable at both Lowden (Table 4.14) and Marrinup (Table 4.15). This can also be seen on Figures 4.7a to m and 4.8a to f. At Lowden the trends in % vegetation cover for left and right quadrats are similar for the different features (old or new downhill curves, downhill straights, flat curves, etc.). The overall trend of a reduction in vegetation cover is most likely due to the seasonal change in vegetation where the annual plants growing in spring vanish over time. Some locations showed an increase in vegetation cover towards the end of the study period (for example Figures 4.7c and e) which can most likely be explained by the growth of perennial vegetation. In Marrinup the trends observed for Lowden were not as pronounced although some reduction of vegetation cover was seen over time (e. g. Figures 4.8c and d).

Table 4.14: Lowden, means, standard deviations and coefficients of variation for % vegetation cover in the 2x1m2 quadrats adjacent to trail

		time1					time2					time3				
Site	Side	Q1	Q2	mean	stdev	CV	Q1	Q2	mean	stdev	CV	Q1	Q2	mean	stdev	CV
ndc1	left	75	75				75	75				50	75			
ndc2	left	huge hollow					huge hollow					huge hollow				
ndc3	left	10	15				10	15				10	20			
ndc	left			43.75	36.14	82.61			43.75	36.14	82.61			38.75	29.55	76.25
ndc1	right	75	90				75	90				70	80			
ndc2	right	30	25				30	25				30	20			
ndc3	right	80	50				80	50				70	30			
ndc	right			58.33	27.33	46.84			58.33	27.33	46.84			50.00	26.08	52.15
nds1	left	10	20				10	20				10	10			
nds2	left	50	25				50	25				50	30			
nds3	left	5	10				5	10				15	10			
nds	left			20.00	16.43	82.16			20.00	16.43	82.16			20.83	16.25	78.02
nds1	right	40	40				40	40				40	30			
nds2	right	50	20				50	20				30	20			
nds3	right	10	10				10	10				5	10			
nds	right			28.33	17.22	60.79			28.33	17.22	60.79			22.50	13.32	59.21
nfc1	left	40	40				40	40				30	30			
nfc2	left	40	70				40	70				30	30			
nfc3	left	70	tree				70	tree				50	tree			
nfc	left			52.00	16.43	31.60			52.00	16.43	31.60			34.00	8.94	26.31
nfc1	right	60	50				60	50				60	50			
nfc2	right	50	50				50	50				40	30			
nfc3	right	10	25				10	25				5	20			
nfc	right			40.83	19.08	46.73			40.83	19.08	46.73			34.17	20.10	58.84
nfs1	left	50	40				50	40				30	30			
nfs2	left	15	15				15	15				10	10			
nfs3	left	25	50				25	50				20	30			
nfs	left			32.50	16.36	50.32			32.50	16.36	50.32			21.67	9.83	45.38
nfs1	right	15	20				15	20				20	30			
nfs2	right	20	5				20	5				20	15			
nfs3	right	20	10				20	10				10	10			
nfs	right			15.00	6.32	42.16			15.00	6.32	42.16			17.50	7.58	43.33
nuc1	left	50	80				50	80				40	80			
nuc2	left	M	M				M	M				M	M			
nuc3	left	40	15				40	15				15	10			
nuc	left			46.25	26.89	58.13			46.25	26.89	58.13			36.25	31.98	88.23
nuc1	right	90	80				90	80				90	75			
nuc2	right															
nuc3	right	10	70				10	70				20	30			
nuc	right			62.50	35.94	57.50			62.50	35.94	57.50			53.75	34.00	63.26
nus1	left	60	tree				60	tree				50	tree			
nus2	left	75	75				75	75				75	70			
nus3	left	50	40				50	40				40	40			
nus	left			60.00	15.41	25.69			60.00	15.41	25.69			55.00	16.58	30.15
nus1	right	50	40				60	40				50	30			
nus2	right	75	60				75	60				80	60			
nus3	right	20	80				20	80				25	80			
nus	right			54.17	22.45	41.45			55.83	22.45	40.22			54.17	23.75	43.85

		time4					time5					time6				
Site	Side	Q1	Q2	mean	stdev	CV	Q1	Q2	mean	stdev	CV	Q1	Q2	mean	stdev	CV
ndc1	left	40	80				30	70				40	70			
ndc2	left	huge hollow					huge hollow					huge hollow				
ndc3	left	10	10				10	15				2	5			
ndc	left			35.00	33.17	94.76			31.25	27.20	87.02			29.25	32.18	110.02
ndc1	right	70	80				70	80				60	80			
ndc2	right	30	20				20	20				30	15			
ndc3	right	60	40				60	40				50	40			
ndc	right			50.00	23.66	47.33			48.33	25.63	53.02			45.83	22.89	49.95
nds1	left	5	10				5	10				5	15			
nds2	left	50	30				30	20				40	10			
nds3	left	20	15				15	10				20	10			
nds	left			21.67	16.33	75.37			15.00	8.94	59.63			16.67	12.52	75.10
nds1	right	40	50				30	40				50	50			
nds2	right	40	15				20	15				30	10			
nds3	right	20	10				10	5				5	5			
nds	right			29.17	16.25	55.73			20.00	13.04	65.19			25.00	21.45	85.79
nfc1	left	25	30				20	20				30	30			
nfc2	left	40	30				40	30				40	30			
nfc3	left	80	tree				60	tree				80	tree			
nfc	left			41.00	22.47	54.81			34.00	16.73	49.22			42.00	21.68	51.62
nfc1	right	60	40				70	30				80	40			
nfc2	right	40	30				20	30				40	20			
nfc3	right	5	10				5	15				2	10			
nfc	right			30.83	20.60	66.80			28.33	22.51	79.44			32.00	28.14	87.95
nfs1	left	40	20				30	20				30	40			
nfs2	left	10	10				5	10				1	5			
nfs3	left	5	10				15	10				5	5			
nfs	left			15.83	12.81	80.92			15.00	8.94	59.63			14.33	16.39	114.36
nfs1	right	20	30				20	20				20	30			
nfs2	right	5	10				1	15				0	5			
nfs3	right	5	2				5	2				0	0			
nfs	right			12.00	10.86	90.52			10.50	8.87	84.49			9.17	12.81	139.78
nuc1	left	40	80				40	90				40	90			
nuc2	left	M	M				M	M				M	M			
nuc3	left	5	10				2	10				1	5			
nuc	left			33.75	34.49	102.19			35.50	39.85	112.24			34.00	41.24	121.29
nuc1	right	10	90				10	90				10	90			
nuc2	right															
nuc3	right	10	60				20	70				5	80			
nuc	right			65.00	40.41	62.18			70.00	35.59	50.84			68.75	43.28	62.95
nus1	left	50	tree				30	tree				40	tree			
nus2	left	80	50				80	80				80	60			
nus3	left	50	50				40	40				40	40			
nus	left			56.00	13.42	23.96			54.00	24.08	44.60			52.00	17.89	34.40
nus1	right	50	40				40	40				60	50			
nus2	right	80	60				80	70				70	60			
nus3	right	20	80				20	80				40	80			
nus	right			55.00	23.45	42.64			55.00	25.10	45.64			60.00	14.14	23.57

site: n=new; o=old; d=downhill; f=flat; u=uphill; c=curve; s=straight; number refers to replicate; Q=quadrat   CV = Coefficient of variation (%); M = missing data; stdev= standard deviation

Table 4.14 continued

Site	Side	time1 Q1	time1 Q2	time1 mean	time1 stdev	time1 CV	time2 Q1	time2 Q2	time2 mean	time2 stdev	time2 CV	time3 Q1	time3 Q2	time3 mean	time3 stdev	time3 CV
odc1	left	20	50				20	50				5	30			
odc2	left	100	70				100	70				50	75			
odc3	left	10	fence				10	fence				20	fence			
odc	left			50.00	36.74	73.48			50.00	36.74	73.48			36.00	27.25	75.69
odc1	right	10	10				10	10				10	10			
odc2	[illegible]	20	10				20	10				20	20			
odc3	[illegible]	5	5				5	5				10	5			
odc	right			10.00	5.48	54.77			10.00	5.48	54.77			12.50	6.12	48.99
ods1	left	10	20				10	20				20	20			
ods2	left	30	15				30	15				10	30			
ods3	left	90	75				90	75				80	50			
ods	left			40.00	33.91	84.78			40.00	33.91	84.78			35.00	25.88	73.96
ods1	right	5	25				5	25				5	5			
ods2	right	50	70				50	70				20	70			
ods3	right	50	80				50	80				60	70			
ods	right			46.67	27.87	59.72			46.67	27.87	59.72			38.33	31.73	82.77
ofc1	left	0	20				5	0				10	10			
ofc2	left	50	50				50	50				50	50			
ofc3	left	big tree		inaccessible			big tree		inaccessible			big tree		inaccessible		
ofc	left			30.00	24.49	81.65			26.25	27.50	104.76			30.00	23.09	76.92
ofc1	right	0	x				5	0				10	0			
ofc2	right	90	20				90	20				90	50			
ofc3	right	20	15				20	15				20	20			
ofc	right			29.00	35.07	120.94			25.00	32.86	131.45			31.67	33.12	104.38
ofs1	left	70	80				70	80				50	70			
ofs2	left	75	60				75	60				60	50			
ofs3	left	20	40				20	40				10	30			
ofs	left			57.50	23.18	40.32			57.50	23.18	40.32			45.00	21.68	48.18
ofs1	right	30	50				30	50				20	40			
ofs2	right	50	40				50	40				40	30			
ofs3	right	15	80				15	80				10	50			
ofs	right			44.17	22.00	49.82			44.17	22.00	49.82			31.67	14.72	46.48
ouc1	left	10	20				5	20				1	20			
ouc2	left	15	50				15	50				20	30			
ouc3	left	25	15				25	15				30	20			
ouc	left			22.50	14.40	64.02			21.67	15.38	71.00			20.17	10.59	52.52
ouc1	right	70	70				30	80				10	80			
ouc2	right	10	10				10	10				50	5			
ouc3	right	50	x				50	x				20	80			
ouc	right			42.00	30.33	72.22			36.00	29.66	82.40			40.83	34.12	83.56
ous1	left	20	40				40	70				30	60			
ous2	left	50	50				50	50				60	50			
ous3	left	5	30				5	30				10	20			
ous	left			32.50	17.82	54.83			40.83	22.00	53.89			38.33	21.37	55.75
ous1	right	50	20				10	65				15	50			
ous2	right	80	20				90	20				90	40			
ous3	right	10	10				10	10				10	10			
ous	right			31.67	27.87	88.01			34.17	34.70	101.56			35.83	31.37	87.55

Site	Side	time4 Q1	time4 Q2	time4 mean	time4 stdev	time4 CV	time5 Q1	time5 Q2	time5 mean	time5 stdev	time5 CV	time6 Q1	time6 Q2	time6 mean	time6 stdev	time6 CV
odc1	left	5	40				10	40				5	30			
odc2	left	50	80				50	75				50	80			
odc3	left	10	fence				5	fence				1	fence			
odc	left			37.00	30.74	83.08			36.00	29.03	80.63			33.20	32.84	98.93
odc1	right	2	5				2	5				1	1			
odc2	[illegible]	10	10				10	5				2	1			
odc3	[illegible]	5	10				2	5				0	5			
odc	right			7.00	3.46	49.49			4.83	2.93	60.56			1.67	1.75	105.07
ods1	left	15	20				10	20				5	10			
ods2	left	10	40				5	25				2	10			
ods3	left	90	50				90	60				90	60			
ods	left			37.50	29.96	79.89			35.00	33.17	94.76			29.50	36.63	124.16
ods1	right	10	5				5	2				5	2			
ods2	right	20	80				20	80				10	80			
ods3	right	50	80				40	80				50	90			
ods	right			40.83	34.12	83.56			37.83	35.33	93.38			39.50	39.41	99.78
ofc1	left	5	10				2	0				0	0			
ofc2	left	40	50				60	50				60	60			
ofc3	left	big tree		inaccessible			big tree		inaccessible			big tree		inaccessible		
ofc	left			26.25	22.13	84.29			28.00	31.45	112.33			30.00	34.64	115.47
ofc1	right	5	0				2	0				2	1			
ofc2	right	10	50				70	50				80	50			
ofc3	right	20	15				15	10				2	5			
ofc	right			31.67	37.77	119.28			24.50	28.73	117.27			23.33	33.67	144.29
ofs1	left	40	80				40	70				50	80			
ofs2	left	50	50				60	50				70	50			
ofs3	left	10	30				10	30				2	30			
ofs	left			43.33	23.38	53.96			43.33	21.60	49.85			47.00	28.11	59.80
ofs1	right	10	40				10	30				10	30			
ofs2	right	30	30				30	30				40	30			
ofs3	right	10	50				5	30				3	50			
ofs	right			28.33	16.02	56.54			22.50	11.73	52.12			27.17	17.78	65.45
ouc1	left	2	40				0	30				0	10			
ouc2	left	15	30				10	25				10	30			
ouc3	left	30	20				30	15				40	15			
ouc	left			22.83	13.42	58.79			18.33	12.11	66.06			17.50	14.75	84.27
ouc1	right	30	70				25	80				30	60			
ouc2	right	10	5				5	2				2	2			
ouc3	right	20	80				20	80				30	70			
ouc	right			35.83	31.69	88.43			35.33	35.67	100.97			32.33	28.41	87.86
ous1	left	30	50				20	60				30	40			
ous2	left	20	10				20	10				20	10			
ous3	left	10	20				5	15				1	5			
ous	left			23.33	15.06	64.52			21.67	19.66	90.76			[illegible]	15.19	85.97
ous1	right	40	50				30	50				20	50			
ous2	right	50	30				50	30				50	30			
ous3	right	10	10				10	10				2	0			
ous	right			31.67	18.35	57.94			30.00	17.89	59.63			25.33	22.15	87.44

site: n=new; o=old; d=downhill; f=flat; u=uphill; c=curve; s=straight; number refers to replicate; Q=quadrat   CV = Coefficient of variation; M = missing data; stdev= standard deviation; x=no data

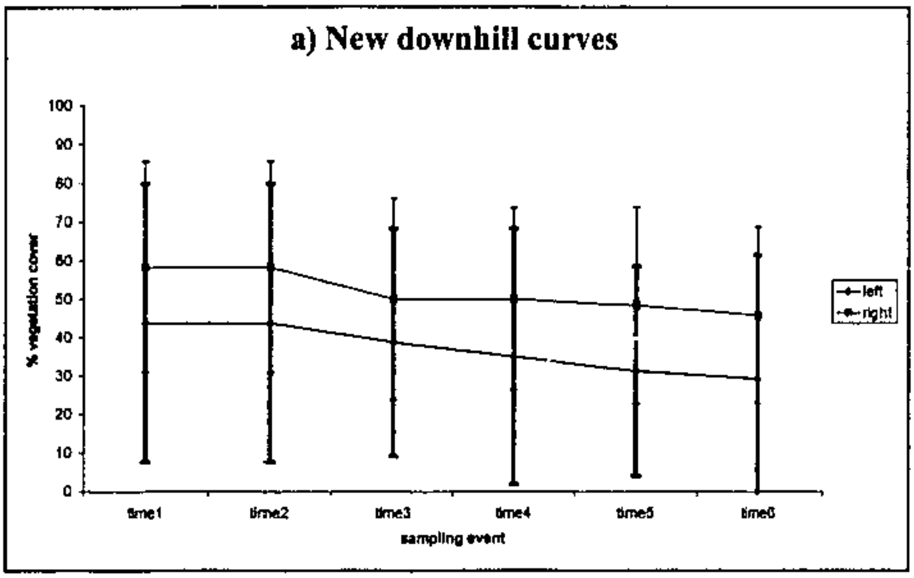
Table 4.15: Marrinup, means, standard deviations and coefficients of variation for % vegetation cover in the quadrats adjacent to trail

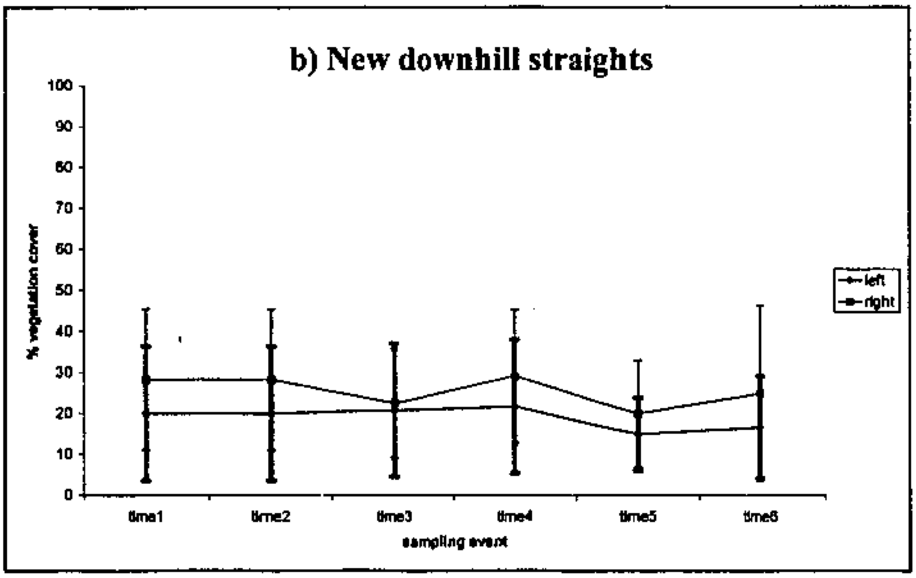
		time 1					time 2					time 3					time 4					time 5				
Site	Side	Q1	Q2	mean	stdev	CV (%)	Q1	Q2	mean	stdev	CV (%)	Q1	Q2	mean	stdev	CV (%)	Q1	Q2	mean	stdev	CV (%)	Q1	Q2	mean	stdev	CV (%)
dc1	left	50	70				50	90				20	80				30	70				30	80			
dc2	left	60	40				70	40				70	40				50	30				70	30			
dc3	left	40	60				50	70				40	70				50	70				50	70			
dc	left			53.33	12.11	22.71			61.67	18.35	29.75			53.33	23.38	43.84			50.00	17.89	35.78			55.00	21.68	39.42
dc1	right	30	80				60	70				40	80				50	70				60	70			
dc2	right	40	40				30	40				50	50				40	60				40	60			
dc3	right	70	50				70	50				80	50				70	50				70	50			
dc	right			51.67	19.41	37.56			53.33	16.33	30.62			58.33	17.22	29.53			56.67	12.11	21.37			58.33	11.69	20.04
ds1	left	90	70				70	70				70	70				70	60				60	50			
ds2	left	50	75				40	80				50	80				50	80				50	70			
ds3	left	25	60				30	70			-	40	80				25	50				30	60			
ds	left			61.67	22.51	36.50			60.00	20.00	33.33			65.00	16.43	25.28			55.83	19.08	34.18			53.33	13.66	25.62
ds1	right	60	75				80	70				80	60				80	70				70	60			
ds2	right	60	50				50	50				50	50				50	50				50	40			
ds3	right	1	10				1	5				3	5				1	10				0	10			
ds	right			42.67	30.01	70.34			42.67	32.87	77.05			41.33	30.93	74.83			43.50	31.77	73.04			38.33	27.87	72.70
fc1	left	50	60				25	75				20	70				20	60				30	50			
fc2	left	70	80				70	80				80	80				70	70				40	50			
fc3	left	5	5				5	10				2	5				5	5				5	5			
fc	left			45.00	32.56	72.35			44.17	34.56	78.24			42.83	37.74	88.10			38.33	31.73	82.77			30.00	20.74	69.12
fc1	right	30	70				30	80				20	70				20	70				20	60			
fc2	right	40	50				30	50				30	50				30	50				20	40			
fc3	right	5	0				5	2				2	1				5	0				5	0			
fc	right			32.50	26.79	82.42			32.83	29.19	88.91			28.83	27.26	94.56			29.17	26.91	92.26			24.17	22.45	92.91
fs1	left	50	40				50	40				80	40				60	30				70	30			
fs2	left	60	90				60	90				60	90				50	90				50	90			
fs3	left	40	50				20	40				30	50				20	30				20	30			
fs	left			55.00	18.71	34.02			50.00	23.66	47.33			58.33	23.17	39.71			46.67	25.82	55.33			48.33	27.14	56.16
fs1	right	20	20				20	15				20	15				10	10				5	10			
fs2	right	40	40				50	50				50	50				30	30				50	40			
fs3	right	60	40				70	50				70	30				60	50				70	40			
fs	right			36.67	15.06	41.06			42.50	20.92	49.22			39.17	21.08	53.81			31.67	20.41	64.46			35.83	24.58	68.59
uc1	left	70	50				40	30				40	30				50	20				40	20			
uc2	left	20	50				25	50				30	50				20	40				70	40			
uc3	left	30	90				50	100				70	80				60	90				60	80			
uc	left			51.67	25.63	49.60			49.17	26.91	54.73			50.00	20.98	41.95			46.67	26.58	56.96			51.67	22.29	43.13
uc1	right	50	40				50	50				50	50				50	40				50	40			
uc2	right	2	2				5	5				1	2				1	10				5	5			
uc3	right	80	80				80	100				80	80				90	80				90	70			
uc	right			42.33	35.09	82.88			48.33	38.56	79.77			43.83	35.43	80.83			45.17	35.95	79.59			43.33	34.30	79.16
us1	left	30	70				30	80				30	70				25	80				20	75			
us2	left	75	60				80	80				80	80				60	70				70	70			
us3	left	25	20				40	20				40	50				25	40				30	40			
left	left			46.67	24.43	52.34			55.00	28.11	51.10			58.33	21.37	36.63			50.00	23.45	46.90			50.83	23.75	46.73
us1	right	50	50				50	70				30	50				50	50				50	50			
us2	right	90	60				90	90				90	80				80	90				70	60			
us3	right	0	2				0	10				0	5				0	5				0	5			
us	right			42.00	34.99	83.30			51.67	39.20	75.87			42.50	37.65	88.59			45.83	37.20	81.17			39.17	29.40	75.06

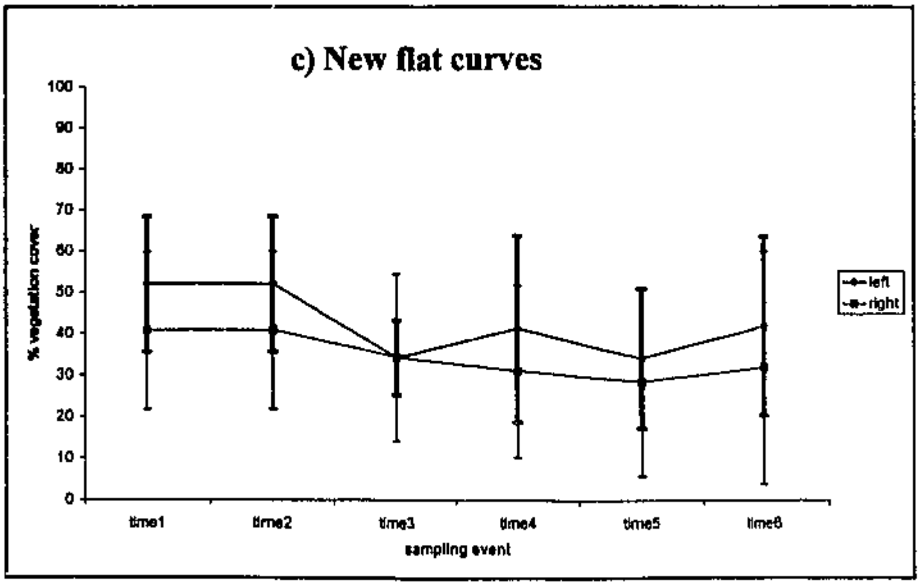
site: d=downhill; f=flat; u=uphill; c=curve; s=straight; numbers refer to replicates; Q=quadrat

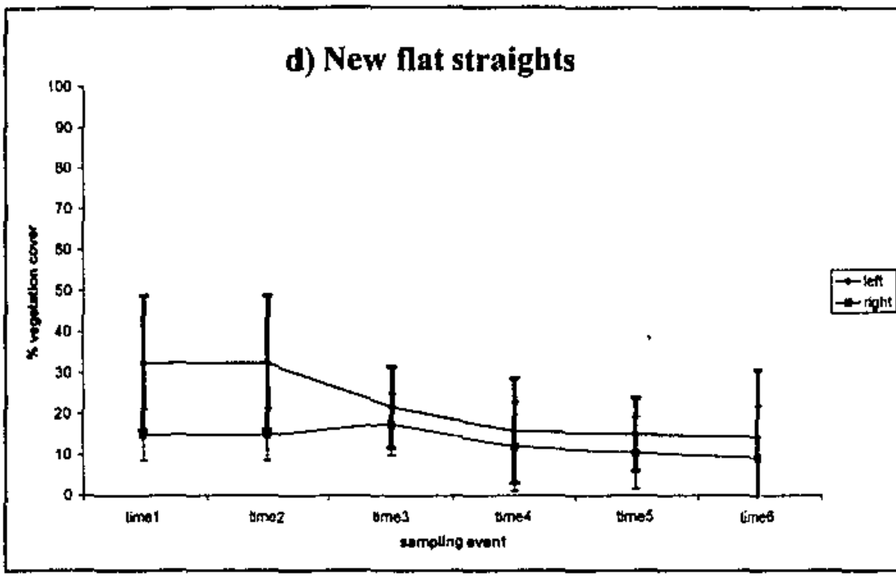
CV=coefficient of variation; stdev= standard deviation

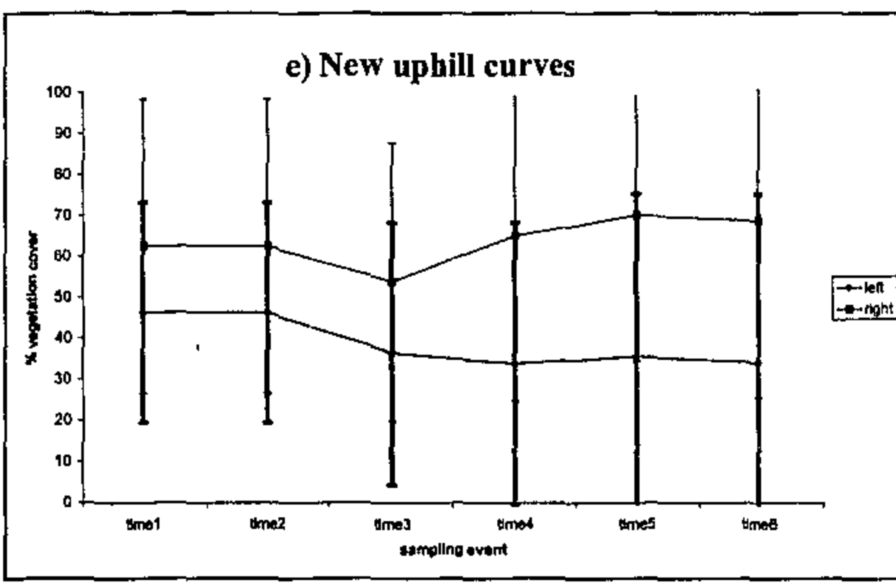
Figure 4.7a-l: Lowden, comparison of % vegetation cover of quadrats adjacent to trail (Error bars represent the 95%confidence intervals)

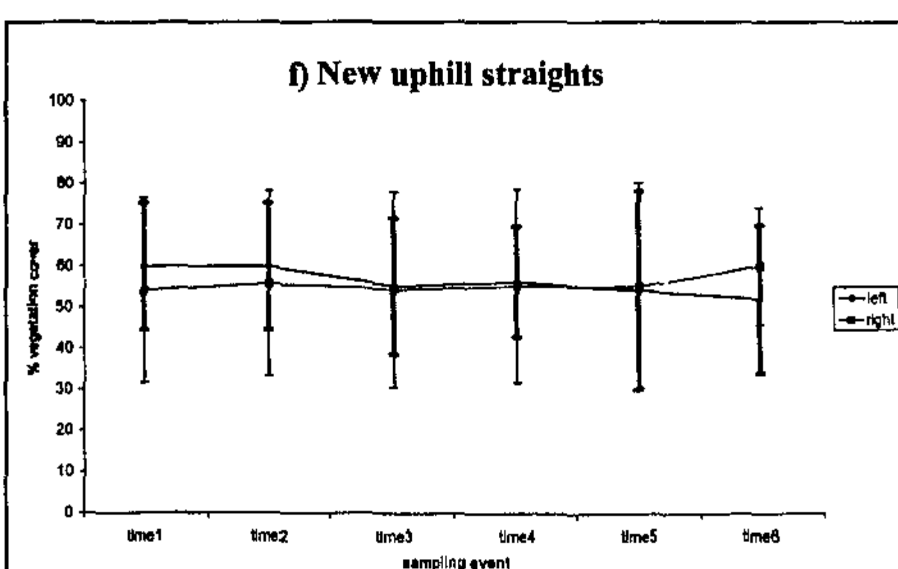


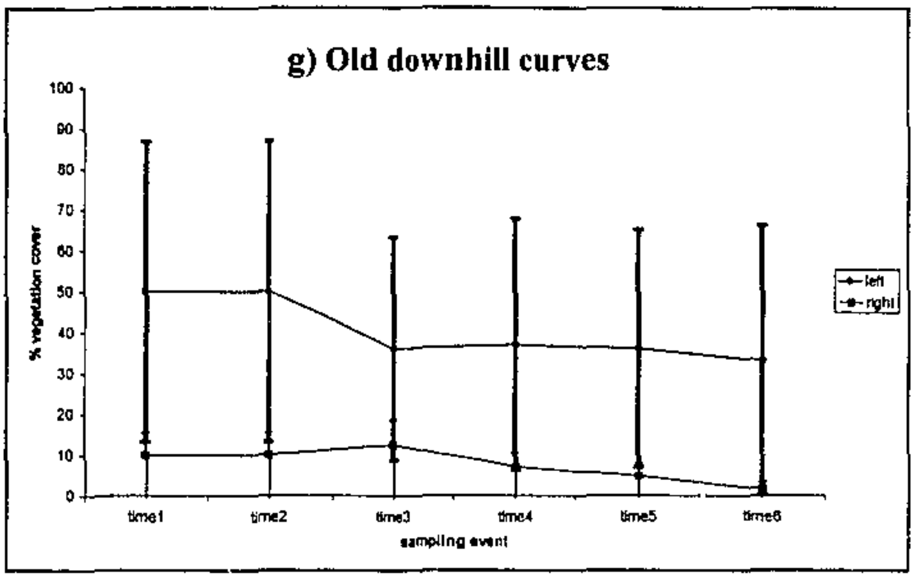


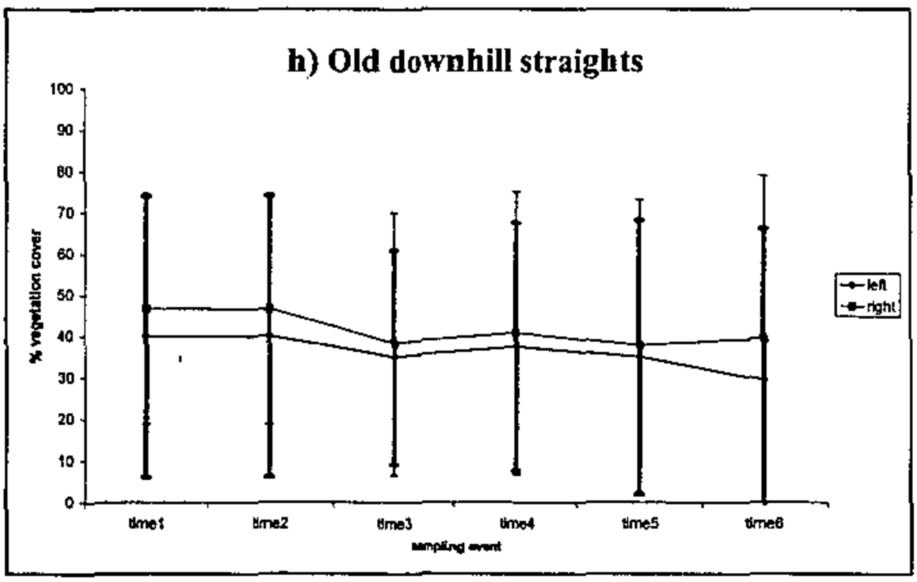


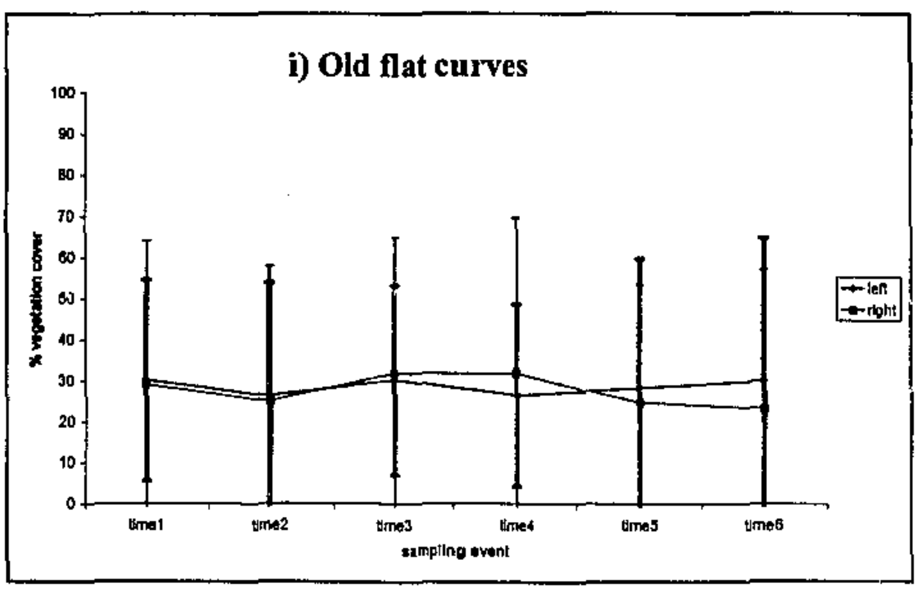

d) New flat straights
% vegetation cover
sampling event
left
right

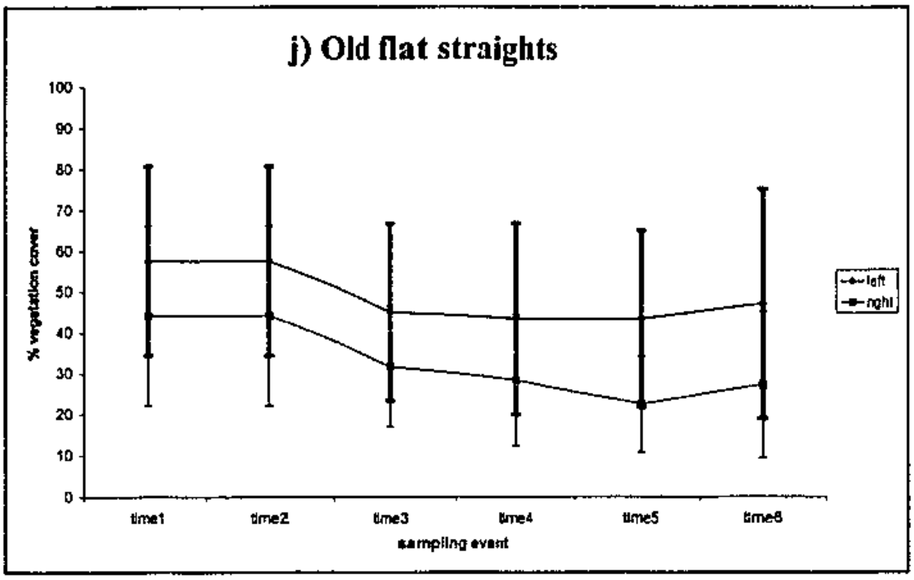

e) New uphill curves
% vegetation cover
sampling event
left
right

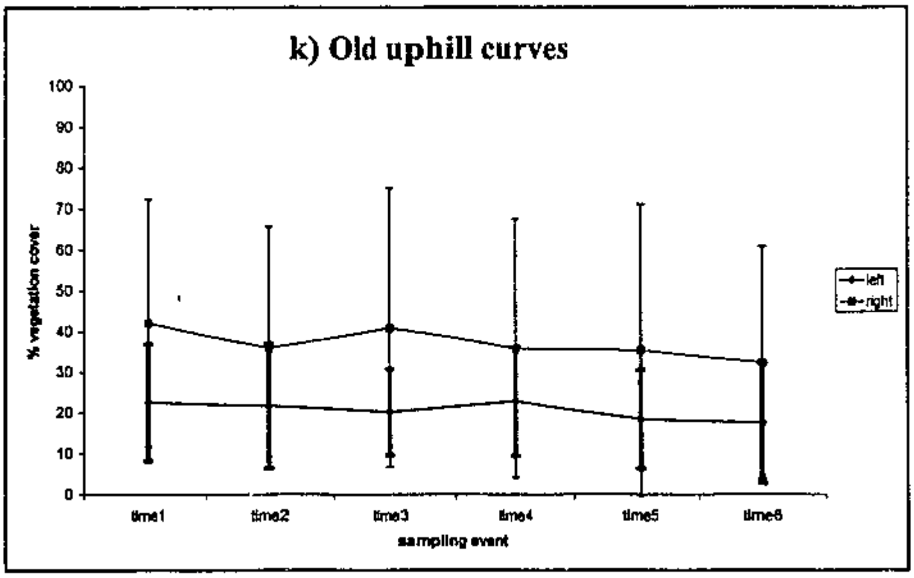

f) New uphill straights
% vegetation cover
sampling event
left
right


g) Old downhill curves
% vegetation cover
100
90
80
70
60
50
40
30
20
10
0
time1
time2
time3
time4
time5
time6
sampling event
left
right


h) Old downhill straights
% vegetation cover
100
90
80
70
60
50
40
30
20
10
0
time1
time2
time3
time4
time5
time6
sampling event
left
right


i) Old flat curves
% vegetation cover
100
90
80
70
60
50
40
30
20
10
0
time1
time2
time3
time4
time5
time6
sampling event
left
right


j) Old flat straights
100
90
80
70
60
50
40
30
20
10
0
% vegetation cover
time1
time2
time3
time4
time5
time6
sampling event
left
right


k) Old uphill curves
100
90
80
70
60
50
40
30
20
10
0
% vegetation cover
time1
time2
time3
time4
time5
time6
sampling event
left
right

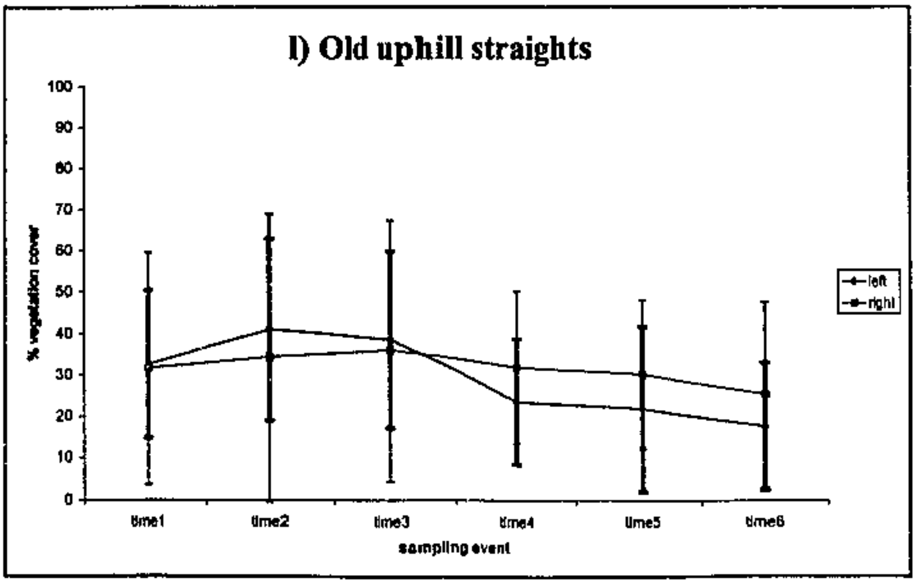
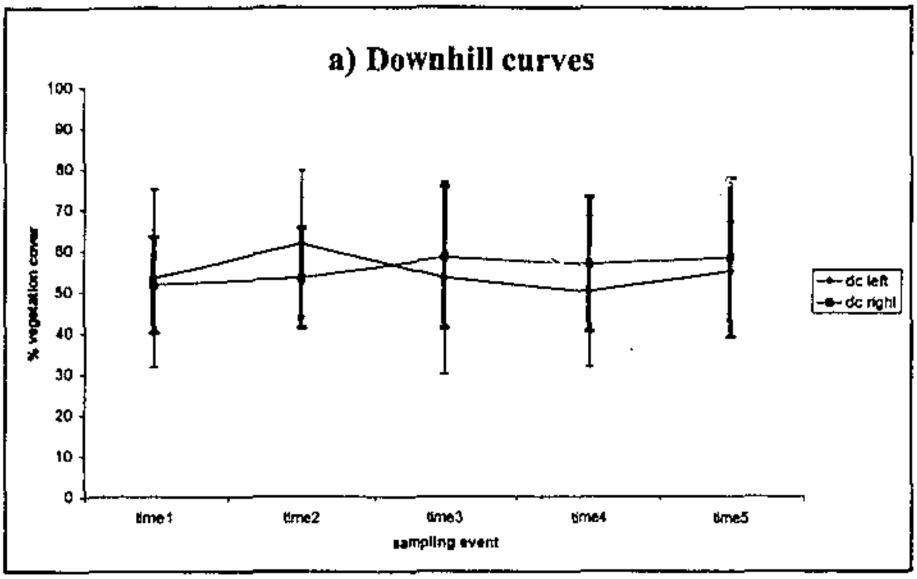
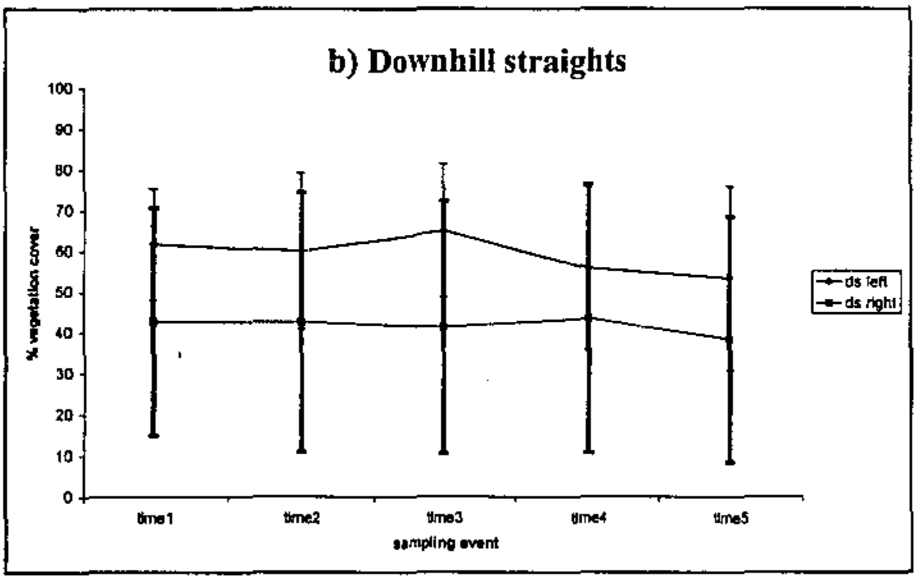
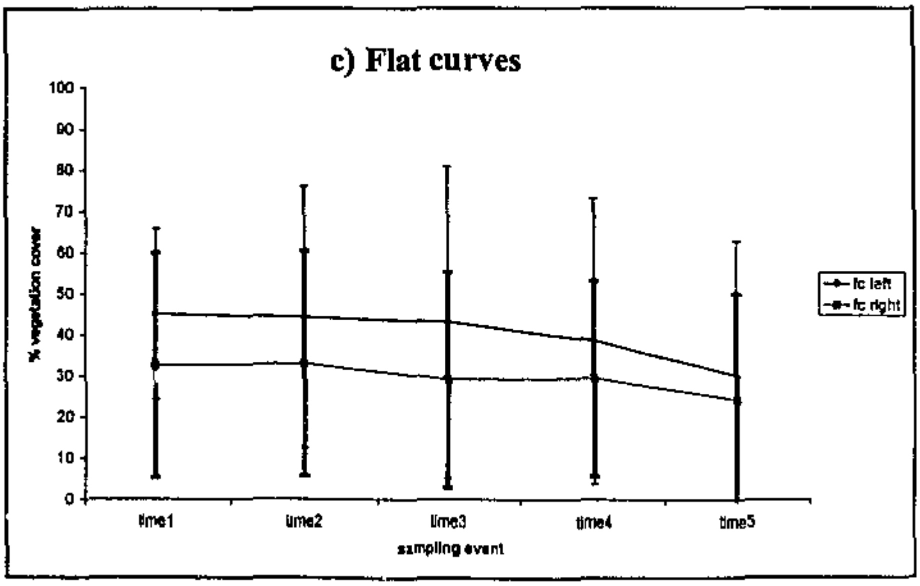
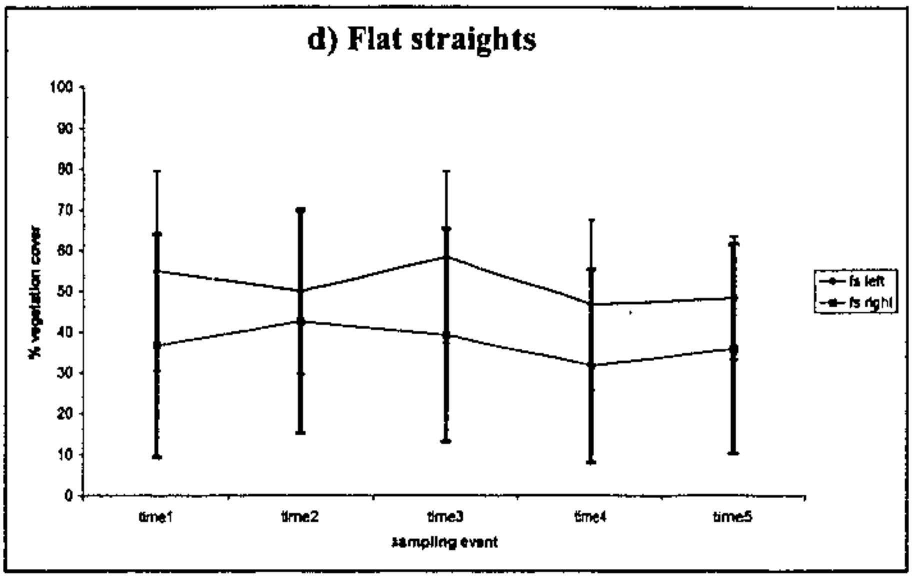

l) Old uphill straights
100
90
80
70
60
50
40
30
20
10
0
% vegetation cover
time1
time2
time3
time4
time5
time6
sampling event
left
right

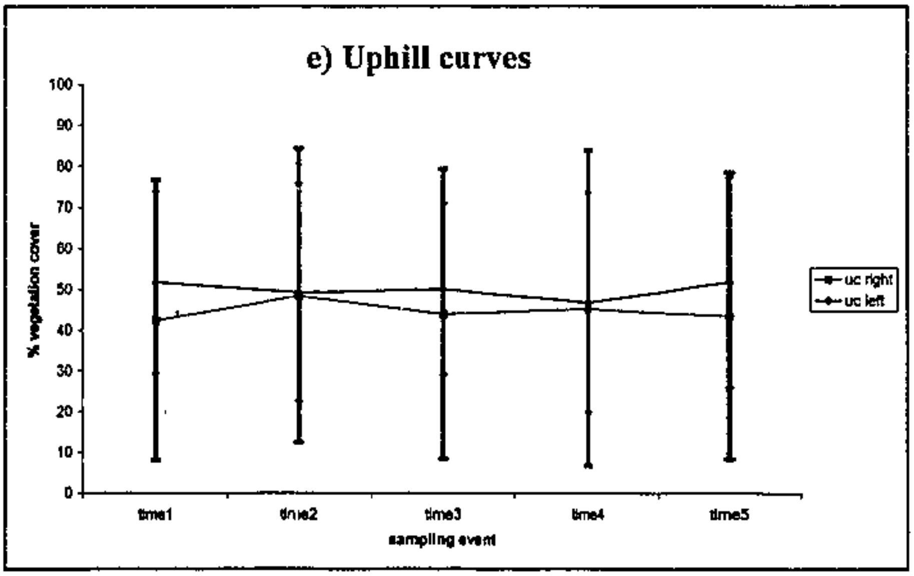
Figure 4.8a-f: Marrinup, comparison of % vegetation cover of quadrats adjacent to trail (Error bars represent the 95% confidence intervals)

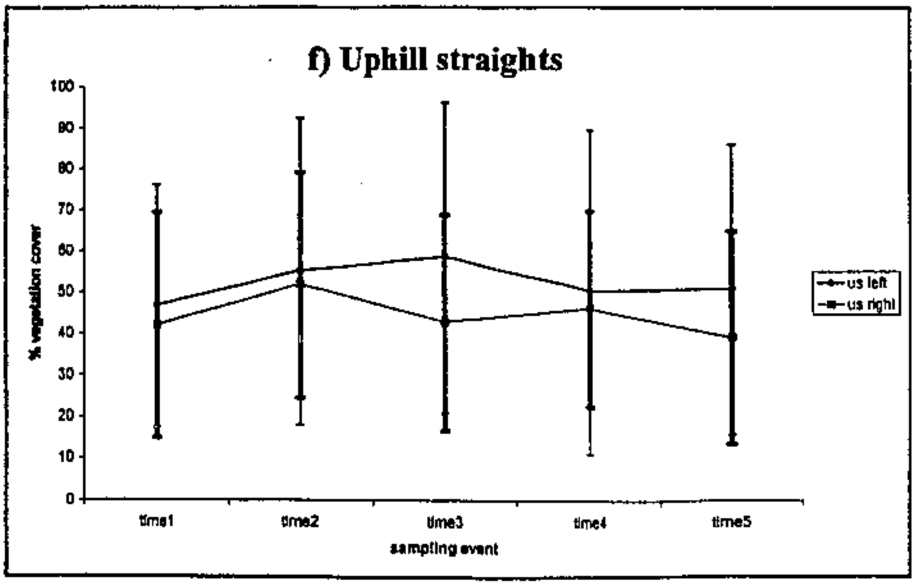







d) Flat straights
% vegetation cover
sampling event
time1
time2
time3
time4
time5
fs left
fs right


e) Uphill curves
% vegetation cover
sampling event
time1
time2
time3
time4
time5
uc right
uc left

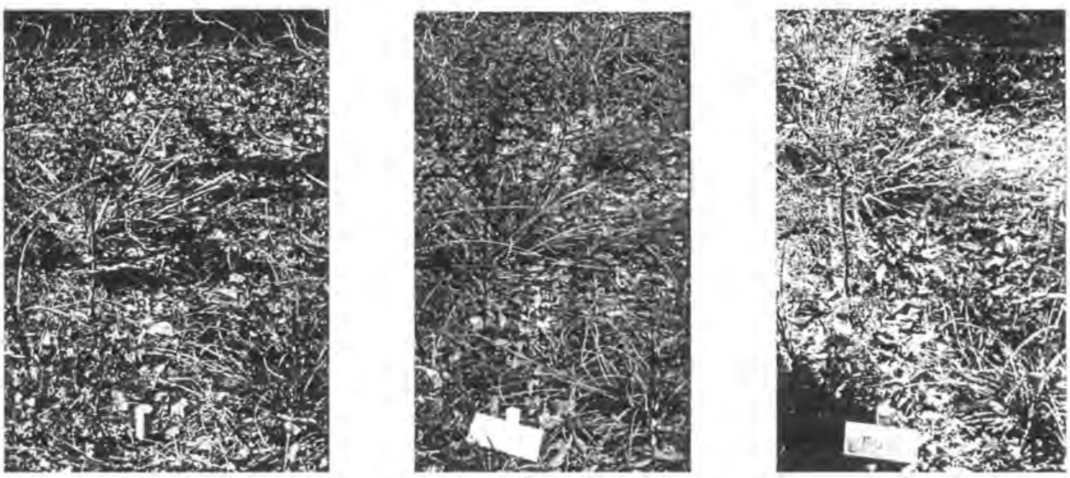

f) Uphill straights
% vegetation cover
sampling event
time1
time2
time3
time4
time5
us left
us right

Disturbance

Evidence of human disturbance beside the trails was minimal and was only recorded for Lowden for 8 instances at time 2 (after the first race) (Table 4.16). These disturbances were of a minor nature and were no longer visible at the next sampling (one month later). At all other times and locations indications of human disturbance were not visible apart from on the trail itself. An inspection of a time series of photographs taken of the left side of the trail at Lowden illustrates the point (Figure 4.9).

Table 4.16: Disturbances in quadrats at Lowden at time 2

Site	Side	Quadrat 1
nds3	right	litter looks disturbed
nfs1	left	some broken plants, broken banksia
nus1	right	deep litter disturbed
odc3	left	grass flattened alongside fence, gravel thrown to side of trail
ofs3	left	1flattened grass plant
ouc1	right	flattened conostylis
ous1	left	some squashed grasses, snapped off banksia leaf
ous2	left	few squashed grasses, 1 footprint



Time 1 Time 4 Time 6

Figure 4.9: Lowden, site new uphill straight replicate 2 (nus2), time series of photographs of left side of the trail

Soil compaction

The right and left quadrat soil compaction along the trails in Lowden as well as in Marrinup was also highly variable (Tables 4.17 and 4.18). A comparison of the soil compaction of the quadrats and of the trail itself can be inspected on Figures 4.10a-m for Lowden and Figures 4.11a-f for Marrinup.

Although the visual depiction of the data for Lowden showed very high variability in some cases (for example Figure 4.10f), the trail itself was almost always more compacted than the quadrats. This was especially pronounced for the 'old' trail sections. For example, the trail soil compaction of the 'old downhill sites' (Figure 4.10h) is significantly different ($p \leq 0.05$) from that of the quadrats. Overall, trail soil compaction was higher for the 'old' sites (around 3 kg/cm^2) than for the 'new' sites (around 2 kg/cm^2) whereas quadrat soil compaction was comparable for most sites (around 1kg/cm^2).

For Marrinup the same trends were visible as for Lowden (Figures 4.11a-f). An increase of vegetation cover over time was seen as well as a significant difference between soil compaction of the trail and the quadrats. However, here the difference between trail soil compaction and quadrat soil compaction was even more pronounced (for example Figures 4.11c and f), whereas the increase in vegetation cover was less conspicuous overall.

Table 4.17: Lowden, means, standard deviations and coefficients of variation for quadrat soil compaction

		time1				time2				time3				time4				time5				time6			
Site	Side	msc	mean	stdev	CV (%)	msc	mean	stdev	CV (%)	msc	mean	stdev	CV (%)	msc	mean	stdev	CV (%)	msc	mean	stdev	CV (%)	msc	mean	stdev	CV (%)
ndc1	left	0.45				0.45				2.47				1.34				0.94				0.61			
ndc2	left	2.00				2.00				2.13				1.50				1.25				1.50			
ndc3	left	0.70				0.70				2.43				2.19				1.85				1.95			
ndc	left		1.05	0.83	79.25		1.05	0.83	79.25		2.34	0.19	8.00		1.68	0.45	26.96		1.35	0.46	34.46		1.35	0.68	50.54
ndc1	right	0.34				0.34				0.94				0.44				0.65				1.07			
ndc2	right	0.40				0.40				1.60				1.40				1.68				2.08			
ndc3	right	0.30				0.30				0.70				0.58				0.35				1.40			
ndc	right		0.35	0.05	14.41		0.35	0.05	14.41		1.08	0.47	43.22		0.80	0.52	64.73		0.89	0.69	77.92		1.52	0.51	33.76
nds1	left	0.11				0.11				0.75				0.22				0.72				0.16			
nds2	left	0.63				0.63				1.20				1.45				1.08				1.75			
nds3	left	0.65				0.65				0.85	-			0.83				1.53				1.33			
nds	left		0.46	0.30	65.83		0.46	0.30	65.83		0.93	0.24	25.32		0.83	0.61	73.75		1.11	0.40	36.43		1.08	0.83	76.54
nds1	right	0.10				0.10				0.20				0.10				0.23				0.53			
nds2	right	0.83				0.83				1.43				2.58				1.95				1.70			
nds3	right	0.05				0.10				0.09				0.18				0.28				0.91			
nds	right		0.33	0.43	133.46		0.34	0.42	122.51		0.57	0.74	129.13		0.95	1.41	147.90		0.82	0.98	119.71		1.04	0.60	57.43
nfc1	left	1.22				1.22				2.89				2.00				1.91				1.44			
nfc2	left	0.19				0.19				1.85				1.80				1.50				2.15			
nfc3	left	0.04				0.04				0.00				0.15				0.10				0.15			
nfc	left		0.48	0.64	132.95		0.48	0.64	132.95		1.58	1.47	92.67		1.32	1.02	77.11		1.17	0.95	81.08		1.25	1.01	81.37
nfc1	right	0.45				0.45				0.55				0.25				0.36				0.34			
nfc2	right	0.38				0.38				0.95				0.78				0.75				0.95			
nfc3	right	1.18				1.18				2.05				1.88				1.65				1.80			
nfc	right		0.67	0.44	66.27		0.67	0.44	66.27		1.18	0.78	65.64		0.97	0.83	85.79		0.92	0.66	72.12		1.03	0.73	70.93
nfs1	left	0.50				0.13				1.00				0.61				1.03				1.18			
nfs2	left	1.10				1.10				1.38				1.55				2.05				1.70			
nfs3	left	1.03				1.03				2.30				2.00				2.35				1.63			
nfs	left		0.88	0.33	37.36		0.75	0.54	72.34		1.56	0.67	42.94		1.39	0.71	51.09		1.81	0.69	38.42		1.50	0.28	18.93
nfs1	right	1.64				1.64				1.00				0.25				0.16				0.28			
nfs2	right	0.30				0.30				0.98				0.69				1.60				1.08			
nfs3	right	0.67				0.67				1.47				1.53				1.41				1.72			
nfs	right		0.87	0.69	79.66		0.87	0.69	79.66		1.15	0.28	24.23		0.83	0.65	78.83		1.05	0.78	74.34		1.03	0.72	70.25
nuc1	left	0.30				0.30				0.78				0.85				0.64				1.35			
nuc2	left																								
nuc3	left	1.63				1.23				2.50				2.33				2.33				2.55			
nuc	left		0.96	0.94	97.34		0.76	0.65	85.78		1.64	1.22	74.49		1.59	1.04	65.70		1.48	1.19	80.45		1.95	0.85	43.51
nuc1	right	0.19				0.19				0.31				0.42				0.00				0.00			
nuc2	right	M				M				M				M				M				M			
nuc3	right	0.92				0.92				0.75				1.25				1.19				1.41			
nuc	right		0.55	0.52	93.39		0.55	0.52	93.39		0.53	0.31	58.23		0.83	0.59	70.71		0.59	0.84	141.42		0.70	0.99	141.42
nus1	left	0.05				0.05				0.65				0.00				0.00				0.70			
nus2	left	0.18				0.18				0.28				0.25				0.11				0.75			
nus3	left	1.13				1.13				3.10				3.17				1.72				1.94			
nus	left		0.45	0.59	130.64		0.45	0.59	130.64		1.34	1.53	114.35		1.14	1.76	154.58		0.61	0.96	157.72		1.13	0.70	62.26
nus1	right	0.03				0.05				0.61				0.08				0.14				0.50			
nus2	right	0.35				0.35				0.95				1.03				0.48				1.55			
nus3	right	0.25				0.25				0.80				0.94				0.47				1.31			
nus	right		0.21	0.17	79.90		0.22	0.15	70.50		0.79	0.17	21.58		0.68	0.53	77.31		0.36	0.19	53.28		1.12	0.55	49.13

site: n=new; o=old; d=downhill; f=flat; u=uphill; c=curve; s=straight; number refers to replicate; msc=mean soil compaction CV = Coefficient of variation; M = missing data; stdev= standard deviation

Table 4.17: continued

		time1				time2				time3				time4				time5				time6			
Site	Side	msc	mean	stdev	CV (%)	msc	mean	stdev	CV (%)	msc	mean	stdev	CV (%)	msc	mean	stdev	CV (%)	msc	mean	stdev	CV (%)	msc	mean	stdev	CV (%)
odc1	left	0.28				0.28				0.97				1.03				1.00				0.53			
odc2	left	0.33				0.33				0.71				0.92				1.15				0.83			
odc3	left	0.79				0.79				1.95				2.79				2.50				1.10			
odc	left		0.46	0.28	60.63		0.46	0.28	60.63		1.21	0.65	54.05		1.58	1.05	66.63		1.55	0.83	53.30		0.82	0.29	34.90
odc1	right	0.48				0.48				0.60				0.88				1.13				1.25			
odc2	right	0.60				0.60				0.90				1.10				1.33				1.53			
odc3	right	1.09				0.42				1.06				1.66				2.04				2.50			
odc	right		0.72	0.33	45.26		0.50	0.09	18.84		0.85	0.23	27.18		1.21	0.40	33.22		1.50	0.48	32.01		1.76	0.66	37.36
ods1	left	1.20				0.90				1.58				1.95				1.33				2.28			
ods2	left	0.43				0.43				0.65				0.68				0.83				1.08			
ods3	left	0.23				0.23				0.65				0.83				0.90				1.19			
ods	left		0.62	0.51	83.51		0.52	0.35	67.11		0.96	0.53	55.73		1.15	0.69	60.28		1.02	0.27	26.52		1.51	0.66	43.82
ods1	right	0.10				0.10				0.23				0.50				0.25				0.38			
ods2	right	0.53				0.53				1.25				1.00				1.14				0.72			
ods3	right	0.86				0.86				0.18				0.83				0.79				1.50			
ods	right		0.49	0.38	76.70		0.49	0.38	76.70		0.55	0.61	109.88		0.78	0.25	32.73		0.72	0.45	61.74		0.86	0.58	66.68
ofc1	left	0.25				0.25				0.00				0.20				0.00				0.03			
ofc2	left	0.65				0.65				2.18				2.53				2.00				3.28			
ofc3	left																								
ofc	left		0.45	0.28	62.85		0.45	0.28	62.85		1.09	1.54	141.42		1.36	1.64	120.66		1.00	1.41	141.42		1.65	2.30	139.28
ofc1	right	0.23				0.23				0.00				0.33				0.00				0.03			
ofc2	right	1.19				1.19				0.82				1.57				1.33				1.42			
ofc3	right	0.86				0.86				2.39				2.31				1.42				2.39			
ofc	right		0.76	0.49	64.79		0.76	0.49	64.79		1.07	1.21	113.42		1.40	1.00	71.48		0.92	0.79	86.72		1.28	1.19	93.05
ofs1	left	2.81				2.81				0.03				0.14				0.13				0.16			
ofs2	left	1.50				1.50				2.15				2.05				3.25				3.25			
ofs3	left	1.03				1.03				1.18				1.25				1.73				1.98			
ofs	left		1.78	0.92	51.89		1.78	0.92	51.89		1.12	1.06	94.79		1.15	0.96	83.73		1.70	1.56	91.92		1.79	1.55	86.68
ofs1	right	0.20				0.20				0.50				0.58				0.59				0.94			
ofs2	right	0.68				0.68				1.73				1.95				1.15				1.95			
ofs3	right	0.38				0.38				1.10				1.53				2.20				1.23			
ofs	right		0.42	0.24	57.65		0.42	0.24	57.65		1.11	0.61	55.27		1.35	0.70	52.15		1.31	0.82	62.05		1.37	0.52	38.06
ouc1	left	0.85				0.89				1.98				2.25				0.88				1.70			
ouc2	left	1.22				1.22				2.78				1.78				3.14				3.18			
ouc3	left	0.35				0.35				0.93				1.10				1.15				1.03			
ouc	left		0.81	0.44	54.08		0.82	0.44	53.53		1.89	0.93	49.15		1.71	0.58	33.82		1.72	1.24	71.85		1.97	1.10	55.97
ouc1	right	0.67				0.28				1.11				0.69				1.06				0.92			
ouc2	right	1.46				1.46				1.83				2.04				1.20				1.71			
ouc3	right	0.08				0.08				0.19				0.50				0.83				0.17			
ouc	right		0.74	0.69	93.92		0.61	0.75	122.49		1.04	0.82	79.11		1.08	0.84	78.15		1.03	0.19	17.95		0.93	0.77	82.85
ous1	left	0.50				0.23				0.80				0.58				0.81				0.38			
ous2	left	3.18				3.90				3.75				3.83				3.48				2.75			
ous3	left	0.53				0.53				2.45				2.75				2.50				1.98			
ous	left		1.40	1.54	109.80		1.55	2.04	131.66		2.33	1.48	63.36		2.39	1.65	69.20		2.26	1.35	59.76		1.70	1.21	71.24
ous1	right	0.90				1.68				1.88				2.63				2.90				2.43			
ous2	right	1.68				1.30				2.65				3.28				2.38				2.97			
ous3	right	0.78				0.78				1.68				1.50				1.53				1.45			
ous	right		1.12	0.49	43.66		1.25	0.45	36.17		2.07	0.51	24.92		2.47	0.90	36.40		2.27	0.69	30.61		2.28	0.77	33.78

site: n=new; o=old; d=downhill; f=flat; u=uphill; c=curve; s=straight; number refers to replicate; msc=mean soil compaction CV = Coefficient of variation; M = missing data; stdev= standard deviation

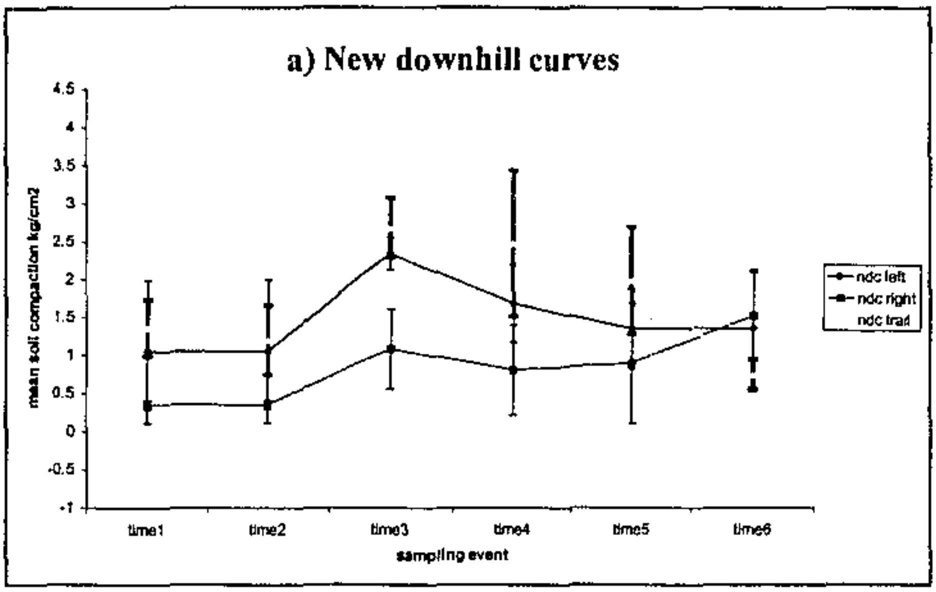
Table 4.18: Marrinup, means, standard deviations and coefficients of variation for quadrat soil compaction

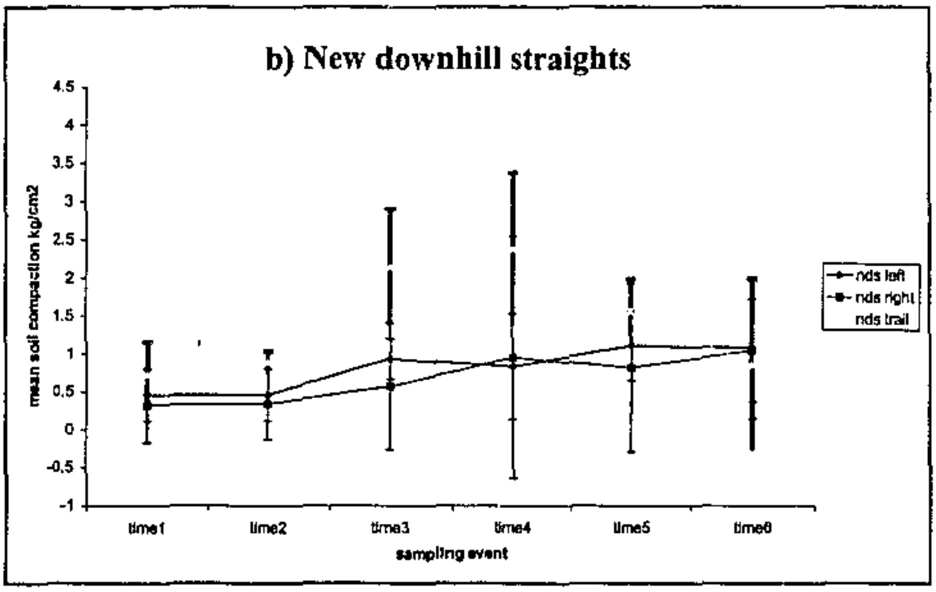
		time1				time2				time3				time4				time5			
Site	Side	msc	mean	stdev	CV (%)	msc	mean	stdev	CV (%)	msc	mean	stdev	CV (%)	msc	mean	stdev	CV (%)	msc	mean	stdev	CV (%)
dc1	left	0.17				0.73				0.67				1.02				0.53			
dc2	left	0.23				0.89				1.13				1.86				1.25			
dc3	left	1.10				0.65				0.78				0.88				0.98			
dc	left		0.50	0.52	105.15		0.75	0.12	16.19		0.86	0.24	28.00		1.27	0.52	41.13		0.92	0.36	39.47
dc1	right	0.35				0.28				0.08				0.36				0.42			
dc2	right	0.13				0.43				0.00				0.00				0.00			
dc3	right	1.55				1.48				1.30				2.75				2.65			
dc	right		0.68	0.77	113.49		0.73	0.65	90.18		0.46	0.73	157.81		1.04	1.49	144.10		1.02	1.43	139.40
ds1	left	1.30				0.28				0.79				0.54				0.57			
ds2	left	0.38				0.50				0.58				0.85				0.72			
ds3	left	0.00				0.00				0.00				0.00				0.00			
ds	left		0.56	0.67	119.84		0.26	0.25	96.94		0.46	0.41	89.40		0.46	0.43	93.05		0.43	0.38	88.35
ds1	right	0.36				2.10				1.98				3.36				2.33			
ds2	right	0.28				0.59				0.56				0.78				0.69			
ds3	right	1.55				1.83				1.83				2.00				1.47			
ds	right		0.73	0.71	97.24		1.51	0.80	53.25		1.45	0.78	53.35		2.05	1.29	63.03		1.49	0.82	54.79
fc1	left	0.00				0.00				0.00				0.00				0.28			
fc2	left	0.19				0.00				0.00				0.30				0.00			
fc3	left	0.08				0.00				0.00				0.00				0.00			
fc	left		0.09	0.10	109.19		0.00	0.00	0.00		0.00	0.00	0.00		0.10	0.17	173.21		0.09	0.16	173.21
fc1	right	0.38				0.19				0.19				0.56				0.56			
fc2	right	0.28				0.31				0.11				0.75				0.47			
fc3	right	0.00				0.00				0.00				0.00				0.00			
fc	right		0.22	0.19	89.44		0.17	0.15	92.80		0.10	0.09	94.72		0.44	0.39	89.21		0.34	0.30	87.53
fs1	left	0.86				0.69				0.89				1.69				1.63			
fs2	left	0.79				1.04				0.70				1.45				1.39			
fs3	left	0.75				0.50				0.25				0.65				0.80			
fs	left		0.80	0.06	7.10		0.74	0.28	37.02		0.61	0.33	53.70		1.26	0.54	43.06		1.27	0.43	33.43
fs1	right	1.15				1.13				1.63				1.55				1.13			
fs2	right	0.53				1.19				0.86				1.45				1.60			
fs3	right	0.48				0.65				0.28				0.25				0.25			
fs	right		0.72	0.38	52.31		0.99	0.30	29.94		0.92	0.68	73.33		1.08	0.72	66.78		0.99	0.68	69.06
uc1	left	0.19				0.14				0.14				1.00				0.67			
uc2	left	0.00				0.00				0.00				0.00				0.00			
uc3	left	0.65				0.80				0.69				1.13				2.56			
uc	left		0.28	0.33	118.53		0.31	0.43	136.59		0.28	0.36	131.97		0.71	0.62	87.05		1.08	1.33	123.51
uc1	right	0.93				0.78				0.61				1.64				2.00			
uc2	right	0.03				0.06				0.00				0.25				0.07			
uc3	right	1.50				1.08				1.33				1.44				2.31			
uc	right		0.82	0.74	91.03		0.64	0.53	82.67		0.65	0.67	103.20		1.11	0.75	67.68		1.46	1.21	83.03
us1	left	0.83				0.63				0.69				1.03				1.13			
us2	left	0.14				0.11				0.36				0.14				0.42			
us3	left	0.00				0.00				0.00				0.00				0.00			
us	left		0.32	0.45	137.77		0.24	0.33	136.96		0.35	0.34	98.74		0.39	0.56	142.76		0.51	0.57	110.68
us1	right	0.25				0.44				0.47				0.66				0.56			
us2	right	0.45				0.22				0.30				0.40				0.75			
us3	right	0.00				0.03				0.00				0.08				0.08			
us	right		0.23	0.23	96.63		0.23	0.21	91.07		0.26	0.24	92.65		0.38	0.29	77.25		0.46	0.35	75.34

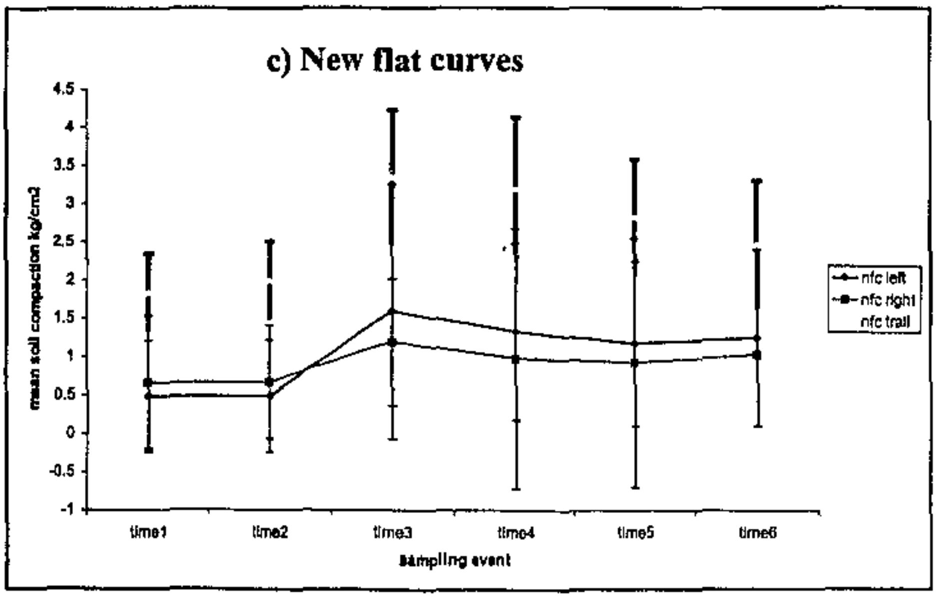
site: n=new; o=old; d=downhill; f=flat; u=uphill; c=curve; s=straight; number refers to replicate; msc=mean soil compaction CV = Coefficient of variation; M = missing data; stdev= standard deviation

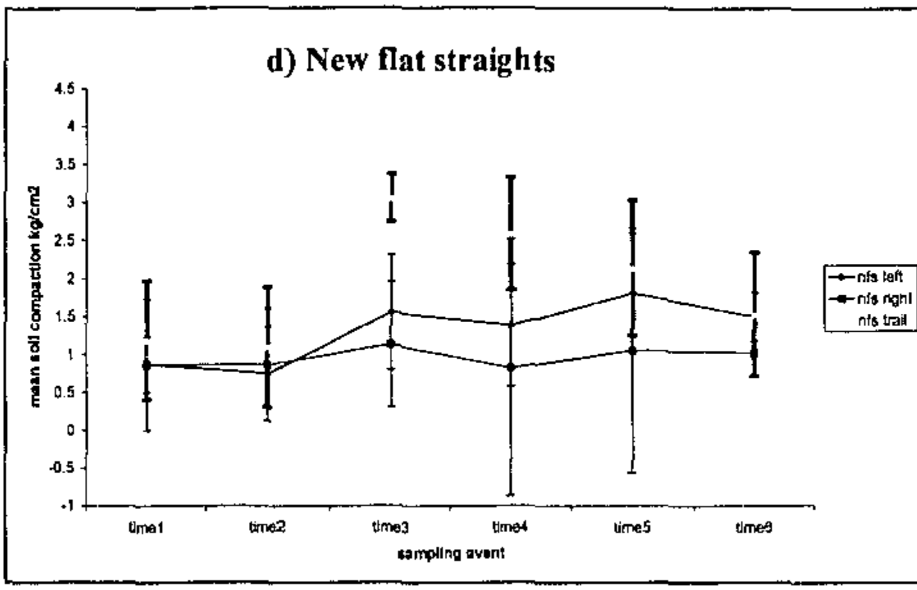
Figure 4.10a-l: Lowden, comparison of soil compaction of trail and quadrats

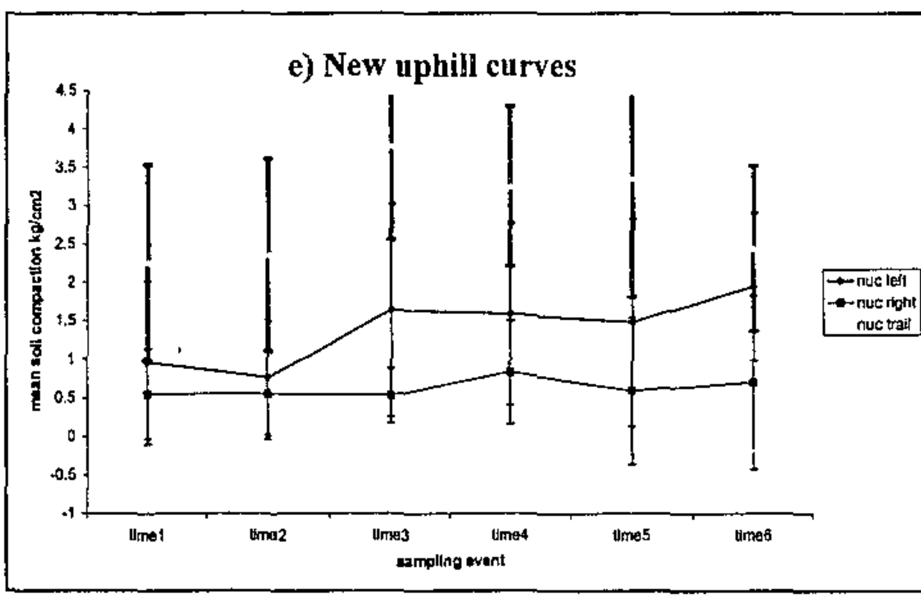
(Error bars represent the 95% confidence intervals)

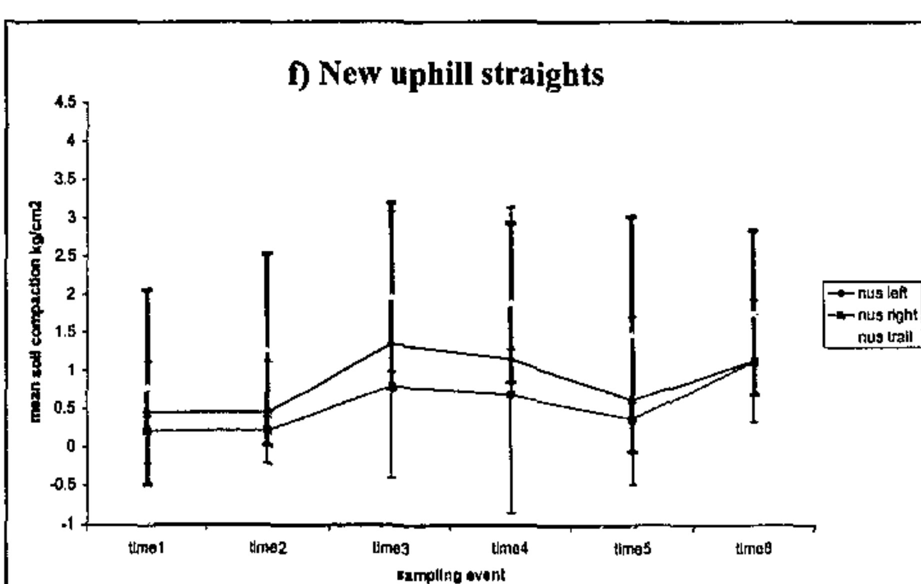


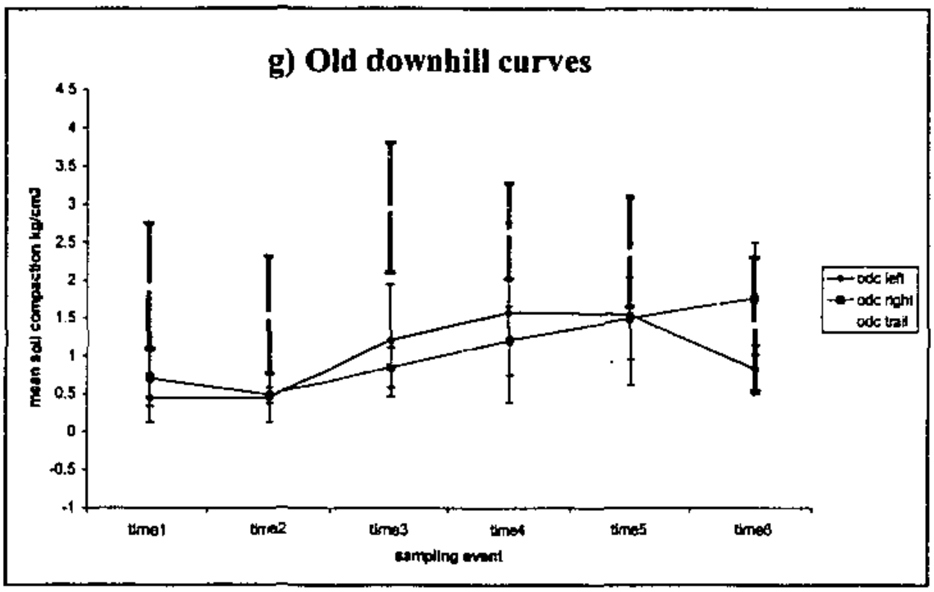


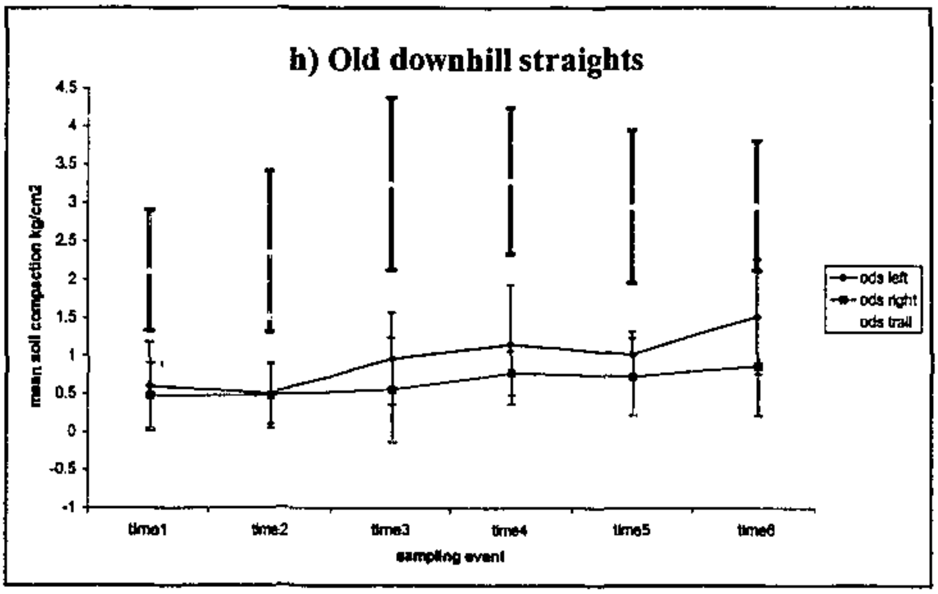


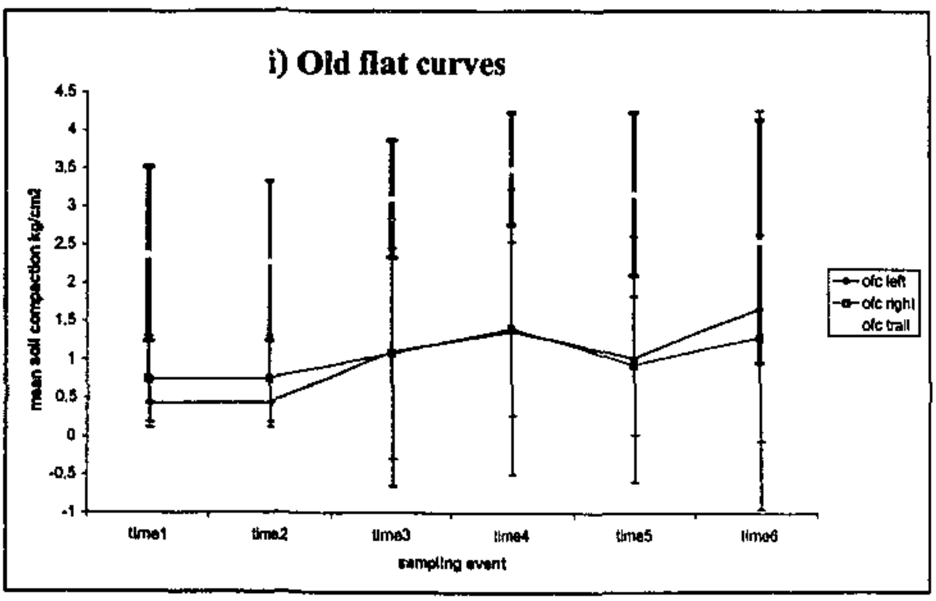

d) New flat straights
mean soil compaction kg/cm2
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
time1
time2
time3
time4
time5
time6
sampling event
nfs left
nfs right
nfs trail

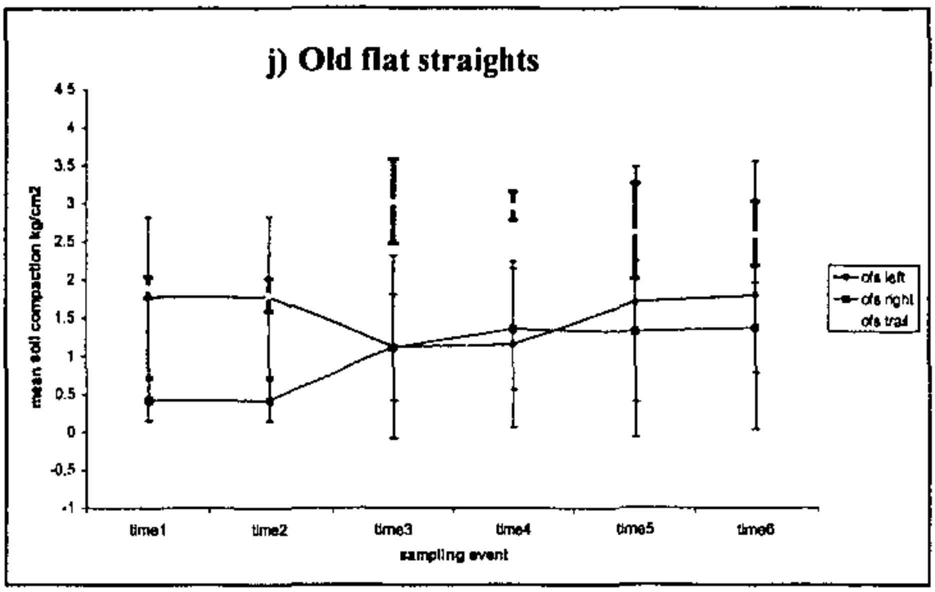

e) New uphill curves
mean soil compaction kg/cm2
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
time1
time2
time3
time4
time5
time6
sampling event
nuc left
nuc right
nuc trail

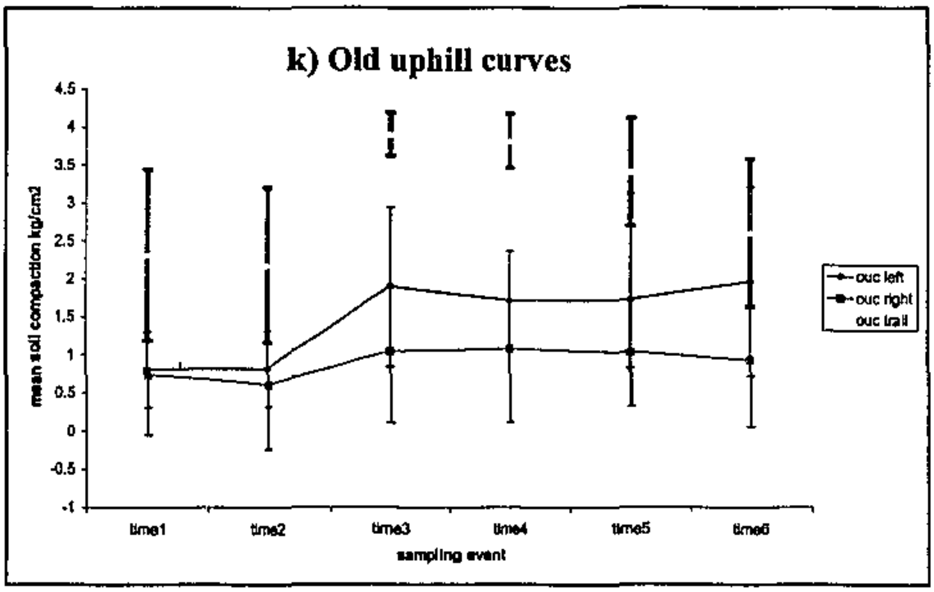

f) New uphill straights
mean soil compaction kg/cm2
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
time1
time2
time3
time4
time5
time6
sampling event
nus left
nus right
nus trail


g) Old downhill curves
mean soil compaction kg/cm2
sampling event
time1
time2
time3
time4
time5
time6
odc left
odc right
odc trail


h) Old downhill straights
mean soil compaction kg/cm2
sampling event
time1
time2
time3
time4
time5
time6
ods left
ods right
ods trail


i) Old flat curves
mean soil compaction kg/cm2
sampling event
time1
time2
time3
time4
time5
time6
ofc left
ofc right
ofc trail


j) Old flat straights
mean soil compaction kg/cm2
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
time1
time2
time3
time4
time5
time6
sampling event
ofs left
ofs right
ofs trail


k) Old uphill curves
mean soil compaction kg/cm2
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
time1
time2
time3
time4
time5
time6
sampling event
ouc left
ouc right
ouc trail

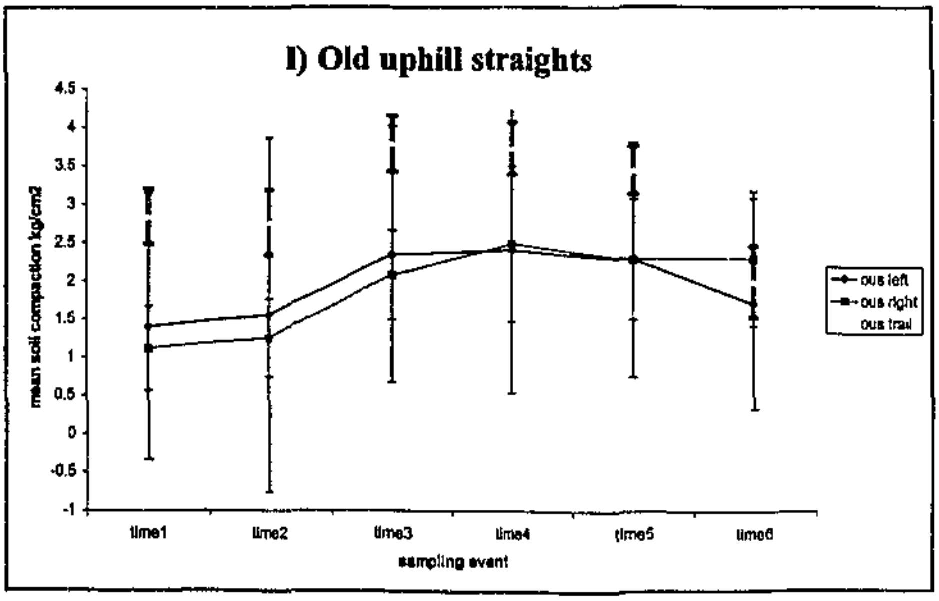
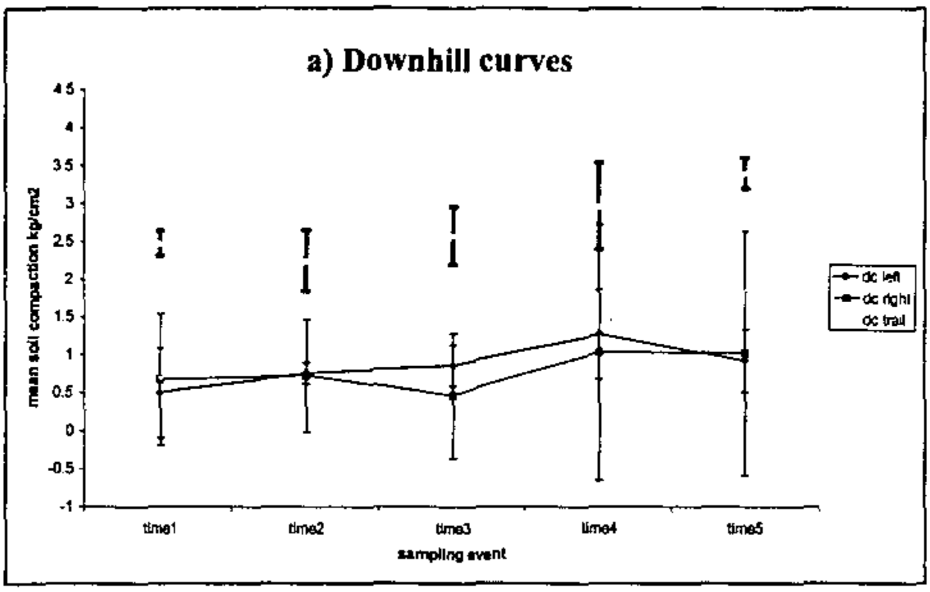
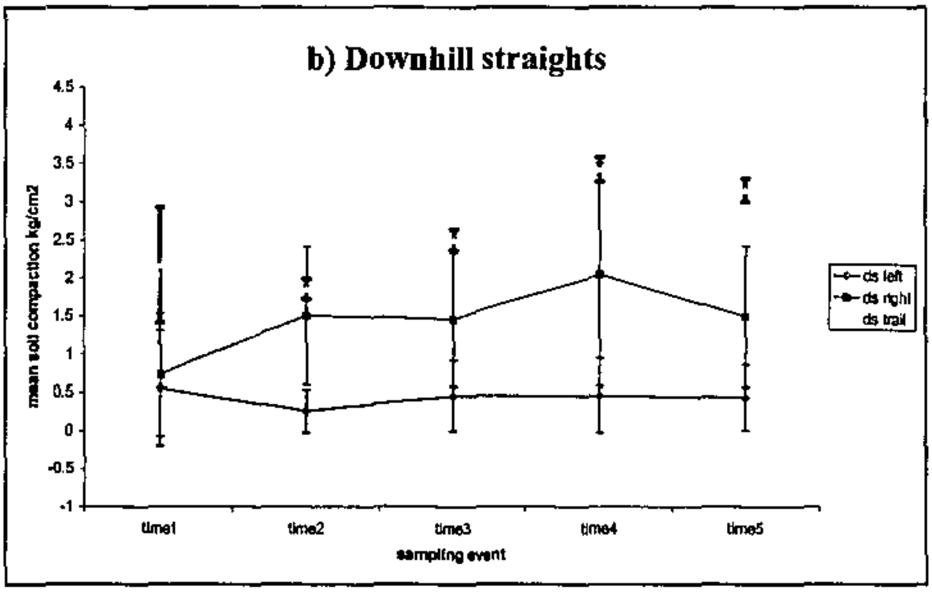
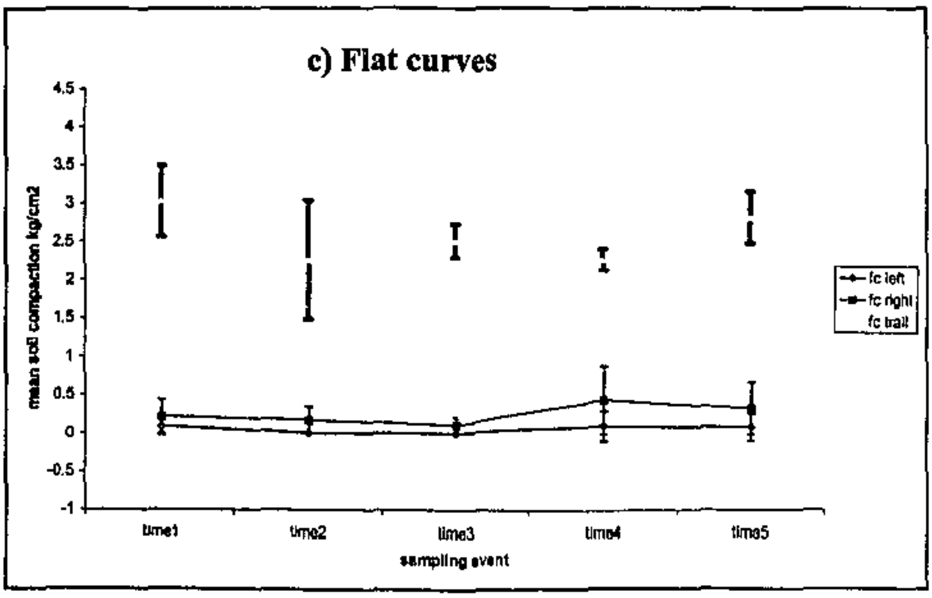

l) Old uphill straights
mean soil compaction kg/cm2
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
time1
time2
time3
time4
time5
time6
sampling event
ous left
ous right
ous trail

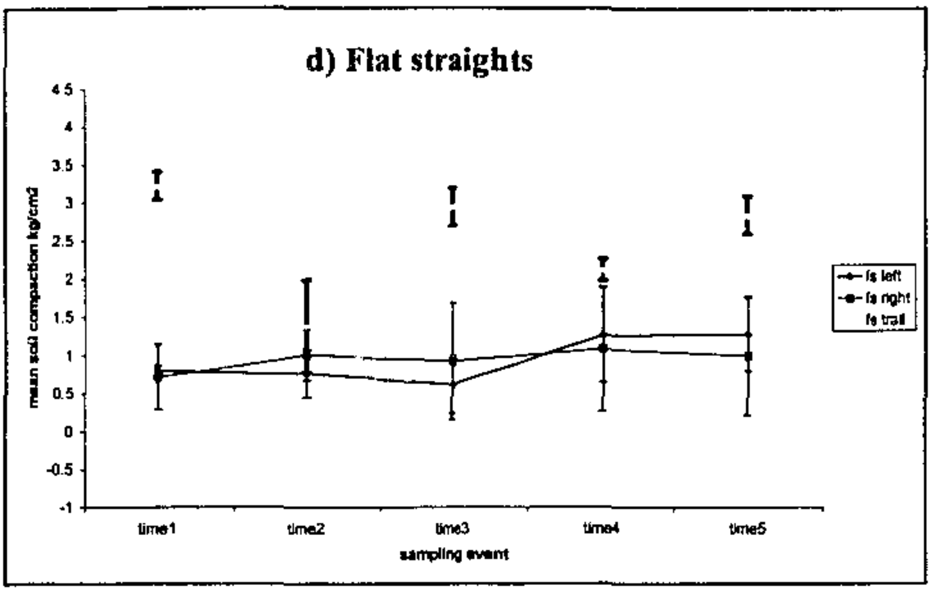
Figure 4.11a-f: Marrinup, comparison of soil compaction of trail and quadrats

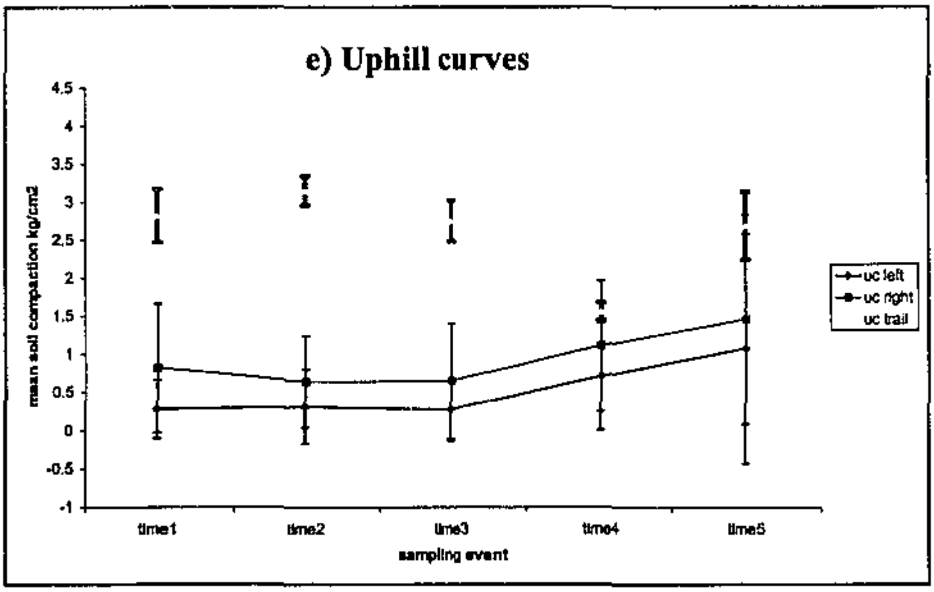
(Error bars represent the 95% confidence intervals)

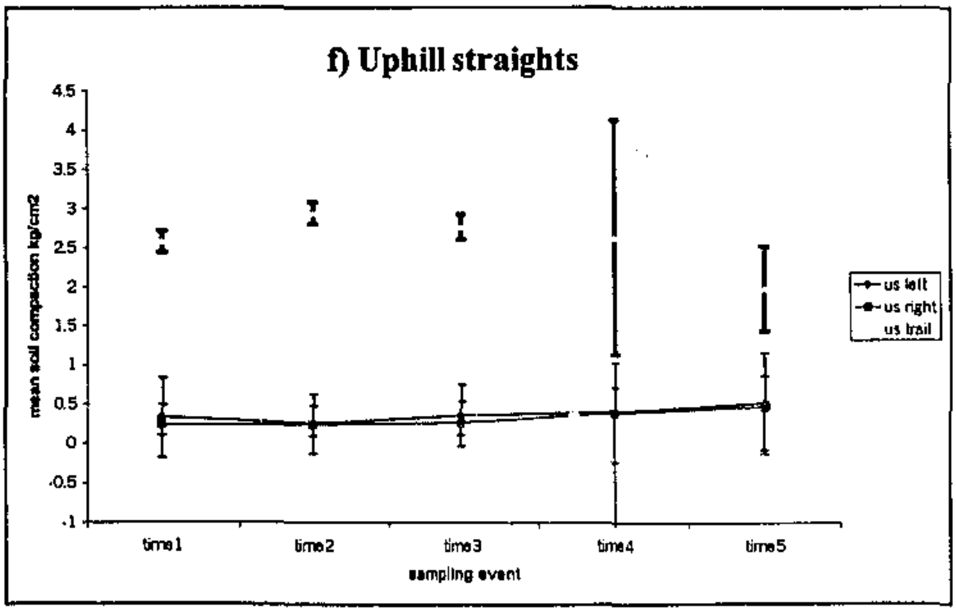







d) Flat straights
mean soil compaction kg/cm2
sampling event
time1
time2
time3
time4
time5
fs left
fs right
fs trail


e) Uphill curves
mean soil compaction kg/cm2
sampling event
time1
time2
time3
time4
time5
uc left
uc right
uc trail


f) Uphill straights
mean soil compaction kg/cm2
sampling event
time1
time2
time3
time4
time5
us left
us right
us trail

4.1.3 Other variables and observations

Incline and aspect

Incline at Lowden ranged from -18° to +15° and aspect varied between 0° and 346° (Table 4.19). At Marrinup incline varied between -11° and +8° and aspect ranged from 36° to 300° (Table 4.19). In comparison Lowden had steeper slopes than Marrinup.

Table 4.19: incline (degrees) and aspect (degrees from North) for Lowden and Marrinup

Lowden					
site	incline	aspect	site	incline	aspect
ndc1	-3	132	odc1	-6	210
ndc2	-5	106	odc2	-8	246
ndc3	-4	55	odc3	-18	29
nds1	-5	74	ods1	-12	230
nds2	-5	66	ods2	-4	324
nds3	-4	86	ods3	-6	286
nfc1	0	174	ofc1	0	282
nfc2	0	185	ofc2	2	346
nfc3	0	132	ofc3	1	9
nfs1	0	136	ofs1	1	337
nfs2	0	30	ofs2	0	322
nfs3	2	143	ofs3	0	3
nuc1	3	210	ouc1	3	182
nuc2	M	M	ouc2	6	181
nuc3	5	240	ouc3	15	253
nus1	5	162	ous1	5	194
nus2	5	216	ous2	6	136
nus3	5	228	ous3	13	245

M= missing values

Marrinup		
site	incline	aspect
dc1	-4	202
dc2	-11	242
dc3	-4	300
ds1	-1.5	156
ds2	-3	224
ds3	-12	152
fc1	-1	346
fc2	3	36
fc3	0	116
fs1	1	166
fs2	0	217
fs3	-1	225
uc1	2.5	90
uc2	11	236
uc3	6	126
us1	6	80
us2	5	88
us3	8	270

Soil characteristics

Table 4.20 and Table 4.21 show the soil characteristics for Lowden and Marrinup respectively. Most of the soils were loamy sands with varying proportions of gravel and other coarse fragments. Many of the soils repelled water when they were dry.

Table 4.20: Lowden, Surface Soils

	O2 horizon	A horizon						B horizon					
Site	Thickness(mm)	Depth(mm	%fragments	Fragm. size	repelsH_2O	Texture*	Colour (moist) **	Depth(mm)	%fragm	Fragm.size	repels H_2O	Texture*	Colour (moist) **
ndc1	5	15	10	m-c	3	LS	10YR2/1 (black)	P	90	vf-vc	3	LS	10YR4/3 (brown)
ndc2	0	35	40	f-m	33	S	2.5Y3/2 (very dark greyish brown)	P	50	f-vc	3	LS	10YR5/3 (brown)
ndc3	0	40	30	m-vc	3	LS	10YR2/1 (black)	P	50	m-vc	3	LS	2.5Y3/2 (very dark greyish brown)
nds1	10	30	10	f-vc	3	LS	10YR2/1 (black)	P	40	f-vc	3	LS	2.5Y3/2 (very dark greyish brown)
nds2	5	60	5	m-c	3	LS	10YR2/1 (black)	P	90	vf-vc	3	LS	10YR3/3 (dark brown)
nds3	10	35	25	m-vc	33	LS	10YR2/2 (very dark brown)	P	80	m-vc	3	S	10YR3/3 (dark brown)
nfc1	5	10	25	m-vc	3	LS	10YR2/2 (very dark brown)	P	60	f-vc	3	LS	2.5Y4/3 (olive brown)
nfc2	5	25	25	f-vc	3	LS	10YR2/2 (very dark brown)	P	60	vf-vc	3	LS	10YR3/2 (very dark greyish brown)
nfc3	15	30	10	c-vc	333	LS	10YR2/1 (black)	P	60	m-vc	3	LS	10YR4/3 (brown)
nfs1	5	10	5	m-c	3	LS	10YR2/1 (black)	P	20	f-vc	3	LS	2.5Y4/1 (dark grey)
nfs2	0	25	30	f-vc	3	SL	10YR2/2 (very dark brown)	P	80	f-vc	3	SL	10YR4/3 (brown)
nfs3	1	45	3	f-m	3	LS	10YR2/2 (very dark brown)	P	50	f-vc	3	LS	10YR4/3 (brown)
nuc1	5	35	20	f-vc	3	LS	2.5Y3/2 (very dark greyish brown)	P	7	f-vc	7	LS	10YR4/4 (dark yellowish brown)
nuc3	10	35	15	m-vc	3	LS	10YR2/1 (black)	P	50	m-vc	3	LS	2.5Y4/2 (dark greyish brown)
nus1	2	30	11	f, 1 c	3	LS	10YR2/2 (very dark brown)	P	90	vf-vc	3	LS	2.5Y3/3 (dark olive brown)
nus2	10	45	15	m-vc	3	LS	2.5Y3/2 (very dark greyish brown)	P	60	m-vc	3	LS	10YR3/3 (dark brown)
nus3	5	40	30	m	3	LS	10YR2/1 (black)	P	70	f-vc	3	LS	10YR3/2 (very dark greyish brown)
odc1	2	80	3	m-vc	3	LS	10YR3/3 (dark brown)	P	3	m-c	7	LS	10YR4/4 (dark yellowish brown)
odc2	2	20	1	c	3	LS	10YR2/2 (very dark brown)	P	10	f-vc	7	LS	10YR3/3 (dark brown)
odc3	2	30	15	m-vc	3	LS	10YR2/2 (very dark brown)	P	20	m-vc	7	SL	7.5YR5/4 (brown)
ods1	5	10	40	f-c	3	LS	10YR3/3 (dark brown)	P	60	f-vc	3	LS	10YR4/3 (brown)
ods2	5	20	2	c-vc	3	LS	10YR3/2 (very dark greyish brown)	P	40	f-vc	3	SL	10YR3/4 (dark yellowish brown)
ods3	5	30	40	f-vc	3	LS	10YR3/2 (very dark greyish brown)	P	40	m-vc	3	SL	10YR4/2 (dark greyish brown)
ofc1	20	170+	40	f-vc	7	SL	10YR2/1 (black)	no sample taken					
ofc2	15	30	40	m-vc	3	LS	10YR2/2 (very dark brown)	P	70	f-vc	3	LS	10YR4/4 (dark yellowish brown)
ofc3	5	30	20	f-c	3	LS	10YR2/2 (very dark brown)	P	70	m-vc	3	LS	10YR4/4 (dark yellowish brown)
ofs1	10	25	10	m-c	3	LS	10YR3/3 (dark brown)	P	40	f-vc	3	SL	10YR4/4 (dark yellowish brown)
ofs2	5	35	30	f-vc	3	LS	10YR2/1 (black)	P	50	f-vc	3	LS	10YR3/3 (dark brown)
ofs3	20	70	30	m-vc	3	LS	10YR2/2 (very dark brown)	MISSING					
ouc1	5	10	20	m-c	3	LS	2.5Y3/2 (very dark greyish brown)	P	60	f-c	3	LS	10YR3/3 (dark brown)
ouc2	2	20	25	f-vc	3	LS	10YR2/2 (very dark brown)	P	50	f-vc	3	LS	7.5YR3/4 (dark brown)
ouc3	10	15	25	f-m	3	LS	10YR3/2 (very dark greyish brown)	P	20	f-vc	7	LS	2.5Y4/3 (olive brown)
ous1	10	30	3	c	3	LS	10YR2/1 (black)	P	60	m-vc	3	LS	10YR3/3 (dark brown)
ous2	0	25	40	m-vc	3	S	10YR2/2 (very dark brown)	P	80	f-vc	7	LS	2.5Y3/2 (very dark greyish brown)
ous3	5	25	3	m-vc	3	LS	7.5YR3/3 (dark brown)	P	49	c-vc	7	SL	7.5YR3/4 (dark brown)

vf=very fine (>1mm D)
f=fine (1-2mm)
m=medium (2-5mm)
c=coarse (5-10mm)
vc=very coarse (<10mm)

LS=loamy sand
S=sand
SL= sandy loam

p=present, sample taken

** Munsell (1994)

**A guide to field assessment of texture for mineral soils.*
By S. Northcliff, Reading University and J.R. Landon, Booker Agriculture

Table 4.11: Marrinup, Surface Soils

	O_1 horizon	A horizon						B horizon					
Site	Thickness(mm	Depth(mm	% fragments	Frag. size	repels H_2O	Texture*	Colour (moist)**	Depth (mm)	% fragm	Frag. Size	repels H_2O	Texture*	Colour (moist)**
dc1	5	30	40	f-vc	3	LS	10YR2/2 (very dark brown)	p	80	80 f-c	3	LS	10YR4/3 (brown)
dc2	3	30	90	f-vc	7	SL	10YR4/3 (brown)	no sample taken					
dc3	5	70	60	f-vc	3	LS	10YR3/3 (dark brown)	p	50	f-c	7	LS	10YR4/3 (brown)
ds1	5	20	70	f-vc	3	S	10YR3/3 (dark brown)	p	50	f-vc	7	SL	10YR4/4 (dark yellowish brown)
ds2	3	25	15	m-vc	3	LS	10YR3/2 (very dark greyish brown)	p	30	f-c	7	LS	10YR4/3 (brown)
ds3	10	30	70	f-vc	3	S	7.5YR3/4 (dark brown)	p	80	f-vc	7	SL	7.5YR4/4 (brown)
fc1	10	30	40	f-vc	33	S	10YR 3/2 (very dark greyish brown)	p	40	f-vc	7	LS	7.5YR5/6 (strong brown)
fc2	40	55	3	m-c	33	S	10YR2/2 (very dark brown)	p	80	f-vc	3	LS	10YR4/4 (dark yellowish brown)
fc3	10	110	2	f-c	3	S-LS	2.5Y3/1 (very dark grey)	p	20	f-vc	3	S	10YR4/3 (brown)
fs1	3	30	20	f-vc	3	S	10YR2/2 (very dark brown)	p	90	f-c	3	LS	10YR3/4 (dark yellowish brown)
fs2	1	40	1	c	3	S	10YR2/2 (very dark brown)	p	60	f-c	3	LS	10YR3/3 (dark brown)
fs3	5	65	50	f-c	3	S-LS	10YR2/1(black)	p	60	f-c	7	SL	10YR4/3 (brown)
uc1	15	30	25	m-vc	3	LS	10YR2/1(black)	p	70	f-c	3	S-LS	10YR4/3 (brown)
uc2	60	60	40	f-vc	3	SL	10YR3/4 (dark yellowish brown)	p	40	vf-vc	3	LS	7.5YR4/6 (strong brown)
uc3	15	60	30	f-vc	33	S	10YR2/1(black)	p	40	m-vc	3	LS	7.5YR3/4 (dark brown)
us1	5	40	15	f-c	33	SL	10YR3/3 (dark brown)	p	40	f-vc	3	SL	10YR4/4 (dark yellowish brown)
us2	20	50	60	m-vc	3	LS	10YR3/3 (dark brown)	P	40	f-vc	3	LS	7.5YR3/3 (dark brown)
us3	10	120	25	f-vc	3	LS	10YR3/2 (very dark greyisn brown)	no sample taken					

vf=very fine (>1mm D)
f=fine (1-2mm)
m=medium (2-5mm)
c=coarse (5-10mm)
vc=very coarse

LS=loamy sand
S=sand
SL= sandy loam

p=present, sample taken

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By S. Northcliff, Reading University and J.R. Landon, Booker Agriculture International.

Trail use (counts of rider passes)

At Lowden (Table 4.22) more passes (274 passes) were recorded than at Marrinup (Table 4.23; 142 passes recorded) during the time of the study. Some of these differences can be explained through the two races that took place at Lowden during that period, which accounted for 149 passes. Another factor is that at Lowden the counter was installed at the end of September whereas the counter at Marrinup was installed at the end of October. In addition the Marrinup counter was not functional between time 4 and time 5 resulting in no records for that period. The high count at Lowden between time 5 and time 6 is also due in part to foot traffic in that particular section of the trail by the owners of the property. The Marrinup trail was also used by trail bikes on a number of occasions. Unfortunately, there is no way to discern between different modes of transport when using these simple counters.

Table 4.22 : Lowden trail use (counter)

Time interval	Count	Racing (laps)
t1-t2	78	race: short laps 20; long laps 48
t2-t3	13	
t3-t4	10	
t4-t5	7	
t5-t6	166	race: short laps 27; long laps 54
Total	**274**	**Short laps 47; long laps 102**

Table 4.13 : Marrinup trail use (counter)

Time interval	Count
t1-t2	110
t2-t3	13
t3-t4	19
t4-t5	not functional
Total	**142**

Rainfall

The rainfall data for Lowden and Marrinup are shown in Table 4.24 and 4.25 respectively. During the time of the study Lowden received a total of 178.5mm of rain whereas at Dwellingup 112.2mm were recorded. The period with the lowest rainfall (4.0mm) for Lowden was from December to February whereas at Dwellingup the period from December to January received the least rain (2.2mm). The highest rainfall at Lowden was received between sampling times 1 and 3 (146.5mm) which includes one night during the sampling for time 1 with 32mm of precipitation. At Dwellingup the highest rainfall was received between time 1 and 2 (69.9mm). These data are consistent with the rainfall pattern of the region (winter rains and dry summers). Average rainfall at Lowden for the last 7 years (1992 to 1998) was 971.4 mm. The official mean rainfall for Donnybrook (15km east of Lowden) is 992mm (Bureau of Meteorology, 1999). Average rainfall for Dwellingup is 1269.5mm per year (Bureau of Meteorology, 1999).

Table 4.24: Lowden, rainfall (mm) and rainfall events (#) during the sampling period.

Sampling events	Time interval	Rainfall (mm)	# of rainfall events
Time 1-2	18/09/1998 to 20/09/1998	32.0 (night 19 - 20/09)	1
Time 2-3	20/09/1998 to 29/10/1998	114.5	17
Time 3-4	30/10/1998 to 22/11/1998	12.5	6
Time 4-5	23/11/1998 to 17/12/1998	15.5	3
Time 5-6	18/12/1998 to 07/02/1999	4.0	1
	Total (18/09/1998-07/02/1999)	**178.5**	**28**

Table 4.25: Dwellingup, rainfall (mm) and rainfall events (#) during the sampling period

Sampling events	Time interval	Rainfall (mm)	# of rainfall events
Time 1-2	24/10/1998 to 21/11/1998	63.9	10
Time 2-3	22/11/1998 to 15/12/1998	32.1	6
Time 3-4	16/12/1998 to 13/01/1999	2.2	1
Time 4-5	14/01/1999 to 12/02/1999	14.0	3
	Total (24/10/1998-12/02/1999)	**112.2**	**20**

4.2 Survey

Nine hundred and eighty questionnaires were distributed through mailing lists, bike shops and CALM offices, and personal contact with riders. The survey response rate was approximately 18%. The response rate of the mail-out to the WAMBA members was over 50%. A more accurate estimate of the return rate of the questionnaires from mountain bike shops and CALM offices could not be achieved because, for reasons of confidentiality, questionnaires were not marked and therefore could not be linked to their origin. The high response rate for WAMBA members was achieved because forms were mailed to individuals with reply paid envelopes attached. The response rate for questionnaires from bike shops and CALM offices was lower because the shops and CALM offices were not frequented by as many mountain bike riders or the questionnaires were given out to riders but were not returned to the shops. Consequently, some responses may be biased and represent the views of people who belong to clubs more so than that of the general mountain bike population. This issue is addressed and presented later in this chapter.

The results of the survey will be described for each question in turn, followed by the results of the cross-tabulations. Tables of results and lists of the written comments are presented in Appendix 2C.

Question 1: Are you a member of a mountain bike club?

The majority of respondents answered with yes (72.1%) and the remainder were either not a club member (22.4%) or did not respond (5.5%).

Question 2: Why do you ride a mountain bike?

Most respondents rode a mountain bike for enjoyment and fun (91%) followed by exercise and training (81%) (Figure 4.12). Racing was the next highest category with 77%. Within this group Cross Country (XC) was the most popular form of racing (62%), followed by Downhill (DH) (43%) and Dual Slalom (DS) (24%). Few people indicated they competed in Trials (OT) (9%).

Sixty-two percent of all respondents ride a mountain bike for a challenge and 58% ride to be with friends. Riding as a form of transport was another reason for using a mountain bike by 50% of respondents, while 47% indicated that they rode to appreciate nature. Relaxation was somewhat less important (40% of respondents) and family outings (15%) were the least important reason to ride a mountain bike in the 'recreation' group.

The 'other' category' as indicated by 13% of the surveyed mountain bikers, included the following reasons such as "adrenaline rush" (5 responses), "adventure" (2 responses), "get away from the computer", "touring" or "to explore the country". In other cases the option was used to specify an answer given in another category for example "work" (3 responses), "to and from school" or "better my fitness". (See Appendix 2C for the complete list of 'other' answers).

In summary, it appears that people ride a mountain bike because it is a fun, healthy, challenging and social activity. Racing is also an important reason although this might be due to the large percentage of club members answering the survey. (See cross tabulations, Table 4.38). Mountain bikes are also seen as a good means of transport and a way to experience nature and to relax.

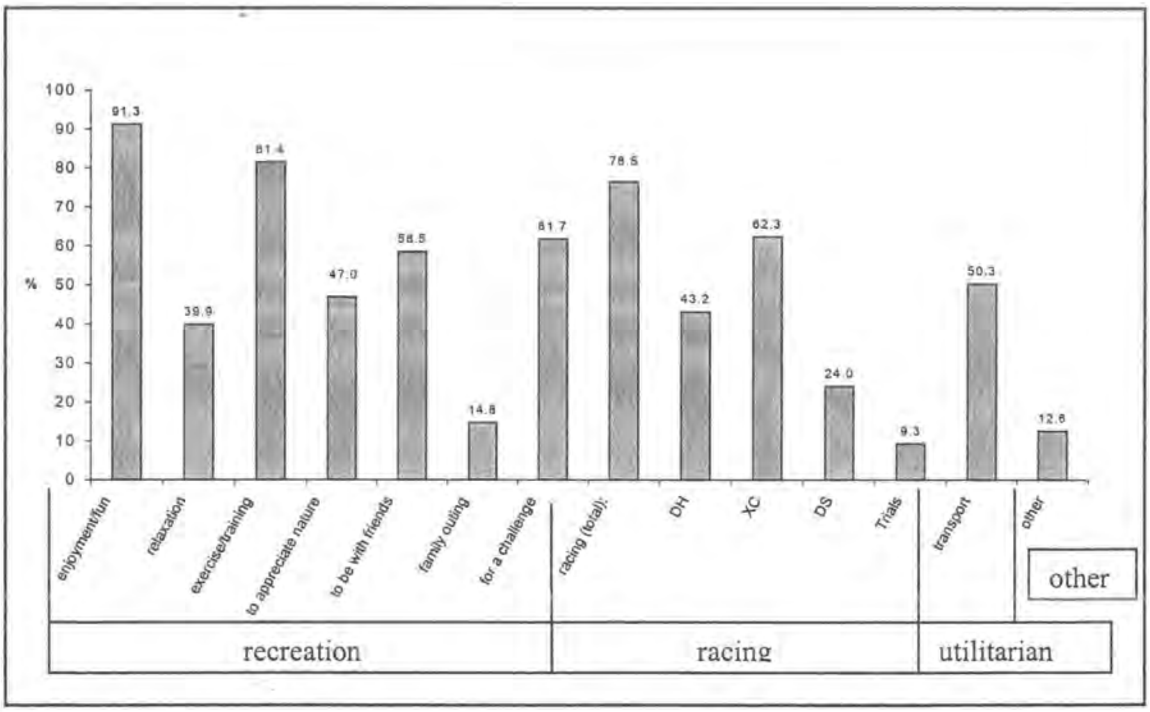

Figure 4.12: Reasons for riding a mountain bike given in answer to question 2 (%)

Question 3: How often do you ride a mountain bike?

The majority (39%) of respondents answered this question with '2-3 times a week' or 'once a day (35%) (Table 4.26). These results were reflected in the average number of rides (3-4 times a week). The next highest categories were 'once a week' (11%) and 'other' (9%). In the 'other' category five respondents indicated that they ride a mountain bike four to five times a week and five respondents indicated they ride more often than five times during the week, whereas three riders answered that they ride more than once a day. Other remarks referred to the length of rides or gave qualitative statements. (See Appendix 2C for full list). Overall few people rode less than two to three times a month.

Table 4.26: Frequency of mountain bike rides (%)

Category	**Responses (%)**
once a day	35
2-3x a week	39
once a week	11
2-3x a month	3
once a month	3
other	9
Total	**100**

Question 4: In what year did you start to ride a mountain bike?

Most respondents started to ride a mountain bike between 1993 and 1997 (altogether 101 respondents or 55.2%) with 1996 being the 'top' year with 34 respondents (18.6%) taking up the sport (Figure 4.13). After 1997, the number of new riders taking up the sport appears to decline and numbers seem to stabilise. Another smaller peak was in the years 1989 (13 riders) and 1990 (12 respondents). Few people started mountain biking before 1987. The low number for 1999 (1 respondent) may reflect the early return date for the questionnaire (mid February). The average number of years of mountain bike riding experience amongst respondents was six.

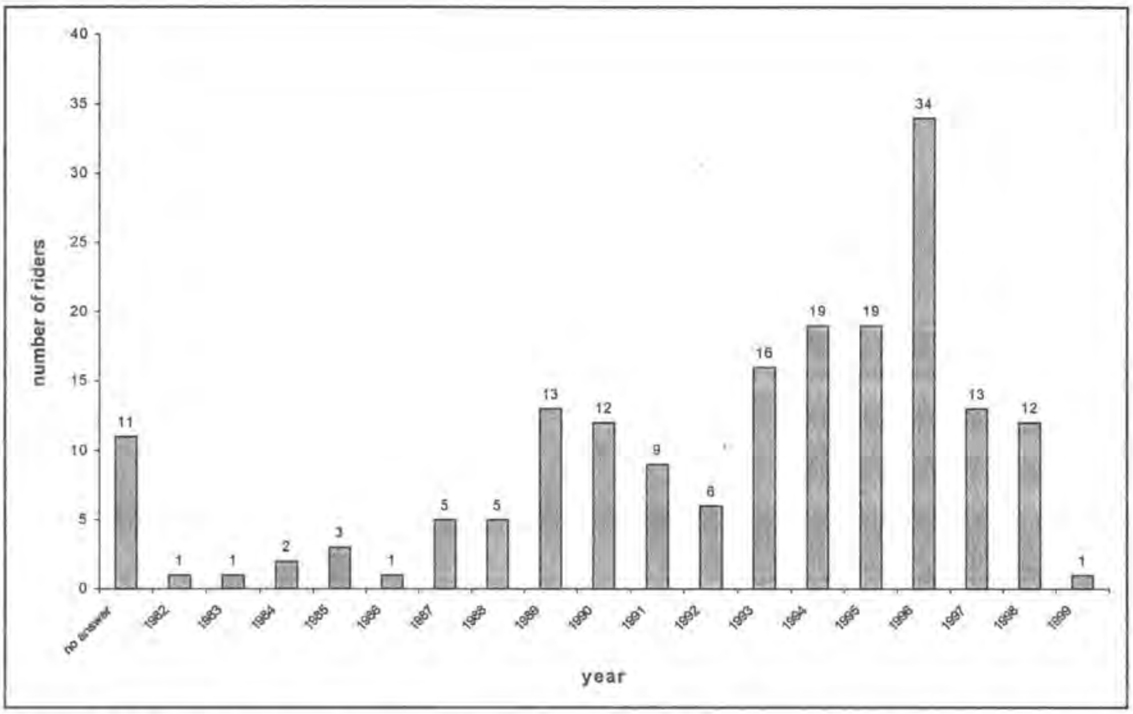

Figure 4.13: Distribution of respondents starting to ride a mountain bike in a particular year

Question 5: How long are your rides on average?

One respondent did not answer this question and six riders gave two answers. The answers of the respondents who indicated two distance ranges were analysed separately (see below).

Most of the respondents who gave a single answer indicated that their average ride length was between 20 and 50km (39.8%) (Table 4.27). This was followed by a riding distance of 10-20km (31.8% of respondents). The 5-10km range was indicated by 11.9% of riders, the 2-5km range by 8.0% and the over 50km range by 6.3%. Few (2.3%) respondents rode distances below 2km.

Table 4.27: Average riding distance

Distance	% of answers (n=176)
under 2 km	2.3
2-5km	8.0
5-10km	11.9
10-20km	31.8
20-50km	39.8
Over 50km	6.3
Total	**100.0**

The double answers were sorted according to the combination of answers given. Three respondents indicated that they were riding distances of 20-50km plus over 50km. The other combinations were indicated once each and were 10-20km plus 20-50km, 2-5km plus 20-50km and under 2km plus 10-20km. The short distances indicated in these combinations may refer to everyday riding to school or work and the longer distances apply to weekend rides. The long distance combinations could refer to different favourite rides or different activities like racing and recreational riding or training.

Question 6: Have you done tours that included overnight stays?

The question was answered by 97.8% of respondents. Most (68.3%) riders indicated that they had not done any tours but over half of these respondents (59.2%) were interested in doing tours (Table 4.28). Close to 30 % of riders said they had done tours. The average number of tours undertaken was 2.6 with an average stay of four nights.

Table 4.28: Number of respondents who have done overnight tours, are interested in doing tours or are not interested (in %)

Yes (n=54)		No (n=125)			No answer (n=4)
29.5%		68.3%			2.2%
Average # of tours	**Average # of nights**	**Are you thinking of doing overnight tours?**			
2.6	4.0	**Yes (n=74)**	**No (n=56)**	**Not specified (n=5)**	
		59.2%	44.8%	4.0%	

Question 7: Where do you like to ride?

This question asked respondents to list their three favourite riding areas or trails in order of preference (1= most preferred, 3= least preferred).

Mundaring (23 responses) and Dwellingup (22 responses) were the most popular locations for mountain bike riding. Equal numbers of respondents listed Kalamunda (8 responses) and the general terms 'bush' and/or 'forest' (8 responses) as first preference destinations. The Goat Farm/Greenmount (7 response) and John Forrest National Park (7 responses) also received equal preference as did Harvey (6 responses) and Jarrahdale (6 responses). Helena Valley and Lowden had received five responses each and four respondents each chose 'the Hills' and the Wellington Dam area as their favourite riding location. There were many locations chosen by one (35 locations), two (11 locations) or three (4 locations) riders as well as four overseas locations. For a complete list see Appendix 2C.

Mundaring (19 responses) and Dwellingup (12 responses) were also the most popular riding destinations in second preferences. Equal numbers of riders chose Helena Valley (9 responses) and Kalmunda (9 responses). Also equal were Goat Farm/Greenmount (8 responses) and John Forrest National Park (8 responses). Margaret River was noted seven times, Jarrahdale, York as well as 'cycle tracks' or '-ways' were listed six times each as second preference mountain biking areas. The Bibbulmun Track received five responses and railway reserves were mentioned four times. As before, many locations were mentioned by one (18 locations), two (10 locations) or three (6 locations) riders as their second preferred riding locations. Two respondents listed areas in Australia and one overseas location was mentioned.

In the third preference category many of the same destinations were listed and the Dwellingup area was the most popular location with 23 responses. Goat Farm/Greenmount was mentioned 14 times followed by Jarrahdale (10 responses). Mundaring was listed nine times and John Forrest National Park received seven responses. Equal numbers of responses were received for 'the Hills' and Margaret River (6 responses each). Kalamunda, Wellington Dam and bush/forest were mentioned five times each and Helena Valley as well as Northcliffe received four responses each. Six locations were listed by three riders each and 14 were chosen by two respondents. Thirty-six locations were mentioned once as a third preference as was one area in Victoria and two overseas.

Irrespective of first, second or third preference the top destinations were:

1. Dwellingup (57 responses)
2. Mundaring (51 responses)
3. Goat Farm/Greenmount (29 responses)
4. Kalamunda, Jarrahdale and John Forrest Nat. Pk (22 responses each)
5. Helena Valley (18 responses)
6. Margaret River (15 responses)
7. Bibbulmun Track (11 responses) and
8. Lowden (10 responses)

Four respondents did not answer the question at all whereas seven respondents chose not to give a second preference and 16 did not give a third preference.

The results of this question show that although riders have personally preferred areas for riding, overall they like to ride in a variety of locations. Nevertheless, most riders tend to ride in relatively close proximity to where they live (see cross tabulations, Table 4.43).

Question 8: Do you mind if you encounter:

This Likert scale question asked respondents to rate their preferences for encounters on a scale of 1 (love it) to 5 (hate it). Overall the respondents were positive to encountering wildlife and other cyclists on their rides (Table 4.29). They were neutral towards walkers and horses whereas they disliked cars and motorbikes. The determination of the modes confirmed these results for cars and motorbikes but indicated that although the means are the same for cars and motorbikes the latter seem to be more disliked than cars.

Table 4.29: Results of Likert scale (1='love it';5='hate it') analysis for Question 8.

Category	mean	mode
wildlife	1.63	1
cyclists	1.65*	1
walkers	2.69	3
horses	3.21	3
cars	3.78	3
motor bikes	3.78	4

Note: Responses ranged from 1 to 5; except: *= range 1-3

Question 9: How important are the following features for you when riding?

In this Likert style question the possible answers ranged from 'essential' (1) to 'don't want at all' (5) in regard to the importance respondents placed on specific trail features. The preferred feature, expressed as the mean response was 'long downhills' (1.47) followed by 'medium length downhills' (1.56), 'long curves' (1.71) and 'tight curves' (1.75). 'Drinking water' (1.81) was seen as 'would be good' as were most other features (see Table 4.30). Of these features 'route markers', 'short downhills', 'steep slopes', 'jumps' and 'rocks/logs' received a mode of 1, indicating that many people deemed these features essential. 'Ditches' (2.54) and 'long uphills' (2.67) were rated as'neutral' in importance although their modes were both 2, indicating that the preference for these features by many people was counterbalanced by the dislike of others. A 'smooth surface', 'overhanging branches', 'muddy/boggy areas' and 'loose sand/gravel' were all considered 'neutral' on average as well as in the mode.

Other features mentioned in the 'other' category (47 answers) were maps (6 times) and a variety of items including different kinds of signs (for example, safety warnings and signs warning walkers that mountain bikes may be on the trail), phones, rubbish bins and overnight shelters (for full list see Appendix 2C). Most of these 'other' features were rated as 'essential'.

Table 4.30: Results from Likert scale (1='essential'; 5='don't want at all') analysis for Question 9

Feature		mean	mode
Long downhills		1.47	1
Medium length downhills		1.56	1
Long curves		1.71*	1
Tight curves		1.75	1
Drinking water		1.81	2
Route markers		1.90	1
Short downhills		1.92	1
Short uphills		1.93	2
Jumps		1.96	1
Moderate slopes		1.99	2
Steep slopes		2.06	1
Parking facilities		2.08	2
Rocks/logs		2.10	1
Toilet facilities		2.12	2
Firm surface		2.14	2
Straight stretches		2.16	2
Setting up area		2.17	2
Easy slopes		2.20	2
Rough surface		2.25	2
Brochures		2.25	2
Interpretive signs		2.30	3
Information shelters		2.32	3
Medium length uphills		2.34	2
Ditches		2.54	2
Long uphills		2.67	2
Smooth surface		2.87	3
Overhanging branches		3.07	3
Muddy/boggy areas		3.09	3
Loose sand/gravel		3.10	3
Other	47 answers	1.30**	1

Note: Responses ranged from 1 to 5; except: *= range 1-4 and **= range 1-3

Question 10: How important are the following settings for you when riding?

This question was similar to Question 9 with the Likert scale ranging from 'essential' (1) to 'don't want at all' (5). The most preferred settings were 'single track' and 'native bush/forest' (Table 4.31). 'Native bush/forest' received answers that ranged from 1 to 4 which means that although some people indicated that they 'try to avoid' (4 on the Likert scale) this setting, no respondent indicated that they did not want the setting at all. 'Sealed road' and 'built up areas/suburbs' were the least preferred settings (means around 3.6) with the latter showing a mode of 4 indicating that many people 'try to avoid' such areas. All other settings were classed as 'desirable (2)' or 'okay (3)'.

Table 4.31: Results of Likert scale (1='essential'; 5='don't know') analysis for Question 10

setting	mean	mode
Single track	1.54	1
Native bush/forest	1.59*	1
Plantation forest	2.32	2
Wide trail	2.54	2
Gravel road	2.72	3
Farmland	2.73	3
Sealed road	3.55	3
Built up areas/suburbs	3.62	4

Note: All ranges = 1 5; except: *= range 1-4

Question 11: Do you agree that:

This question asked respondents to indicate their agreement with 13 statements on a Likert scale. The range was from 1-'strongly agree' to 5-'strongly disagree' plus an extra category 6-'don't know'.

Respondents agreed with the statement that 'trail damage by mountain bikes is overrated' (1.73) with a tendency to strongly agree as indicated by the mode (1) (Table 4.32). The next ten statements (ranked by mean response) were grouped around a mean of two ('agree') with five of these showing a range of 1 to 4 for their answers, indicating that of the respondents who gave an opinion no one disagreed strongly with these statements (see Table 4.31). Although the statement 'mountain bikes should be allowed on all trails' had a mean of 2.20 its mode was 1. This reflects that, although many people strongly agreed with the statement, some were quite opposed to the idea.

Two of the statements were clearly classed as 'disagree' indicating that respondents think that there are not enough mountain bike trails and that mountain bikes do not damage trails. The latter statement was, in essence, the opposite of the statement 'trail damage by mountain bikes is overrated' with the reactions to both statements confirming each other.

Six of the statements received more than 10 'don't know' answers (Table 4.32). Two statements related to dieback and attracted the most 'don't know' answers (38 and 37 responses respectively) followed by statements referring to trail damage. Here 'mtb racing has more impact than touring' and 'most trail damage occurs in downhill curves' received 22 'don't know' responses each. Two other statements relating to trail damage ('trail damage by mountain bikes is overrated' and 'trail damage varies with soil type') also attracted a fairly high amount of 'don't know' answers (19 and 15 respectively). The least 'don't know' answers (1 response) was given for the statement 'it is enjoyable to ride the same trail repeatedly' whereas the remaining statements received between two and nine 'don't know' answers.

Table 4.32: Results of Likert scale (1='strongly agree'; 5='strongly disagree') analysis for Question 11

Statement	mean	mode	# of no answers	'Don't know' answers (#)
Trail damage by mountain bikes is overrated	1.73	1	4	19
Good trail design can reduce trail damage	1.75*	2	1	9
Good riding technique reduces trail damage	1.86*	2	0	7
Trail damage varies with soil type	1.94	2	1	15
Rider education could reduce trail damage	1.92*	2	2	3
Dieback is a big environmental problem in WA	2.03*	2	1	37
Mountain bikes should be allowed on all trails	2.20	1	1	2
Mtb racing has more impact than touring	2.34	2	3	22
Most trail damage occurs in downhill curves	2.46	2	5	22
It is enjoyable to ride the same trail repeatedly	2.48	2	1	1
Mountain bikes can spread dieback disease	2.75	2	2	38
Mountain bike riding damages trails	3.82	4	2	6
There are enough mtb trails	4.05	4	2	3

(means and modes exclude no answer and 'don't know')

N=183

Note: Responses ranged from 1 to 5; except: *= range 1-4

Question 12: Would you be prepared to accept a voluntary code of conduct/trail etiquette?

This question asked respondents to tick either 'Yes' or 'No' and specify their answer. The question was answered by 95% of respondents, of whom 91% answered with 'yes'. Sixteen (9.6%) of the respondents who said 'yes' did not specify an aspect of the code that would be important to them (Table 4.33). Of the 4% 'no' answers, reasons for negating the code ranged from 'freedom' to 'not needed' (for full comments see Appendix 2C) and only one person (14.3% of 'no' answers) did not specify why they would not support a code of conduct.

The respondents who supported a code of conduct gave various aspects that would be important to them. 'Respect for other trail users' was most often stated (67 responses) followed by safety (60 responses) (see Appendix 2C). How much this result was influenced by the example given on the survey form (Appendix 2B) is hard to assess. Respect for the bush/environment (including wildlife) was mentioned 42 times while for 22 respondents respect for the trail (including no skidding and minimise damage) was important. In addition, 21 riders referred to 'leave no trace' or low impact behaviour in the bush. Courtesy and friendliness were important to 11 people and nine referred to trail maintenance. Different preferences were given in regard to right of way rules. The full list of all comments in regard to important aspects of a code of conduct can be viewed in Appendix 2C.

Table 4.33: Results of Question 12

Category	'yes'	'no'	No answer	Total
%	91	4	5	100
not specified (% of yes or no answers)	9.6	14.3		

Question 13: What type of mountain bike do you ride?

Some respondents own more than one mountain bike hence the number of bikes (n=244) was greater than the number of respondents (n=183). Most respondent (69.9%) owned one bicycle, 27.9% owned two bikes, 1.6% owned three bicycles and 0.5% (1 person) owned four bikes (Table 4.34).

The majority of bicycles were equipped with front suspension (49.2%), 31.1% had dual suspension (Table 4.35), 16.4% of bicycles had no suspension. Few bicycle (3.3%) were classed as 'other' bicycles, these included "trial" bikes and 'don't know'.

Where respondents only owned one bike most bikes had front suspension (56.3%) with dual (22.7%) and no suspension (19.5%) bicycles. The owners of two bicycles owned mainly a front suspension as well as a dual suspension bike (70.6%). A combination of no suspension and front suspension was the next most common mix (9.8%) followed by no suspension and dual suspension (5.9%). The other combinations are displayed in Appendix 2C.

Table 4.34: Number of bikes owned per rider in percent

Number of bikes owned	1	2	3	4	Total
Respondents (%)	69.9	27.9	1.6	0.5	100.0

Table 4.35: Types of bicycles owned in percent

Type of bike	No suspension	Front suspension	Dual suspension	Other	Total
% of 244 bikes	16.4	49.2	31.1	3.3	100.0

Question 14: How often do you clean your bike (including tyres and treads)?

All respondents answered this question but 13 riders ticked two boxes. Most of the respondents who ticked one box cleaned their bikes 'after every race/ride' (40.0%) (Table 4.36). The double category for this question precludes a totally clear result but the large number of responses nevertheless indicates that many riders clean their bicycles often. The next highest frequency for bike cleaning was once a week (15.3%) followed by once a fortnight (13.5%). The 'other' category received 8.8% of answers which ranged from "whenever required" and "whenever it's dirty" (three responses each to a variety of "depends on..." comments (for list see Appendix 2C).

The 13 respondents who gave double answers most often indicated combinations of 'after every race/ride' plus 'other' and 'once a fortnight' plus 'every race/ride' (3 responses each). 'Once a fortnight' plus 'other' as well as 'once a month' plus 'every race/ride' received two responses each. The other response combinations as well as the answers in the 'other' category of these dual answers can be viewed in Appendix 2C.

Table 4.36: Frequency of bike cleaning by single answer respondents (in %)

Frequency	%	n
once a week	15.3	26
once a fortnight	13.5	23
once a month	10.0	17
every 3 months	5.3	9
every six months	4.1	7
once a year	1.2	2
after every race/ride	40.0	68
never	1.8	3
other	8.8	15
Total	**100.0**	**170**

Question 15: Are you aware of dieback risk areas?

A majority of respondents (59%, n=108) indicated that they were aware of dieback risk areas and 39% (n=72) gave a negative answer. Of the 'yes' answers 16 respondents (15%) did not specify what dieback risk areas are or where they are found.

When respondents who answered 'yes' to the question were asked to describe what dieback risk areas are, 18 respondents said they were areas affected with dieback and/or that the fungus or *P. cinnamomi* is present. Seven respondents did not quite answer the question by commenting that dieback is a disease that kills bush and trees. Dieback risk areas were also described as areas free of dieback; the lack of information was commented on; and the explanation that dieback spores get transmitted by traffic through a dieback area were given by six respondents each. Other suggestions of what dieback risk areas are or what dieback is are listed in Appendix 2C.

In answer to where dieback risk areas were found, 25 riders mentioned the Mundaring area, 18 said bush/forest and Jarrah forest and 15 respondents said that the areas were signposted. Four respondents specified that dieback risk areas were located in the State Forest and a variety of other locations were mentioned. The full list of responses is given in Appendix 2C.

Question 16: What age group do you belong to?

Most respondents were between 15 and 39 years old (77%) with age group 25-39 (40%) being slightly larger than group 15-24 (37%). 16% of riders were older than 40 and 6% were under 15 (Table 4.37).

Table 4.37: Survey respondents according to age groups in percent

Age group	%
under 15	6.0
15-24	37.2
25-39	39.3
40-59	15.3
60+	1.1
no answer	1.1
Total	**100**

Question 17: Are you female or male?

Most respondents were male (88%) and only 11% were female. One percent of respondents did not answer the question.

Question 18: Please tell us your post-code

The majority of respondents (73.8%) gave a metropolitan post-code in answer to this question, whereas 26.2% indicated they were living in a non-metropolitan area, including one overseas location. To some extent this result reflects the population distribution in Western Australia, where 63.5% of inhabitants live in the Perth metropolitan area. For the full list of post-codes see Appendix 2C.

Question 19: Is there anything else you would like to tell us?

Many respondents (n=101) made one or more comments. The comments were grouped into categories (Appendix 2B). The category 'trails', with 37 comments the largest category, was subdivided into 'Bibbulmun track', 'more trails', 'single track', 'location', 'metro trails' and 'access'. The next largest category was 'other' (24 comments) with comments on a wide range of subjects. Twelve comments were related to 'environmental damage' and in most cases referred to the minimal impact that mountain bikes have on the environment. Ten responses commented on the survey itself, often complimenting it, and another ten referred to 'information' about trails and the lack of it or need for it. Another category of answers commented on 'dieback', referring to various aspects of the issue.

Three categories received six comments each. These categories were 'No', referring to the literal comment, 'trail maintenance', in which various aspects of trail maintenance were mentioned, in particular voluntary participation, and 'multiple answers', which contains the comments referring to various issues that could not be separated any further without loss of meaning. Four riders each commented on 'code of conduct' and 'shared use' and one on 'safety. A variety of other comments were made. The full list of comments can be viewed in Appendix 2B.

Cross tabulations

Club membership

Cross tabulations were undertaken to investigate if rider motivation, frequency of riding, rider experience, riding distance, preferred encounters, preferred features, preferred settings, responses to the statements in Question 11, frequency of bike cleaning, amount of bikes owned, and age were independent of club membership. Significant dependence was detected for the following cross tabulations (Table 4.38).

Table 4.38 cross tabulations that showed significant dependence on club membership

Club Membership (Q1)	Response variable	df	χ^2 value	Significance
	Q2 a) To be with friends	1	8.825	0.003
	b) For a challenge	1	18.324	0.000
	c) Racing (all except Trials)	1	83.284	0.000
	Q9 a) Long downhills	1	14.228	0.000
	b) Medium length downhills	1	10.039	0.002
	c) Long curves	2	10.881	0.004
	d) Tight curves	2	12.797	0.002
	e) Short downhills	2	11.082	0.004
	f) Jumps	1	30.710	0.000
	g) Steep slopes	2	21.828	0.000
	Q 10 a) Single track	2	31.097	0.000
	b) Sealed roads	2	9.052	0.011
	Q 13 Bike ownership (1 or more bikes)	1	12.092	0.001
	Q16 Age	2	10.548	0.005

The results indicate that mountain bike club members prefer to ride with friends (65.2% of members) whereas only 39.9% of non-members ticked that box. Members also ride for a challenge (71.2%, compared to 34.9% of non-members) which complements the result that they are much more likely to participate in racing (93.2%) than non-members (24.4%).

Club members regard long downhills as essential (72.5%) whereas non-members tend to rate them as good to dislike (60.0%). The same is true for medium length downhills which members rated as essential (63.4%) and non-members rated as good to dislike 65.0%). Members (45.8%) rated short downhills as essential whereas non-members rated them as good (48.8%) or neutral to dislike (34.1%). Club members regard steep slopes as essential (46.7%) or good (31.1%) however non-members (60%) rated steep slopes as neutral to dislike. Club members are diverse (essential 51.5% and neutral 15.9%) in their regard to long curves, whereas non-members rate long curves as a good feature of a mountain bike trail (60.1%). Club members prefer tight curves (57.6%) whereas non-members tend to be neutral to averse towards them (36.6%), although both groups also find them 'good' (28.7% of members and 31.7% of non-members). This split is clearly pronounced in regard to jumps where most club members see jumps as essential (84.7%) and non-members tend to dislike them (58.5%).

Single track is essential to club members (69.5%) whereas non-members do like single track (36.6%) but are also neutral to averse to it (34.2%). Sealed road is avoided (35.4%) or not at all wanted (20.8%) by club members but non-members tend to rate sealed road as okay or better (70.7%, as opposed to 43.8% of members).

Only 7.9% of non-members possess two or more bicycles whereas 37.6% of club members own two or more mountain bikes. Nearly half of the respondent club members were under 25 years of age (48.5%) whereas only 26.2% of non-members were in that age group. Around 40% of both non-members and members are between 25 and 39 years old whereas non-members are more likely to be older than 39 years (30.1%) in comparison to club members (12.1%).

Rider Motivation

The relationships between rider motivation and trail use, touring, meeting other users, specific trail features and settings as well as rider opinion were investigated. Significant relationships are detailed below (Table 4.39).

Table 4.39: Significant results of cross tabulations with rider motivation

Q2 Motivation to ride (recreation or mix of recreation & racing)	Response variable	df	χ^2 value	Significance
	Q3 Frequency of rides	2	7.597	0.022
	Q6 Done tours	1	3.609	0.057
	Q8 Cyclists	2	5.250	0.072
	Q9 a) Long downhills	1	14.193	0.000
	b) Medium length downhills	1	6.347	0.012
	c) Long curves	2	5.975	0.050
	d) Tight curves	2	15.161	0.001
	e) Drinking water	2	7.175	0.028
	f) Route markers	2	6.994	0.030
	g) Short downhills	2	8.421	0.015
	h) Short uphills	2	8.210	0.016
	j) Jumps	2	33.532	0.000
	Q10 a) Single track	1	24.830	0.000
	b) Gravel roads	1	3.615	0.057
	c) Plantation forest	1	5.343	0.021
	d) Sealed roads	2	15.549	0.000
	Q11 a) Mountain bikes should be allowed on all trails	2	5.151	0.076
	b) Mountain bike riding damages trails	1	6.737	0.009
	c) Trail damage by mountain bikes is overrated	2	28.987	0.000
	e) Good riding technique reduces trail damage	2	6.706	0.035
	Q13 Number of bikes owned	1	16.416	0.000
	Q16 Age	2	12.965	0.002

Of riders who race, 42.1% also ride daily, compared to 25% of riders who do not race. In both groups, around 45% of riders ride 2-3 times a week, but more recreational riders (30.6%) than racers (12.3%) ride once a month or less.

More racers (35.4%) than recreational riders (18.9%) indicated that they had done tours. Many racers also like to encounter other cyclists (53.5%) whereas recreational riders like to encounter cyclists to a lesser extent (38.5%). Twenty three percent of recreational riders tend to be neutral towards other cyclists or even dislike them whereas few racers (10.1%) had that attitude.

Significant racer and recreational rider preferences for specific trail features are detailed in Table 4.40. Riders who race regard long downhills and medium length downhills as essential. Long curves are also essential for racers but recreational riders 'only' regard them as good. Tight curves are essential for racers, neutral for recreational riders. In contrast, recreational riders regard drinking water as essential or as good and racers are more neutral. The same is true for route markers. Short downhills are regarded as essential by racing riders whereas recreational riders think they would be good. Recreational riders also think that short uphills would be good features on mountain bike trails, whereas racers think that short uphills are essential or neutral. Riders who race regard jumps as essential and find them good in comparison with recreational riders who are neutral to negative towards them.

Table 4.40: Results of significant cross tabulations of rider motivation with trail features (Question 9) in %

Trail feature	category	Recreation only riders	Racing & recreation riders
		(n=38)	(n=128)
Long downhills	essential	39.5%	72.7%
Long downhills	good	44.7%	18.8%
Long downhills	neutral to dislike	15.8%	8.6%
Medium downhills	essential	39.5%	62.5%
Medium downhills	good	47.4%	28.1%
Medium downhills	neutral to dislike	12.8%	9.4%
		(n=39)	(n=129)
Long curves	essential	30.8%	49.6%
Long curves	good	56.4%	34.9%
Long curves	neutral to dislike	12.8%	15.5%
Tight curves	essential	30.8%	57.4%
Tight curves	good	30.8%	30.2%
Tight curves	neutral to dislike	38.4%	12.4%
Water	essential	41.0%	37.2%
Water	good	53.8%	38.8%
Water	neutral to dislike	5.1%	24.0%
Route markers	essential	51.3%	30.2%
Route markers	good	35.9%	41.1%
Route markers	neutral to dislike	12.8%	28.7%
Short uphills	essential	25.6%	35.7%
Short uphills	good	66.7%	41.9%
Short uphills	neutral to dislike	7.7%	22.5%
Jumps	essential	28.2%	49.6%
Jumps	good	10.3%	34.9%
Jumps	neutral to dislike	61.5%	15.5%
		(n=39)	(n=128)
Short downhills	essential	20.5%	46.1%
Short downhills	good	51.3%	32.0%
Short downhills	neutral to dislike	28.2%	21.9%

Significant racer and recreational rider preferences for settings are detailed in Table 4.41. Riders who race regard single tracks as essential (70.3%)and consider plantation forest to be desirable (66.7%) in comparison to recreational riders (25.6% and 46.2% respectivley). In contrast gravel road is regarded as desirable by recreational riders and sealed road is classed as neutral by recreational riders whereas racers try to avoid it or do not want it at all.

Table 4.41: Results of significant cross tabulations of rider motivation with settings in percent

Setting	category	Recreation only riders	Racing & recreation riders
		(n=39)	(n=128)
Single trail	essential	25.6%	70.3%
Single trail	good	35.9%	25.0%
Single trail	neutral to dislike	38.5%	4.7%
Gravel road	essential to good	51.3%	34.4%
Gravel road	neutral to dislike	48.7%	65.6%
		(n=39)	(n=129)
Plantation	essential to good	46.2%	66.7%
Plantation	neutral	41%	26.4%
Plantation	avoid to dislike	12.8%	6.9%
		(n=39)	(n=127)
Sealed road	essential to good	17.9%	9.4%
Sealed road	neutral	59.0%	32.3%
Sealed road	avoid to dislike	23.1%	58.3%

Racing riders agree (34.1%) and agree strongly (53.2%) that trail damage by mountain bikes is overrated. Although recreational riders (33.3%) as well as racers (36.5%) strongly agree that good riding technique reduces trail damage, racers tend to also agree (50.8%) whereas many recreational riders are neutral (30.6%) towards the issue. Many of both racers (42.2%) and recreational riders (42.1%) agree that all trails should be open to mountain bikes, but racers tend to also be neutral (41.2%) towards the issue whereas recreational riders tend to disagree (31.6%) with the idea. Many racers disagreed (36.4%) with the notion that mountain bike riding causes trail damage whereas recreational riders tended to agree (23.1%).

Recreational riders tend to own one bicycle (94.9%), racing riders tend to own two or more bikes (39.5%) and riders up to 24 years of age are more likely to race (47.3%) while riders above 40 years old are more likely not to race (35.9%).

Rider experience

Cross tabulations were calculated to explore the relationships between rider experience (in riding years) and average riding distance, preference of specific trail features and settings as well as awareness of dieback risk areas and age. Significant relationships are listed in Table 4.42.

Table 4.42: Significant cross tabulations in regard to rider experience

Q4 Year started to ride (rider experience)	Response variable	df	χ^2 value	Significance
	Q5 Average distance of rides	4	14.026	0.007
	Q9 Route markers	4	10.584	0.032
	Q9 Jumps	4	8.965	0.062
	Q10 Gravel roads	2	6.626	0.036
	Q15 Awareness of DRA's	2	5.136	0.077
	Q16 Age	2	7.784	0.020

Of those riders who started to ride in 1995 or later most ride between 10 and 20km on average (45.1%). Riders who started to ride between 1990 and 1994 tend to ride distances of below 10 km (23.3%) as well as above 20 km (56.7%) and riders who started before 1990 ride mainly long distances (20 km and more) (65.4%).

Riders who started to ride between 1990 and 1994 would like to have route markers (50.0%) whereas many riders who started after 1994 have a neutral to negative attitude (36.5%) toward them. Inexperienced riders (starting after 1994) regard jumps as essential (52.7%) and medium experienced riders (starting to ride between 1990 and 1994) like them (42.0%). Experienced riders (who started mountain biking before 1990) are neutral to negative (38.5%) toward them.

Inexperienced riders who have been riding for five years or less tend to prefer gravel roads (47.9%) whereas riders who have been riding for ten years and longer tend to be neutral (81.5%). Inexperienced riders are less aware of dieback risk areas (51.3%) than more experienced riders (70.5% of riders who started between 90 and 94 and 61.5% of riders who started before 1989).

Other relationships

Various other questions were explored for relationships by undertaking cross tabulations. These were 'done tours' with setting and postal code with respondents' first preference riding area. Only two relationships were significant (Table 4.43).

Table 4.43: Significant cross tabulations of various questions

	Response variable	df	χ^2 value	Significance
Q6 done tours	Q10 plantation forest	2	6.844	0.033
Q18 post code	Q7 first preference riding area	1	27.527	0.033

Fewer riders who have undertaken bicycle tours regard plantation forests as essential settings (26.9%) compared to riders who have no touring experience who found them desirable (50.4%) in addition to the general perception of riders regarding plantation forests as neutral or negative.

Generally, respondents who live in the metropolitan area prefer to ride in the metropolitan area (45.2%) and riders who live in the country prefer to ride there (22.2%). In addition, many riders who live in the metropolitan area prefer to ride in the country (31.1%) whereas very few riders who live in the country prefer to ride in the metropolitan area (1.5%).

5 Discussion

5.1 Physical impacts

5.1.1 Soil loss - micro relief (% area change in relation to time 1)

As Liddle (1997) points out, erosion is a natural process of great magnitude against which erosion caused by recreational activities is minimal in extent. Nevertheless, recreation can lead to locally increased erosion that has to be considered for aesthetic and management reasons.

The measurement of soil loss can be used to document erosion on a trail (Whinam and Comfort, 1996). Soil loss and erosion need to be kept to acceptable levels on trails to ensure satisfactory trail experiences in terms of aesthetics and user safety (Liddle, 1997). In addition, trail erosion can lead to trail deepening and widening and excessively eroded trails can be the origin of more widespread environmental damage. High maintenance costs are another effect of trail erosion (for example: Wöhrstein, 1998; Bjorkman, 1996; Burde and Renfro, 1986; Garland, 1990).

Soil loss and erosion are complex processes that are influenced by a variety of parameters (Wilson and Seney, 1994). This was shown in the present study where, at Lowden, the various interactions of time, age and slope indicate that all these factors have to be taken into consideration when examining soil loss on a trail. In addition, the factor feature (curves and straights) also revealed an effect on soil loss although it did not interact with the other parameters. ANOCOVA revealed a significant relationship of soil loss with texture A (soil texture of the A horizon) for the whole micro relief and of thickness O_2 (the thickness of the O_2 horizon) for the trail only. When the data were adjusted for the interactions with these covariates they showed similar results as the ANOVA's. Consequently, feature should be taken into consideration for soil loss as well as soil texture in addition to all the other parameters. The thickness of the O_2 horizon may have to be considered as well although feature does not appear to interact with this parameter. In contrast, at Marrinup the only factor showing an effect on soil loss was slope. Feature and soil characteristics seem to have less influence here.

Some of these differences in the results may be explained by the fact that the trail at Lowden is subjected to greater variations in riding impacts due to the episodic racing use in contrast to the recreational use at Marrinup. Racing, due to its competitive nature and increased speed, can lead to increased loosening of the soil surface and to more skidding, especially before and in curves and on steep downhill sections. This can result in soil movement and cause changes to the soil profile. These effects were observed at a race at Lowden just before sampling time 6, although they appear to be small (compare Figures 2 and19 in Appendix 1A). In addition, the Lowden data was more variable than the Marrinup data, which in part reflects the greater changes in plant presence and growth within the micro relief profiles at Lowden, as well as a potentially higher sampling error. The limited accuracy of the measuring apparatus may have contributed to the high variability in the micro relief data in this study. An interpretation of these results therefore requires a certain amount of caution.

Nevertheless, the results of this study are in line with other studies which found that slope has an influence on trail erosion, for example Seney and Wilson (1994), Garland (1990), Burde and Renfro (1986), Cole (1983) as well as Bratton et al. (1979). Some of these authors also detected a correlation of soil type with trail erosion (Burde and Renfro, 1986; Garland, 1990), whereas Seney and Wilson (1994) concluded that texture, structure and moisture content which determine resistance to erosion were of secondary importance for soil loss.

The slopes at both study sites exceeded 15% (or 9°) in a few cases only. Consequently, most of the observed slopes are not expected to be particularly prone to erosion, according to observations by Bjorkman (1996) and as stated by Marsh (1991). The erosion that was visible on the trail at Lowden was in fact restricted to the steep slopes. The soils at both locations in this study did not fall into the highly erodible category since, although sandy, they are well graded. They contain some organic material and fine particles that effect adherence of soils as pointed out by Bjorkman (1996) and Liddle (1997). The O_2 horizon is by definition composed of organic material and some of the A horizon soils at Lowden appear to have considerable organic content (according to their colour). If the observation by Bjorkman (1996) holds, they would be expected to erode quickly. The interaction of the thickness of the O_2 horizon with soil loss indicates that this may be the case at Lowden, which is supported by the observations that the O_2 and A horizons were generally thin and had disappeared on the old section of the trail at various sites.

The short period of the present study also may have contributed to the low erosion impacts found. In addition, the study took place during spring and summer outside the mountain bike season, therefore the main rainfall events were missed and rider numbers were low. Consequently, the effect of rainfall on the trails as well as the impacts of greater rider numbers were not measured. Some authors (Wöhrstein, 1998; Calais and Kirkpatrick, 1986; Lance et al., 1989) have referred to erosion being positively related to amount of use. Garland (1990) as well as Seney and Wilson (1994) point out that rainfall and rainfall intensity influence soil loss. Little rainfall was recorded over the period of this study (Table 4.24 and Table 4.25), therefore its effect on soil loss could not be ascertained. A follow-up sampling in winter may be more informative in that respect, but for a thorough evaluation of rainfall on soil loss a longer-term study is needed. In this context, the fact that both the trails are located in well-vegetated forested areas and are partly covered with leaf litter may explain the little erosion that was apparent. As Wöhrstein (1998) and Marsh (1991) point out, a vegetation canopy as well as litter cover can substantially reduce surface runoff and therefore erosion.

Cole (1983), Bratton et al. (1979) and Weaver and Dale (1978) have associated erosion with poor location and trail design. However, all the factors mentioned above taken together make it difficult to assess location and trail design effects on erosion and soil movement. Nevertheless, the results of this study may indicate that to achieve well designed low erosion trails, care must be taken when siting trail features, e.g. considering where to put the downhill curves to have the least impact or how long a downhill straight should be and at what angle it should run.

The conclusion that can be drawn from this study in regard to soil loss and erosion in southwest Western Australia can be summarised as follows:

- mountain bike use on these trails can cause soil loss and changes to the trail profile;

- the observed changes in this study were very variable but appeared to be small for both the racing and recreation trail during the sampling period (spring and summer);
- soil loss depends on many factors, but primarily on slope of the trail, trail features and soil characteristics;
- soil characteristics as well as slope and features should be taken into consideration when designing a mountain bike trail in the southwest of Western Australia;
- a long-term study with improved measuring equipment is needed to improve the predictions in low-erosion trail design.

5.1.2 Soil compaction

The trail surface

Soil compaction is the primary effect of trampling on soil (De Gouvenain, 1996). The same can be said for mountain biking (Wöhrstein, 1998). The findings of this study also reveal soil compaction as a consequence of mountain biking. A compacted trail surface is, in most cases, desirable for mountain biking. It makes for a comfortable and easy ride and allows for safe riding under control. In contrast, a loose surface can lead to increased skidding, thereby increasing trail damage and consequently increasing maintenance efforts and costs. A loose trail surface can also be a safety hazard, especially in curves. Soil compaction levels can give an indication of trail condition and, when measured over time, can reveal changes to trail surface stability and trail width.

The soil compaction values generated in this study give a limited impression of soil compaction since the hand-held penetrometer which was used for this study, by its nature and design, can only measure compaction at the very surface (5mm) of a soil. It nevertheless gives an indication as to the stability of a trail surface and can detect surface disturbances such as loosening.

The monitoring of the newly built trail sections at Lowden clearly showed that the trail surface was increasingly compacted over time. This is expected according to Cole

(1985) who found the greatest impacts on soil disturbance, e.g. soil compaction, with initial use, and Kuss and Hall (1991) who observed an increase in soil compaction with increased use. This was reflected by the measurements at time 1, which generally revealed the lowest soil compaction values, and higher compaction values at subsequent times. In some cases, a loosening of the trail surfaces with lower compaction values could be observed at time 2 and at time 6, due to the racing impacts (greater speed and increased skidding) (Figures 1 to 17, Appendix 1D). A direct association of soil compaction with user numbers could not be made due to the high variability of the data. User numbers, however, indicate the cumulative increase in use over time (Table 4.22).

The findings of this study reveal an interaction of time*age*slope for soil compaction at Lowden. This indicates that all these factors are important for trail soil compaction and that they cannot be separated but must be looked at in combination. Features (curves and straights) seem to have less effect on trail surface compaction than age or slope at Lowden. The relationships of fragment size B and texture B with soil compaction which were found for Lowden by ANOCOVA (Tables 4.10), highlight the influence of these parameters on soil compaction there. At the same time, they also reveal that feature influences soil compaction in a minor way at Lowden. In contrast, at Marrinup all the examined factors (features, slopes and time) clearly interact in the compaction of the trail surface (Table 4.11 and Figure 4.4), indicating that none of them can be considered in isolation. For Marrinup, relationships of soil characteristics (texture B, texture A and % fragments B) with soil compaction were also uncovered and at this location feature played a role in many interactions.

As Liddle (1997) points out, the compactability of a soil depends on various soil characteristics such as particle size and the mixture of particles of various sizes. A soil that is 'well-graded', meaning it contains a range of fine to coarse particles, compacts more slowly, but to a greater extent in the long run than soils that are poorly graded and contain mainly particles of the same size. Other parameters such as soil structure and organic content also influence soil compaction. At the 'new' sites at Lowden the soil surface is comprised of the O_2 horizon or the A horizon which contain organic material, whereas at many of the 'old' sites the trail surface consists of the B horizon. The compaction measurements therefore reflect these differences in soils (Appendix 1C).

In addition to the greater interactions of features and soil characteristics, Marrinup showed greater compaction levels in comparison to Lowden. These differences are partly explained by the fact that the mountain bike trail at Marrinup has had more intense use than the Lowden course and consequently a more compacted trail surface. Differences in soil texture and particle size may also contribute to these variations. The 'old' straight stretches at Lowden (for example Figures 21 to 23, in Appendix 1C), which could be expected to receive less loosening than curves, even in a racing situation, were more variable in their soil compaction than the equivalent Marrinup sites (Appendix 1D, Figures 4 to 6).

Therefore, when siting a trail, the characteristics that determine the compactability of the soils at the site in question, the slopes and the intended features, must be considered together to provide a trail that is interesting to ride, maintains a firm surface, resists erosion and is low in maintenance. How exactly these different aspects of a trail interact is beyond the scope of this study. However, this point needs further investigation to be of more predictive value.

An interesting trend was observed for the soil compaction data at Lowden when the data were compared visually for features over time (Figures 4.3a-f). Soil compaction was relatively low at time 1 and 2 but rose in all cases at time 3 and then slowly declined again over time. This phenomenon may be due to changes in soil moisture levels. The soil was quite moist at time 1 and time 2 (end of winter) and started to dry out at time 3 (spring). At this time (time 3), soil moisture may have been at a low enough level to cause maximum adherence of soil particles (i.e. increased compaction). Ongoing reduction in soil moisture then led to reduced particle adherence, resulting in reduced surface soil compaction over the remaining sampling period at Lowden. Time 6 (post race) (for example Figures 1-3, 11, 24 and 30, Appendix 1C) then clearly demonstrates that such dry soils are easily loosened by an event such as a race. This observation compares with the findings by Wilson and Seney (1994) that sediment yield was high on dry trails and mainly due to soil detachment.

Liddle (1997) remarks that recreational use of trails especially by wheels often exerts lateral forces on a trail surface, resulting in soil displacement which then can be detected as loosening of the surface. The findings of this study indicate that differences in use of a mountain bike trail (recreation versus racing) may be reflected in its surface. The Marrinup track has been used for some time now primarily for recreational riding and showed a more stable trail surface and more consistent soil compaction readings over time (Figures 1 to 18, Appendix 1D). The racing trail at Lowden receives a greater variation in use (episodic racing and recreation) and the two racing events clearly contributed to the more variable soil compaction found over time (Figures 1 to 35, Appendix 1C). This can be explained by the higher speeds reached by riders during racing and the associated increase in skidding and loosening of the soil surface. This study is the first to compare mountain bike racing impacts with those of recreational riding.

Areas adjacent to a trail

Soil compaction measured next to a trail can show if, and how badly, the vicinity of the trail is affected by the presence and use of the trail. An increase in soil compaction would be expected if people leave the trail, as would be the case with spectators at a mountain bike race or when users pass each other on a narrow trail. This could have an effect on the vegetation growing in the vicinity of the trail, ultimately leading to vegetation death and to trail widening.

The comparison of the soil compaction on the trail itself and that of the adjacent areas at Lowden and at Marrinup, revealed that the trails are clearly more compacted than the sides at both locations (Figures 4.10a-m and 4.11a-f). Also changes in soil compaction next to the trail were, although often more variable, overall smaller than on the trail itself. This was especially pronounced at some of the sites at Marrinup where soil compaction adjacent to the trail changed very little (Figures 4.11c and f). These findings are clearly supported by those of Cessford (1995b) who associated increased damage to vegetation and its removal to soil compaction. Here the area denuded of vegetation, i.e. the trail itself, was much more compacted than the areas where vegetation was growing, i.e. adjacent to the trails. At Lowden the changes in soil compaction next to the trail followed the trend that was seen for the trail soil compaction (peak at time 3; e.g. Figures 4.10a, c and f) which was possibly related to the changes in soil moisture over time. This trend was not seen at Marrinup.

The low impact detected on the soils adjacent to the trails appears to be in contrast with the observations by Lance, et al. (1989). They found that walking trails typically showed two types of ground, the central part of a trail devoid, or nearly devoid, of vegetation and on both sides a zone of trampled/stunted vegetation with more bare ground than in undamaged areas. This apparent difference, however, might be due to the difference in use of trails by mountain bikers and walkers. Mountain bike riders tend not to get off their bicycles very often unless there is a need to, or they fall off. In addition, both trails in this study are one-way trails and therefore riders do not have to pass each other often, only for overtaking, reducing the need to leave the trail. This result is also in part explained through the low user numbers for both trails (Tables 4.22 and 4.23) and the few spectators who were attracted to the races. In Lance et al. (1989) trails received higher use in different environmental conditions. Another consideration in the compaction of areas adjacent to trails must be the density and nature of that vegetation, which determines if trails can be left easily or not (Bright, 1986). In the conditions encountered in this study, it would have been hard for the mountain bikers to leave the trails on their bicycles in the observed conditions where the trails were flanked by varying combinations of woody vegetation, some of it spiky, and deep litter.

In this study, soil compaction in the areas adjacent to the trails indicated low impact on theses areas, even on the racing trail. However, on some occasions, especially on the Marrinup trail, trail braiding was observed in instances where riders have circumvented obstacles and created new trail 'sections'. These 'detours' were only short and the resulting new trail sections are comparable to the rest of the trail in terms of width and impact. Cole (1983), Bratton et al. (1979) and Weaver and Dale (1978) have associated multiple trailing with poor location and trail design and the observations made in this study highlight the importance of anticipating these occurrences. When constructing a trail, these 'detours' can be designed from the outset, still providing challenges for riders who like to ride them, while catering for less experienced and less challenge orientated riders. In one case, a water bar was circumvented leading to localised trail widening (Figure 5.1) illustrating the point made by Hain (1986; cited by Chavez et al., 1993, on p. 30) who linked these occurrences with increased erosion. These occurrences should be avoided by constructing water bars that cannot be circumvented.

Figure 5.1: Marrinup, trail widening caused by circumvention of a water bar

The effects of mountain biking on soil compaction on and adjacent to trails in this study can be summarised as:

- mountain bike traffic does lead to soil compaction;
- this compaction appears to be confined to the trail corridor and the soil to each side of the trail seems little affected;
- trail compaction is influenced by factors such as slope, feature and age of a trail as well as soil characteristics such as texture, particle size and particle content;
- a dry trail surface can be loosened more easily by mountain bikes than a moist one especially during races on sandy soils.

5.1.3 Trail width

Trail width is a trail parameter that can indicate how much a trail is used (Lance et. al, 1989; Bright, 1986). In addition, an increase in trail width over time could indicate a problem on the trail (e. g. an eroded or boggy area that is circumvented) or with the trail design (e.g. curves too tight). This parameter is easily measured.

In this study trail width varied over time at Lowden but did not show any effects or relationship with any of the site parameters or the covariates. Marrinup produced also a time effect but in addition revealed a relationship with % fragments A (the percentage of fragments present in the A horizon), albeit not a strong one. This indicates that the relative amount of fragments in the soil can affect trail width and should be taken into consideration when siting a trail.

The changes of trail width over time coincided with the use of the trail. The greatest trail width at Lowden was observed at time 2 after the race in early spring (Figure 4.5) and may reflect the greater number of riders using the trail before and during the race (Table 4.22). An additional effect of racing, which can lead to trail widening, may be due to the speed of the mountain bikes resulting in overshooting corners and inaccurate riding. Overtaking may also contribute to trail widening. These effects appear to be of a temporary nature at the use levels observed at Lowden because all of the subsequent sampling events revealed a progressive reduction in trail width. This trend seems to reflect the reduction in use (Table 4.22) on the trail and was only reversed at time 6 showing the effects of another race. At that time widening of the trail was less pronounced than at time 2, possibly reflecting the dryer trail conditions with a more stable soil surface (see section 5.1.2). At Marrinup a similar trend of trail width reduction with reduced use was visible (Figure 4.6), albeit not as pronounced as at Lowden, possibly reflecting the more stable trail surface at Marrinup.

Overall both trails did not increase in width over time, and according to observations by the owners of the Lowden property the changes in trail width over the last five years at Lowden have been insubstantial (Barrie and Sherry Thomas, pers. comm., 1998, 1999). This observation is probably connected to a variety of parameters such as low user numbers and one-way traffic, but also to soil characteristics. As outlined in section 5.1.1 the soils at both locations in this study are well graded and contain some fine particles which increase the adherence of a soil. This may partially explain that trail widening, as observed by Bjorkman (1996) on sandy soils, was not observed in this study.

The findings of this study also relate well to studies by Cole (1983) and Lance et al. (1989) who have associated trail width with trail erosion, whereby the latter also found that these parameters were correlated with the amount of use. Burde and Renfro (1986) found a relationship between trail width and soil type and Bright (1986) found that the amount of trail use was influential on trail width as well as the type and density of trailside vegetation. The latter influence could have played a role in keeping trail width low because both of the trails were flanked by woody vegetation most of their length.

To summarise the findings of this study in regard to trail width:

- changes in trail width were small and have not led to a widening of trails;
- changes in trail width appear to reflect amount of use and type of use;
- racing, due to its nature, seems to have a greater effect on trail width than recreational riding;
- effects of racing on trail widening appear more pronounced in moist soil conditions than on dry soils.

5.1.4 Vegetation adjacent to trails (percent cover)

Changes in vegetation cover adjacent to a trail can give an indication of the impacts a trail has on its surroundings. If vegetation cover is reduced over time a user impact can be considered with trail widening as the ultimate result. No change or indeed an increase in vegetation alongside a trail can reasonably be assumed to indicate that users do not leave the trail or at least not to an extent that has adverse effects on the vegetation. Obviously seasonal fluctuations of the local vegetation and local conditions have to be taken into consideration when interpreting results.

The findings of this study indicate that at both locations the impacts of the trails on the adjacent vegetation are small. A reduction in vegetation cover in Lowden at the beginning of the study could have been associated with the impacts of spectators at the race between time 1 and time 2. However, these impacts were low and on only seven occasions damage to vegetation adjacent to the trail was observed. These impacts were no longer visible at the next sampling event a month later. Considering the time of year and the local vegetation the reduction in vegetation cover was most likely due to the disappearance of the annual wildflowers and grasses. This effect was not as pronounced at Marrinup and, indeed, not as many wildflowers and annual grasses were seen there. An increase in vegetation cover at some sites is most likely due to the growth of perennial vegetation. In addition, this data has to be treated with a certain amount of caution due to its subjective nature.

Weaver and Dale (1978) quote a study by Dale and Weaver (1974) who found that vegetation more than 2m from the edge of a trail is often little affected by trail use. In this study little impact was seen even within those 2m. As mentioned above, this is most likely explained by the fact that mountain bike riders only rarely leave a trail under the observed circumstances. The few occasions when riders do leave a trail appear not to impact sufficiently on the adjacent vegetation to cause considerable and observable long-term damage. Bright (1986) found a negative correlation of herbaceous plant cover with shading which might explain some of the differences of changes in vegetation cover between Lowden and Marrinup. In this study however shading was not considered and therefore this connection must remain speculative.

Consequently the following conclusions regarding vegetation adjacent to mountain bike trails can be drawn from this study:

- mountain biking at the two locations appeared to have little effect on the vegetation adjacent to the trails;
- racing can result in damage to trailside vegetation which was short-term at the observed use level.

5.2 Rider profile, preferences, perception and practices

A questionnaire survey was chosen for this study as a tool to gauge the preferences of mountain bike riders in terms of trail design and setting as well as to investigate their awareness in respect to issues of mountain bike management. This information is considered to be a basic requirement for the appropriate management of mountain biking and the design of mountain bike trails (Cessford, 1995a).

The low return rate (18%) of the questionnaire can be explained in part by the low numbers of mountain bike riders inquiring about mountain bike trails at most of the CALM offices. In addition many bike shops disregarded the instructions given in the cover letter (Appendix 2A) and gave many questionnaires away. If the latter had been anticipated, the return rate could possibly have been increased by attaching reply paid envelopes to all questionnaires. In addition, visits to popular mountain bike trails on weekends could have possibly increased the numbers of returned questionnaires. However, time, as well as budget constraints, did not allow for these measures. Nevertheless, the data generated by the survey are valuable and indicative of rider preferences and awareness and therefore useful for the management of mountain biking in the southwest of Western Australia. Comparisons with findings by other studies are valuable to explore similarities as well as discrepancies between different localities. At the same time, caution needs to be exercised due to differences in the survey formats, the target populations and the questions asked.

5.2.1 Profile

In this study most respondents were between 15 and 39 years old with a slight trend to being younger than 25 years. This result is consistent with the findings by all the researchers who have explored aspects of mountain biking through surveys (see section 2.5). They found an average age of 30 years for mountain bikers which is consistent with the classification of mountain biking as a form of adventure recreation where participants look for excitement and risk (Ewert, 1989; Priest and Dixon, 1990; Hollenhorst et al, 1995). Nevertheless, the high range in age of respondents (from under 15 to over 60 years) indicates the suitability of the sport for all ages.

Further analysis in this study revealed that the participants of mountain bike racing are more likely to be in the younger age bracket (under 25 years) whereas riders above 40 years of age tend not to race. This is perhaps not surprising given the even greater challenge and risk associated with racing, which was confirmed by Kronisch and Rubin (1994). They found that significant traumatic injuries in mountain biking were associated with high speeds and racing.

A large majority of respondents were male, with only 11% of respondents being female. The finding is also consistent with those by Caltabiano and Caltabiano (1994) who found marked differences in the participation of females and males in different categories of leisure pursuits. Females preferred 'cultural-hobbies leisure' such as crafts, cultural events and activities, gardening and volunteer community work, whereas males preferred the 'outdoor/active/sport activities' such as swimming, fishing, team sports and cycling just to name a few. The Australian Bureau of Statistics (1999b) confirms that males participate in sport and physical activities at a higher rate than females regardless of age group. This result is also consistent with all the other surveys on mountain bikers (see section 2.5). Due to the low number of female respondents further analysis in regard to the relationships of sex with other factors was not explored.

Over 70% of respondents to this questionnaire were mountain bike club members. This result is not representative of the total mountain bike ownership in Western Australia. By far the majority of mountain bike owners are not club members as indicated by annual sales.This high number of members as respondents was attributed to the high return rate of questionnaires that were sent to the members of WAMBA and the completion of questionnaires by most of the participants at the summer race at Lowden (immediately before time 6). In addition, some of the bike shop staff may have had the impression that the questionnaire was only aimed at 'serious' riders and therefore may have only asked these riders to complete a survey form. Alternatively, the result may also reflect the greater interest of mountain bike club members in the management of mountain biking and the greater awareness of these riders in regard to associated issues. In Germany, Wöhrstein (1998) found that only 15% of respondents to his survey were club members. This result can probably be considered as representative of the actual situation in Germany due to the great number of returned questionnaires (3,100). Chavez (1993) also found low club membership in users of the San Jacinto region in the USA. It can, therefore, probably be assumed that the actual ratio of club members to non-members in Western Australia is likely to be much lower than the survey result suggests.

5.2.2 Preferences

An exploration of the relationship of club membership with the results of other questions revealed that mountain bike club members like to ride with friends, ride for a challenge and participate in all forms of racing (except trials) much more so than riders who do not belong to a club (Table 4.38). All three of these associations seem to go hand in hand, with racing being a sociable and challenging activity. Many clubs are also racing orientated therefore this association is not surprising (Ewen MacGregor; Peter Gaull; Les Machin; pers. comm., 1998). In addition, mountain bike club members are more likely to be under 39 years of age, whereas older riders tend not to belong to a club. Further relationships with other items are discussed in the relevant sections.

The findings of this study in regard to rider motivation indicate that mountain bikers in the southwest of Western Australia ride a mountain bike above all because they enjoy it and it is fun (Figure 4.12). Exercise and training is the next important reason for riding. Hollenhorst et al. (1995) had a similar result in respect to these two motivations. Ruff and Mellors (1991) also found a high percentage of riders who rode a mountain bike for training for competition and fitness, which was explained by the fact that their study only investigated mountain bike club members. In Western Australia apparently non-club members were also interested in the fitness and training aspect of mountain biking because no association of this motivation with club membership was found. Racing, the challenge, and to be with friends were also very important incentives for riding in this study but were associated with club membership as indicated above. Although Hollenhorst et al. (1995) as well as Chavez (1993) found that many mountain bikers ride with friends those results are not directly comparable with this study because these studies did not explore club membership. Cessford (1995c) also found that socialising as well as speed and excitement were important to mountain bikers. His findings are in some contrast to this study because he found very low club membership with his respondents. However, club membership was, as in this study, also associated with racing. Consequently, in the international comparison some differences as well as similarities between mountain bike riders in regard to rider motivation and club membership can be assumed.

Many riders in this study also indicated transport, appreciation of nature and relaxation as reasons for riding a mountain bike. In respect to transport, Ruff and Mellors (1991) found that a small proportion of club members also rode to work which is in contrast to this study where 50% of all respondents indicated that they use a mountain bike for transport. On the other hand, Wöhrstein (1998) also found that a high proportion (37%) of respondents used their mountain bikes to ride around the city or to work. Hollenhorst et al. (1995) observed that mountain bikers ride with the purpose of being in nature although to a lesser extent than was found in this study. The family outing was the least popular motivation in this study, which is consistent with Chavez (1993) who found that relatively few mountain bikers rode with their families. Overall, these findings show that mountain biking is considered to be an enjoyable, healthy sport and recreational activity that is pursued for a variety of reasons and can provide a variety of experiences.

When the relationship of rider motivation with the results of other questions (such as preference of trail features and settings, bike ownership and age) was explored, some of the results were similar to those of the club membership comparisons. This can be explained by the division of respondents into riders who indicated they ride for recreation purposes only and riders who indicated that they also race. Racers only could not be included in the analysis because of low numbers. This division reflects to some extent the association of club membership with racing as outlined above, although many differences between the two analyses were apparent. Overall, there were more significant relationships found in the racing versus recreation analysis than in the membership analysis indicating that the differences between riders who race and riders who ride for recreation only are greater than the ones between mountain bike club members and riders not affiliated with a club. The different associations are outlined in the appropriate sections of this discussion.

The majority of mountain bikers indicated that they ride a mountain bike two to three times a week although nearly as many said that they ride more often than that. An association of this result with racing participation was found with racers tending to ride daily, possibly reflecting their need for training as well as their greater enthusiasm for the sport. The few riders indicating that they ride less often than two to three times a week tended to be recreational riders. The average riding frequency was found to be three to four times a week. These results reflect the dedication of mountain bike riders in general and the even greater dedication of racing riders towards their sport. This finding compares well to that by Wöhrstein (1998) who found that German mountain bikers rode their bikes on average four times a week, despite the more adverse climatic conditions in Germany.

When asked the year that respondents had taken up mountain biking the period from 1993 to 1997 was mentioned most often. Wether this coincides with a boom in mountain bike sales is impossible to say because no statistics on bicycle sales are available in this country. Bicycle import figures for that period are inconclusive (Bicycling Trade Magazine, 1998). The trend in riders taking up mountain biking showed an increase in mountain bike participants from the early 1980s onwards with a small peak in 1989/1990 and the maximum in 1996. Since then the number of riders taking up mountain biking appears to have stabilised. Average rider experience in years of riding was six years, which was longer than that of the 4.6 years found by Chavez (1993) and the 3.75 years averaged by Hollenhorst et al. (1995). This discrepancy can be attributed to the later date of this study. Rider experience in amount of years of riding is not necessarily correlated with rider experience in terms of expertise, as Cessford (1995c) points out.

Mountain bikers apparently ride reasonably long distances. Over 70% indicated that they ride over 10 km on average and over half of these rides were over 20 km. These findings are comparable to those by Chavez (1993) who found that mountain bikers rode an average of 14.2 miles (22.7 km) and the 15 mile (24 km) average rides found by Hollenhorst et al. (1995). Wöhrstein (1998) found that German riders on average rode 16.5km. No association of riding distance was found with racing riders or club members indicating that all mountain bikers enjoy riding their bikes quite extensively. However, the year riders started to mountain bike, or rider experience, revealed a relationship with the distance of rides. Accordingly riders who started to ride after 1995 tended to ride distances of between 10 and 20 km whereas riders who took up mountain biking between 1990 and 1994 rode both short distances (below 10 km) and distances of more than 20 km. Riders who started mountain biking before 1990 ride mainly long distances (20 km and above). This relationship indicates that riders with more experience tend to ride greater distances, reflecting their commitment to the sport both in time and effort.

Nearly 30% of respondents had done overnight tours, which is somewhat less than the 43% of riders that indicated to Wöhrstein (1998) that they had done tours. Nevertheless, these numbers indicate a great interest in touring which is supported by the finding that close to 60% of the over two-thirds of riders who had not done overnight tours were interested in doing so. Cessford (1995c) found a relationship of greater rider experience with number of overnight tours, which is comparable to this study where more racers than recreational riders did overnight tours. This highlights once more the greater dedication of racing riders to mountain biking.

Overall Dwellingup and Mundaring were the most preferred areas for riding. The Goat Farm at Greenmount, Jarrahdale, Kalamunda and John Forrest National Park were also quite popular. This reflects that nearly three quarters of all respondents live in the metropolitan area and a significant relationship exists between the most preferred riding location and the post-code respondents have supplied (Table 4.43). Of the country locations, besides Dwellingup, Margaret River and Lowden were popular areas for mountain biking (full list in Appendix 2C). Many riders also mentioned forest and bush as preferred riding locations which follows the trend for natural areas which is indicated by all the other first preference locations. These results are in keeping with the answers to the question on preferred settings, where riders indicated that they like to ride in forest or bush areas. Various riders also mentioned the Bibbulmun Track, which possibly indicates that they like to ride long-distance single track. The preference for single track may also be reflected by the popularity of the other preferred areas where at least some of the mountain bike trails are single track.

Mountain bike riders like to meet wildlife and other cyclists on their rides, although racers like to encounter other cyclists more so than recreational riders, which could once more reflect the social nature of mountain bike racing (Table 4.39). Cessford (1995c) found a similar preference of more experienced riders for meeting other cyclists and he suggests that possibly novice riders are more intimidated by these encounters. Respondents were neutral towards walkers and horses, which is not directly comparable to Watson et al. (1991) who found that few mountain bikers disliked hikers, and Wöhrstein (1998) who noted that few mountain bikers experienced problems with walkers. The result seems, however, slightly more positive than the finding by Cessford (1995c) that riders were tolerant to negative towards walkers. The findings of this study in regard to horses are similar to the findings by Brindal and CALM (1995) who found a mixed response towards these trail users. In the case of walkers, however, most respondents of their survey were happy to meet walkers on bush tracks The differences in regard to walkers may be due to an increased number of mountain bike riders and a related increase of conflict situations.

In contrast, cars and motorcycles were disliked by respondents in this study in line with those questioned by Cessford (1995c). Brindal and CALM (1995) also found that riders did not want to share trails with trail bikes. All these findings appear to be consistent with Devall and Harry (1981, p. 399) who found that: "Users of less obtrusive technologies seem to dislike the more obtrusive much more than the latter dislike the former." The dislike of motorised vehicles is possibly associated with the noise and the exhaust fumes they produce as well as the speed with which they can move. In addition, motorcycles, especially trail bikes, can use narrow mountain bike trails and are therefore in direct competition with mountain bikes. As Wilson and Seney (1994) and Weaver and Dale (1978) point out, motorcycles have a greater potential to damage trails than mountain bikes, which may also play a role in the dislike of these trail users by mountain bikers. Trail damage attributable to trail bikes was observed at Marrinup at one of the sampling events (time 4) after two trail bikes were encountered on the trail. An example can be seen on Figure 5.2 where a trail bike dug a hole of 5 cm depth (16 cm wide and 32 cm long) while attempting to cross a log.

Figure 5.2: Marrinup, trail damage caused by trail bike in an attempt to cross a log

Of all trail features listed in the questionnaire, long and medium length downhills were by far the most preferred features closely followed by long as well as tight curves (Table 4.30). The preference of these features, challenging and technical in nature, showed an association with mountain bike club members as well as with riders who partake in mountain bike racing (Tables 4.38 and 4.39). The preference for long and medium length downhills may also reflect the bias of downhill racers who only ride downhill. Other features associated with these two groups were short downhills and jumps. Steep slopes were associated with club members only whereas short uphills were a preference of racers which probably reflects the competitive nature of racing where longer uphills mean a loss in time. Cessford (1995c) found essentially the same trends, with more experienced riders being more interested in technical difficulties, fast downhills and steep slopes as well as in racing.

In contrast, the recreation only riders in this study preferred drinking water and route markers as the most popular amenity features. In the first case, this is possibly due to the fact that many racers are well equipped with water supply gear (e.g. 'camel backs' - a type of backpack specifically for liquids) whereas for recreational riders the lower riding frequency may not warrant the considerable expense of special gear. They therefore are much more reliant on rainwater tanks or taps for drinking water. In the second instance racers ride on well-marked racecourses and in addition they are probably more familiar with the places where they normally and frequently ride. They also may not require markers because they are better equipped with maps or have better access to word-of-mouth information about riding areas (through club membership). Brindal and CALM (1995) determined that the most important trail facilities were water and clear signposting. Chavez (1993) also found that riders wanted to have drinking water available at the trailhead.

Overall, respondents were not particularly keen on smooth surfaces, overhanging branches, muddy or boggy areas and loose sand or gravel surfaces. These findings are supported by Cessford (1995c) who found that most riders did not like loose sand or gravel, muddy or boggy areas and branches. For smooth surface he found differences in opinion and many riders actually preferred this condition. The other mountain bike trail features listed (moderate slopes, steep slopes, rocks and logs, firm surface, straight stretches, easy slopes, rough surface, medium length uphills) were rated as desirable on average. Ditches and long uphills were rated as more neutral. Some respondents remarked that a 'good' mountain bike trail has to have a good variety of features to be interesting to ride. The listed amenities (parking facilities, toilet facilities, setting up area, brochures, interpretive signs, information shelters) were regarded as desirable on average. Chavez (1993) also found that toilets and parking were amenities that were of medium importance to riders. In addition, maps of the trail with mileage and signs indicating permitted and prohibited trail users were regarded as desirable in her study. In this survey various respondents mentioned maps and signs of a similar description in the 'other' category, indicating their importance as amenity features. Brindal and CALM (1995) found that information boards were ranked in third position followed by rubbish bins, toilets, campsites, information pamphlets and car parks.

In terms of settings, respondents clearly preferred single tracks and native bush or forest but also liked plantation forest and wide trails. Farmland and gravel road were more acceptable than sealed road whereas most respondents avoided built up areas or suburbs. All researchers who examined that aspect (Ruff and Mellors, 1993; Cessford, 1995c) found a preference for natural areas. Hollenhorst et al. (1995) also found that riders preferred trails to roads, although Wöhrstein (1998) found that in Germany gravel roads were more popular than wide trails, sealed roads and narrow footpaths in order of preference. His findings, however, can be explained by the different situation in Germany in terms of landscape as well as legally, where in some areas mountain biking is prohibited on trails under 2m wide. The survey respondents in Brindal and CALM (1995) preferred compacted or hard soils over gravel, sealed and rock surfaces, which was very much in keeping with the results of this study.

Further analysis of the survey findings revealed that racers, as opposed to recreational riders, clearly prefer the greater challenge, technical difficulty and variety provided by a single track. Recreational riders on the other hand are more open to the idea of riding on a gravel road and, although they do not like them, find sealed roads less objectionable than do the racing riders. These findings were also described by Cessford (1995c). Interestingly, riders who race rate plantation forests quite highly as a setting in contrast to recreational riders, which was also noted by Cessford (1995c). A possible explanation for this could be that racers mainly ride for sport and not sightseeing and as long as the requirements for a 'good' mountain bike trail (see above) are fulfilled, racers do not care as much about the surroundings as recreational riders. In addition, racing riders might be more aware of the difficulties associated with trail access in native forests and may view plantation forest as an opportunity to expand their 'territory'. The same may be true for riders who have done tours because they are also more accepting of plantation forest than riders who have not done overnight tours.

5.2.3 Perceptions

Respondents were quite united in their disagreement with the statement that there are enough mountain bike trails (Table 4.32). Many of the comments provided at the end of the questionnaire also referred to the lack of mountain bike trails (Appendix 2C, Question 19). A lack of mountain bike trails was associated with damage to trails by Wisconsin mountain bikers (Bjorkman, 1996), with the implication that more mountain bike trails would result in less damage to trails. This was not the context here but the perception of a lack of mountain bike trails obviously needs to be addressed. Various riders also requested more information on where mountain bikers can ride and information on and maps of existing trails (mainly at Question 9: trail features and Question 19: comments) indicating that there may be areas and trails available for riding that are not generally known.

Riders also agree in general that trail damage by mountain bikes is overrated, which matches the disagreement voiced to the opposing statement that mountain biking damages trails. Cessford (1995c) asked a similar question and found a similar answer. These perceptions seem to be supported by the findings of Wilson and Seney (1994) in the USA and Wöhrstein (1998) in Germany who both found little damage by mountain bikes, but appear to be in opposition to Cessford (1995a) and Keller (1990, cited in Cessford, 1995b) who have associated mountain bikes with trail damage. However, they conceded that the extent of damage depended on riding technique (see below).

Good trail design as well as good riding technique was seen by respondents as avenues to reduce trail damage. Riders had perceived a difference in trail damage in relation to soil type and also saw rider education as a means to reduce trail damage. These findings seem to indicate awareness by mountain bikers of these issues in accordance with the findings of various researchers. Bjorkman (1996) observed that trail erosion caused by mountain bikes could be controlled by appropriate siting. Chavez et al. (1993) found that trail erosion depends on site conditions and rider behaviour and Cessford (1995a), as well as Keller (1990, cited in Cessford, 1995b), has associated trail damage by mountain bikes with poor riding technique. Widmer (1997) points to the importance of education to reduce trail damage because aware riders ride more responsibly. He recommends a code of conduct.

Dieback was acknowledged as a serious environmental problem in Western Australia but mountain bikers were not as readily accepting of the notion that their bicycles are potential disease carriers. In fact, many respondents remarked on the questionnaire adjacent to the question that walkers and wildlife are likely to spread the disease to the same extent and that it was unfair to single out mountain bikes and prohibit them riding in the forest. However, due to the existing management guidelines of CALM and the limited knowledge and lack of research into the potential spread of dieback by mountain bikes, walkers or wildlife a change in the current situation seems unlikely.

The statement that mountain biking should be allowed on all trails provoked both strong agreement and neutral or even negative answers. This same wide spread in opinion was observed by Cessford (1995c) for a similar statement. The rest of the statements posed in the question, which referred to racing having more impact than touring, most trail damage occurring in downhill curves and the enjoyment of riding a trail repeatedly, received responses that differed widely. Somewhat in contrast with the statement on repeatedly riding a trail, Cessford (1995c) found that most riders in New Zealand found it important to explore new areas.

For some of the statements on various mountain bike issues, differences between racing riders and recreational riders have emerged. The notion that trail damage by mountain bikes is overrated found greater support amongst racers and they also tended to disagree much more with the associated test question that mountain bikes cause trail damage than recreational riders. This difference was not found by Cessford (1995c). Factors leading to these differences in opinion may be that racers, who ride more often than recreational riders (see above), have experienced how little the trails they ride change over time. On the other hand, they may have become used to the impacts of mountain bikes, not noticing them any more or accepting them as part of the sport. For an occasional recreational rider a worn curve, an eroded downhill section or skid marks may be more noticeable. The statement that good riding technique reduces trail damage was strongly agreed to by both groups of mountain bikers to the same extent although, in addition, many more racers agreed to it than recreational riders. This discrepancy may reflect the greater knowledge of riding techniques and the better riding skills of racing riders. Some keen recreational riders may also be aware whereas the occasional recreation rider may not have that knowledge. Personal observation at racing events supports this statement.

Riders who appeared to have great mastery over their bicycles were skidding very little in or before curves thus reducing damage to the trail surface. Amongst the racing community there seems to be more support for the notion that all trails should be open to mountain bikes whereas amongst recreational riders many disagree with the idea. This may reflect the perception by racers that mountain bikes do little damage to trails especially when good riding technique is employed. In addition, because they ride more often than recreational riders, racers may be more interested in having access to more trails, particularly walking trails which are often single track, which is their preferred option. Racers also do more tours, and in answering this question, many may have had the Bibbulmun Track in mind, which is now closed to mountain bikes.

5.2.4 Practice

Nearly all respondents supported a code of conduct. The most important aspects of such a code were cited as respect for other trail users, safety, respect for the environment and respect for the trail. Interestingly, some mountain bikers asked for hikers to also respect them. Chavez (1993) also found that most riders supported trail etiquette and environmentally responsible behaviour, and Cessford (1995c) found that voluntary codes of conduct were seen as the preferred management option for mountain biking by riders. Overall, it appears that mountain bike riders are friendly, responsible and environmentally aware trail users who are aware of the problems and potential problems of trail use and shared trail use in particular. Naturally, as with all groups, there are some riders who do not see the necessity of a code of conduct or are only interested in rules that privilege mountain bikers. Perhaps some rider education could change this.

Many respondents owned more than one mountain bike. Interestingly, nearly all recreational riders (95%) owned only one mountain bike whereas over a third of racing participants own two or more bikes. This difference is easily explained by the different equipment requirements for racing. When attending a race sophisticated racing bikes with front or dual suspension are conspicuous. This is especially the case in downhill racing. Consequently, depending on the type of racing they participate in, racers tend to have specialised bicycles and often more than one. Of these 'multiple bike owners' the majority own a front suspension as well as a dual suspension bike. This also points to the commitment that racing riders have towards their sport because many of these bicycles are expensive, costing up to $5,000 or more.

The respondents of the questionnaire appear to be very conscientious and look after their bikes very well. A great majority of riders clean their bicycles at least monthly and 40% of riders indicated that they clean their bikes after every race or ride. Considering that many mountain bikes are expensive this cleanliness makes sense. It also means that the risk of the spread of dieback by mountain bikes is probably relatively low amongst mountain bike riders. This is also indicated by the fact that many riders remarked that they clean their bikes after muddy rides, that is, when they have been riding in conditions that are conducive to the spread of Phytophthora spores (Shearer and Tippet, 1989). Naturally, this survey can only give a rough indication and the subject needs further investigation.

Over half of the survey respondents indicated that they were aware of dieback risk areas (DRA). Many of the comments supported this claim but at the same time the answers also hinted at a great lack of knowledge in this respect. Some respondents lamented a lack of information. Indeed, the DRA system seems rather confusing and some clear definitions might be helpful in order to increase the understanding in the community about dieback and the measures taken to prevent its spread. The lack of understanding was also apparent in the answers to the statements that related to dieback (see above) which received the highest amount of 'don't know' answers (Table 4.32). A connection seems to be apparent where younger respondents are less aware of DRA, which may be related to their lack of life experience. This may also hint to a window of opportunity where information about dieback and its management could be disseminated through schools.

The majority of respondents live in the metropolitan area, which can in part be explained by the distribution of the questionnaire. A majority of WAMBA members live in Perth and many of the bike shops that received questionnaires were also in Perth. In addition the bike shops in Perth seemed to be more successful in getting survey forms filled out than the country shops. The same was true for the CALM offices. The distribution of survey respondents can also be partly explained by the fact that the majority of the population of Western Australia lives in the Perth metropolitan area (63.5%) as the Australian Bureau of Statistics (1999a) data show.

A comparison of riding areas given as first preference with post-codes indicated that riders mostly prefer to ride in the general area where they live. That means riders who live in the metropolitan area also prefer to ride in the metropolitan area whereas riders who live in the country preferably ride there. In addition, a sizeable proportion of metropolitan riders prefer to ride in the country whereas the reverse is true only to a minimal extent. Some riders living at the edge of the metropolitan area and therefore having easy access to 'the country' can explain this latter finding. In other cases, riders may have been on holidays or at racing events in areas where they prefer to ride, although they may not do it regularly.

Surprisingly many respondents took the opportunity to comment on a wide range of subjects. The issues raised most often were in relation to trails. Here riders asked for access to the Bibbulmun Track or the provision of a long-distance 'Bibbulmun style' track. Riders also generally want more trails, more single track and more trails within the metropolitan area. Respondents also stressed that mountain biking has little impact on the environment and asked for more information in regard to trails. Various aspects of dieback were also commented on, as were a variety of other subjects.

In summary, the survey allows the following conclusions in regard to mountain biking in the southwest of Western Australia:

- Mountain biking in Western Australia as elsewhere in the world is dominated by young males.
- Younger riders tend to be members of a mountain bike club and are more likely to race. They prefer the more challenging features of mountain bike trails such as longer downhills, curves and jumps.
- Mountain biking is considered to be a fun and healthy activity and is pursued by a wide range of participants in terms of age and motivation.
- Mountain bikers ride on average 2-3 times a week for distances of over 10 km.
- One third of mountain bikers have done tours and another third is interested in doing so.

- Mountain biking in Western Australia has increased until 1996 and seems to have stabilised now. Riders have ridden a mountain bike on average for 6 years.
- The most preferred riding areas in Western Australia are Dwellingup and Mundaring.
- Mountain bikers like to meet wildlife and other cyclists, are neutral towards horses and walkers and dislike cars and especially motor bikes.
- The most preferred features of mountain bike trails are long and medium length downhills and long, as well as tight, curves. Of the amenity features drinking water and trail markers were the most preferred.
- Smooth surfaces, overhanging branches, muddy or boggy areas and loose sand or gravel surfaces were liked least.
- Single track and forest or bush were the most preferred settings, followed by farmland and wide trails. Farmland and gravel roads were more acceptable than sealed road and built up areas or suburbs were disliked.
- Riders agree that trail damage by mountain bikes is overrated and disagree that there are enough mountain bike trails and that mountain biking damages trails.
- They also agree that good trail design and good riding technique as well as rider education can reduce trail damage.
- There is strong support for a code of conduct with the main aspects of respect for other trail users, safety, respect for the environment and respect for the trail. In addition hikers are asked to respect bikers.
- Most recreational riders own one mountain bike whereas many racing participants own two or more bikes.
- Most mountain bikers clean their bikes at least once a month.
- Many mountain bikers are aware of dieback risk areas although there is some confusion as to what they actually are and what it means.
- Most mountain bike riders prefer to ride relatively close to home.

6 Implications, Conclusions and Recommendations

6.1 Implications for Trail Design

The analysis and discussion of the project outcomes have highlighted several implications for the design of mountain bike trails. However, these implications may only be applicable for the southwest of Western Australia and even then not equally so for all conditions encountered in this area.

Designs need to vary with the type of rider

The findings of the survey clearly indicate that racing riders look for different trail experiences than recreational riders. For racers a single track that is challenging, technical and steep with lots of downhills of varying length and short uphills is essential. In contrast, recreational riders also like some of these features such as downhills of various lengths and long curves, but many dislike features such as tight curves and especially jumps. In contrast to racers they also quite like gravel roads and seem to be more tolerant towards sealed road. On the other hand, all riders like to ride in native forest or bush but, in addition, racers also consider plantation forests as a good setting. That may indicate that racing trails and trails for racing riders can be situated in plantation forest as well as native bush as long as they are challenging and technical in nature. Trails for recreational riders should be situated in native forest, be less technical and demanding and can incorporate wider trails, gravel roads and even short stretches of sealed road.

A variety of distances and settings for trails

Trails of differing length and difficulty should be provided. Ideally, this would be achieved with an interconnected system of mountain bike circuits or loops of differing length and difficulty in a native forest setting. In this context the proposal by Brindal and CALM (1995) for a long-distance mountain bike trail offers many valuable suggestions and should be taken into consideration where appropriate.

Obstacles and difficult trail sections should be reserved for the trail loops whereas the connecting trail should be of a difficulty level that allows for relaxed riding and is suitable for riders with relatively little experience. The presence of obstacles should be clearly stated at the trailhead and their difficulty incorporated into a rating system. This would give riders the opportunity to choose the trails according to their riding level and the potential for injury and conflict between riders of different ability would be reduced.

Information requirements

All trails should be clearly marked and graded for difficulty. Signs at the trailhead should show a map of the trail, state the length of the trail as well as its difficulty rating. The signs should also clearly state the users allowed on the trail (preferably explaining why use is restricted if it is) and state if it is a one way track. Especially in the case of multiple-use trails the appropriate trail etiquette should be stated. Some provisions to that effect are proposed by CALM (1999b). Trail markers should be clearly visible along the length of the trail and all the loops. Warning signs will be necessary for road crossings or other features that require extra caution.

Managing different trail users

A minimisation of the conflict potential with other users is only possible if the trail system consists of mountain bike only trails. However, this may not be possible, considering the limited resource, and is probably not desirable. As Wöhrstein (1998) pointed out, multiple-use trails may be advantageous because user-specific impacts such as tracks may be deformed and smoothed by other users resulting in reduced trail erosion and maintenance. In addition, as some respondents pointed out, the natural environment should be shared, but segregation does not educate about shared use. Therefore, in cases of multiple-use, care has to be taken that all potential users are aware of each other's presence on the trail by adequate signage and dissemination of information such as maps and brochures (see also CALM, 1999b). Education and information are probably the best ways of addressing the potential problems associated with shared use (Moore, 1994). The survey showed clearly that the majority of mountain bikers would support a code of conduct, hence this avenue of influencing rider behaviour should be utilised. From the survey it is also clear that shared use with motor bikes and cars or four-wheel-drive vehicles should be avoided. Horses could pose a problem in terms of added erosional impacts but could be accommodated, at least on some trails, if resistant soils are chosen and their presence is clearly advertised. Other problems associated with horse use such as spread of weeds and nutrient rich manure has to be evaluated separately.

Environmental factors and trail features

According to the findings of this study a trail system such as the one outlined above can be environmentally appropriate and low in maintenance if certain points are observed. Clearly soil characteristics, features (curves and straights) and slope (length and incline as well as side slope) have to be taken into consideration in the design of mountain bike trails. Preferably the trail should be sited on well-graded soils that contain a proportion of fine particles to maintain a firm trail surface. Sandy soils and soils that loosen easily when dry should be avoided as well as areas that tend to get muddy. These soils should be avoided especially for racecourses where the impacts on the trail surface appear to be greater due to increased speed and skidding. This is especially true for curves where the exertion of lateral forces of mountain bike wheels is most pronounced. Long steep slopes at steep angles to the hillside should also be avoided to prevent erosion. Where steep downhills are desired (e.g. on a racing trail) precautionary measures such as water bars should be incorporated into the trail at the design stage to counteract the erosive forces acting upon these trail sections. These features can be designed in such a way that they can serve as jumps or obstacles and add interest or difficulty to the trail. When designing jumps and obstacles on a trail, however, care should be taken to ensure that these obstacles can not be circumvented. If this is not possible, detours should be anticipated and designed in an environmentally satisfactory way.

Minimise maintenance costs

Other issues that need to be considered in the design of mountain bike trails are varied. Firstly, mountain bike trails should be sited in such a way that the need for maintenance is minimised. This reduces cost and the amount of work hours needed to keep a trail in a satisfactory condition. This is especially important for a long-distance trail system as that planned by WAMBA and recommended here. Therefore care should be taken to avoid the soils and features outlined above as well as siting trails too close to vegetation that is liable to overgrow the trail. In addition, riders should be educated about low impact riding techniques (through brochures and possibly even through mountain bike courses) and asked to either contribute to basic maintenance (e.g. removal of debris) while riding a trail or to report trail damage to an appropriate authority. Riders, and other users, should also be encouraged to participate in organised volunteer trail maintenance events. This would be especially appropriate for racing riders because they ride significantly more often than recreation riders and appear to have more impact on the trails. In addition, these riders are relatively easy to contact because many of them are affiliated with clubs and can also be reached when they register for racing events.

Tourism potential

Consideration should be given to mountain bike tourism. According to Thomas Wöhrstein (pers. comm., 1999) if a long distance trail with substantial single track sections through native forest was promoted in Germany it would attract great attention and potentially a great number of mountain bike riders. Trails such as this are not available in Europe and would greatly add to the already substantial attractiveness of Australia to European and especially German tourists. The economic gains for the southwest of Western Australia could be substantial.

Other

Other considerations should be given to the amenity features of long and short distance recreation trails. The provision of water is an important criterion. Adequate parking facilities and setting up areas, toilets and shelters as well as emergency access should be considered when siting a trail (for a more detailed description of some or these amenities see Brindal and CALM, 1995).

In summary, the implications for trail design in the southwest of Western Australia as found by this study are as follows:

- Slopes, features and soil characteristics need to be considered to minimise trail erosion.
- Racing has different impacts than recreational mountain biking.

- Different users (recreational and racing riders) have different requirements for trails, therefore, provision of a variety of trails of differing difficulty and length, marked and rated for difficulties should be provided.
- Trails in some settings will be readily accepted and others will be avoided, therefore trails in native forest away from suburbs but still close to where riders live should be provided. These trails need a firm surface and roads should be avoided.
- Variety in terms of features and settings should be provided.

6.2 Conclusions and Recommendations

In addition to the implications for trail design, a variety of conclusions can be drawn from the results of this study. These are closely associated with the recommendations that can be made and therefore will be combined. Given the limitations discussed in section 5 the following conclusions and recommendations may only be applicable to conditions similar to those of the study sites during spring and summer only and with low use.

Mountain biking in the southwest of Western Australia can be environmentally sustainable with good trail design

As the physical impact study has indicated, the impacts of mountain biking on trails are small. Some impacts were found such as compaction of the trail surface and changes in the micro relief. These changes are, however, to be expected for a trail and are not problematic as long as they remain within the limits deemed acceptable for a trail, that is, a firm trail surface is maintained, the trail does not widen and erosion is minimal. These conditions appear to be obtainable through good trail placement and design. The main points that need to be considered are appropriate soils that can withstand the impacts created by mountain bikes and the avoidance of steep downhill sections. Where steep downhills cannot be avoided or are desired erosion prevention measures (e.g. water bars) should be included in the planning stage. Consideration should be given to the inclusion of curves, which could reduce the steepness of a slope and effectively reduce its length. However, care should be taken to ensure that the curves are designed in such a way that they do not add to the erosion potential through increased skidding.

Provision of more mountain bike trails, especially in and close to the metropolitan area

The survey has clearly shown that riders want more trails. These should be provided in close proximity to where riders live, hence there appears to be a particular need for mountain bike trails within the Perth metropolitan area. This is especially important for younger riders who do not have a driver's licence and have to rely on other people to take them to trails that are further away and not accessible by bicycle or public transport.

More information concerning trails

More information about trails and mountain biking areas are clearly wanted and needed. Maps and brochures can be used to disseminate this information through bicycle retail outlets, mountain bike clubs and appropriate agencies (Trailswest, Bikewest, CALM). The maps should take the format of those produced by Bikewest and Trailswest and should contain information about the trail (length, difficulty) and how to access it. In addition, these publications should contain a code of conduct and information on low impact mountain biking. Information requested by survey respondents concerned public telephones and the nearest bicycle shops. This information could be contained in the maps.

Better information about dieback and dieback risk areas (DRA)

As the survey showed, many respondents are not aware that dieback is a major environmental problem in Western Australia. Consequently, there appears to be a need for more information about dieback and dieback risk areas, in particular what DRA are and what they are there for. Mountain bike specific publications could be used to disseminate information about DRA and why mountain bikes are not allowed in these areas. Informational talks on the topic could be given to mountain bike clubs. Schools should also be considered for the dissemination of information about dieback and DRA because younger mountain bike riders appear to be less aware about these issues.

Research into the spread of dieback by mountain bikes

CALM should consider initiating research into the spread of dieback (*Phytophthora cinnamomi*) by mountain bikes and other forms of recreation. Many survey respondents have expressed the opinion that walkers (and wildlife) have a potential to spread dieback similar to that of mountain bikes. Respondents feel they are treated unfairly because they are not allowed on trails in the State forest and within DRA, whereas walkers are. An examination of the potential to spread dieback by various forms of recreation would be beneficial for all concerned.

Trail bikes should be discouraged from using mountain bike trails

Clearly mountain bike riders do not like to encounter trail bikes on mountain bike trails. Although the reasons for that dislike were not explored, issues of safety and trail damage support a ban of trail bikes from designated mountain bike specific trails, especially if they are single tracks. Trailhead signage should clearly state the ban and the reasons for it. In areas where trail biking is a problem on mountain bike trails the provision of specific resources for this form of recreation should be considered.

Development of a rating system for mountain bike trails

A rating system for mountain bike trails would be helpful for mountain bikers to choose trails appropriate to their riding level and skills. This would ensure satisfactory trail experiences and could reduce the potential for injury. A rating system should include the length of trail, technical difficulty including obstacles and amount as well as steepness of slopes. WAMBA should be considering such a rating system (Les Machin, pers. comm., 1998).

Development of a code of conduct

The support of a code of conduct was clearly stated by the vast majority of respondents therefore this willingness to comply with such a code should be utilised. A code of conduct as planned by WAMBA (Les Machin, pers. comm., 1998) should include aspects of safety (always wear a helmet; no speeding), respect for other users (announce yourself; be courteous) and respect for the environment (stay on the trail; leave no trace). Low impact riding behaviour (respect for the trail) should also be included (avoid skidding; ride on open trails only). Riders also expressed confusion about right of way issues. Rules that are acceptable to the majority of trail users could reduce conflict and increase safety.

Provision of mountain biking courses

Consideration should be given to the provision of mountain bike courses for the public (as suggested by a respondent). These should include aspects of rider safety, trail etiquette (code of conduct), riding techniques (including low impact), dieback awareness and bicycle maintenance. Some educational institutions (high schools, Edith Cowan University) provide courses for their students but these are not open to the public. These institutions may want to consider providing such courses, utilising their resources and knowledge base during holiday periods while generating some additional income and providing a valuable service for the public. Some operators conduct mountain bike tours but these allow for limited instruction only. However, as a service for their customers they may want to consider specific courses. Bike shops could hold workshops or sponsor such events. Mountain biking courses can be tailored to suit the skill levels of participants and the capability of their bicycles.

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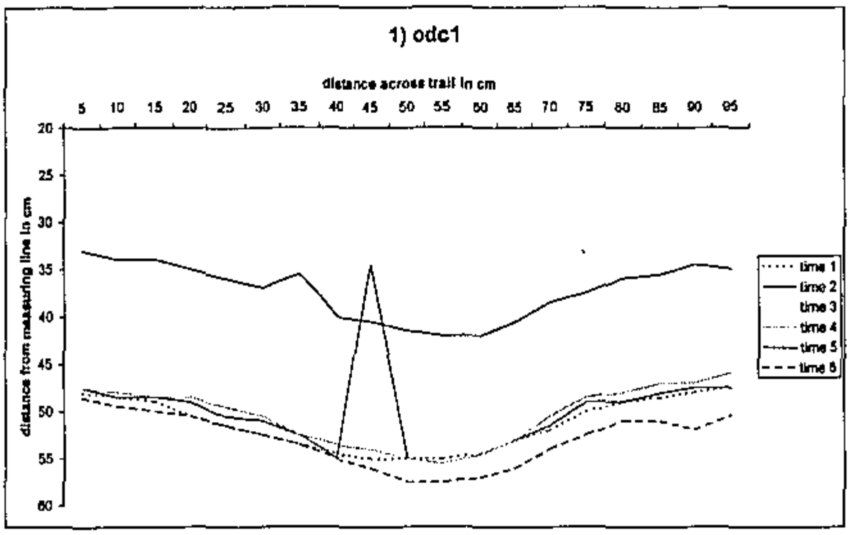
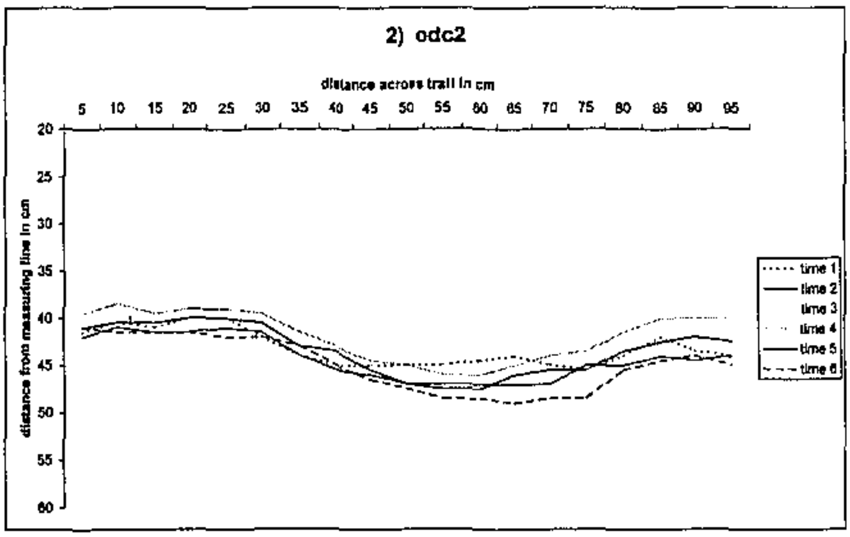
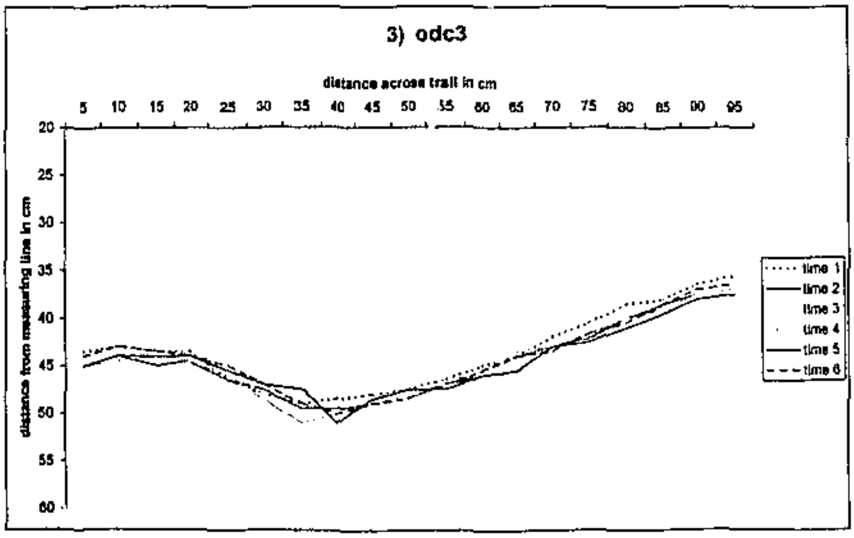
Appendix 1A

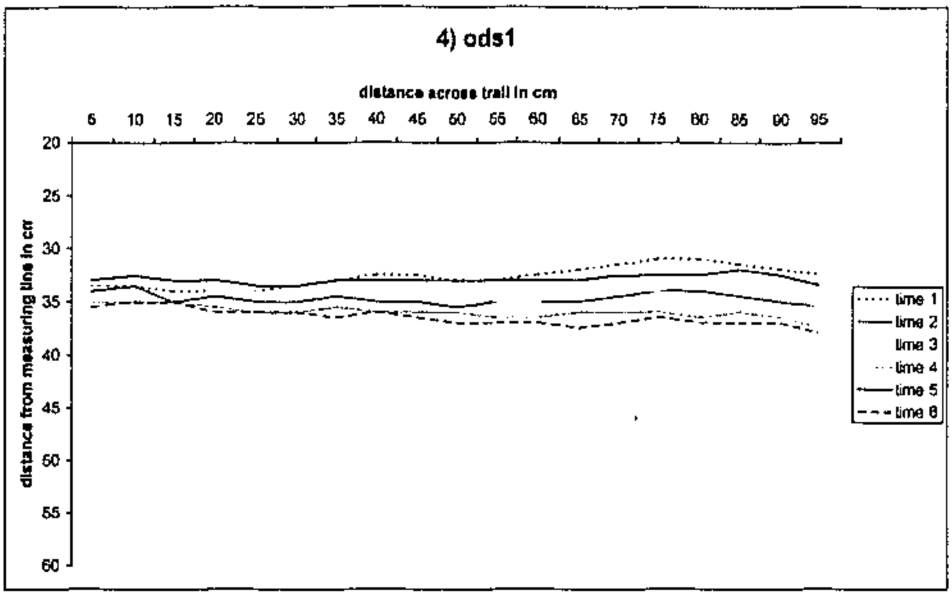
Figures 1-35: Lowden, micro relief profiles

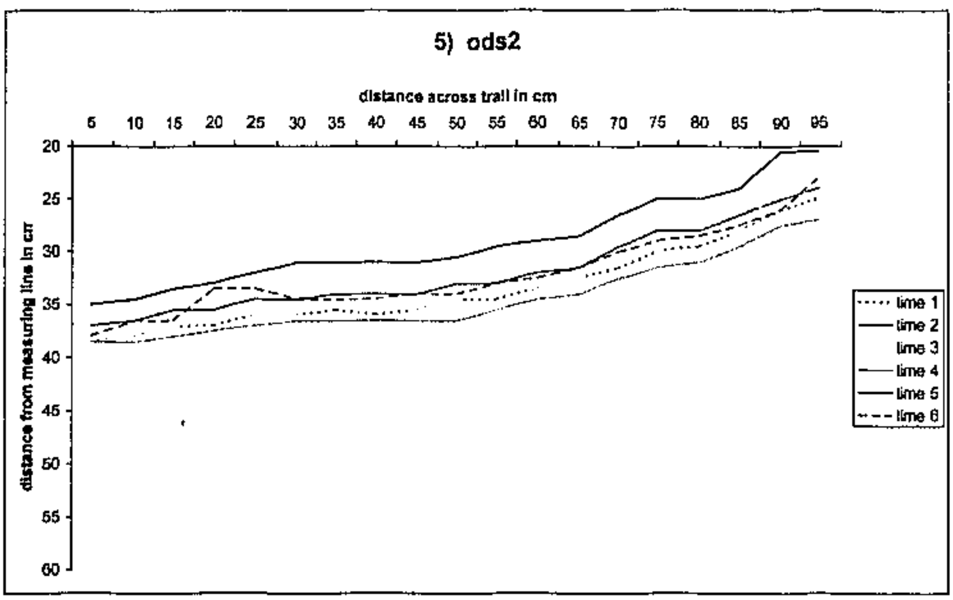
(o= old; n= new; d= downhill; f= flat; u= uphill; c= curve; s= straight)

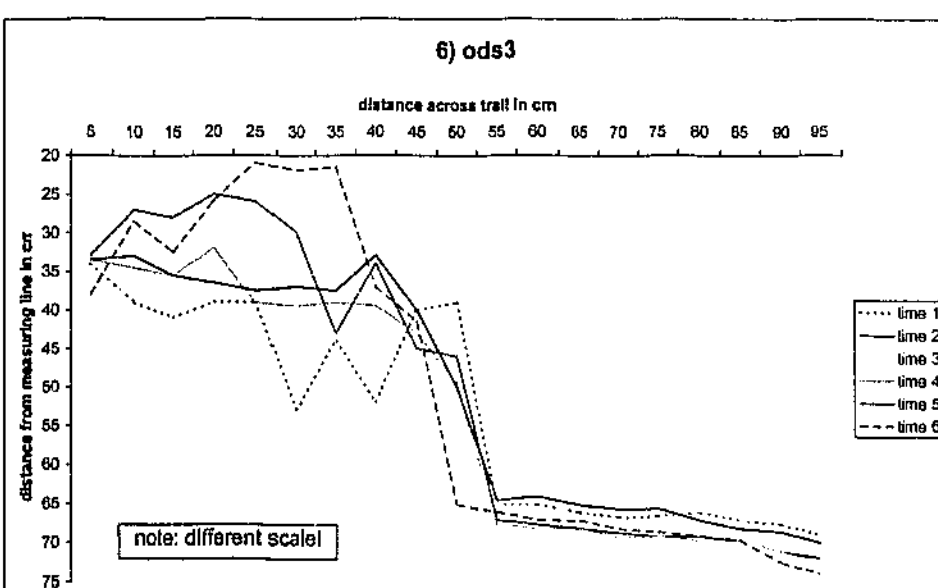


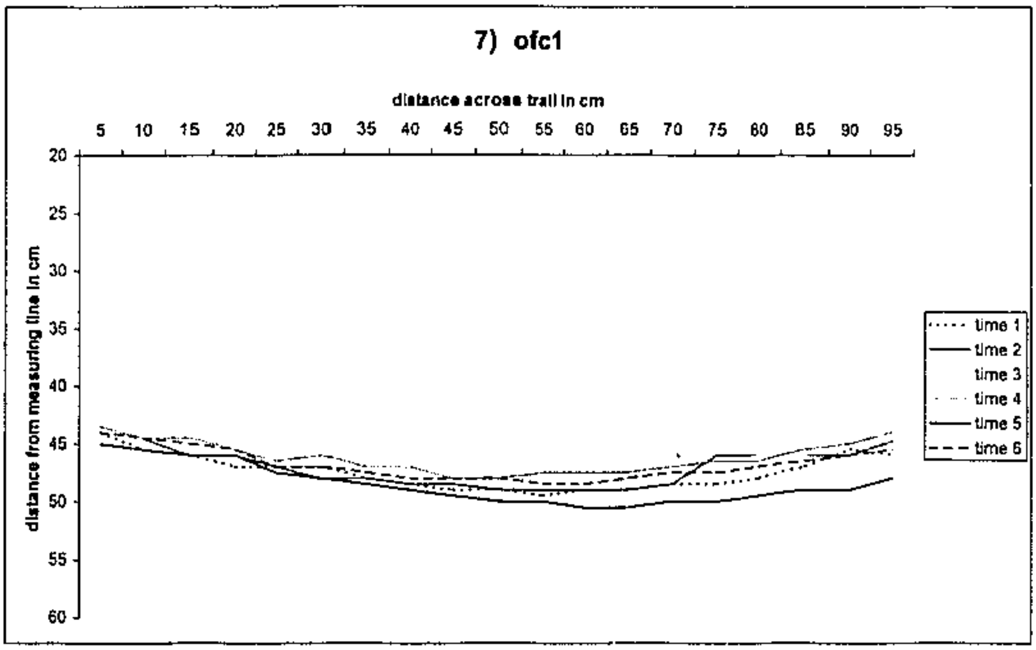


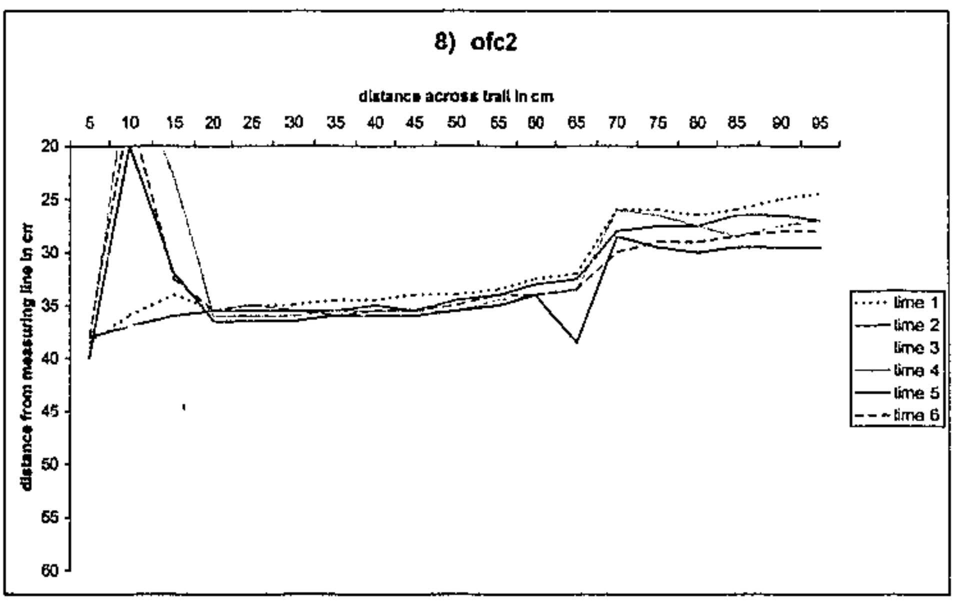


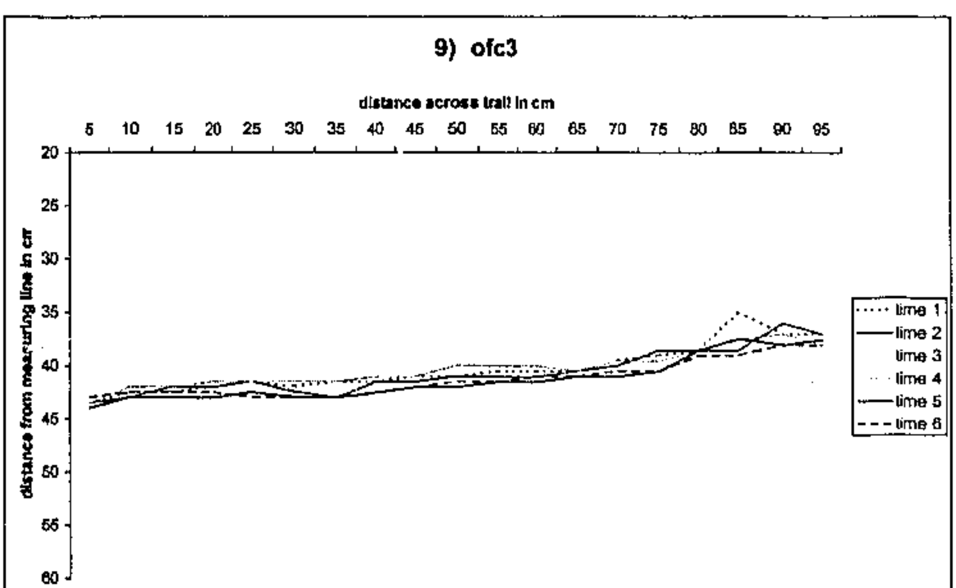

4) ods1
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

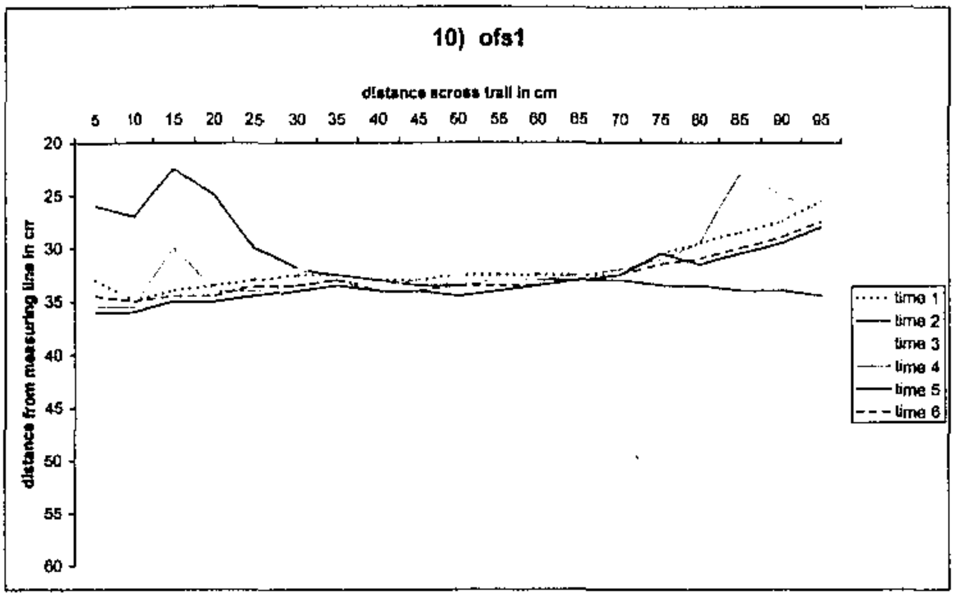

5) ods2
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

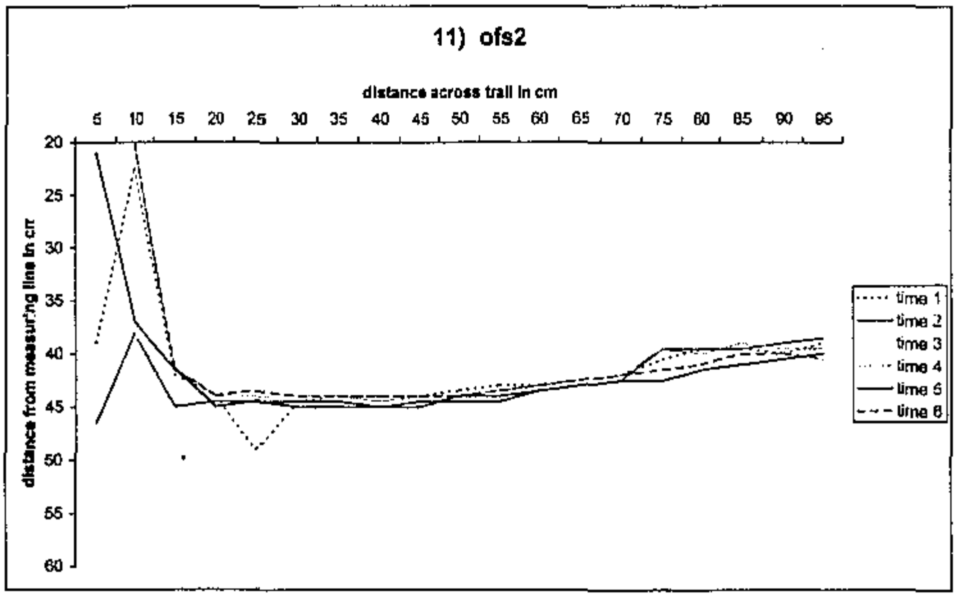

6) ods3
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6
note: different scale!

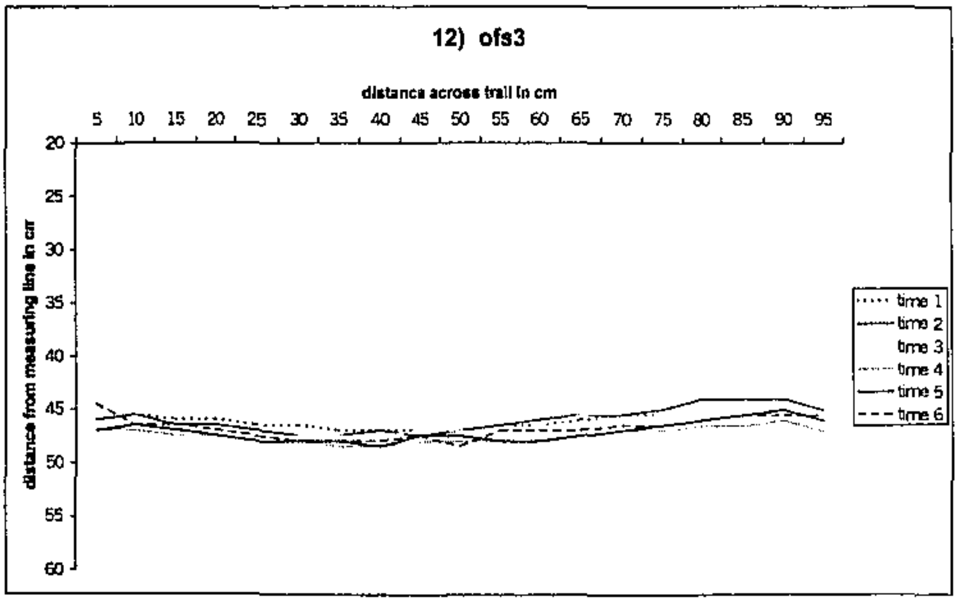

7) ofc1
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
20 25 30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

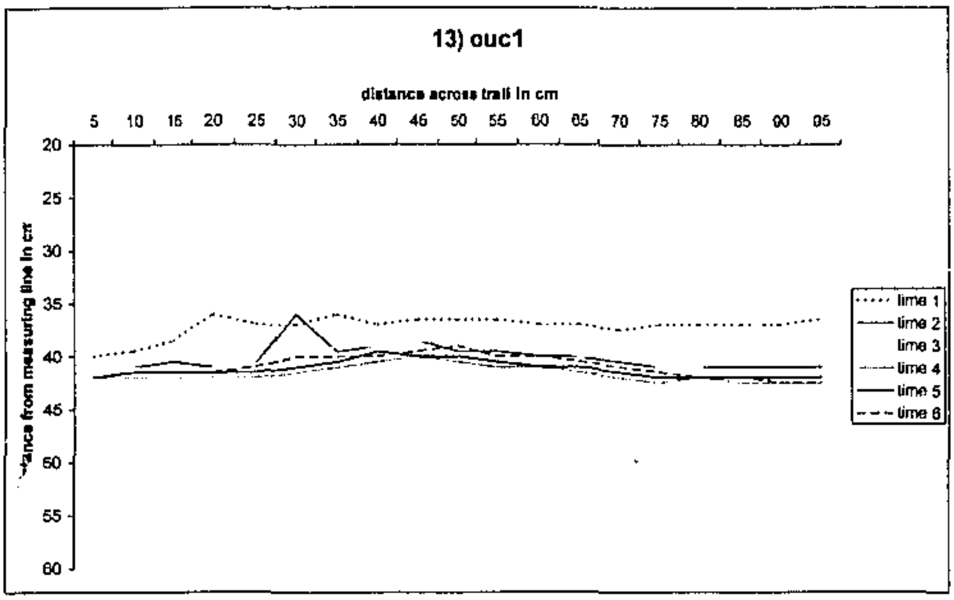

8) ofc2
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
20 25 30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

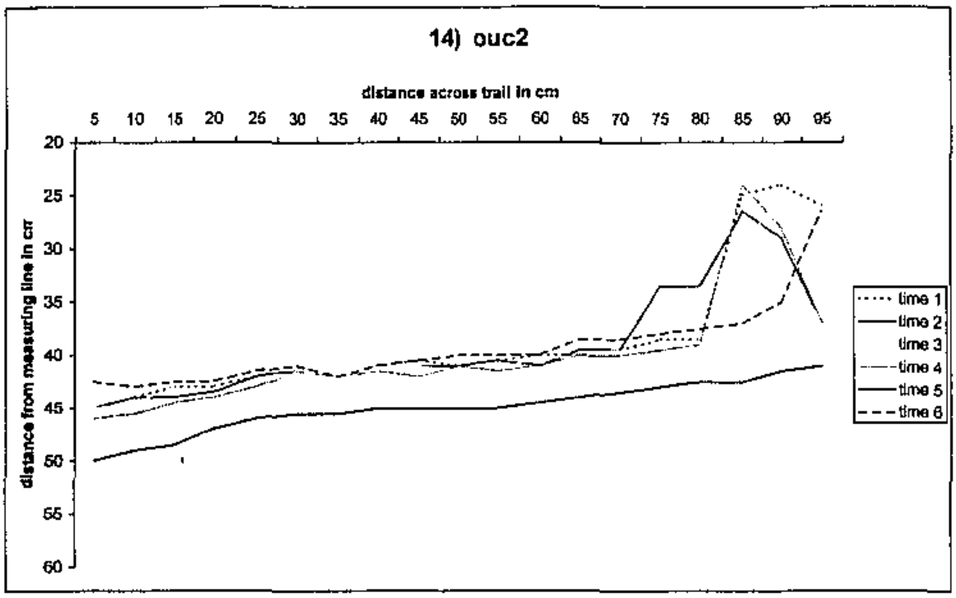

9) ofc3
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
20 25 30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

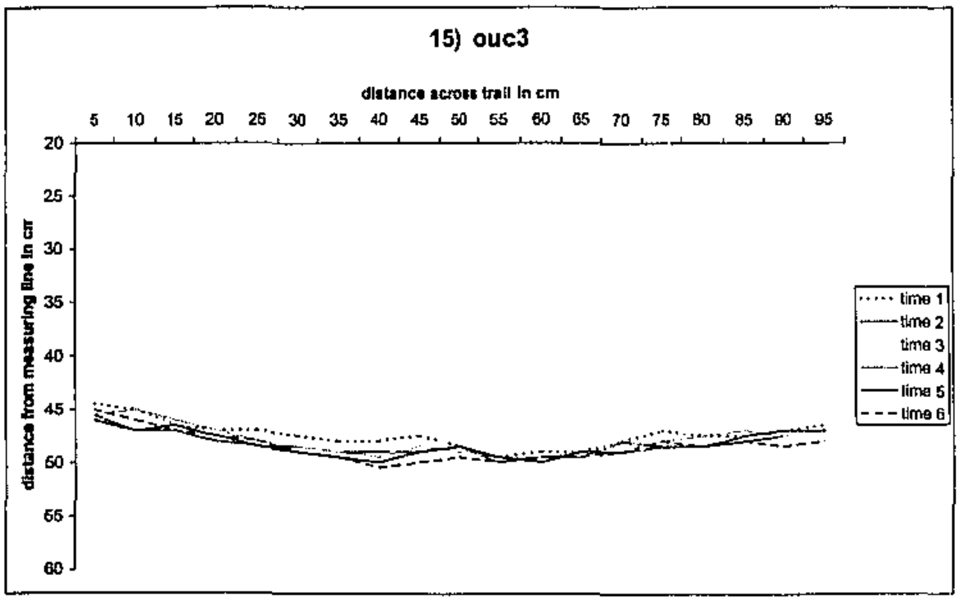

10) ofs1
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

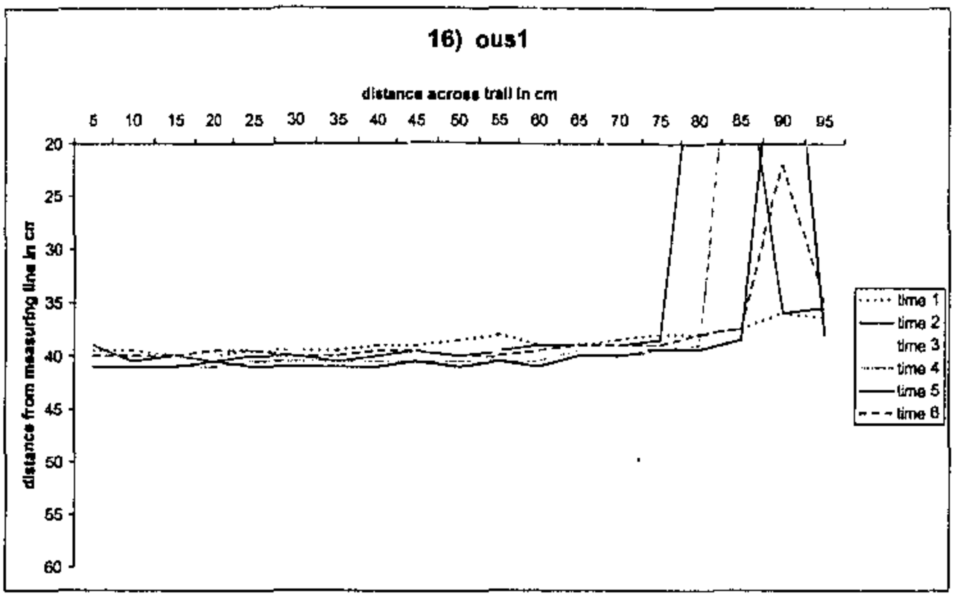

11) ofs2
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

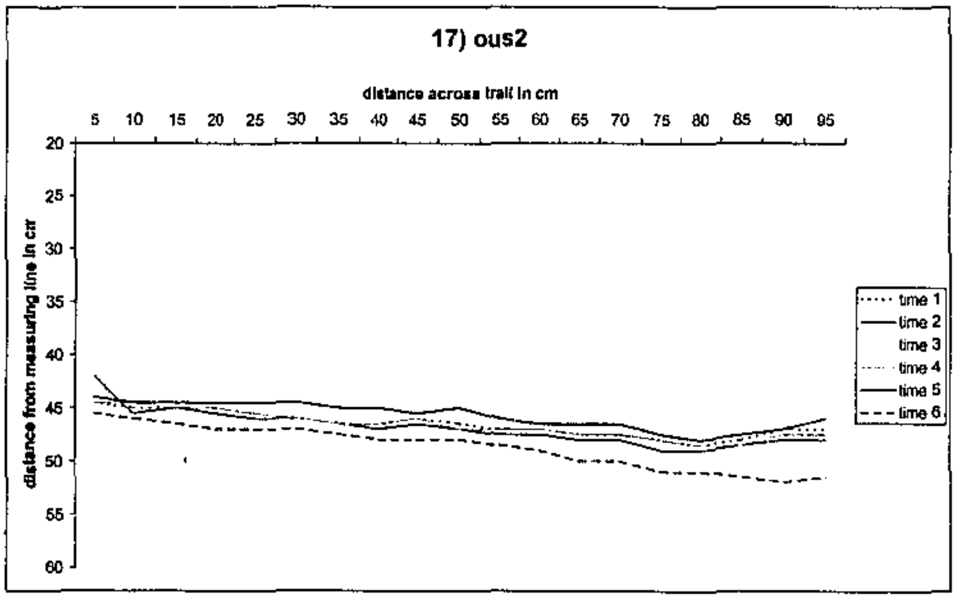

12) ofs3
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

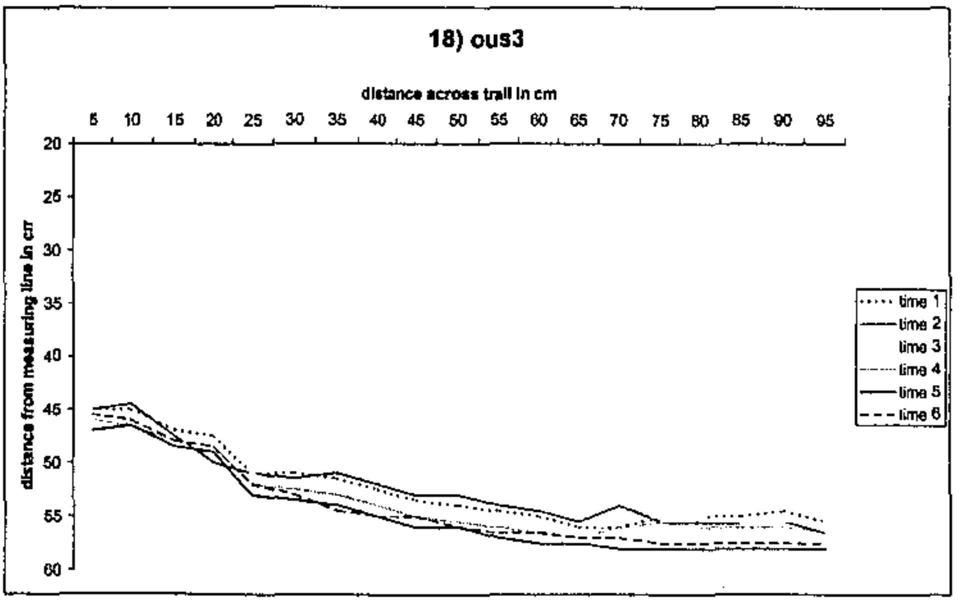

13) ouc1
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

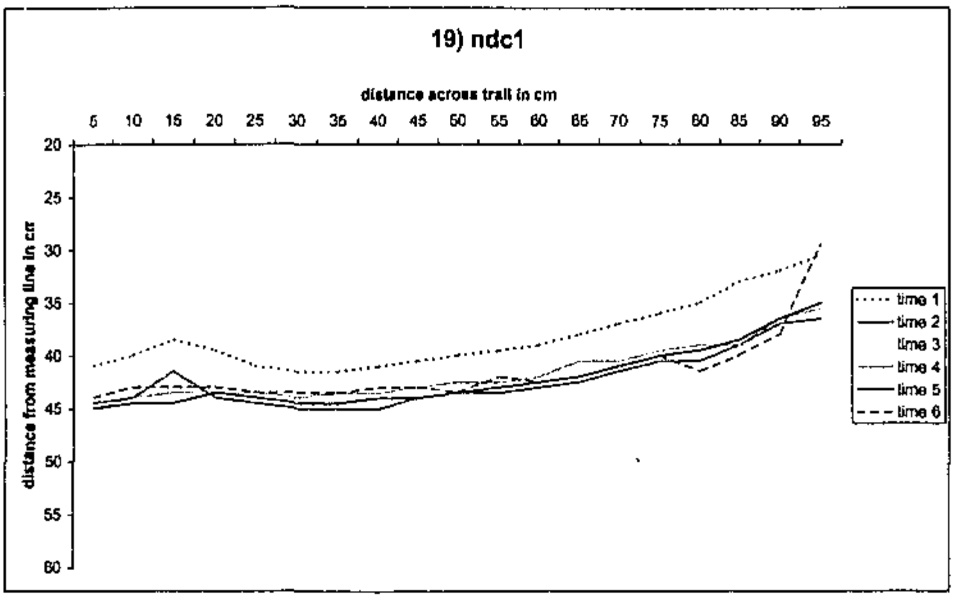

14) ouc2
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

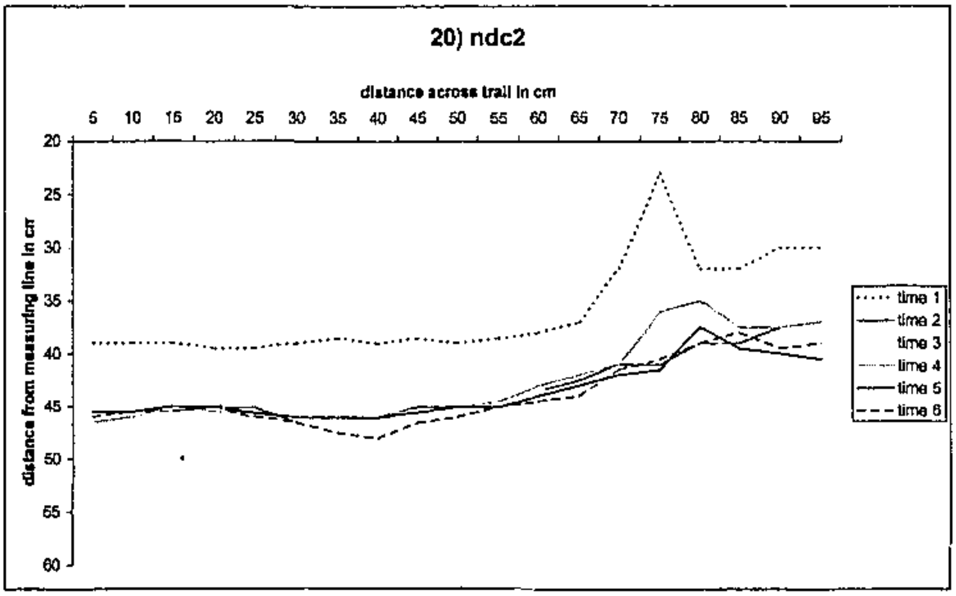

15) ouc3
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

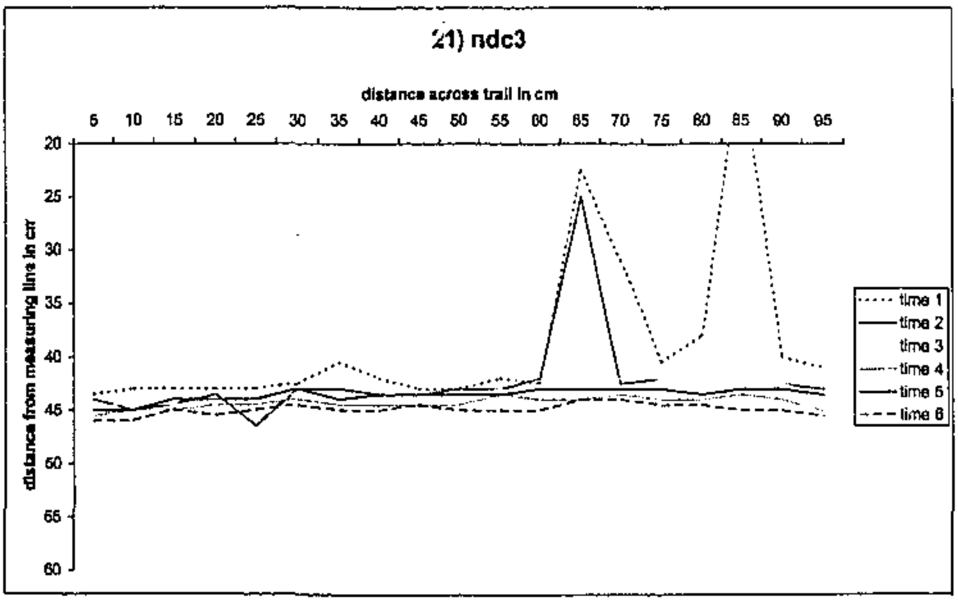

16) ous1
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
20 25 30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

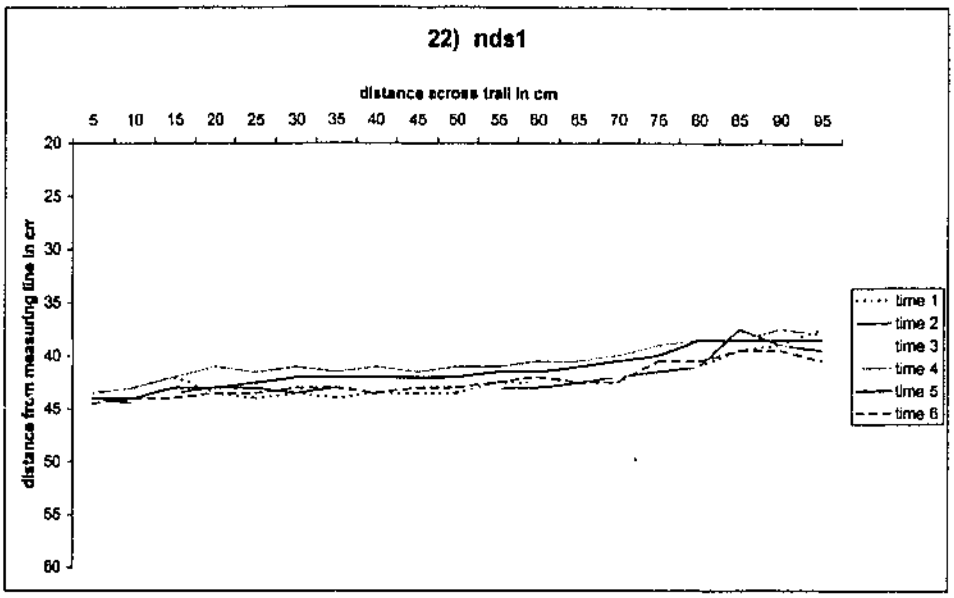

17) ous2
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
20 25 30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

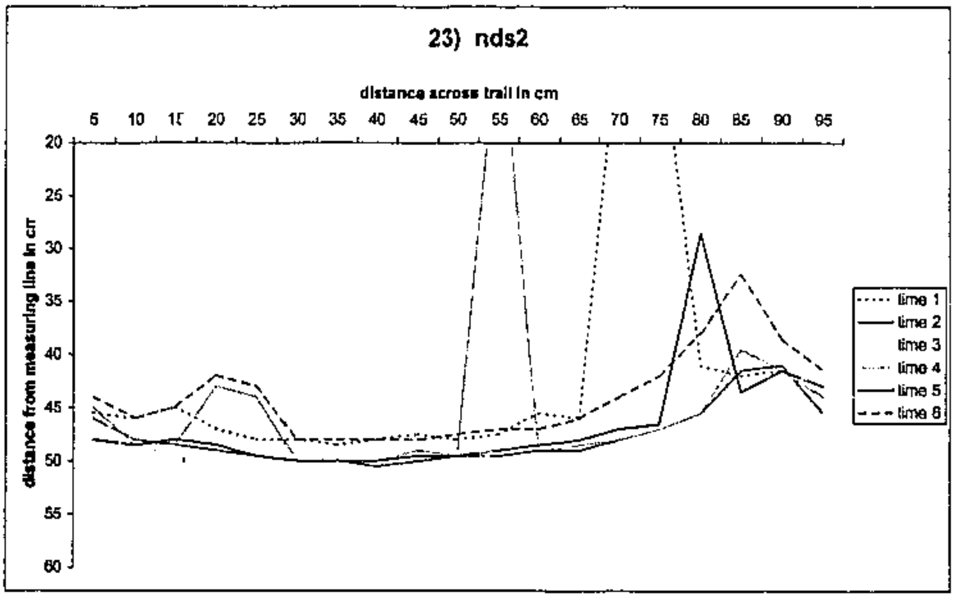

18) ous3
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
20 25 30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

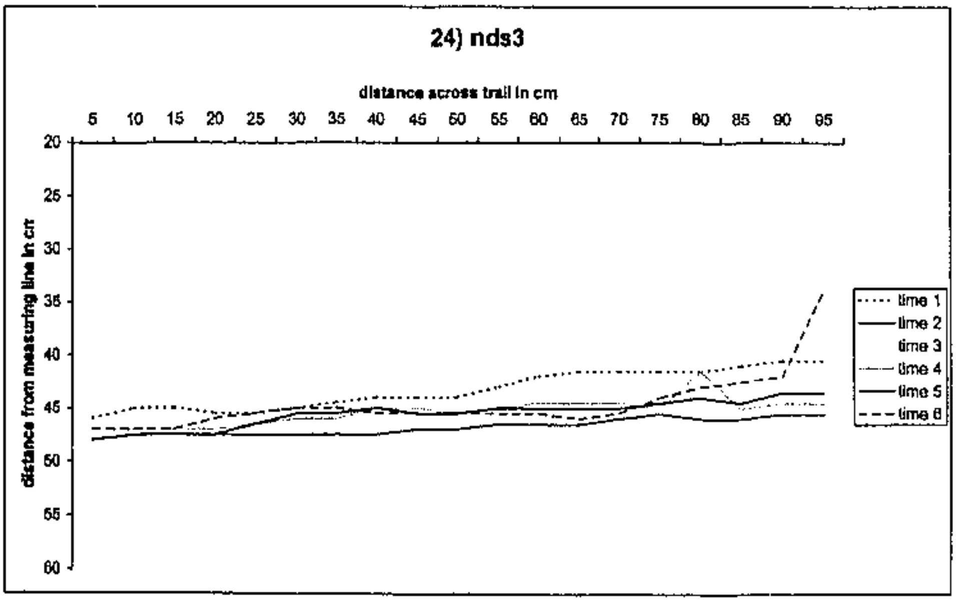

19) ndc1
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

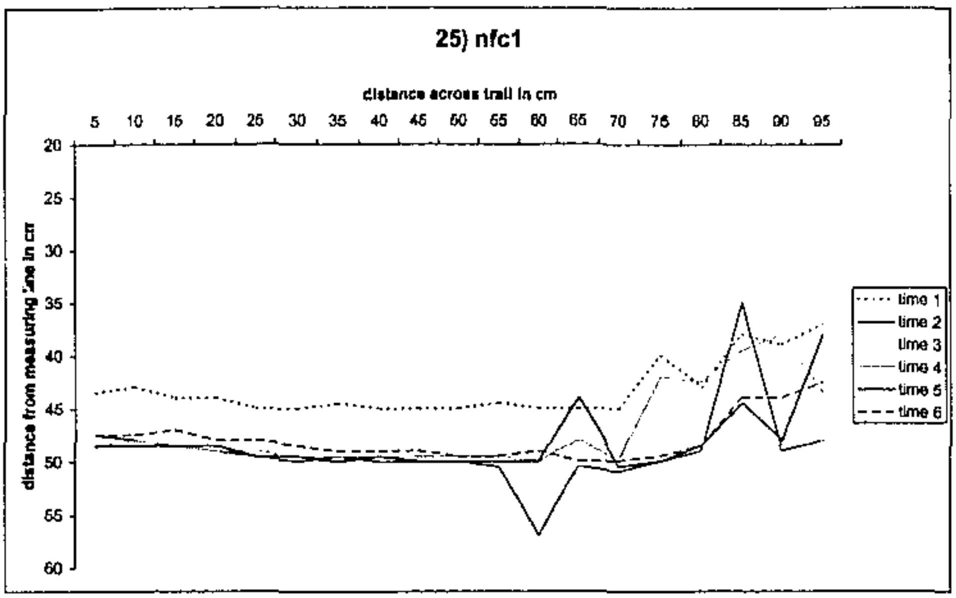

20) ndc2
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

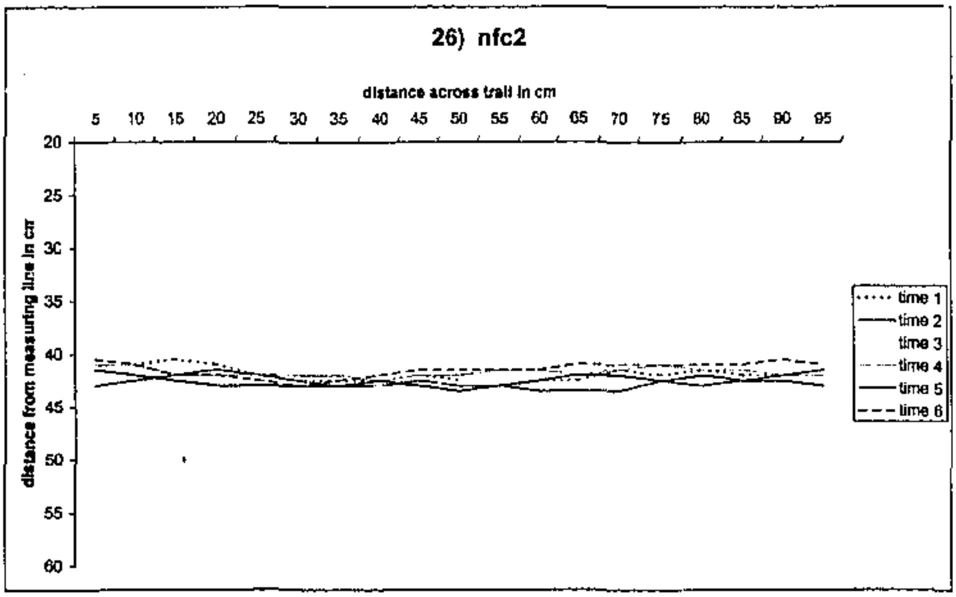

21) ndc3
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

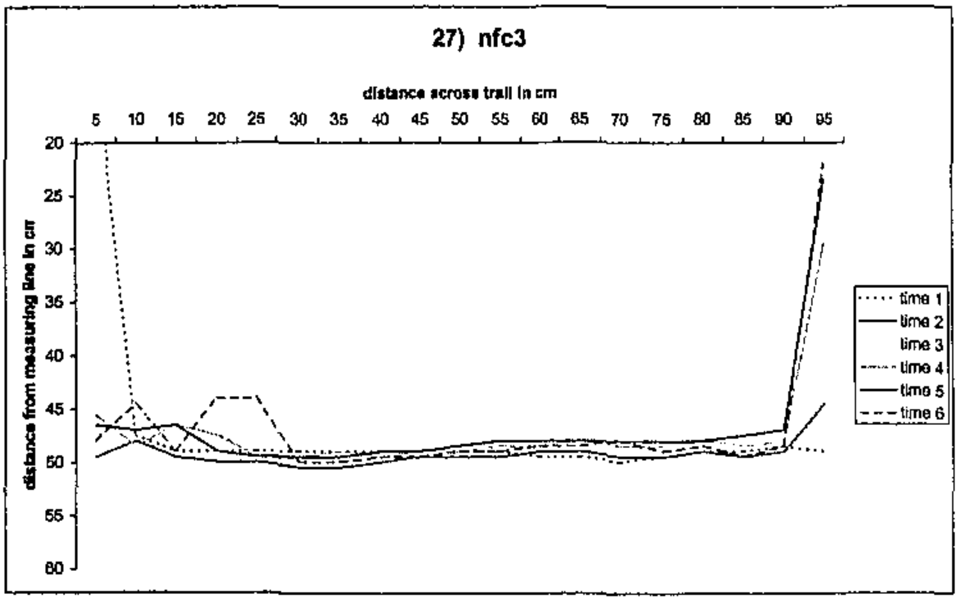

22) nds1
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
20 25 30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

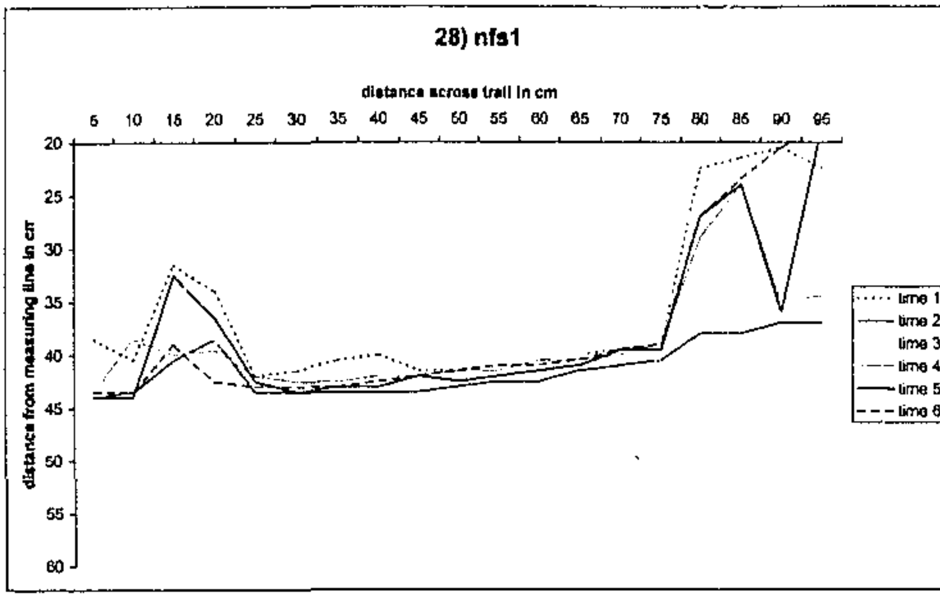

23) nds2
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
20 25 30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

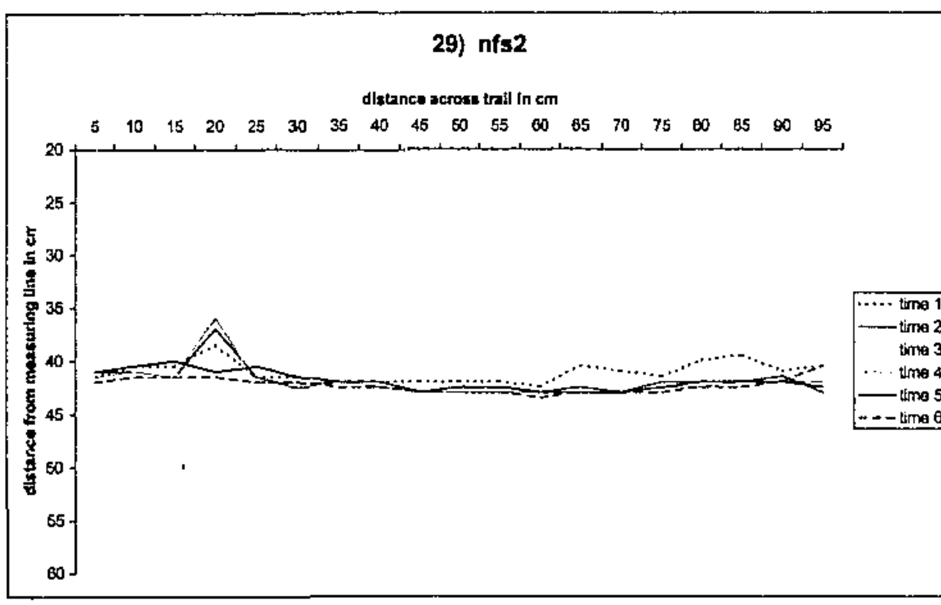

24) nds3
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
20 25 30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

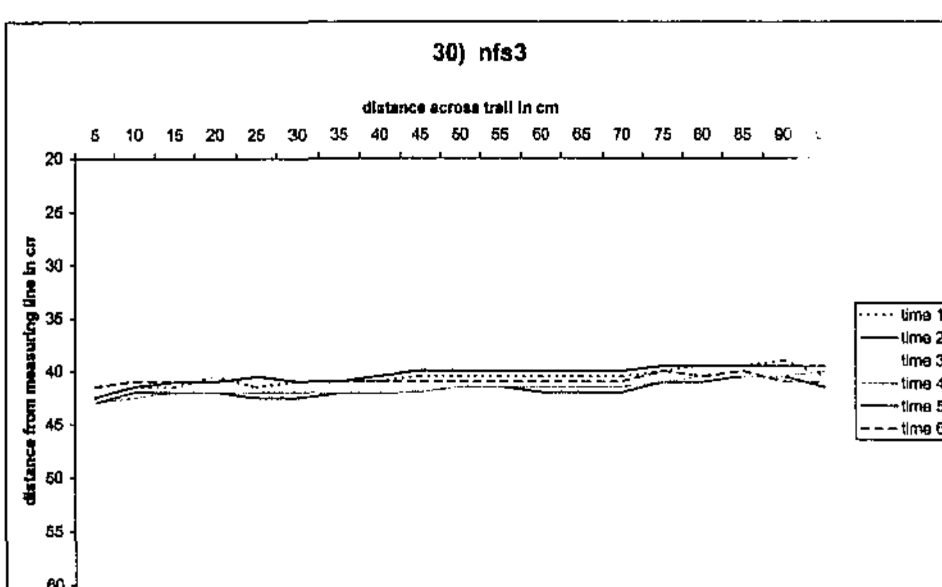

25) nfc1
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

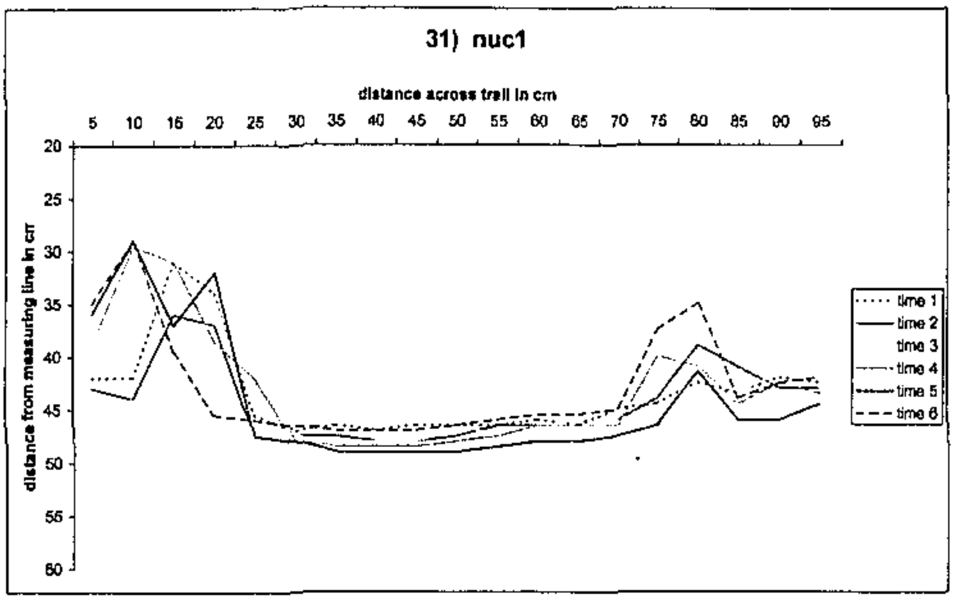

26) nfc2
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

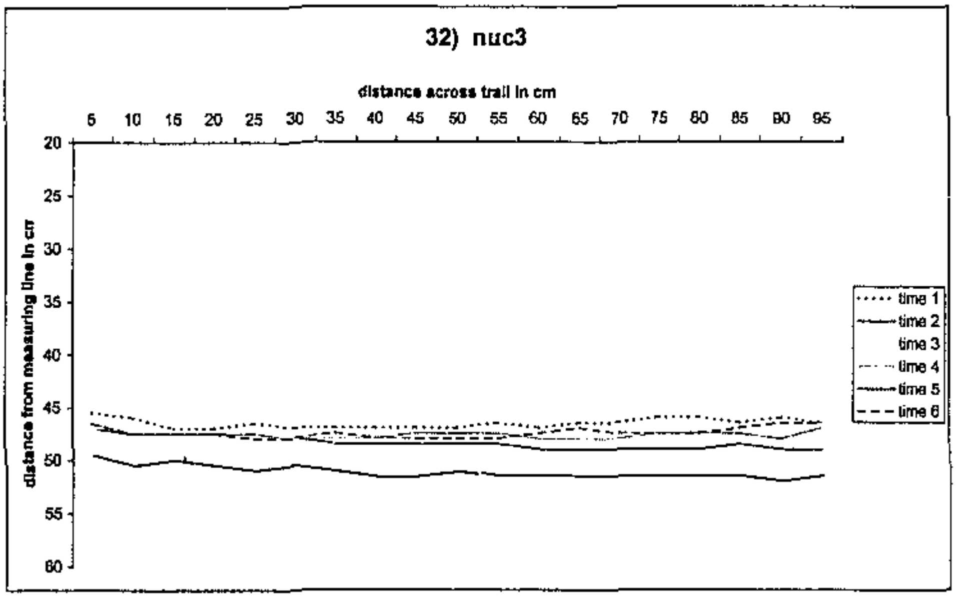

27) nfc3
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

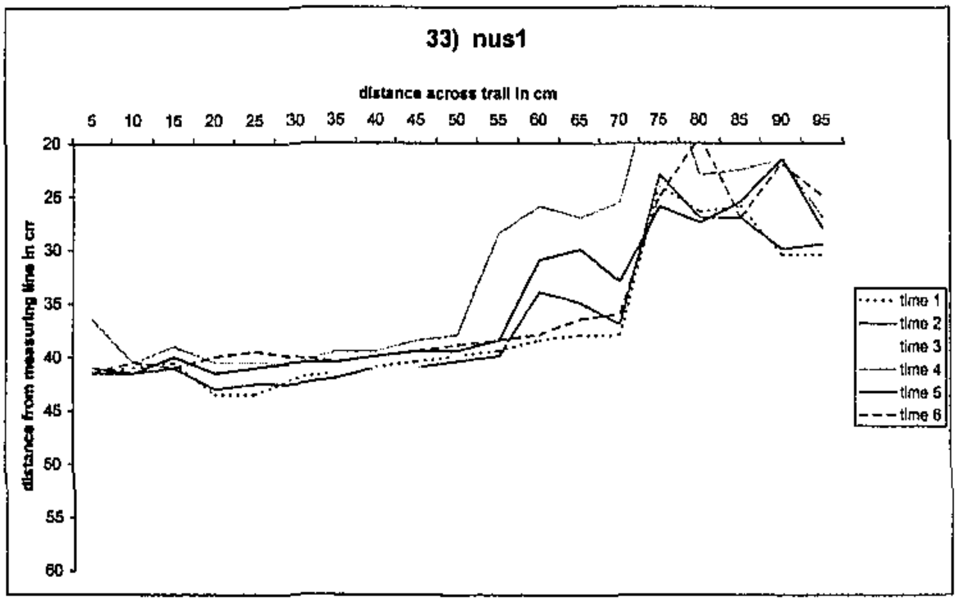

28) nfs1
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
20 25 30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

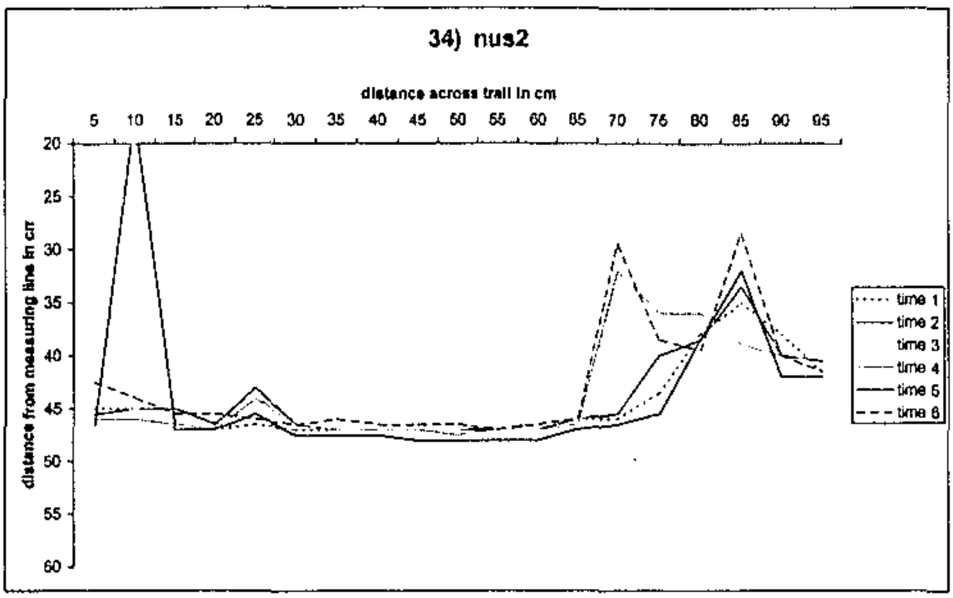

29) nfs2
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
20 25 30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

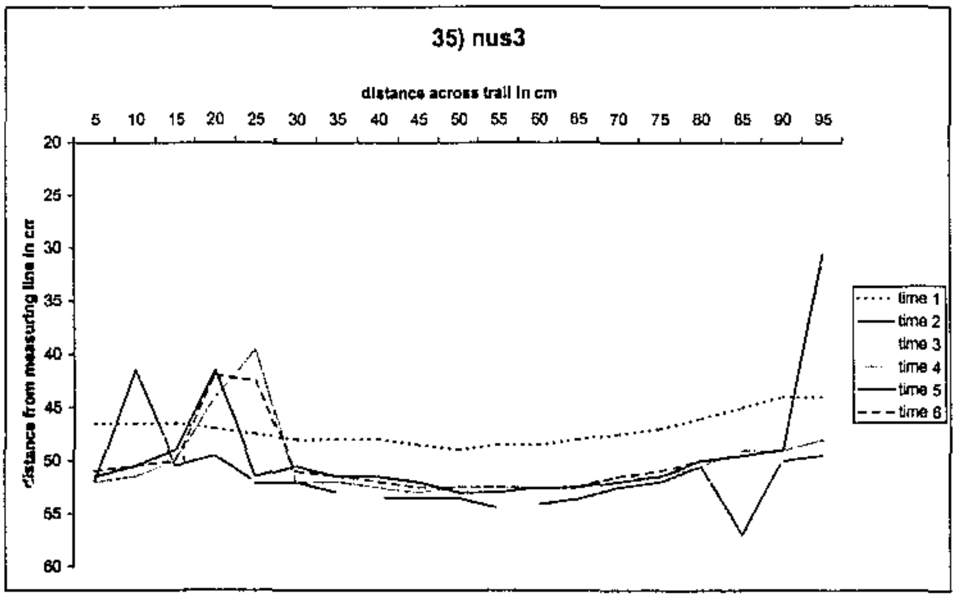

30) nfs3
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
20 25 30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6


31) nuc1
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6


32) nuc3
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

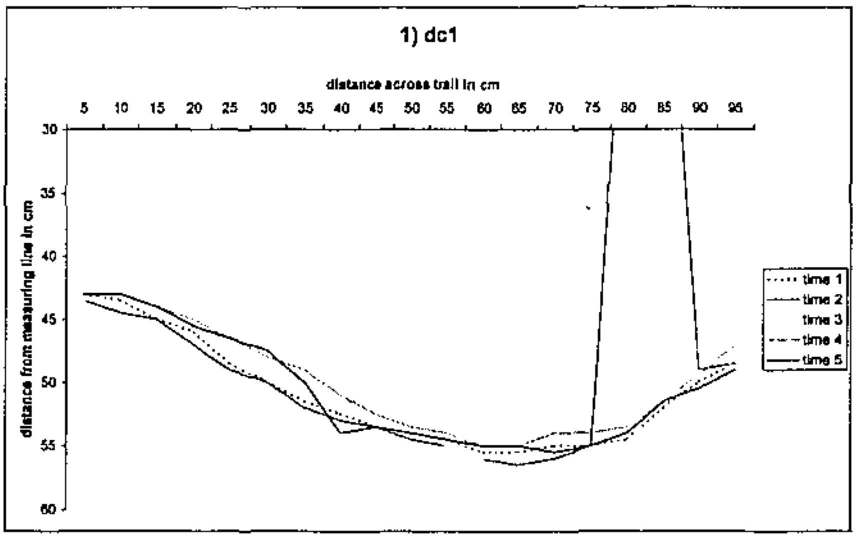

33) nus1
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

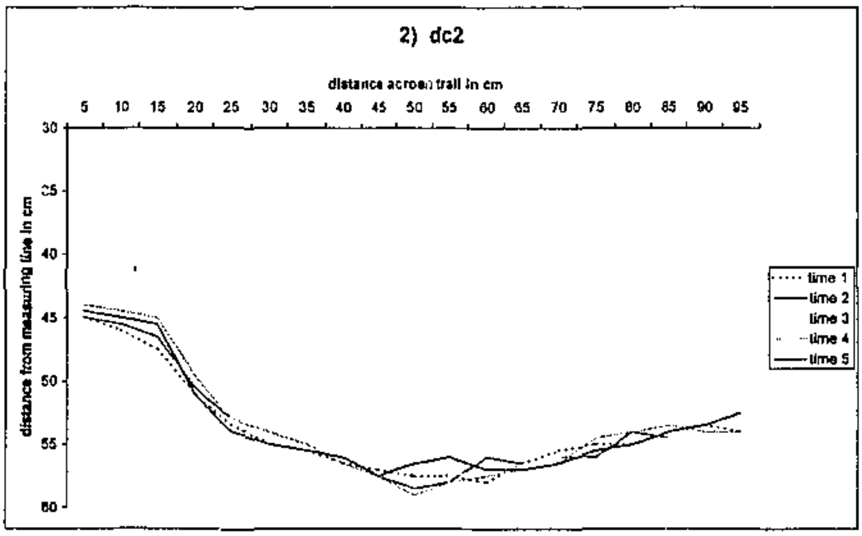

34) nus2
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

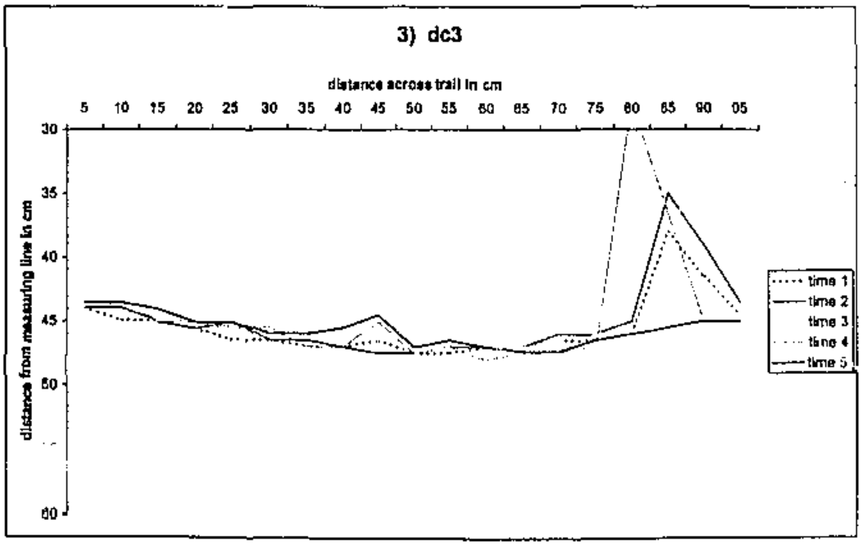

35) nus3
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5
time 6

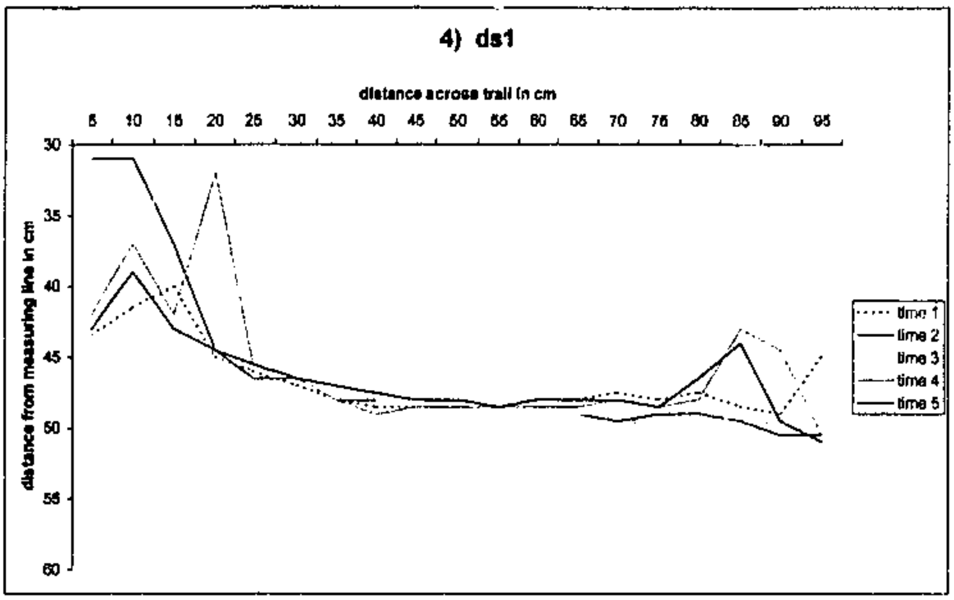
Appendix 1B

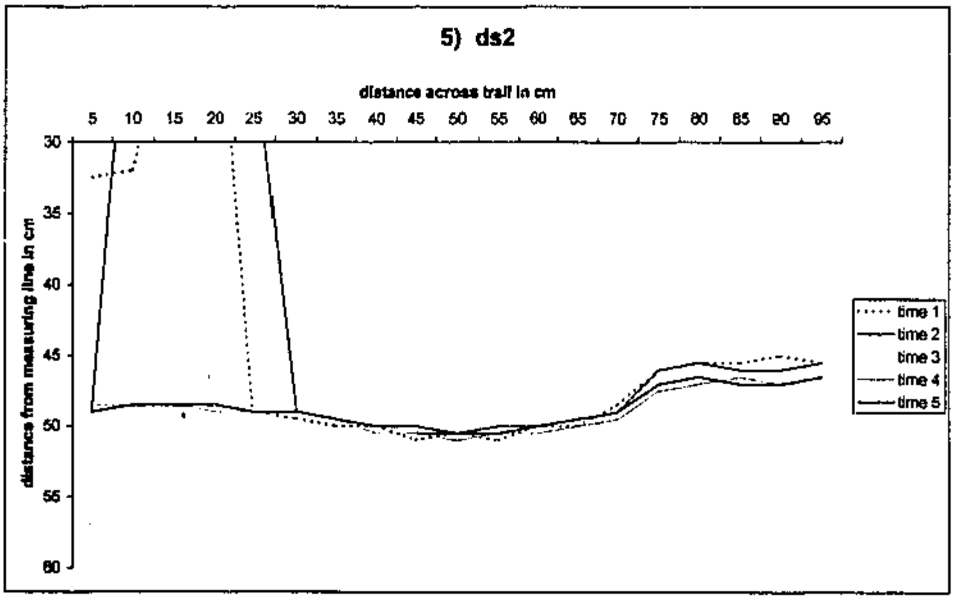
Figures 1-18: Marrinup, micro relief profiles
(d= downhill; f= flat; u= uphill; c= curve; s= straight)

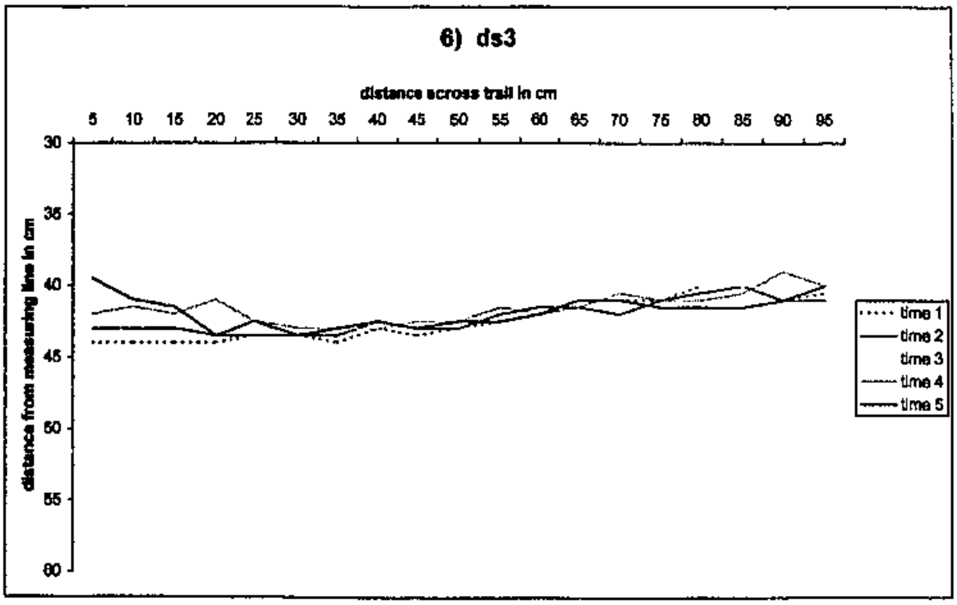


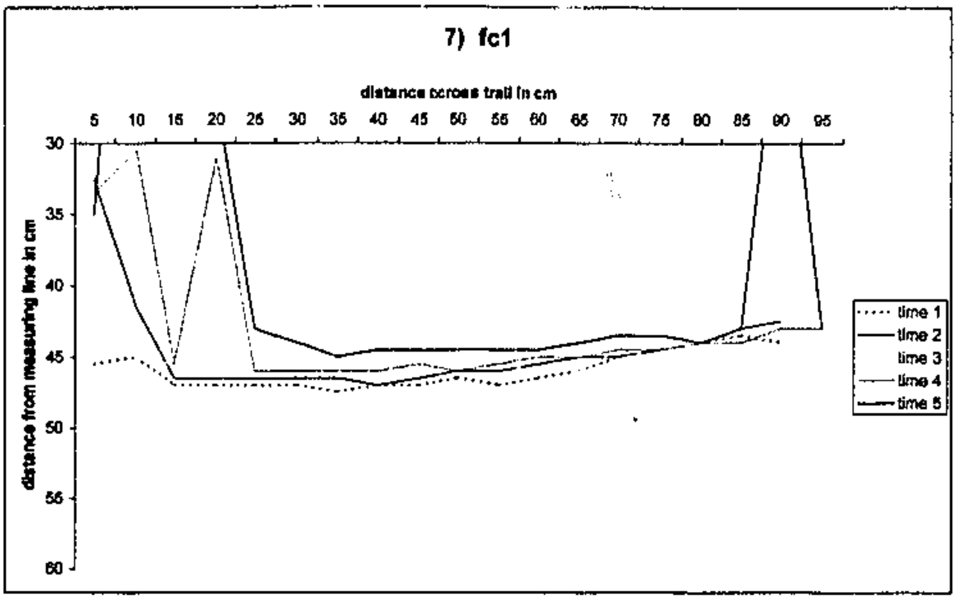


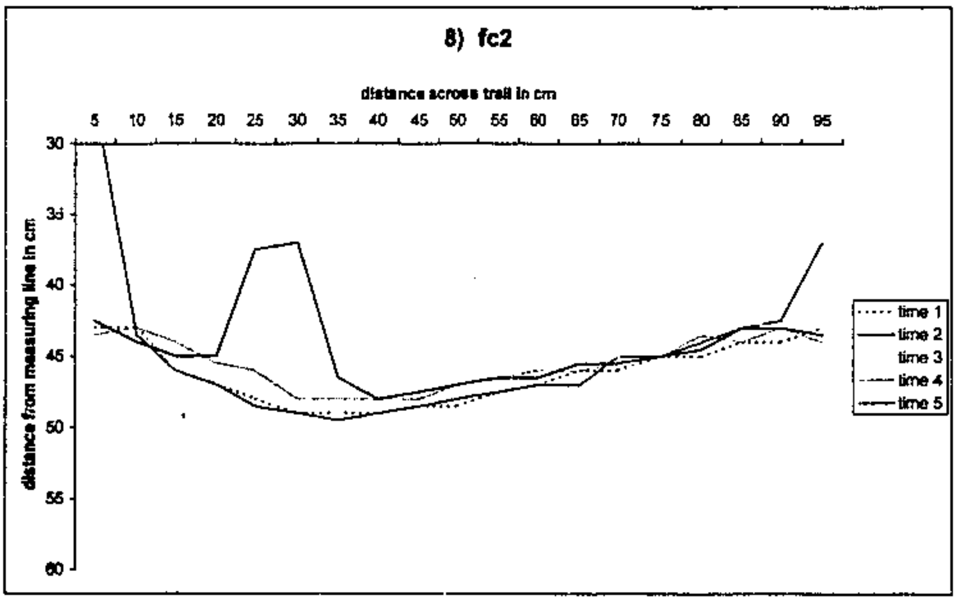


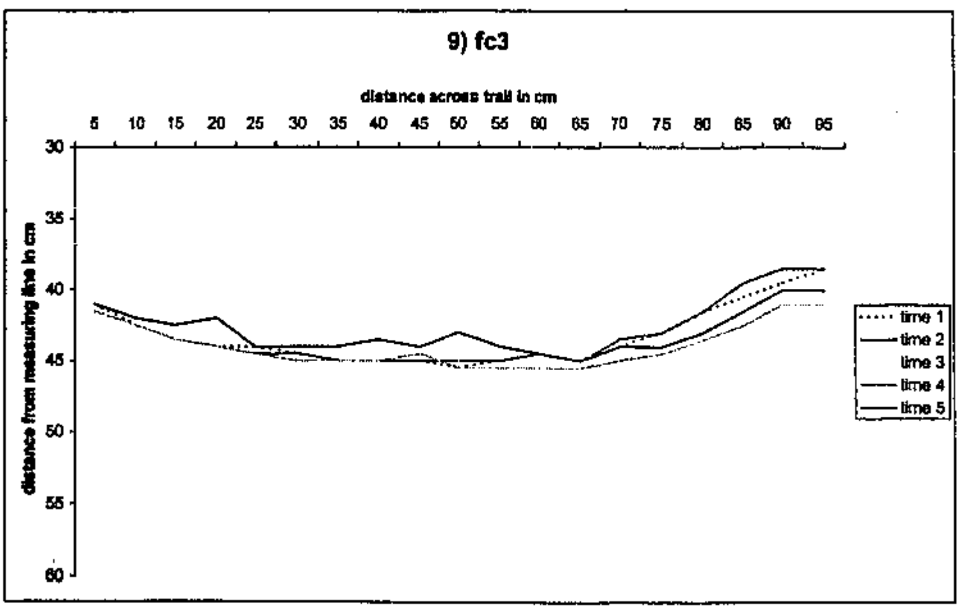

4) ds1
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5

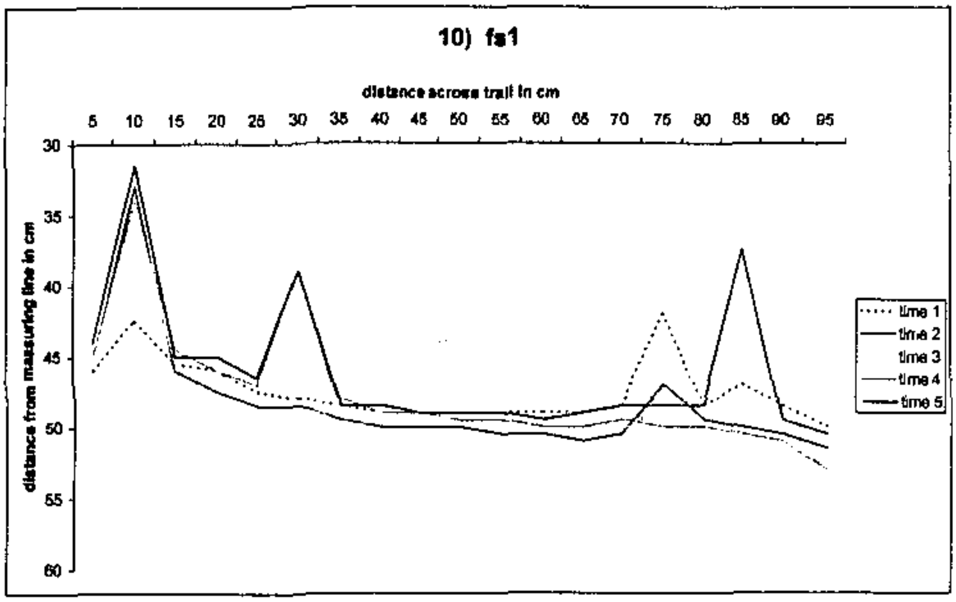

5) ds2
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5

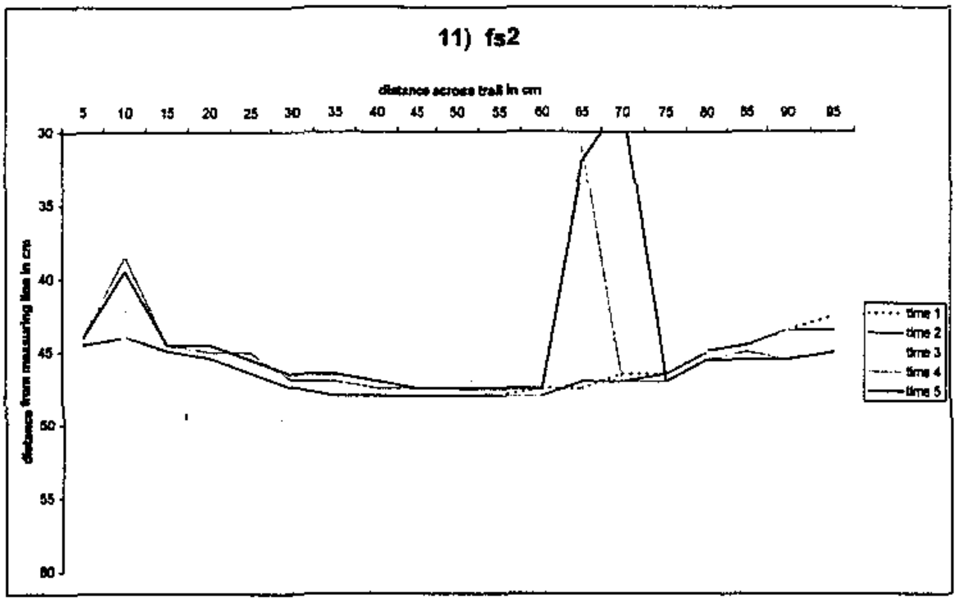

6) ds3
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5

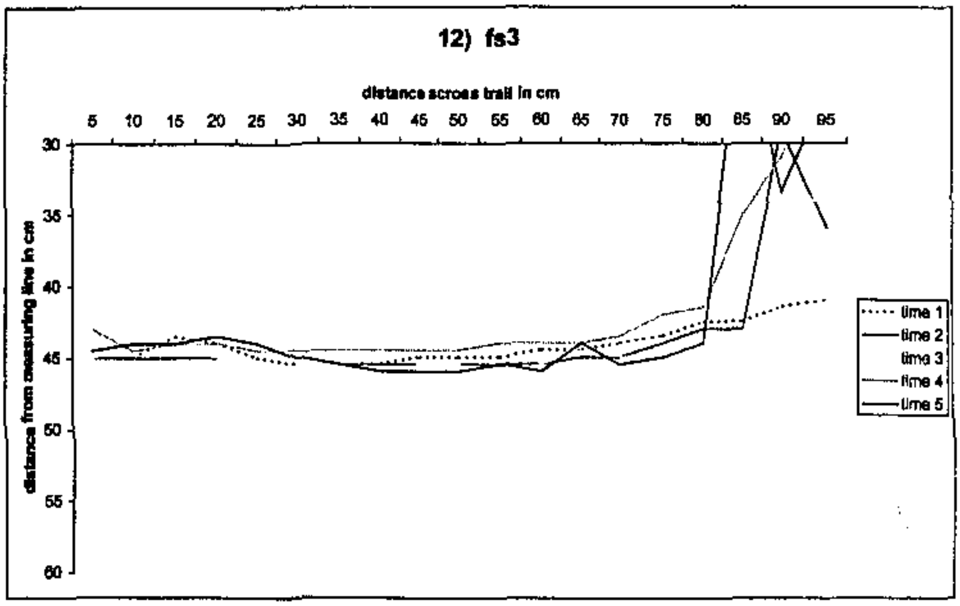

7) fc1
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5

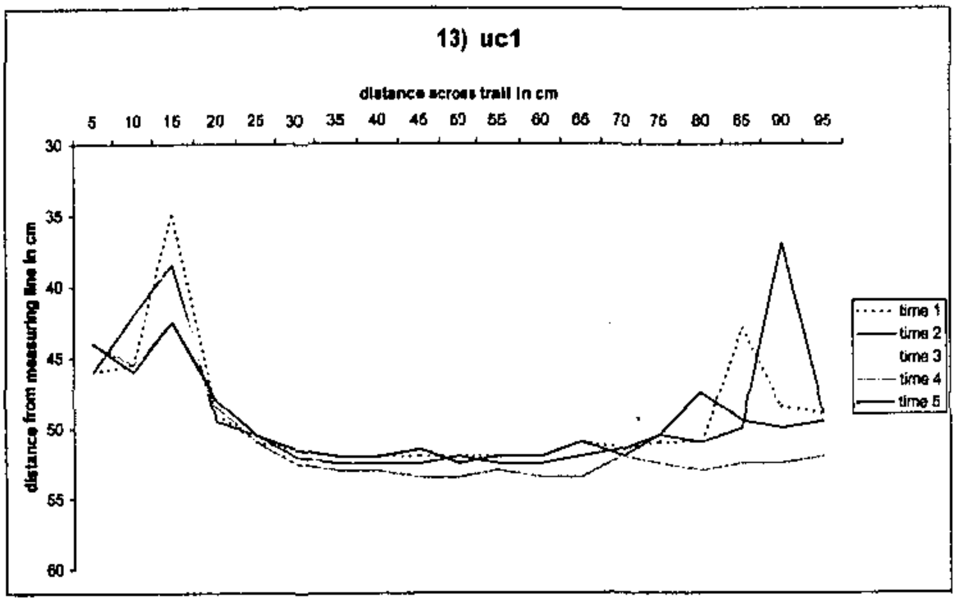

8) fc2
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5

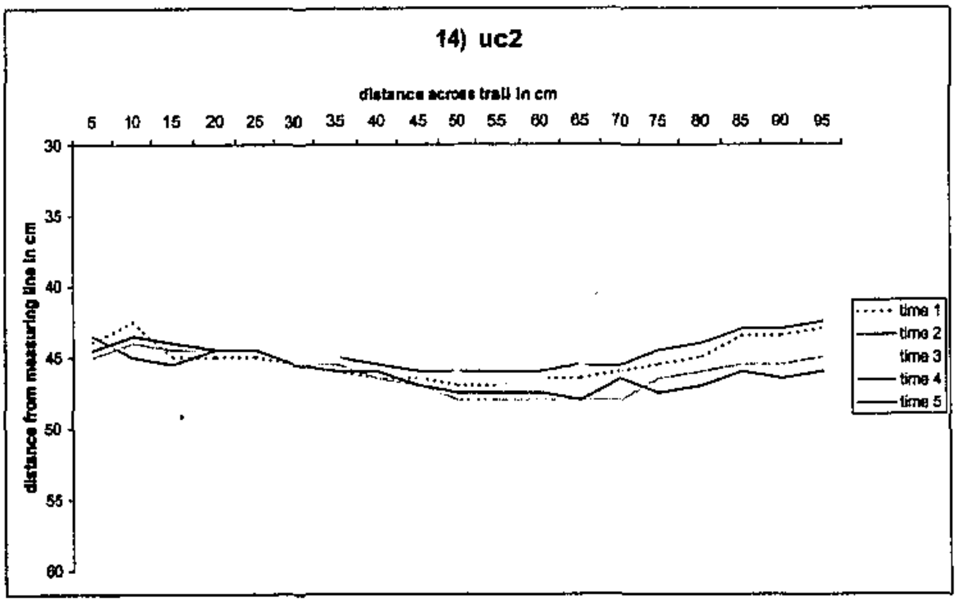

9) fc3
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5

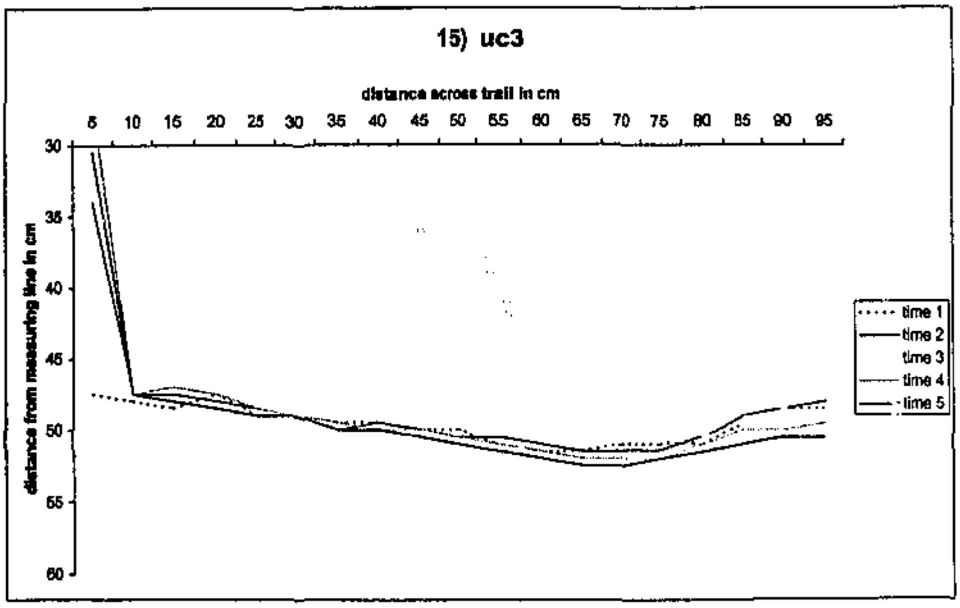

10) fs1
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5

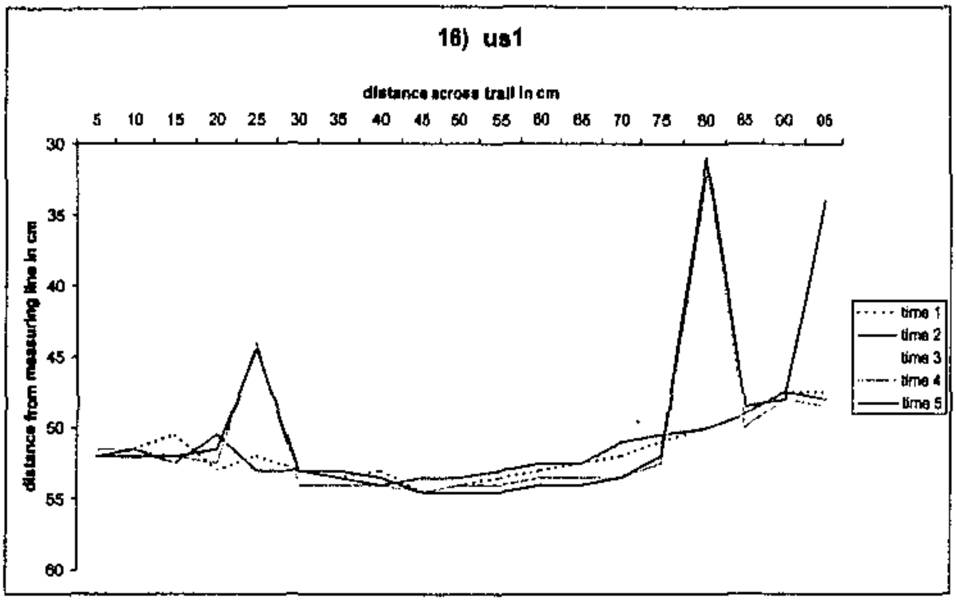

11) fs2
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5

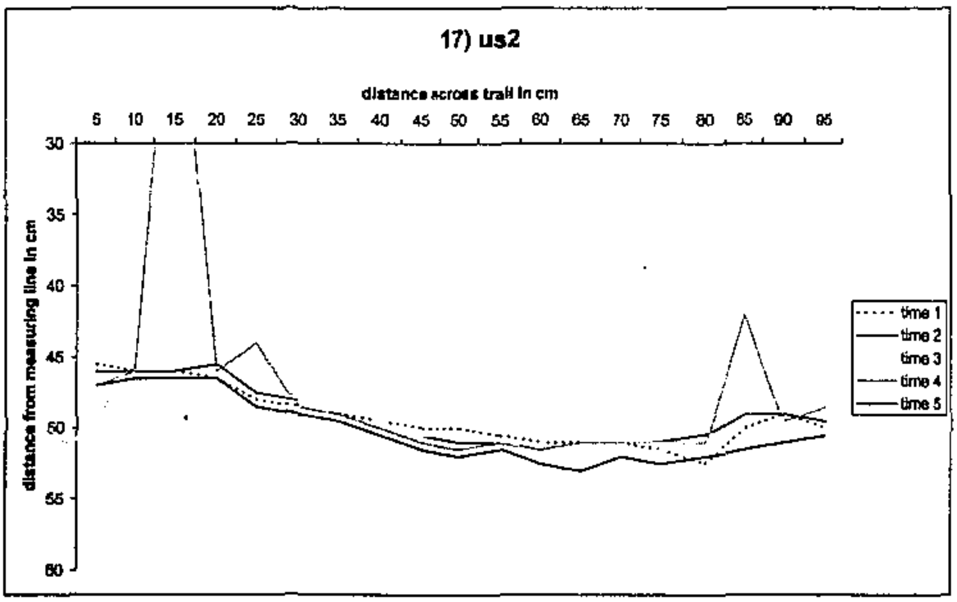

12) fs3
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5

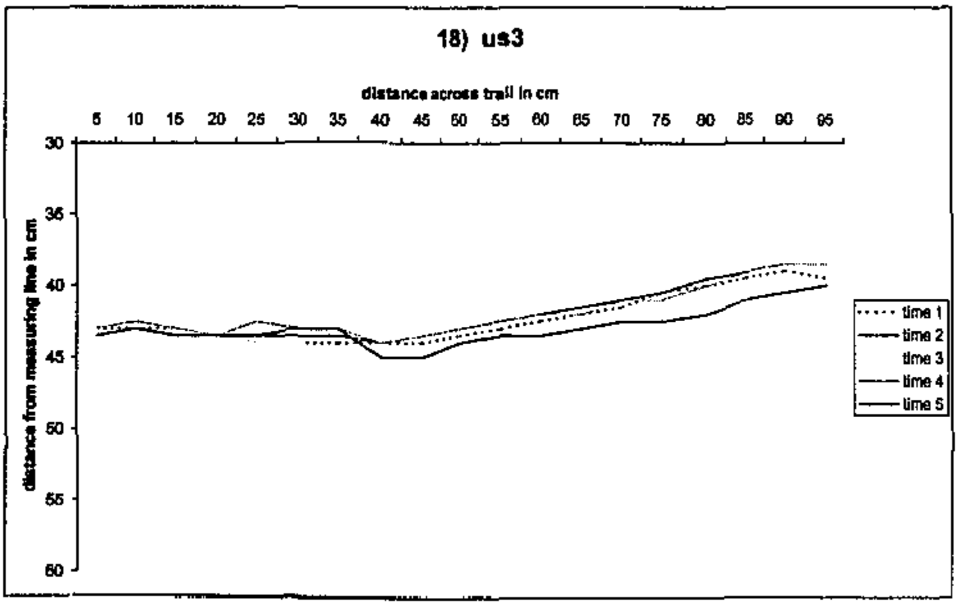

13) uc1
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5


14) uc2
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5


15) uc3
distance across trail in cm
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
30 35 40 45 50 55 60
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5


16) us1
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5

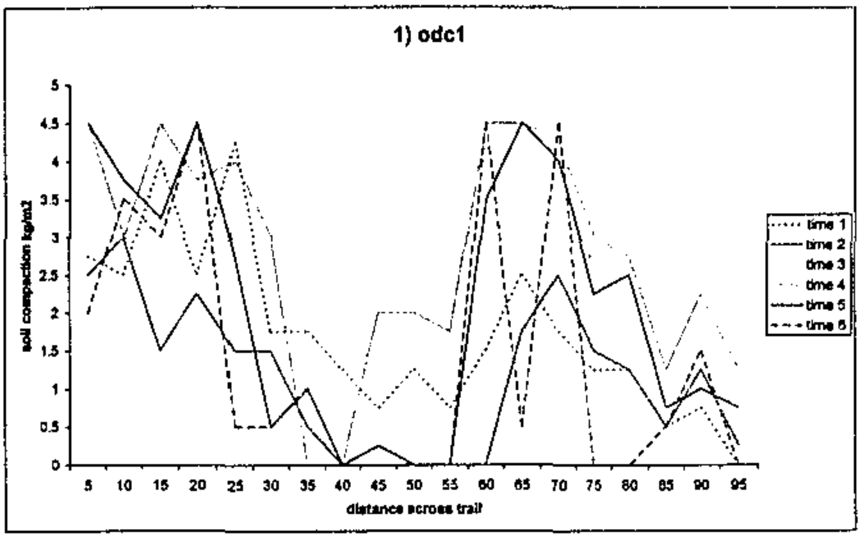

17) us2
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5

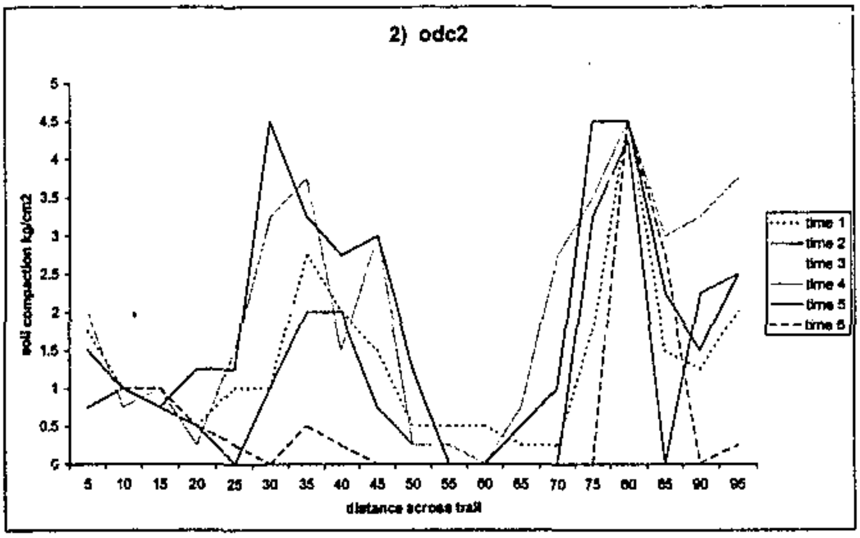

18) us3
distance across trail in cm
distance from measuring line in cm
time 1
time 2
time 3
time 4
time 5

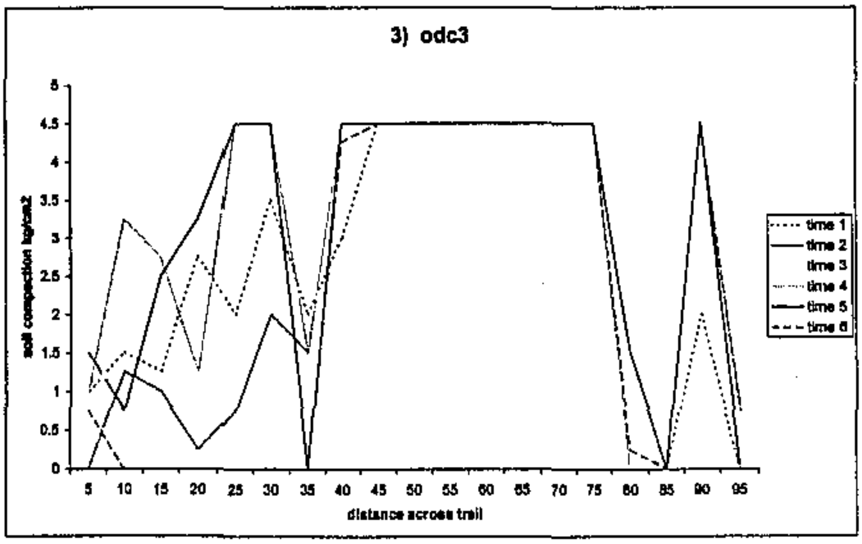
Appendix 1C

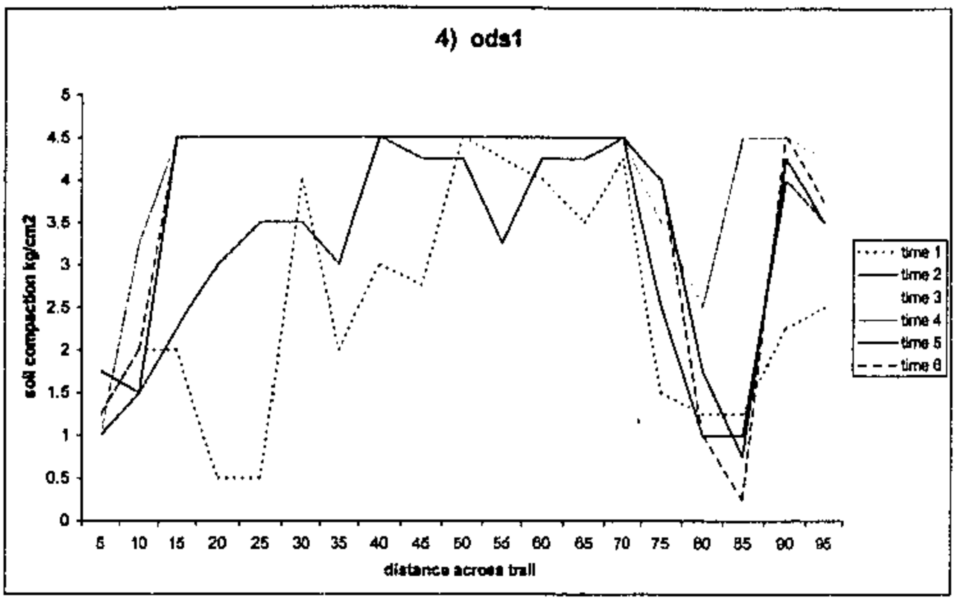
Figures 1-35: Lowden, soil compaction

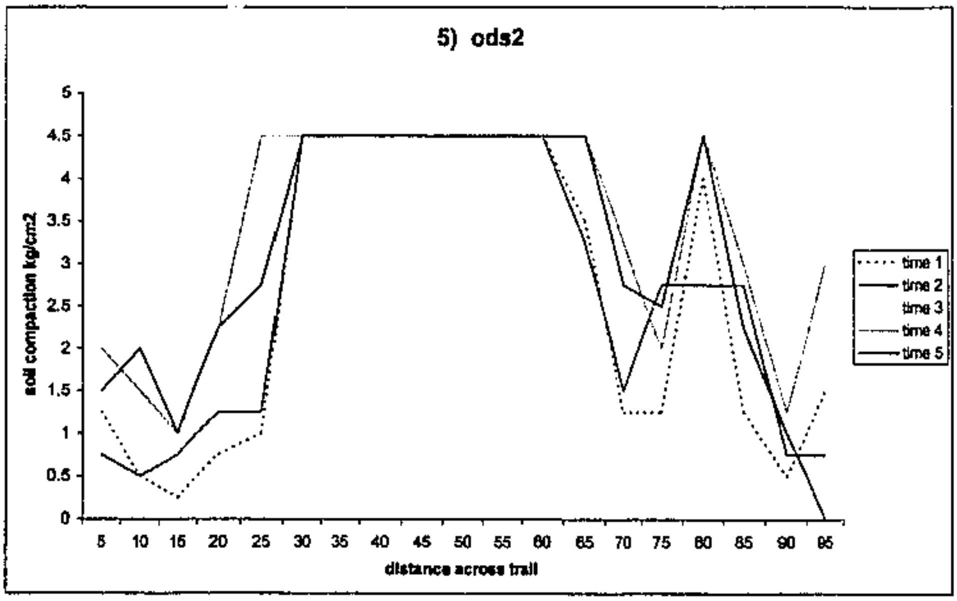
(o= old; n= new; d= downhill; f= flat; u= uphill; c= curve; s= straight)

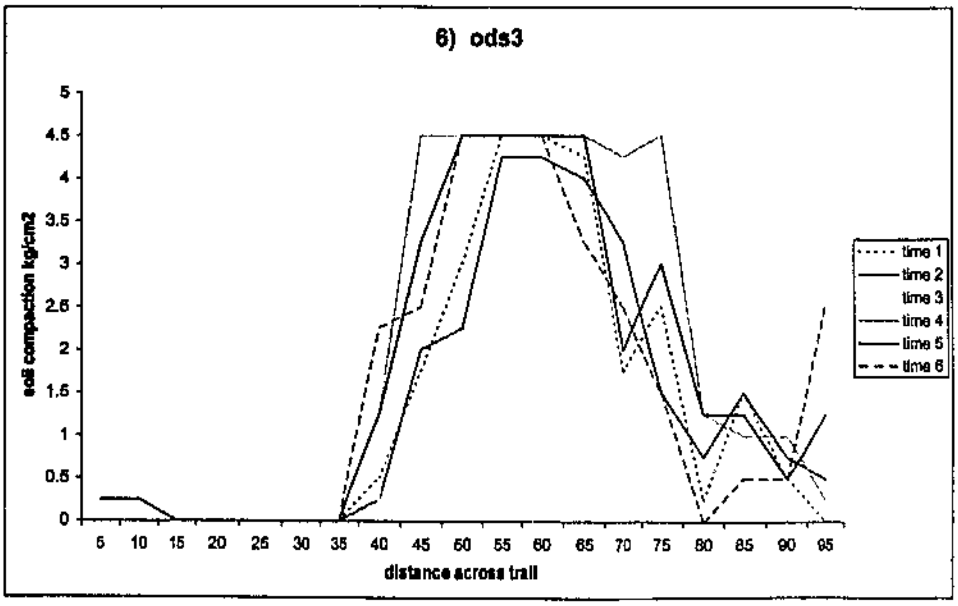


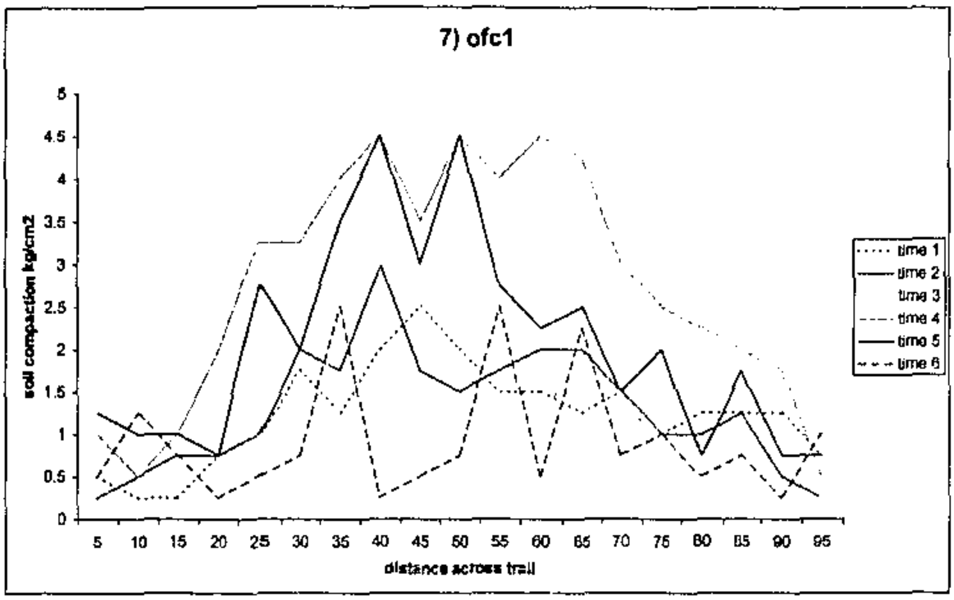


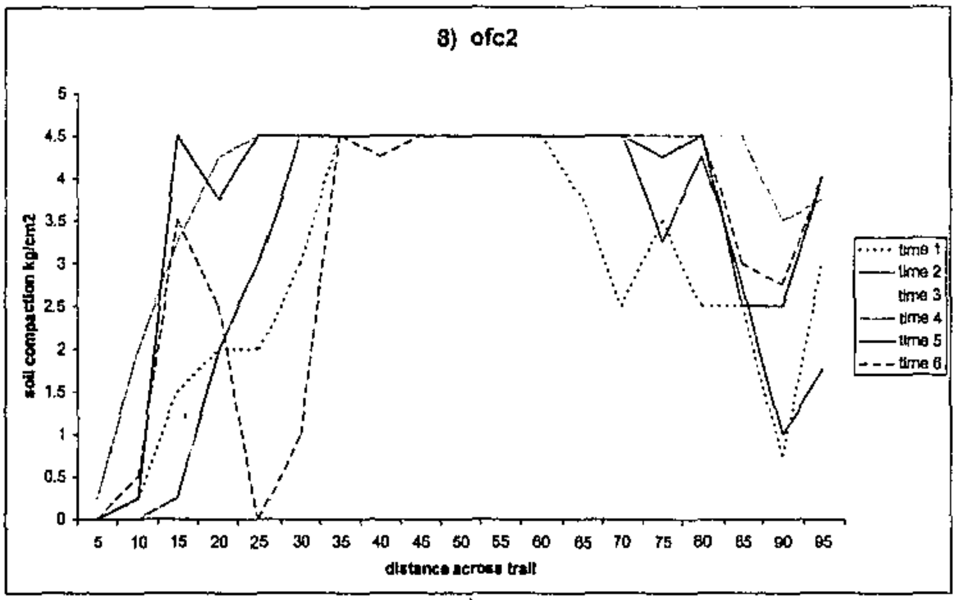


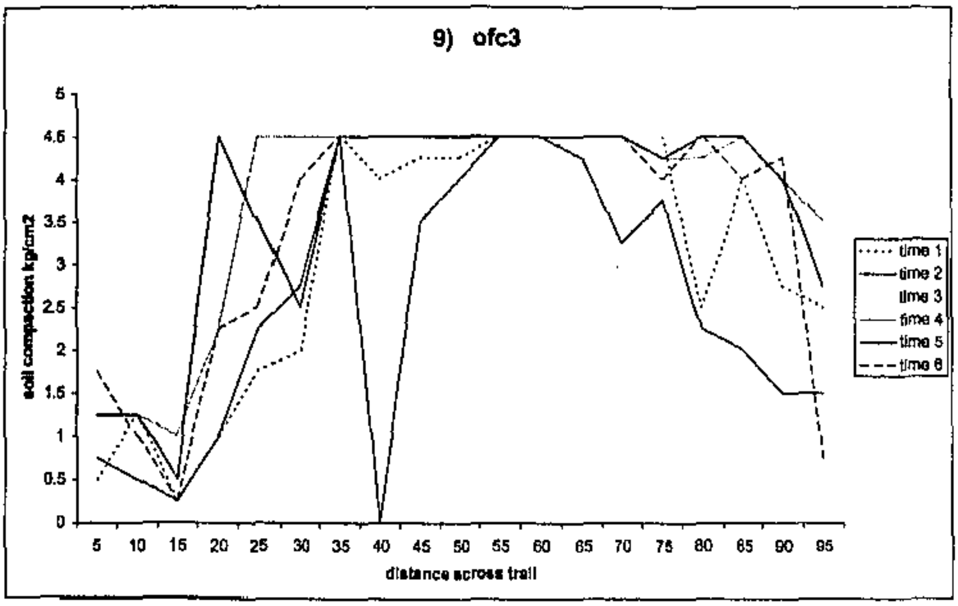

4) ods1
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

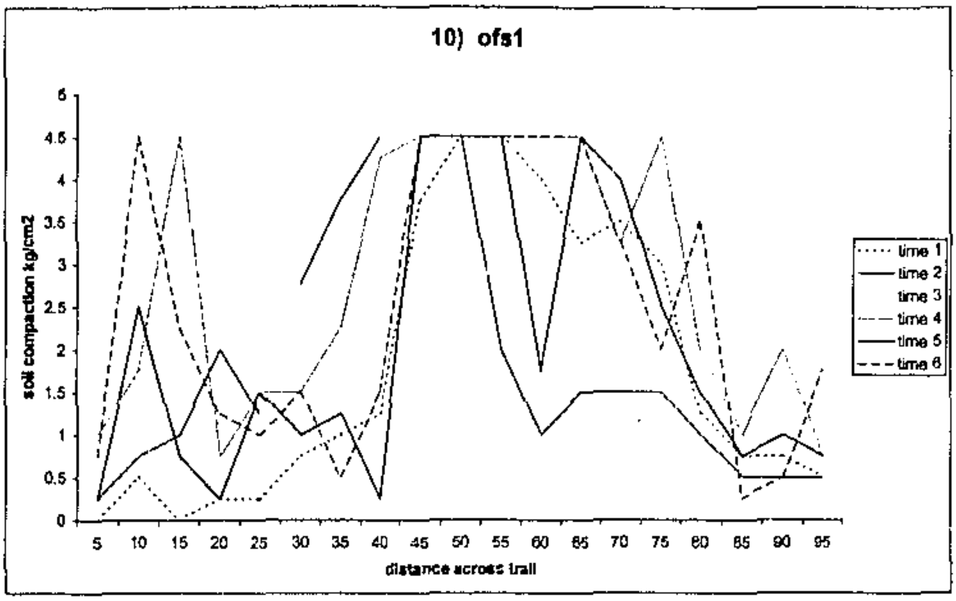

5) ods2
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5

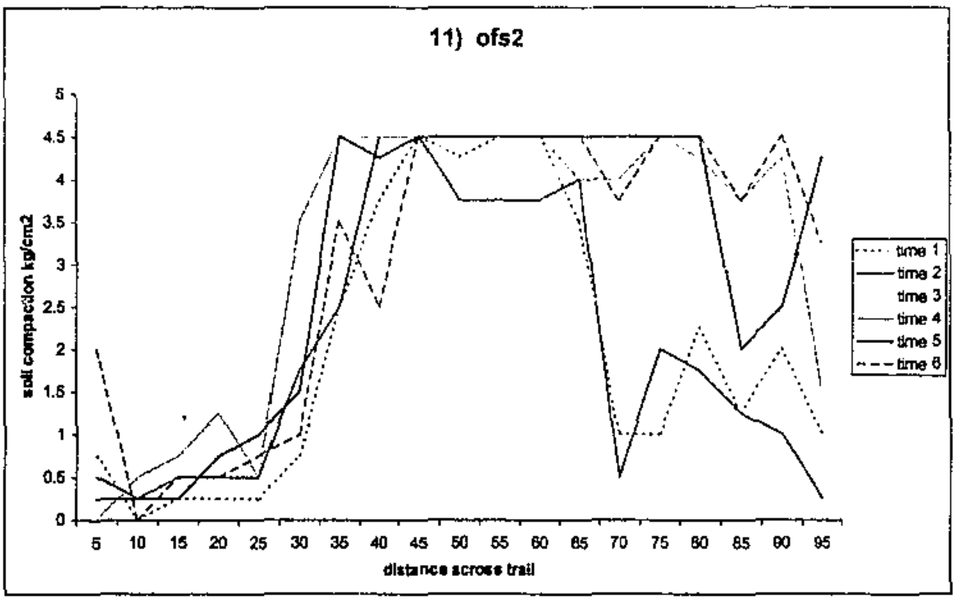

6) ods3
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

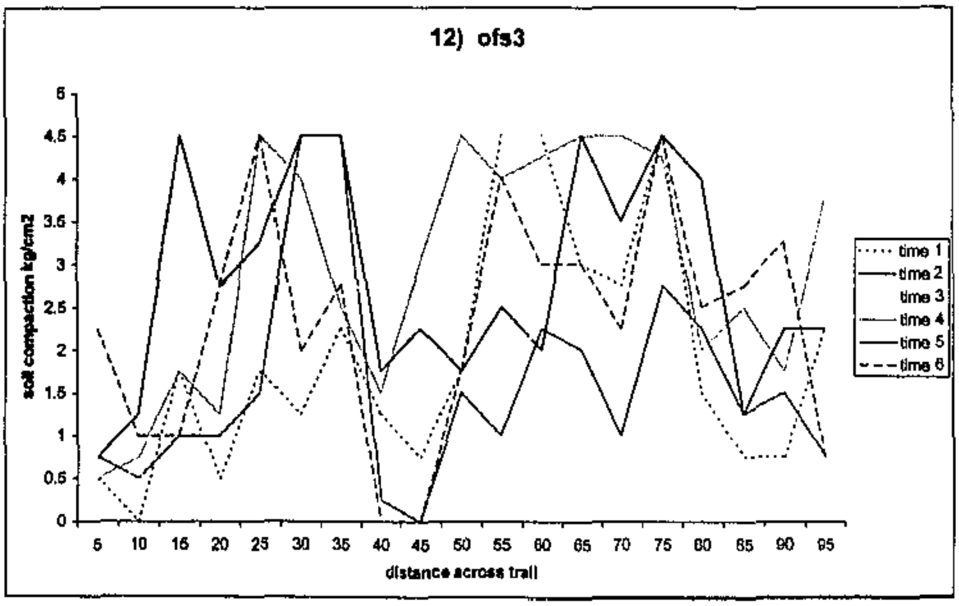

7) ofc1
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

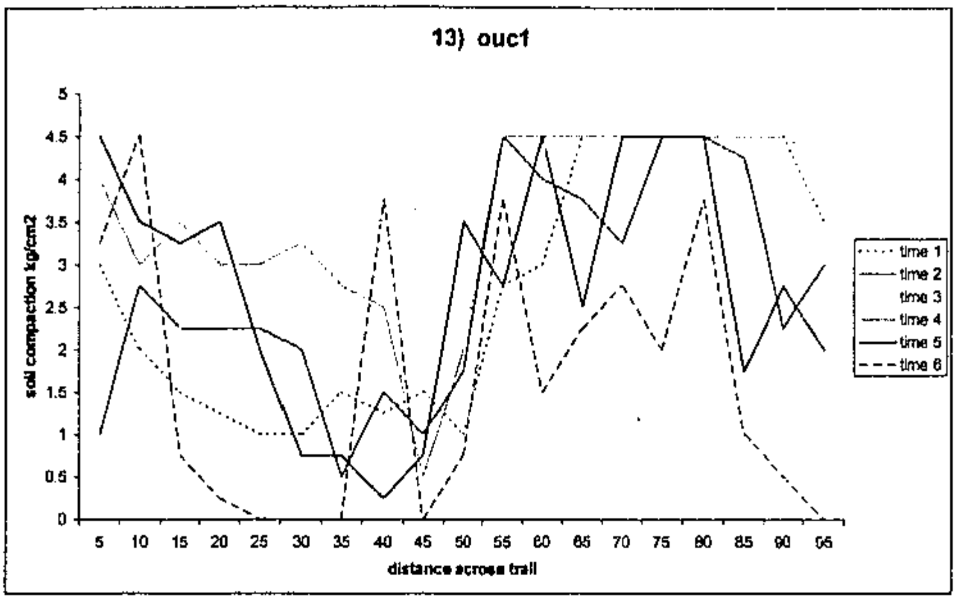

8) ofc2
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

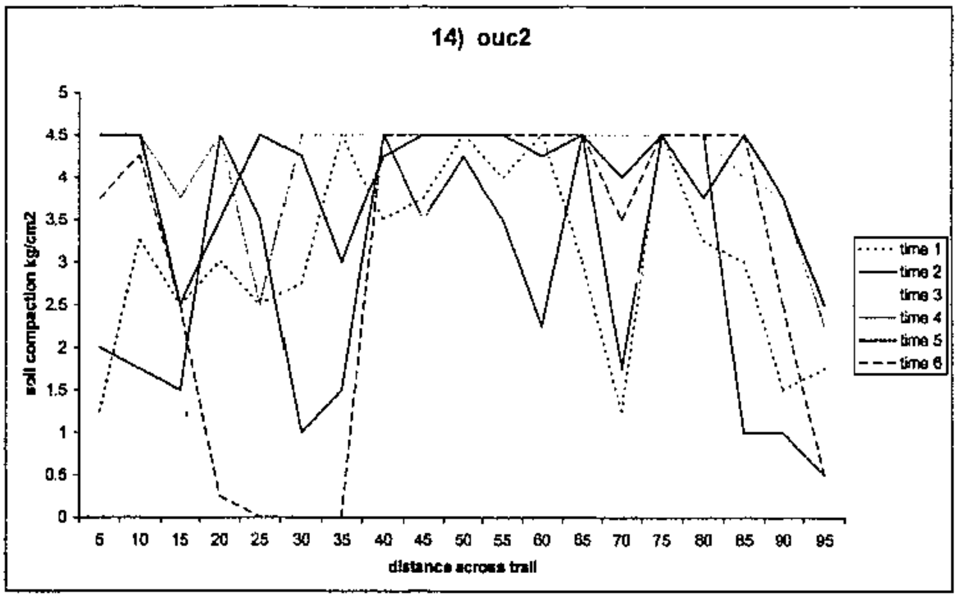

9) ofc3
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

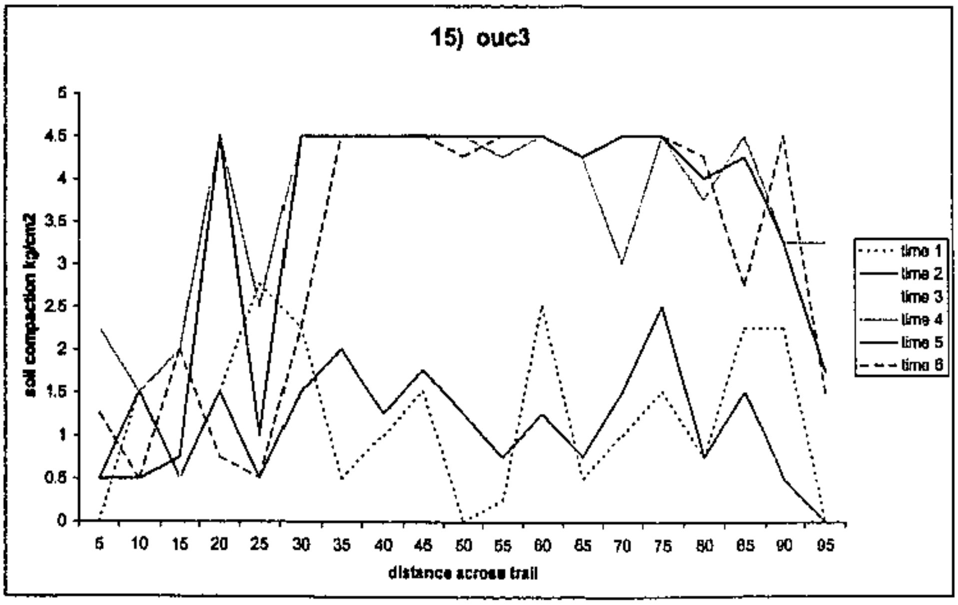

10) ofs1
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

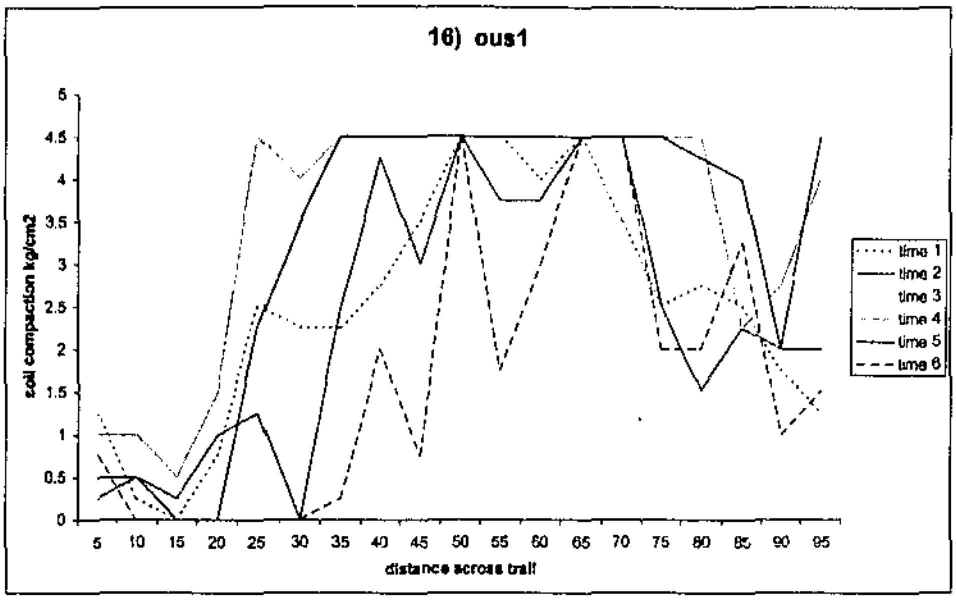

11) ofs2
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

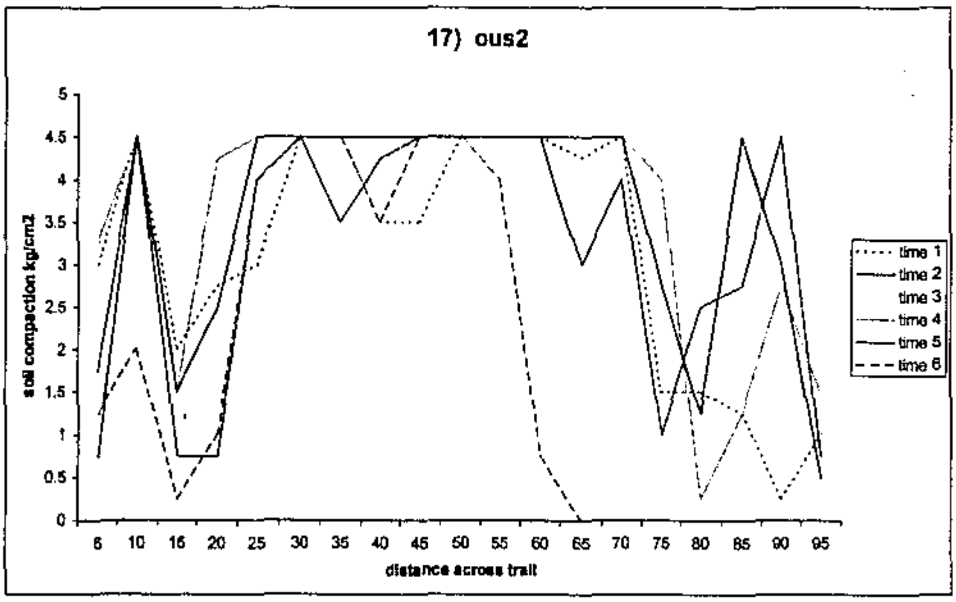

12) ofs3
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

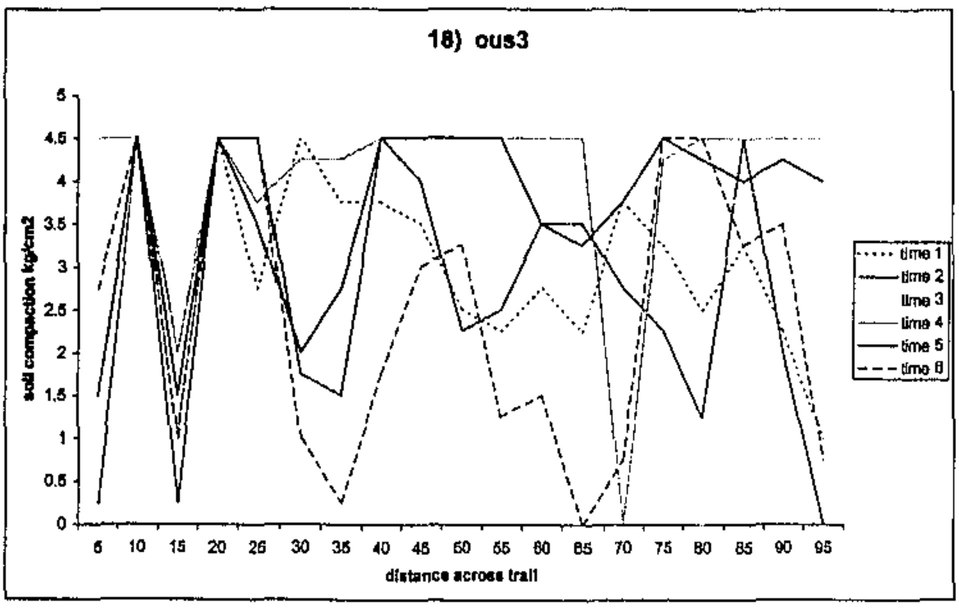

13) ouc1
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

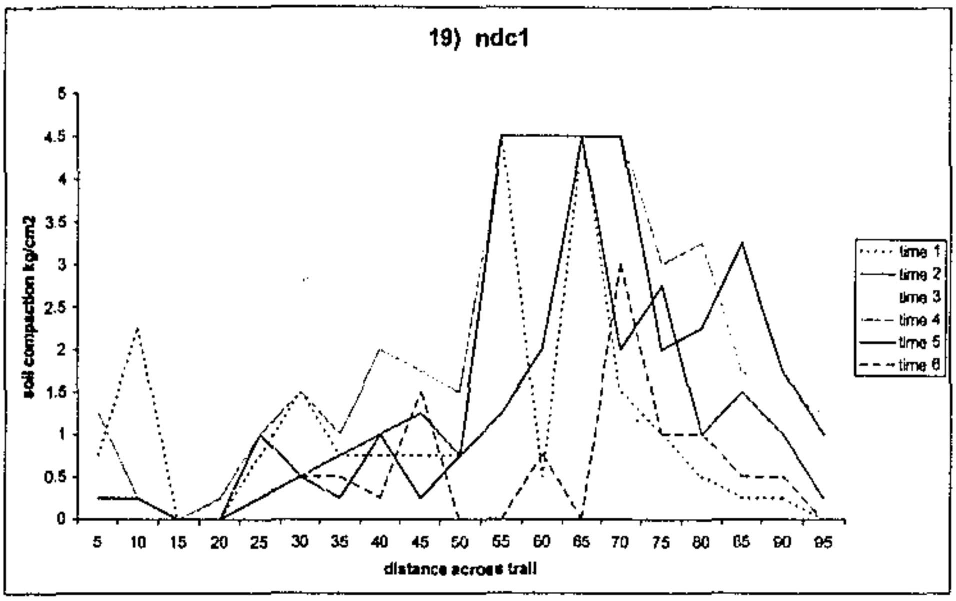

14) ouc2
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

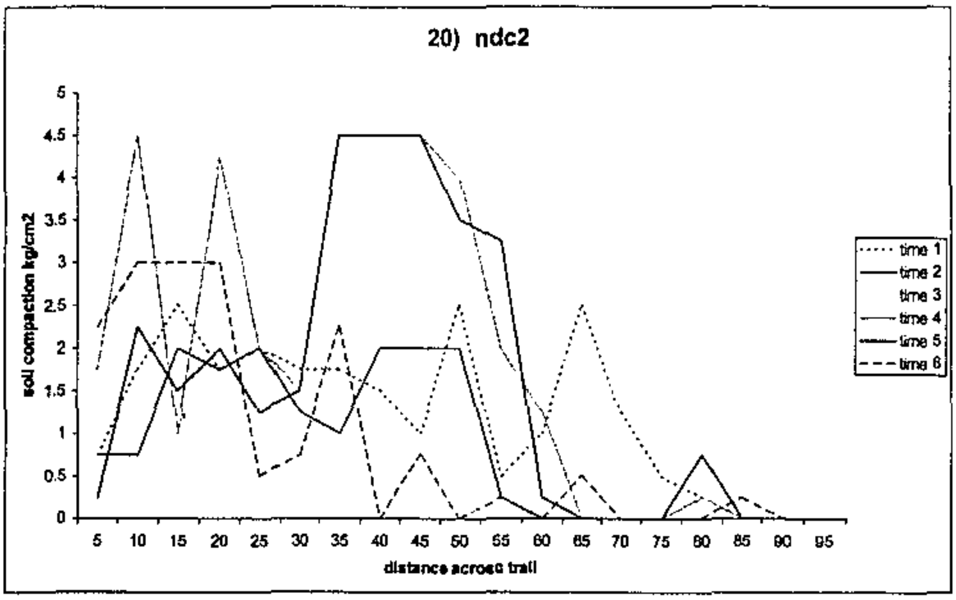

15) ouc3
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

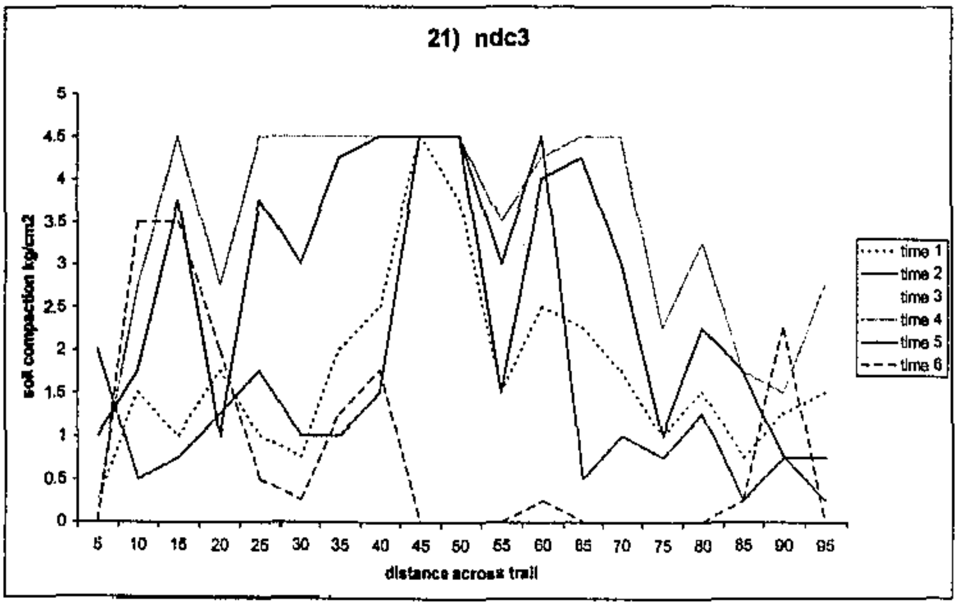

16) ous1
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

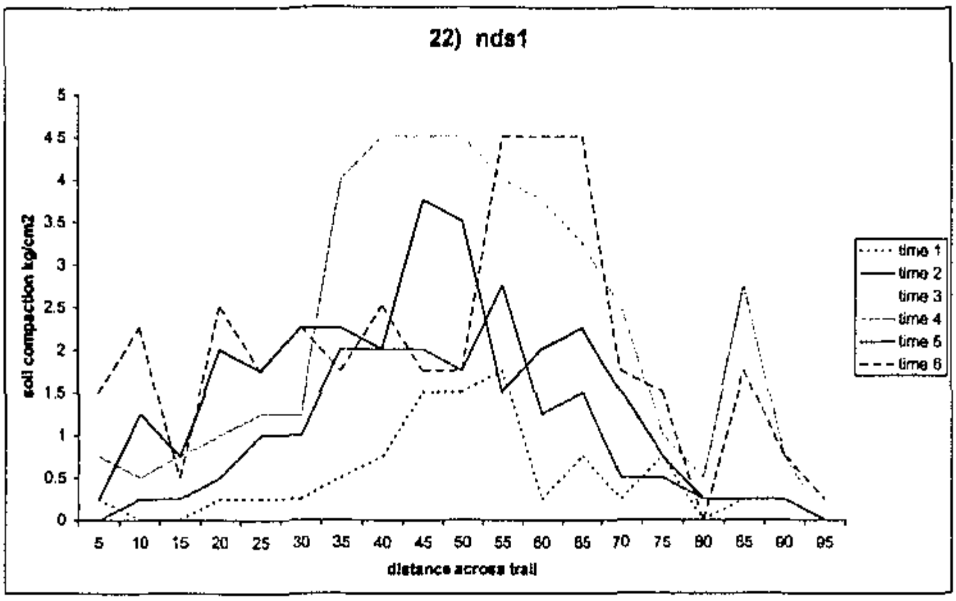

17) ous2
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

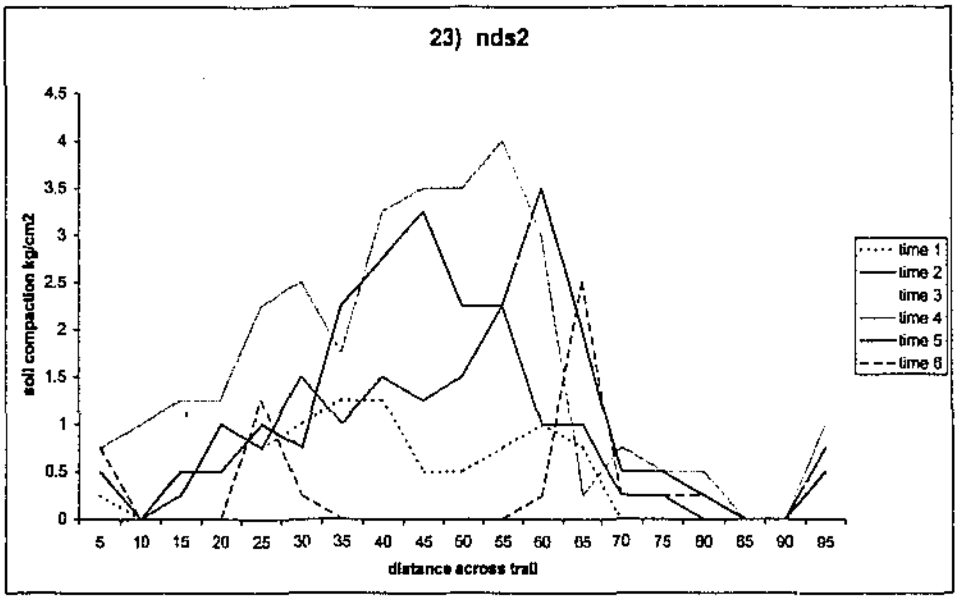

18) ous3
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

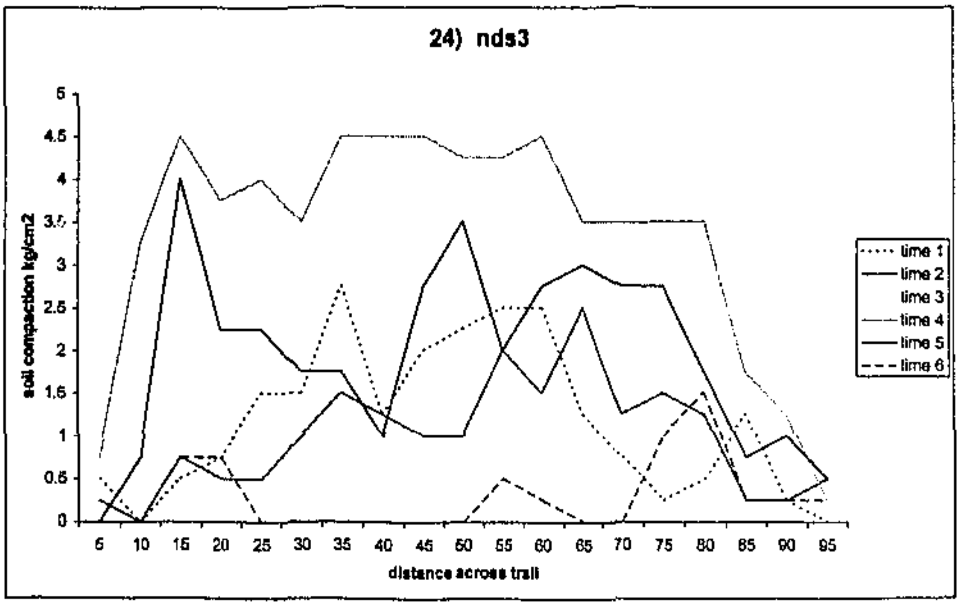

19) ndc1
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

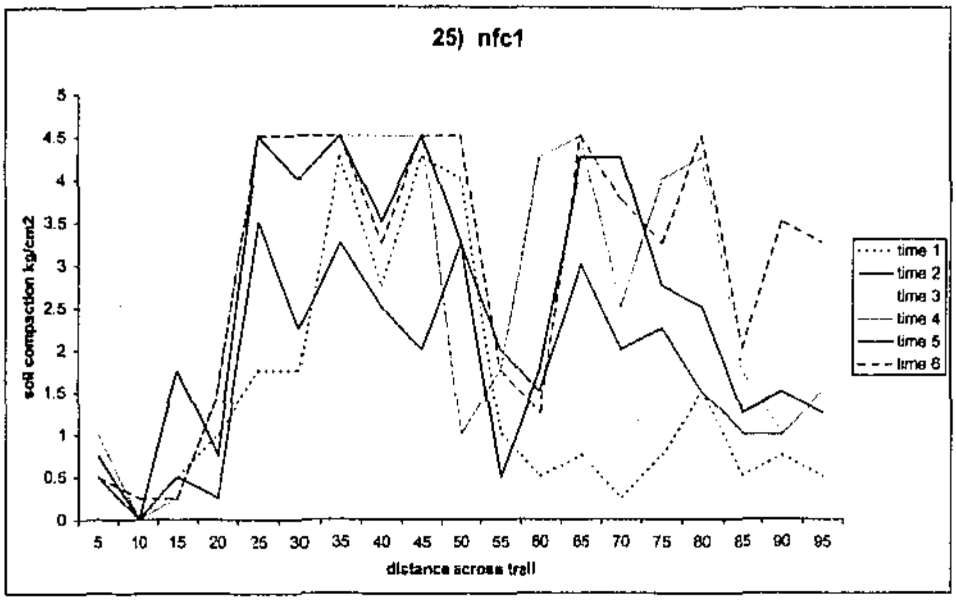

20) ndc2
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

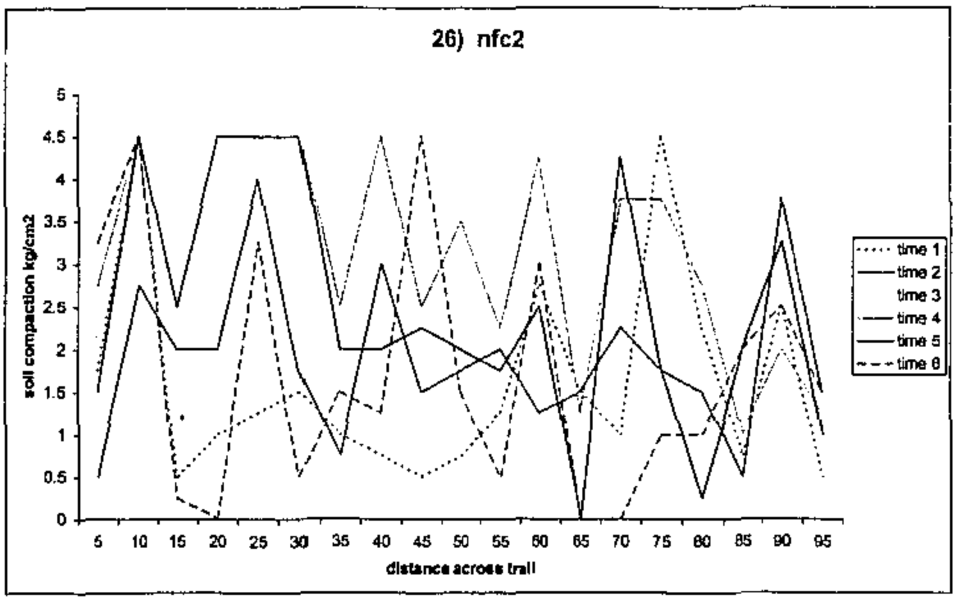

21) ndc3
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

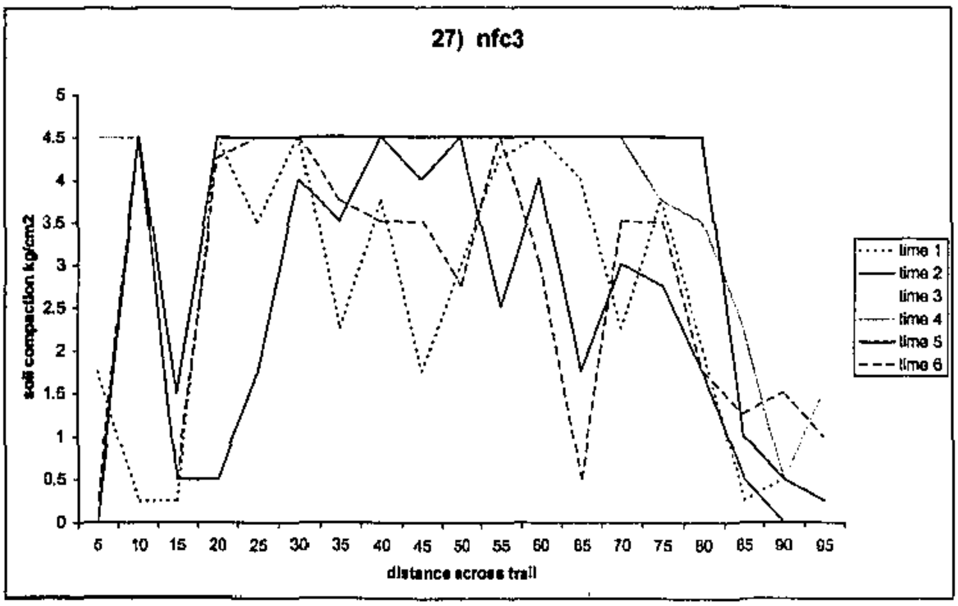

22) nds1
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

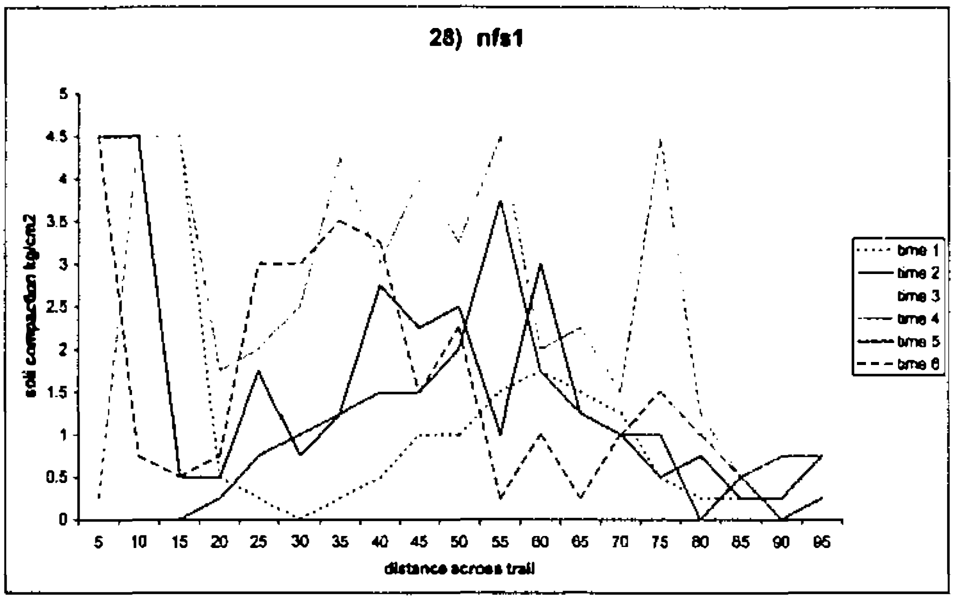

23) nds2
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

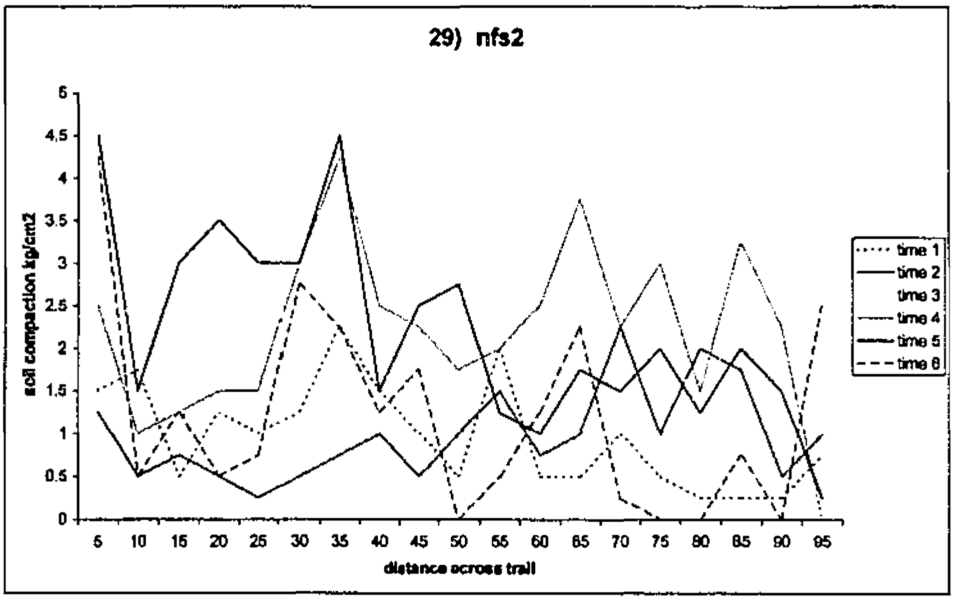

24) nds3
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

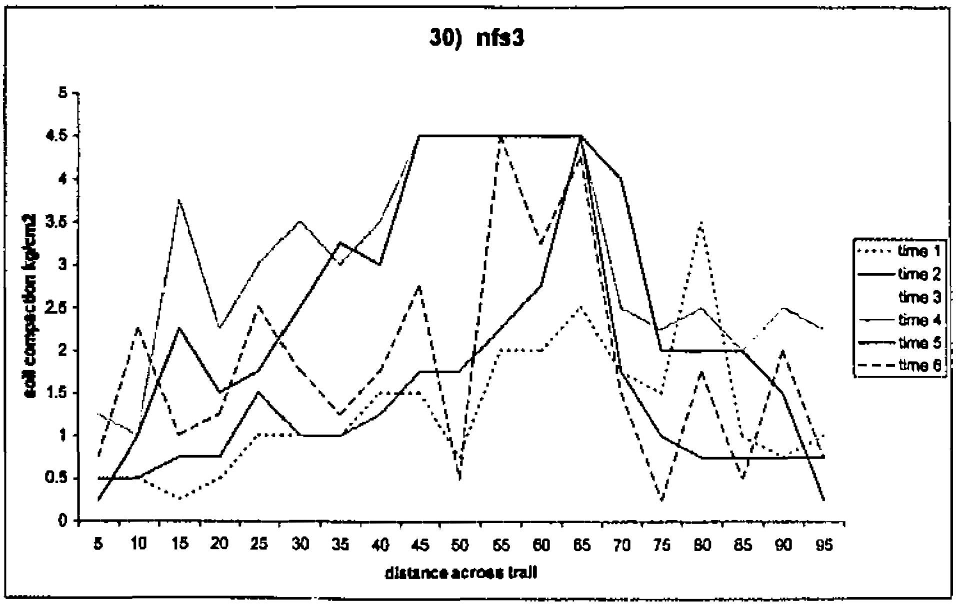

25) nfc1
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

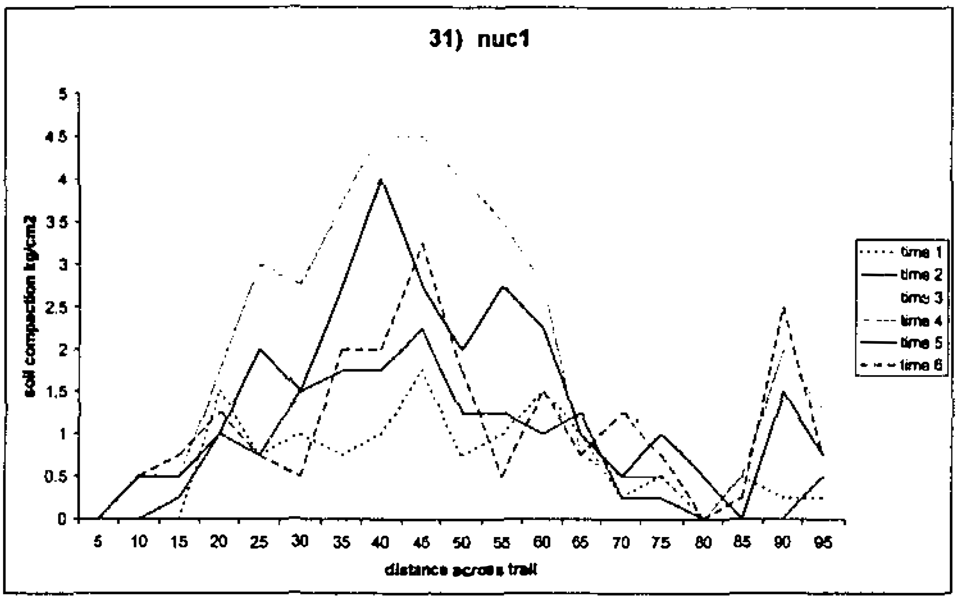

26) nfc2
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

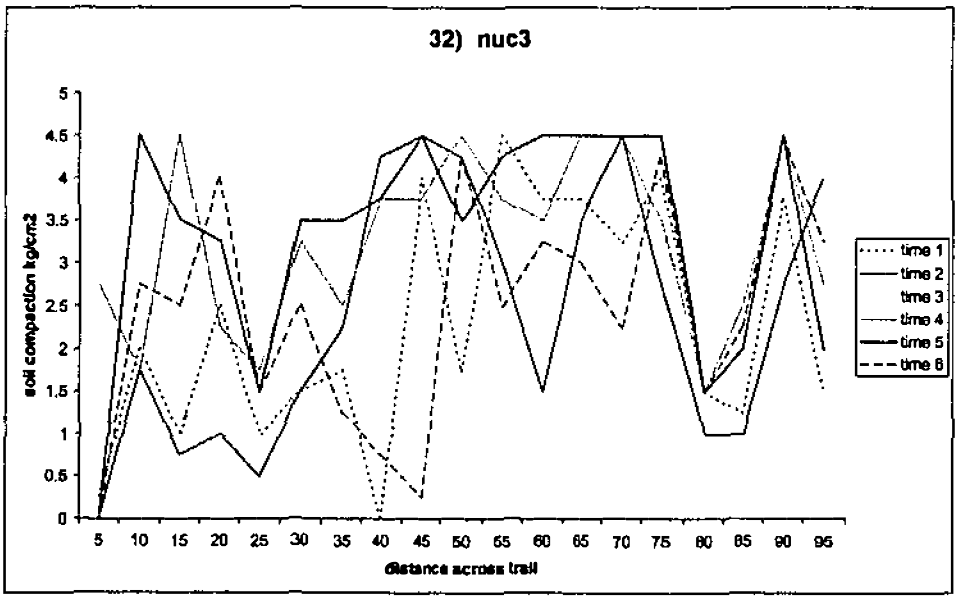

27) nfc3
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

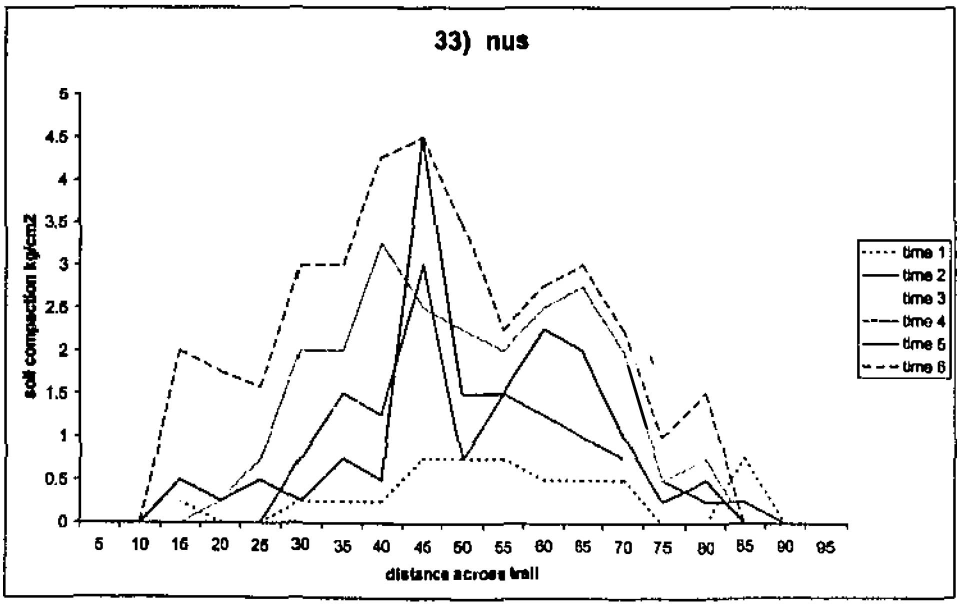

28) nfs1
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

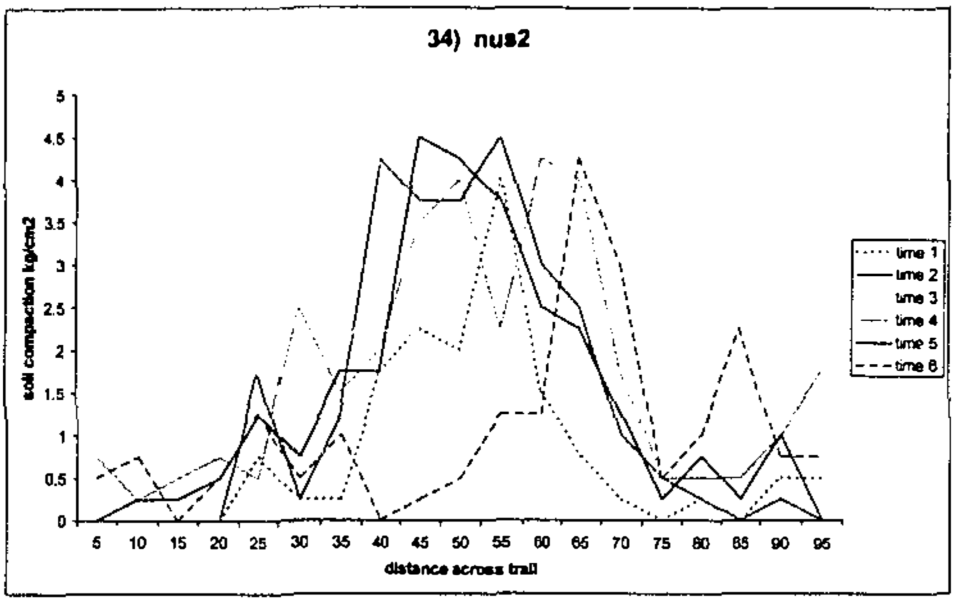

29) nfs2
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

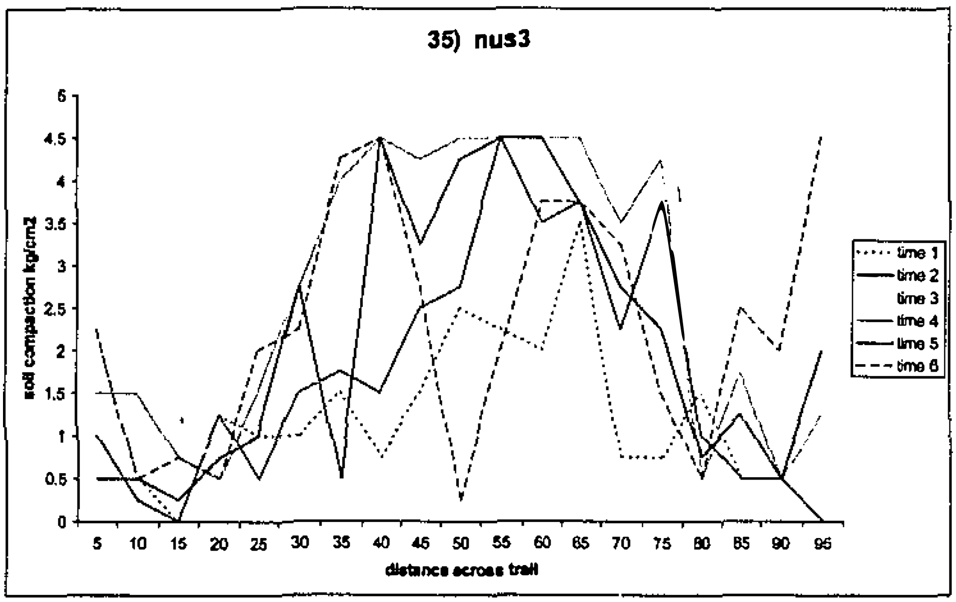

30) nfs3
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6


31) nuc1
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6


32) nuc3
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

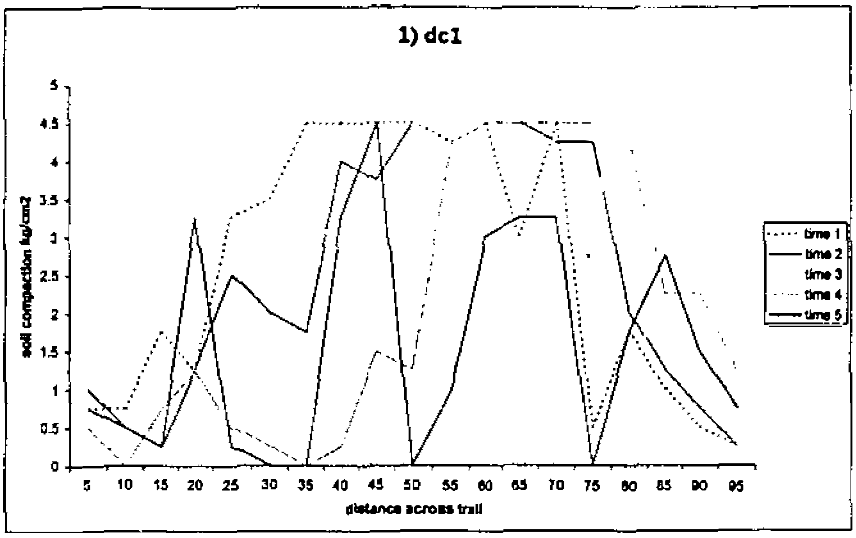

33) nus
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

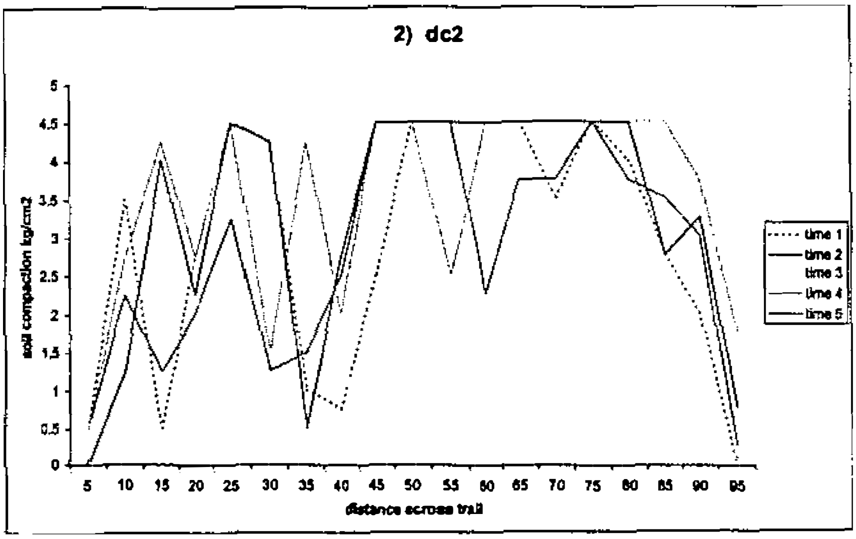

34) nus2
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

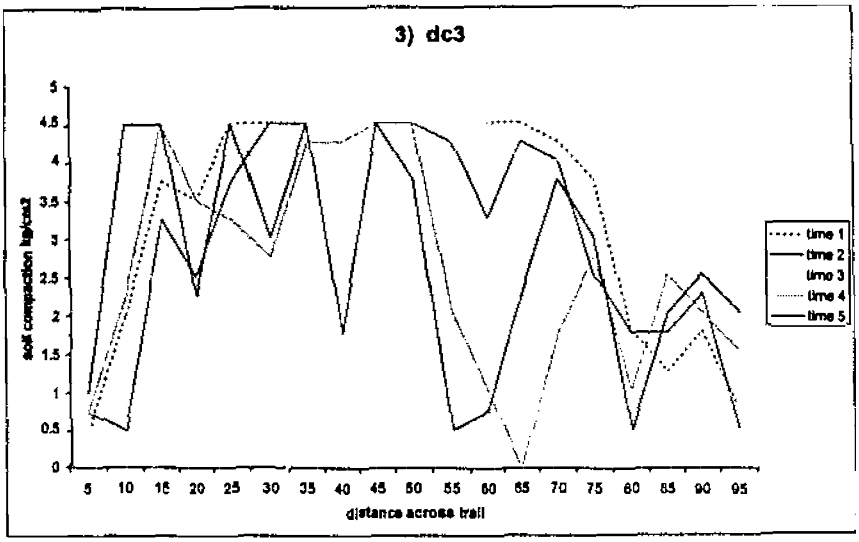

35) nus3
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5
time 6

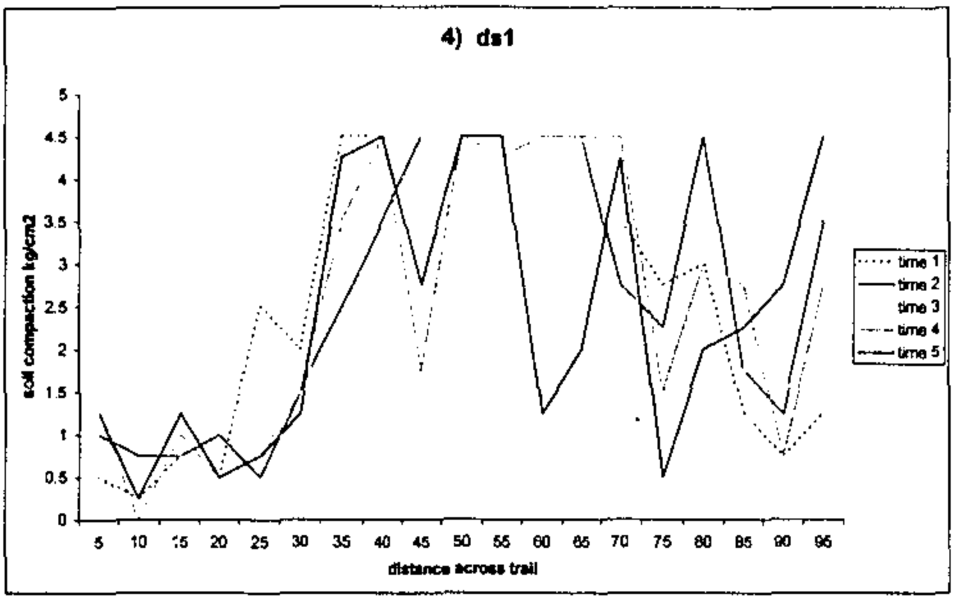
Appendix 1D

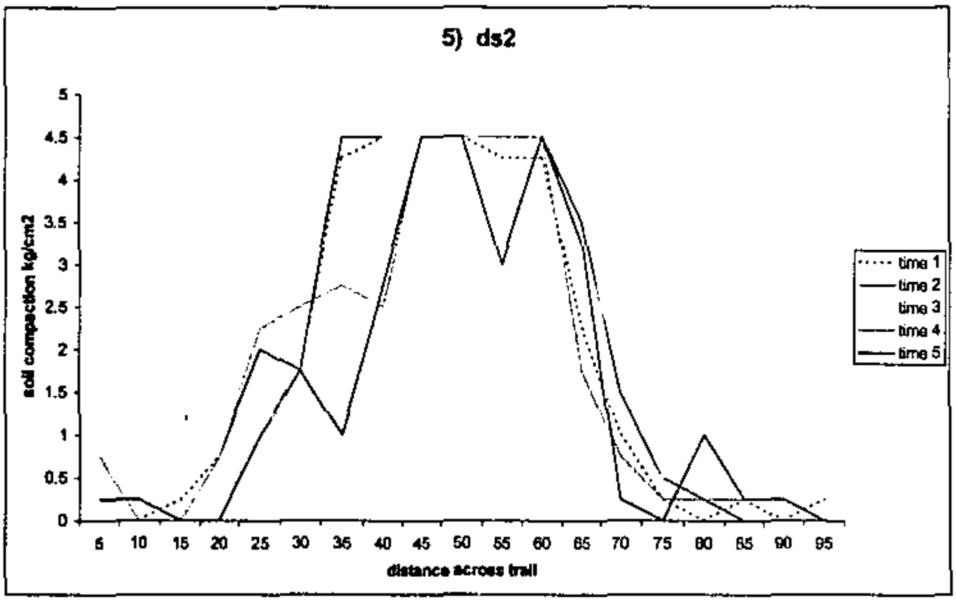
Figures 1-18: Marrinup, soil compaction
(o= old; n= new; d= downhill; f= flat; u= uphill)

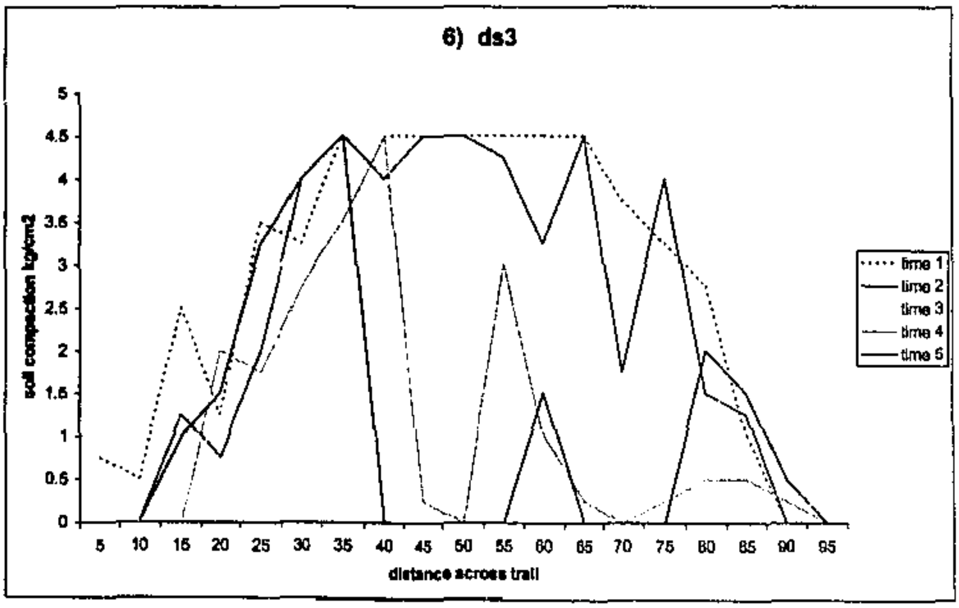


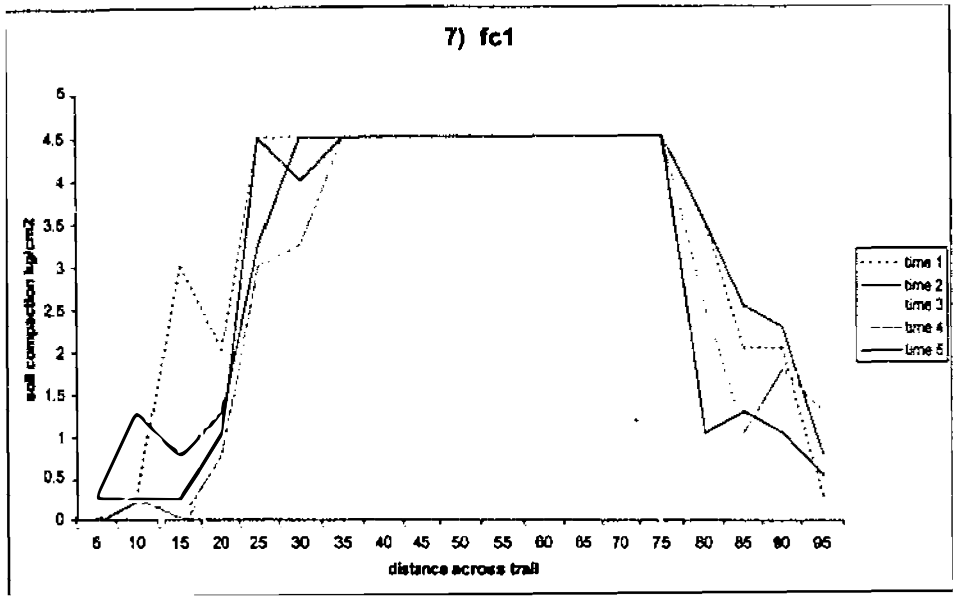


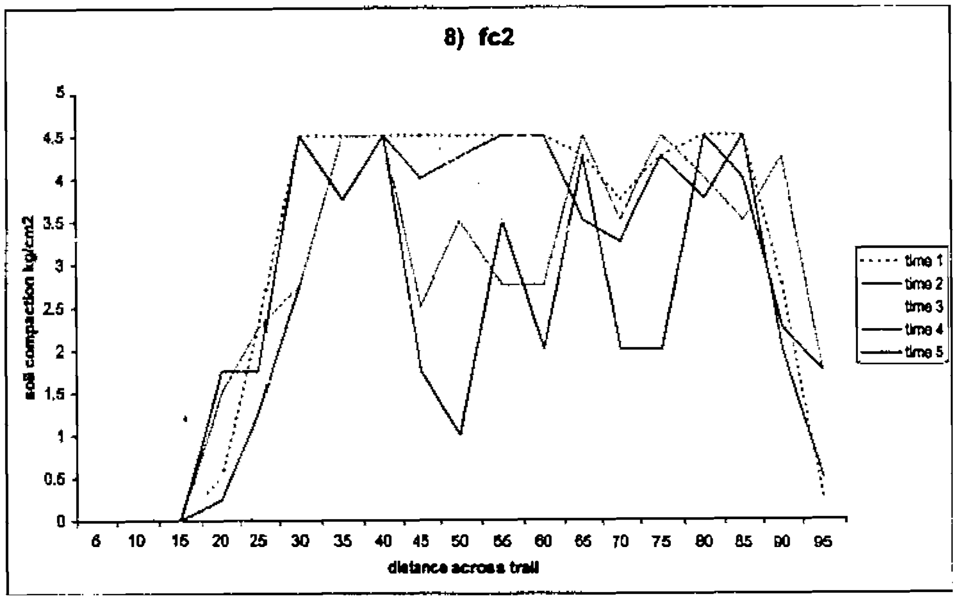


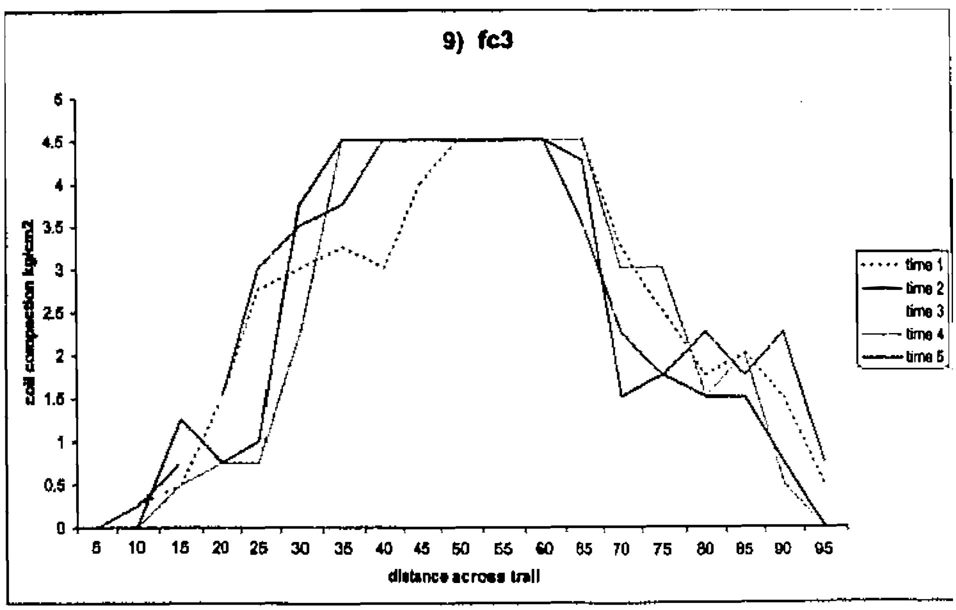

4) ds1
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5

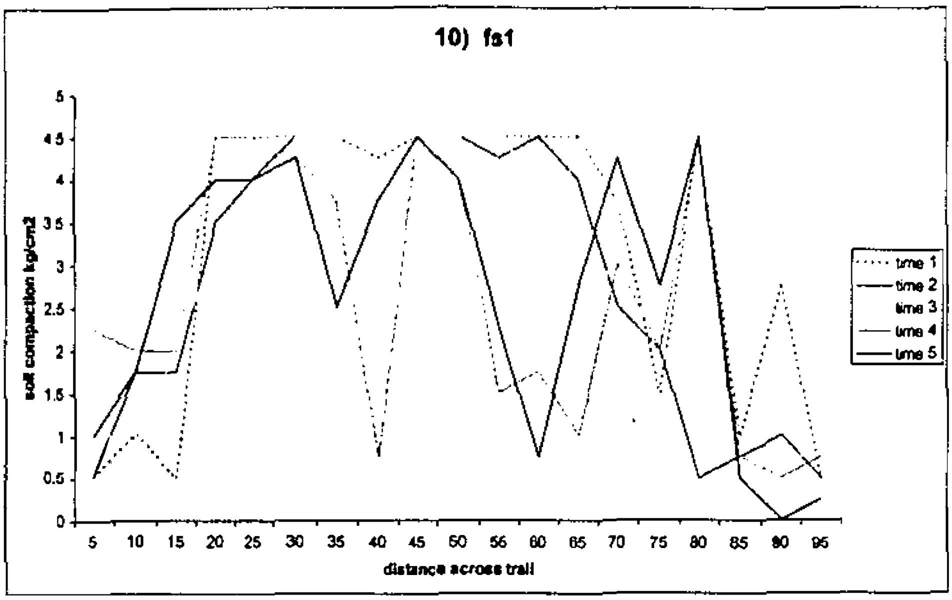

5) ds2
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5

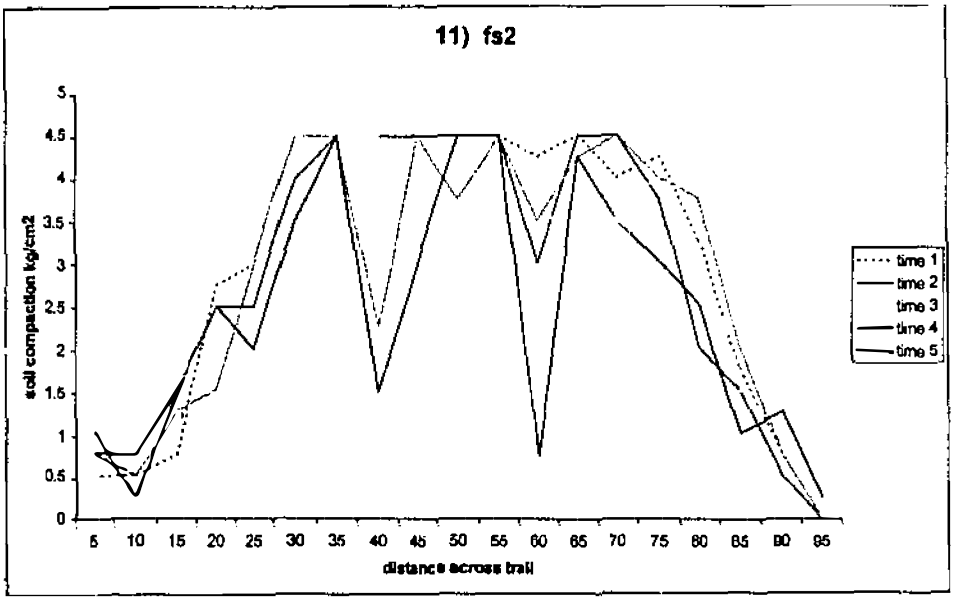

6) ds3
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5

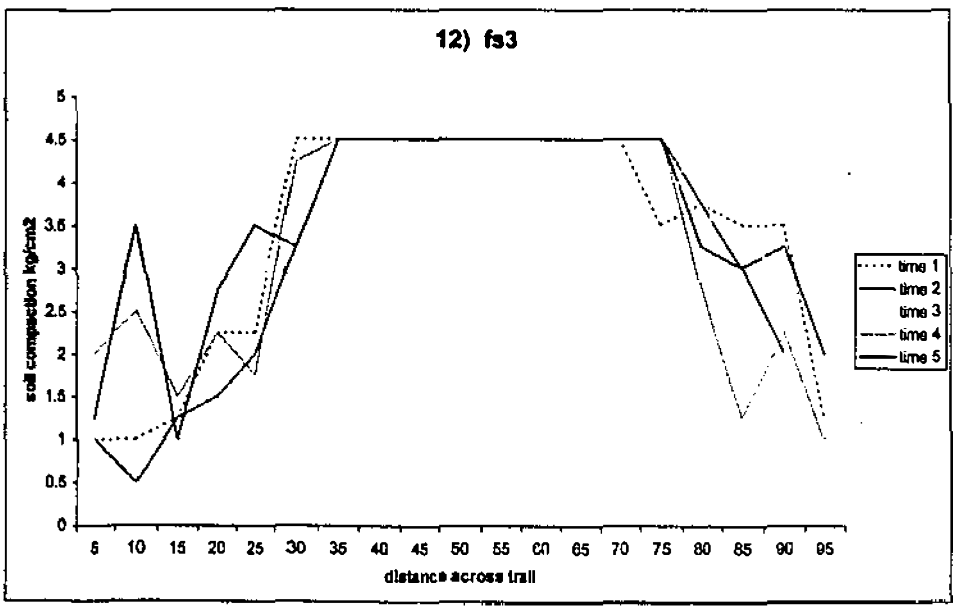

7) fc1
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5

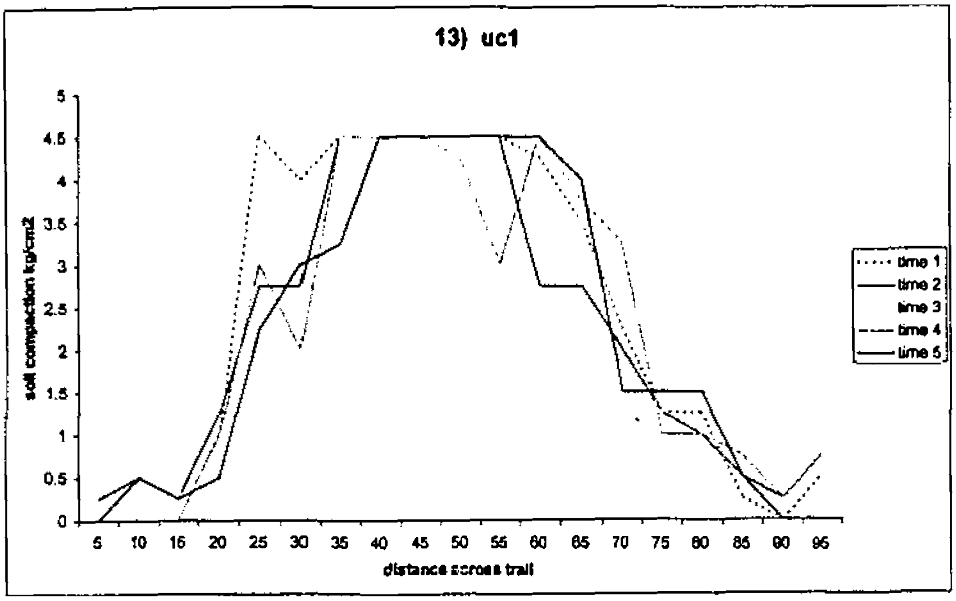

8) fc2
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5


9) fc3
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5

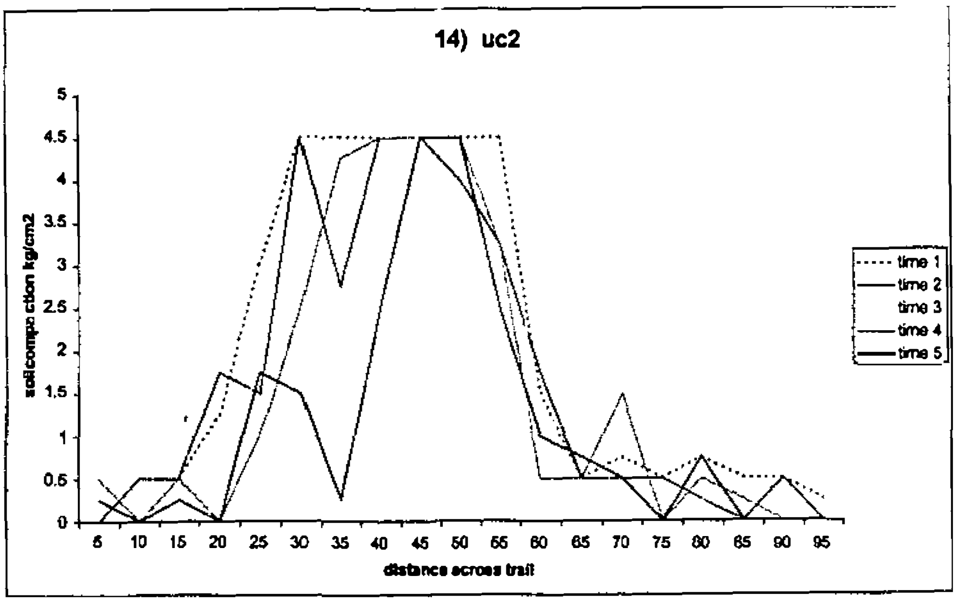

10) fs1
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5


11) fs2
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5

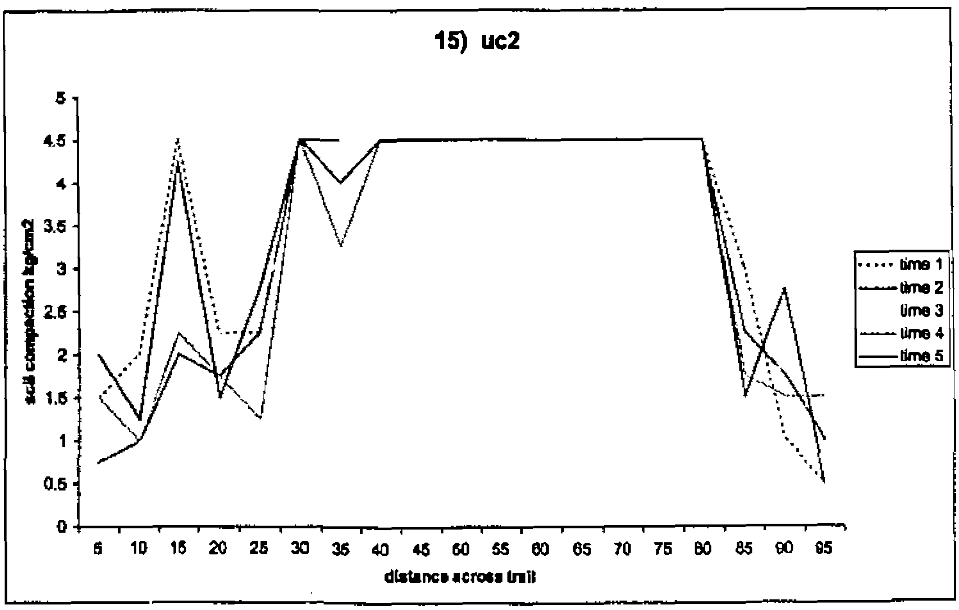

12) fs3
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5



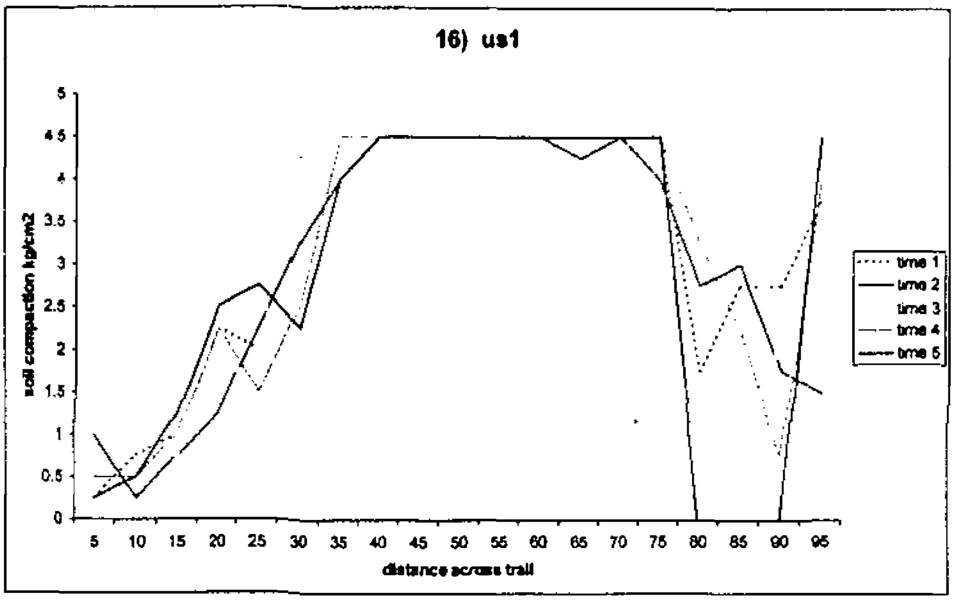
13) uc1
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5

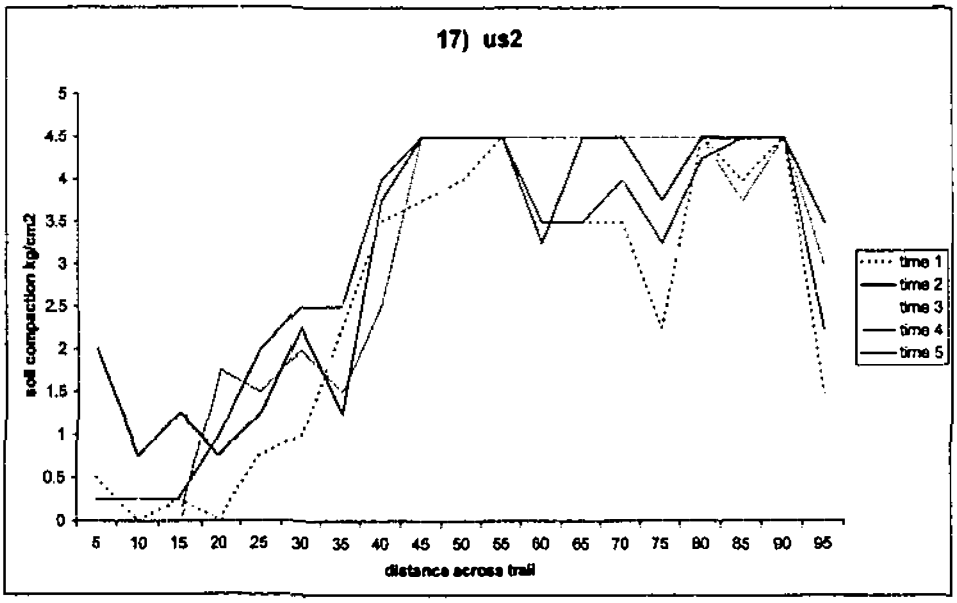


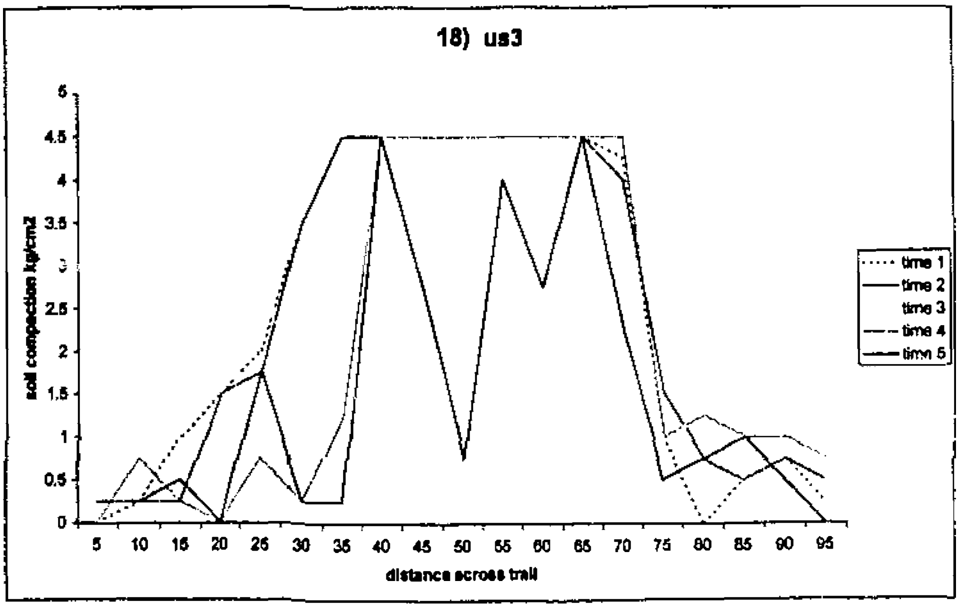
14) uc2
soilcompaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5



15) uc2
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5


16) us1
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5


17) us2
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5


18) us3
soil compaction kg/cm2
distance across trail
time 1
time 2
time 3
time 4
time 5

Appendix 2A

Cover Letter

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28 June 1999

Dear Retailer, Operator, Officer,

Today we ask for your help with a research project which aims to improve mountain trails and facilities in Western Australia. This should be of great value to anyone interested in mountain biking and associated activities.

The research is conducted by Ute Goeft, an honours student at Edith Cowan University in Joondalup and supported by Trailswest, the Department of Conservation and Land Management (CALM) and the Western Australian Mountain Bike Association (WAMBA). We all want to have the best possible and environmentally sound mountain bike facilities. To achieve this aim we need to know what mountain bike riders want and for that we need your help.

This letter is accompanied by a number of questionnaires, which are aimed specifically at mountain bike riders. We now ask your help in distributing these forms to mountain bike riders who visit your shop or office. The questionnaire takes about 8 minutes to fill out and is self-explanatory. We suggest that you ask your customers to fill out the forms on your premises and hand them back to you. Once all forms are completed please place them in the reply paid envelope (no stamp needed!). Please send them back as soon as possible, the latest by 1st February 1999.

If you need more questionnaires or if you have any questions concerning the research project please contact Ute or Ewen (see letterhead). Trailswest are currently developing a network of recreation trails around the State and if you would like more information please contact Ewen at Trailswest or visit the Trailswest web site: www.msr.wa.gov.au

Thank you very much for your cooperation !
Sincerely,

Ute Goeft,
Edith Cowan University

Ewen MacGregor,
Trailswest

Appendix 2B

Questionnaire

Dear Mountain Bike Rider,

This questionnaire is part of a research project designed to help improve mountain bike trails and facilities in Western Australia.

The project is run by Ute Goeft, an Environmental Management honours student at Edith Cowan University in Joondalup. The research will help Trailswest, the Department of Conservation and Land Management (CALM) and Western Australian mountain bike clubs to locate, construct and maintain better and environmentally sound mountain bike trails and facilities. To achieve this aim it is important to know what mountain bike riders actually want in a trail and therefore **we need your help !**

The information you provide will be completely confidential.

Please take a few minutes and fill in this form. Thank you.

<<< ❖ >>>

1. Do you belong to a mountain bike club? ❑ Yes ❑ No

2. Why do you ride a mountain bike? (tick as many boxes as you like)

❑ enjoyment/fun ❑ relaxation ❑ exercise/training
❑ to appreciate nature ❑ to be with friends ❑ family outing
❑ for a challenge ❑ racing ➪ DH ❑; XC ❑; DS ❑; Trials ❑
❑ transport ❑ other (please specify) ....

3. How often do you ride a mountain bike? (please tick one box only)

❑ once a day ❑ 2 - 3 times a week ❑ once a week
❑ 2 - 3 times a month ❑ once a month ❑ other (specify) ....

4. In what year did you start to ride a mountain bike? (please specify) 19..........

5. How long are your rides on average? (please tick one box only)

❑ under 2 km ❑ 2 - 5 km ❑ 5 - 10 km
❑ 10 - 20 km ❑ 20 - 50 km ❑ over 50 km

6. Have you done tours that included over night stays?

❑ Yes ➪ how many tours have you done? Please specify number of tours ....
➪ how many nights did you stay away on your last trip?
Please specify number of nights ....
❑ No ➪ are you thinking of doing overnight tours? ❑ Yes ❑ No

7. Where do you like to ride? (please list your 3 favourite areas/trails according to preference)

a. .... b. .... c. ....

8. Do you mind if you encounter: (please circle 1 number per row)

	love it	quite good	neutral	don't like	hate it
cars/4WDs	1	2	3	4	5
motor bikes	1	2	3	4	5
horses	1	2	3	4	5
wildlife	1	2	3	4	5
walkers	1	2	3	4	5
other cyclists	1	2	3	4	5

9. How important are the following features for you when riding? (circle 1 no. per row)

	essential	would be good	neutral	don't like it	don't want at all
smooth surface	1	2	3	4	5
rough surface	1	2	3	4	5
loose sand/gravel	1	2	3	4	5
firm surface	1	2	3	4	5
muddy/boggy areas	1	2	3	4	5
easy slopes	1	2	3	4	5
moderate slopes	1	2	3	4	5
steep slopes	1	2	3	4	5
short uphills	1	2	3	4	5
long uphills	1	2	3	4	5
medium length uphills	1	2	3	4	5
short downhills	1	2	3	4	5
long downhills	1	2	3	4	5
medium length downhills	1	2	3	4	5
tight curves	1	2	3	4	5
long curves	1	2	3	4	5
straight stretches	1	2	3	4	5
jumps	1	2	3	4	5
rocks/logs	1	2	3	4	5
overhanging branches	1	2	3	4	5
ditches	1	2	3	4	5
parking facilities	1	2	3	4	5
setting up area	1	2	3	4	5
drinking water (tap/tank)	1	2	3	4	5
toilet facilities	1	2	3	4	5
route markers	1	2	3	4	5
information shelters	1	2	3	4	5
brochures	1	2	3	4	5
interpretive signs	1	2	3	4	5
other (specify)	1	2	3	4	5

10. How important are the following settings for you when riding? (circle 1 number per row)

	essential	desirable	okay	try to avoid	don't want at all
native bush/forest	1	2	3	4	5
plantation forest	1	2	3	4	5
farmland/meadows	1	2	3	4	5
built up areas/suburbs	1	2	3	4	5
sealed road	1	2	3	4	5
gravel road	1	2	3	4	5
wide trail	1	2	3	4	5
single track	1	2	3	4	5

11. Do you agree that: (circle one number per row)

	strongly agree	agree	neutral	disagree	strongly disagree	don't know
- there are enough mountain bike trails	1	2	3	4	5	6
- mountain bikes should be allowed on all trails	1	2	3	4	5	6
- mountain bike riding damages trails	1	2	3	4	5	6
- good riding technique reduces trail damage	1	2	3	4	5	6
- rider education could reduce trail damage	1	2	3	4	5	6
- mountain bikes can spread dieback disease	1	2	3	4	5	6
- trail damage varies with soil type	1	2	3	4	5	6
- most trail damage occurs in downhill curves	1	2	3	4	5	6
- trail damage by mountain bikes is overrated	1	2	3	4	5	6
- it is enjoyable to ride the same trail repeatedly	1	2	3	4	5	6
- mtb racing has more impact than touring	1	2	3	4	5	6
- good trail design can reduce trail damage	1	2	3	4	5	6
- dieback is a big environmental problem in WA	1	2	3	4	5	6

12. Would you be prepared to accept a voluntary code of conduct/trail etiquette?

❑ Yes ⇨ What would be important to you (e.g. safety, respect other trail users)?

(please specify) ....

....

....

❑ No ⇨ Why not? (please specify) ....

....

13. What type of mountain bike do you ride? ❑ no suspension

❑ front suspension ❑ dual suspension ❑ other ....

14. How often do you clean your bike (including tyres and treads)? (tick one box only)

- ❑ once a week
- ❑ once a fortnight
- ❑ once a month
- ❑ every 3 months
- ❑ every six months
- ❑ once a year
- ❑ after every race/ride
- ❑ never
- ❑ other ....

15. Are you aware of dieback risk areas? ❑ No ❑ Yes ➪ see below

If yes, please specify below what a dieback risk area is and where they are found

....

....

16. What age group do you belong to?

❑ under 15 ❑ 15 - 24 ❑ 25 - 39 ❑ 40 - 59 ❑ 60 & over

17. Are you female or male? ❑ female ❑ male

18. Please tell us your post code ❑❑❑❑

if you are visiting Australia please tell us your home country ....

19. Is there anything else you would like to tell us? Please do ! ....

....

....

....

....

Please **return this form** to the person who gave it to you or

mail it in the reply paid envelope provided **as soon as possible** (latest by 15 February, 1999).

Thank you very much for your time & happy riding ! ☺

✂--

Trailswest are currently developing a network of recreation trails around the State, for information please contact Ewen MacGregor at Trailswest: ☎ 9387 9700; FAX 9387 9726; email: emacgregor@wamsr.ausport.gov.au or visit the Trailswest website: www.msr.gov.au

For information on the project please contact Ute Goeft: ph. 9400 5058; email: u.goeft@cowan.edu.au

If you want more questionnaires please contact Ute or Ewen.

Appendix 2C

Summary of survey responses
(n= sample size)

Question 1: Are you a member of a mountain bike club? (n=183)

Answers to Question 1 in percent

category	no answer	yes	no	total
%	5.5	72.1	22.4	100.0

Question 2: Why do you ride a mountain bike? (n=183)

Answers per category in percent

category	%
enjoyment/fun	91.3
relaxation	39.9
exercise/training	81.4
to appreciate nature	47.0
to be with friends	58.5
family outing	14.8
for a challenge	61.7
racing:	76.5
DH	43.2
XC	62.3
DS	24.0
Trials	9.3
transport	50.3
other	12.6
total	**672.7**

List of answers given in the 'other' category:

Adrenalin rush (5)
adventure, Quad Compressor
all of the above
better my fitness
escape the city
extreme riding adventure
get away from the computer
hammer single track
I am training to race
my income
practice skills/tricks/jumps etc.
something to do
testing new parts and tyres
to and from school
to explore the country
touring
Work: in bike shop (1); courier (2)

Question 3: How often do you ride a mountain bike? (n=183)

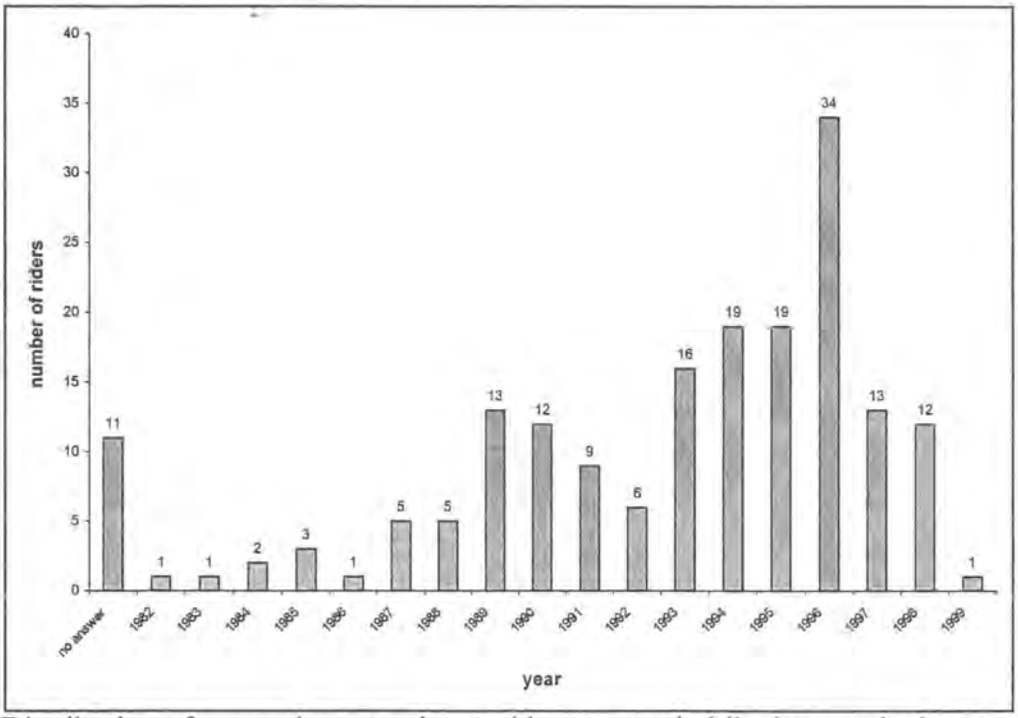
Responses to Question 3 in percent

Category	Responses (%)
once a day	35
2-3x a week	39
once a week	11
2-3x a month	3
once a month	3
other	9
total	100

List of answers given in the 'other' category:

more than once a day
2-3 times a day
2 x a day (2)
every day
every day 120+ km
3-4 times a week
4-5 times a week (5)
5 x a week (2)
6 days a week
1-2 x per week (Aug)
only off-road at races
SLOWED DOWN

Question 4: In what year did you start to ride a mountain bike? (n=183)



Distribution of respondents starting to ride a mountain bike in a particular year

Question 5: How long are your rides on average? (n=176)

Single answers given in response to Question 5 in percent

distance	% of answers
under 2 km	2.3
2-5km	8.0
5-10km	11.9
10-20km	31.8
20-50km	39.8
Over 50km	6.3
Total	**100.0**

No answer: n=1

Combinations of double answers (n=6)

frequency	combination
3	20-50km & over 50 km
1	10-10km & 20-50km
1	2-5km & 20-50km
1	Under 2km & 10-20km

Question 6: Have you done tours that included overnight stays? (n=183)

Responses to Question 6

<table>
<tr><th colspan="2">Yes (n=54)</th><th colspan="3">No (n=125)</th><th>No answer (n=4)</th></tr>
<tr><td colspan="2">29.5%</td><td colspan="3">68.3%</td><td>2.2%</td></tr>
<tr><td>average # of tours</td><td>average # of nights</td><td colspan="3">Are you thinking of doing overnight tours?</td><td></td></tr>
<tr><td>2.6</td><td>4.0</td><td>Yes (n=74)</td><td>No (n=56)</td><td>Not specified (n=5)</td><td></td></tr>
<tr><td></td><td></td><td>59.2%</td><td>44.8%</td><td>4.0%</td><td></td></tr>
</table>

Question 7: Where do you like to ride? (n=183)

List of answers sorted according to preference and frequency

Preference 1		Preference 2		Preference 3	
Specific location	#	Specific location	#	Specific location	#
no answer	*4*	*no answer*	*12*	*no answer*	*23*
Mundaring	23	Mundaring	19	Dwellingup	23
Dwellingup	22	Dwellingup	12	Goat Farm/Greenmount	14
Kalamunda	8	Helena Valley	9	Jarrahdale	10
Goat Farm/Greenmount	7	Kalamunda	9	Mundaring	9
John Forrest Nat. Park	7	Goat Farm/Greenmount	8	John Forrest N/P	7
Harvey	6	John Forrest Nat. Park	8	Margaret River	6
Jarrahdale	6	Margaret River	7	Kalamunda	5
Helena Valley	5	Jarrahdale	6	Wellington Dam	5
Lowden	5	York	6	Helena Valley	4
		Bibbulmun Track	5	Northcliffe	4
Wellington Dam	4	Bickley	3	Bibbulmun track	3
Bibbulmun Track	3	Gleneagle	3	Collie	3
Chittering	3	Kelmscott	3	Lowden	3
Katamorda Trail	3	Little Oven circuit	3	Manjimup	3
Manjimup	3	Pemberton	3	Ocean routes	3
Bridal track	2	Chidlow	2	river foreshore	3
Darlington	2	Chittering	2	Bickley	2
Gungin	2	Darling Range	2	Bridgetown	2
Margaret River	2	Glen Forest	2	Dardanup	2
Northcliffe	2	Katamorda Trail	2	Denmark	2
Ravensthorpe	2	Lowden	2	Esperance	2
river	2	Maddington	2	Fremantle (fun & Trials)	2
Bickley	2	Midland	2	Kelmscott/Gosnells	3
around Bunbury (The		Mt. Lennard	2	Little Oven	2
Maidens, Leschenault)	1	Winjin	2	York	2
Balingup	1	Augusta	1	Albany	1
Beach	1	Balingup	1	around the Lakes Rdhouse	1
Bunbury - Mt. Lennard	1	Bunbury	1	At home, Toodyay	1
coast, Fremantle to Hillarys	1	Harvey	1	Bridal Trail	1
Collie	1	Leederville	1	Busselton area	1
cycle ways Esperance	1	Lesmurdie Falls	1	Byford	1
Fremantle	1	Mandalay Beach Rd.	1	Chidlow	1
Gleneagle	1	Manjimup	1	Chittering	1
Guildford	1	Northcliffe	1	Coogee	1
Kelmscott	1	Perth Hills	1	Donnybrook	1
Keystone State Forest	1	Pilbara	1	Fremantle->Hillarys	1
Kings Park	1	Pile Rd, Dardanup	1	Glen Forrest	1
Lewanna	1	Point Walter	1	Gleneagle	1
local bush (Stratham)	1	Quad Compressor	1	Greystones	1
Midland	1	Wallesten BMX	1	Harvey	1
Mt Helena	1	Walpole	1	Katamorda Track	1
Mt. Lennard	1	Wellington Dam	1	Kings Park	1
Nannup	1		1	Lewana	1
Peel District	1			North of Perth	1
Pemberton- local area	1			Own & neighbours property	1
Railway Heritage Trail	1			Pemberton	1
Darlington/Clackline	1			Perth	1

Sawyers Valley	1			Perth-Fremantle	1
South West	1			Pickering Brook/Bickley	1
Star Swamp	1			Pile Rd	1
Trigg Beach Reserve	1			Ravensthorpe	1
				Rottnest	1
				Southern Areas	1
General location	**#**	**General location**	**#**	**General location**	**#**
bush/forest	8	cycle tracks/cycle ways	6	Hills	6
Hills	4	railway reserves	4	bush/forest	5
Local trails	2	club days	2	around town	2
single track	2	coastal areas	2	beach	2
UWA (trials)	2	heritage trails	2	long (walk) trails	2
anywhere	1	South West	3	race tracks	2
anywhere allowed	1	4WD track or fire break	1	roads	2
country side trails	1	anywhere	1	anywhere	1
cross country	1	Around town	1	city trails	1
cycle tracks	1	country towns	1	cycle ways	1
off road	1	DH racing	1	DH	1
scenic routes (swan river; westcoast hwy)	1	dirt roads	1	dirt road	1
single track XC	1	local hills	1	tracks	1
trails	1	river	1	XC without too many hills	1
		road	1		
		XC tracks	1		
Outside WA	**#**	**Outside WA**	**#**	**Outside WA**	**#**
Bromont/Canada	1	Mt. Beauty/Vic.	1	Victoria (Wodonga)	1
Holland	1	Australia	1	Colorado	1
Wales	1	Banff	1	New Zealand	1
Whistler Mtn. (B.C.)	1				

Question 8: Do you mind if you encounter:

Means and modes of Likert scale (1='love it'; 5='hate it') for Question 8

Category	mean	mode	n
wildlife	1.63	1	182
cyclists	1.65*	1	183
walkers	2.69	3	183
horses	3.21	3	181
cars	3.78	3	183
motor bikes	3.78	4	183

Note: Responses ranged from 1 to 5; except *: range = 1-3

Question 9: How important are the following features for you when riding?

Results from Likert scale (1='essential'; 5='don't want at all')analysis for Question 9.

Feature	mean	mode	n
Long downhills	1.47	1	180
Medium length downhills	1.56	1	180
Long curves	1.71*	1	182
Tight curves	1.75	1	182
Drinking water	1.81	2	182
Route markers	1.90	1	183
Short downhills	1.92	1	182
Short uphills	1.93	2	182
Jumps	1.96	1	183
Moderate slopes	1.99	2	183
Steep slopes	2.06	1	181
Parking facilities	2.08	2	183
Rocks/logs	2.10	1	182
Toilet facilities	2.12	2	182
Firm surface	2.14	2	182
Straight stretches	2.16	2	182
Setting up area	2.17	2	182
Easy slopes	2.20	2	181
Rough surface	2.25	2	181
Brochures	2.25	2	180
Interpretive signs	2.30	3	179
Information shelters	2.32	3	181
Medium length ubhills	2.34	2	181
Ditches	2.54	2	182
Long uphills	2.67	2	181
Smooth surface	2.87	3	182
Overhanging branches	3.07	3	182
Muddy/boggy areas	3.09	3	181
Loose sand/gravel	3.10	3	181
Other	1.30**	1	47

Ratings and answers given in the 'other' category.

Rating	Remark/item
0	**'smooth surface' to 'ditches' (see Appendix survey form)**: As a mountain biker most of these aren't really important. Trails/tracks need a bit of everything. So I don't mind if they are there or not!)
0	all **(from smooth surface to straight stretches; see Appendix survey form)** are needed for good track to be challenging and enjoyable. would stop people using same part of a track all the time
0	maps-mtb specific; MANY MTB track(single) in diff. locations/destinations
0	sand too soft
1	good map of MTB trail
1	maps
1	Maps: both of rides and where the trails are!
1	trail maps
1	trail maps including small single track trails
2	maps
1	variety
1	variety is great; as long it's a good, officially ok, hassle free place to ride!!
1	variety of terrain
1	a bit of all on racetracks
1	safety
1	safety warnings
1	signs to warn walkers of mtbs
1	Track rules as per Margaret River Pt.Surfing, Tribal Law signs; 1) Hail to walker/horse 2) whistle bell prior to seeing walker 3) no major skids
2	signs warning bushwalkers and other trail users of mountain bikers using the trails would be good.
2	location signs
1	single track
1	twisty single track
1	drop offs
1	drop-offs
1	challenging terrain
1	wide variety of long linking trails
1	chair lifts
1	large berms
1	rhythms
1	emergency services phone no's
1	mobile towers (to get help when hurt)
3	payphones
1	facilities for changing punctures; road sweepers to clear away broken glass
1	ice cream machines
1	Mr whippy van
1	girls
1	good scenery, views, creek crossings
1	rubbish bins
1	trail maintenance
2	clean/not overgrown trails
2	details of nearest bike shop
2	difficulty ratings
2	friendly walkers
2	narrow
2	overnight shelters, water/cooking facilities
2	small camp sites similar to those planned for Hills Forest walkers

Question 10: How important are the following settings for you when riding?

Results of Likert scale (1='essential; 5='don't want at all') analysis for Question 10

Setting	mean	mode	n
Single track	1.54	1	181
Native bush/forest	1.59*	1	182
Plantation forest	2.32	2	182
Wide trail	2.54	2	181
Gravel road	2.72	3	181
Farmland	2.73	3	181
Sealed road	3.55	3	181
Built up areas/suburbs	3.62	4	182

Note: Responses ranged from 1 to 5; except *: range = 1-4

Question 11: Do you agree that: (n=183)

Results of Likert scale (1='strongly agree'; 5='strongly disagree')analysis for Question 11

Statement	mean	mode	No answer (#)	'Don't know' answers (#)
Trail damage by mountain bikes is overrated	1.65	1	5	17
Dieback is a big environmental problem in WA	1.70*	2	2	35
Good trail design can reduce trail damage	1.74*	2	2	7
Good riding technique reduces trail damage	1.81*	2	2	7
Trail damage varies with soil type	1.86	2	2	13
Rider education could reduce trail damage	1.91*	2	3	3
Mtb racing has more impact than touring	2.15	2	4	20
Mountain bikes should be allowed on all trails	2.19	1	2	2
Mountain bikes can spread dieback disease	2.26	2	3	36
Most trail damage occurs in downhill curves	2.26	2	6	20
It is enjoyable to ride the same trail repeatedly	2.49	2	2	1
Mountain bike riding damages trails	3.73	4	3	6
There are enough mtb trails	4.02	4	3	3
(means and modes exclude no answer and 'don't know')				

Note: Responses ranged from 1 to 5; except *: range = 1-4

Question 12: Would you be prepared to accept a voluntary code of conduct/trail etiquette? (n=183)

Results of Question 12

Category	'yes'	'no'	No answer	Total
%	91	4	5	100
not specified (% of yes or no answers)	9.6	14.3		

List of comments in answer to question 12:

n	Comment/Item
	If YES, what aspects would be important to you?
n	**Comment/Item**
65	respect other trail users
57	safety, both for riders and other users/ wear helmet; Notification on return
37	look after/respect environment/ flora & fauna; respect for bush
32	respect the trail; trail friendly riding style; stay on trail; minimise skids; tips to avoid excessive trail damage
17	leave no trace; no litter
10	courtesy, be friendly; Tolerance, consideration; cooperation
10	shared use by all, everyone has right to be on trail
9	maintenance of trails
6	respect from walkers/other trail users towards mtb (no pulling logs/rocks across trail)
5	cleaning bikes to ensure dieback is not spread; areas to scrub down tyres
5	let walkers and other riders know when you're coming./all mtb's should have bells
4	slower trail users give way to faster ones,
3	bikes should always give way to other trail users
3	refer to IMBA code of conduct
3	ride open trails
3	ride to your own ability; ride under control;
2	rubbish bins to reduce littering
2	common sense
2	do's and don'ts when riding
2	extreme care when meeting horses; slow down for horses;
2	help others in need
2	How to behave when warned by a cyclist (walker esp.) ie. move to a particular side of the track!!
2	pass walkers slowly/ slow down for walkers
2	restricting speed in certain areas
2	Ride in groups if possible; safety in numbers when in the bush
2	ride sensibly,
2	right of way for different users
2	Right of way guidelines,
2	same rules apply to all trail users
2	skilled riders to be patient & new riders to give way to skilled riders
2	trails to ride, locations etc (maps, brochures)
2	walkers have right of way
2	yield to horse riders & hikers
1	agreement on working to improve bush conditions (e.g. report fires, damage, clean up rubbish left by others)
1	Camp only where designated. follow usual bush safety + warning code of ethics + bike riding safety rules i.e. water, tool kit, emergency shelter, etc.
1	clearly mark no-go areas
1	dieback information, helpful hints
1	enjoy the outdoors
1	keep motor bikes off!
1	make dog walkers keep their digs on a lead.
1	plan ahead (ref: Australian Mountain Bike Magazine)
1	walk your bike around horses.
1	any user going downhill has right of way,
1	Avoid head on's with motor bikes
1	different COC's to suit type of trail: race vs multi-use;
1	do what you want, but don't harm others
1	education for all trail users (possibly license)
1	I will follow all codes just to be able to ride in more areas as I believe that this is important
1	keep left at all times; WALKERS give way to cyclists, cyclists give way to horse riders
1	no large groups other than racing (<10 riders)
1	nothing but bikes should be allowed on race courses.
1	parents control their children when riding in public places
1	Racing for race day! One way trails preferred on single track
1	run courses on mtb riding
1	separate trails for walkers
1	usual statutes and laws should apply
1	when someone stops in front of you they should get out of the way
	If NO, why not?
n	**Comment/Item**
1	freedom
1	people should ride the way they want
1	don't want to do too much work (just ride)
1	because I don't have enough time
1	It's not that important if you're mature enough and not an idiot.
1	not needed where I ride, not enough traffic

Question 13: What type of mountain bike do you ride? (n=183)

Answers to Question 13

Type of bike	No suspension	Front suspension	Dual suspension	Other	Total
% of 244 bikes (some respondents indicated more than 1 bike)	16	49	31	3	100

Number of bikes owned	1	2	3	4	Total
Respondents (%)	70	28	2	1	100

Owners of 1 bike	
Type	**%**
no suspension	19.5
Front suspension	56.3
Dual suspension	22.7
Other	1.6
Total	**100.0**

Owners of 2 bikes	
Bike combination	**%**
Front & dual suspension	70.6
No & front suspension	9.8
No & dual suspension	5.9
2 dual suspension	3.9
Front & dual suspension	3.9
Front suspension & other	2.0
Dual suspension & other	2.0
2 front suspension	2.0
Total	**100.0**

Owners of 3 bikes	
Bike combination	**%**
No & front & dual	75.0
No & front & other	25.0
Total	**100.0**

Question 14: How often do you clean your bike (including tyres and treads)? (n=183)

Frequency of bike cleaning by single answer respondents (in %)

Frequency	%	n
once a week	15.3	26
once a fortnight	13.5	23
once a month	10.0	17
every 3 months	5.3	9
every six months	4.1	7
once a year	1.2	2
after every race/ride	40.0	68
never	1.8	3
other	8.8	15
Total	**100.0**	**170**

List of answers given in the 'other' category by single answer respondents:

n	Comment
3	whenever it's dirty
3	whenever required
1	after really muddy rides
1	when it's muddy I hose it down at home
1	depends on how dirty it gets
1	depends where we have been riding
1	after riding in bush
1	general care as required
1	couple months if not race
1	when using for work on suburban roads: every two weeks; every time after use on dirt/trails
1	never tyres/treads; depends on season
15	**Total**
plus	**Specification of 'after every race/ride'**
3	after every race

Double answers: frequencies of combinations

n	Combination
3	After every race/ride & other
3	Once a fortnight & after every race/ride
2	Once a fortnight & other
2	Once a month & after every race/ride
1	Once a week & other
1	Once a month & other
1	Once a week & after every race/ride
13	**Total**

Answers in the 'other' category with frequencies

n	Answers in 'other' category
1	after every race
1	or if muddy, cleaned straight away
1	after muddy rides
1	when it's dirty
1	or as needed
1	whenever it needs it
1	depends if winter or summer
7	**Total**

Question 15: Are you aware of dieback risk areas? (n=183)

Answers to Question 15 in percent

Category	No answer	'no'	'yes'			Total
answers (%)	1.6	39.3	59.0			100.0
			Specified	**Not specified**	**Total**	
			85.2	14.8	100.0	

List of specified answers (n=167):

If yes please specify what a dieback risk area is and where they are found.			
#	Comments 'what'	#	Comments 'where'
18	area affected by dieback; fungus is present	25	Mundaring
7	fungal disease that kills bush and trees	18	native forest/bush; Jarrah forest
6	areas free of dieback	15	signposted
6	not enough information supplied	7	SW; Perth-Northcliffe; Mundaring-Albany
6	transfer of dieback spores by moving/taffic through affected areas.	4	State Forest
3	along ridges & streams where fungus can spread through water run-off	3	forest areas in SW with moist conditions essential for spread of dieback
3	An area of bush CALM has closed to public access to prevent the spread of dieback.	3	in the hills; Darling Scarp
3	area at risk as a dieback area is very close/surrounding it	3	marked on maps as DRA
3	soil borne tree disease	3	Sections of the Bibbulmun track
2	Dieback mainly affects Jarrah in WA	2	all around the southwest forest
1	A risk area is sensitive and travelling in the area could spread dieback.	2	National Parks
1	An area susceptible to the spread of phytophthora (cinnamomi usually) spores in soil carried by vehicles/shoes, etc.	1	around Dwellingup
1	An area where a permit is needed to enter so that dieback is not introduced to that area.	1	Bridgetown/Greenbushes
1	area is constantly at risk of being infected with the disease.	1	Donelly River
1	area where dieback may be present	1	Found all over
1	Area where native forests are threatened by dieback disease	1	found wherever Alcoa has been
1	areas CALM cannot properly manage so they keep closed using dieback excuse	1	Jarrahdale
1	areas where there is dieback or risk of same	1	Kalamunda trail, near Canning dam
1	Dieback is an accepted forest risk.	1	near the observatory
1	Dieback transmitted though soil/water	1	Pickering Brook forest
1	I am aware of them but not where they are and don't know a lot about them	1	some parts of Pile Rd.
1	I am now	1	some rehabilitation areas
1	Some areas are quarantined and cars/bikes would need to be cleaned of mud and soil to avoid spreading dieback.	1	too many to list
1	where CALM (etc) "believe" it is risk of fungi spores being spread. (It seems to be OK to do logging and for rangers to drive round in these areas?!...)	1	Unfortunately CALM/BUNNINGS appear to use it as an excuse to close areas.
1	Where CALM has block(ed) of(f) the track + trails because they perceive a dieback risk	1	Walpole
1	Where dieback can affect vegetation by intoduction. Not necessarily there yet.	1	Wellington Mills
	Tree and ground(?) soil affected areas need to have wash bays etc for users.		

Question 16: What age group do you belong to? (n=183)

Answers to Question 16 in percent

Age group	%
under 15	6.0
15-24	37.2
25-39	39.3
40-59	15.3
60+	1.1
no answer	1.1
Total	**100**

Question 17: Are you female or male? (n=183)

Answers to question 17 in percent

Category	Female	Male	No answer	Total
%	11	88	1	100

Question 18: Please tell us your post code (n=183)

List of post codes (in ascending order) and their frequencies

Metropolitan area (n=135) 73.8%									
#	**Post-code**	**#**	**Post-code**	**#**	**Post-code**	**#**	**Post-code**	**#**	**Post-code**
2	6000	2	6023	2	6061	2	6101	3	6153
1	6006	1	6024	3	6062	5	6102	1	6154
2	6008	3	6025	1	6063	1	6107	5	6155
4	6009	1	6027	1	6065	2	6110	1	6156
1	6011	2	6050	5	6070	2	6111	2	6157
5	6014	3	6051	2	6071	2	6112	1	6158
4	6016	3	6053	5	6076	1	6121	1	6160
1	6018	2	6054	2	6081	3	6148	1	6162
4	6019	2	6055	4	6082	3	6149	4	6163
2	6020	9	6056	1	6083	3	6151	1	6168
1	6021	1	6057	2	6100	3	6152	1	6169
1	6022	2	6058						

Non-metropolitan areas (n=48) 26.2%					
#	**Post-code**	**Town/area**	**#**	**Post-code**	**Town/area**
1	6201	Byford	1	6253	Balingup
1	6210	Mandurah	4	6258	Manjimup
2	6213	Dwellingup	1	6280	Busselton
1	6220	Harvey	1	6330	Middleton Beach
10	6230	Bunbury area	3	6398	Walpole
2	6232	Eaton	5	6450	Esperance
4	6233	Australind/Leschenault	2	6531	Geraldton
1	6234	?	1	6566	Toodyay
3	6236	Wellington Mills			
4	6237	Boyanup	1		**Holland**

Question 19: Is there anything else you would like to tell us? (n=99)

List of comments sorted by theme and frequency:

Frequency	Category and comments (comments transcribe literally)
101	**Total**
37	**Trails** ***(sub-categories)***
9	***Bibbulmun Track***
	trail similar to Bib Track should be established; old Bib Track marked out properly
	like to see all forms of MTB racing catered for in WA. Would like a Bib style track in WA to cater for touring through forest
	A MTB "Bibbulmun Track" designed by MTBers and built by the prisoners. Huts at every 51km's + #erous loops from Perth.
	A touring trail similar to the Bibbulmun track would be good - ideal for all ages and fitness levels and skill I.e. family - no too technical or difficult.
	What is the possibility of setting up a mountain bike only network of trails in the same area that the Bib track covers. This is what mountain bikers need. An alternative to race tracks. Some areas where you can carve up tracks and maintain them with voluntary work. Should have printed this ahead of the question EWEN.
	Marked trails like the Bibbulmun are essential for mountain bikes. web site wrong
	We want Bib track
	Push for access to the Bibbulmun track. It should not be for a few elite walkers.
	"why not" use old (disused) railway tracks as bike trails (as in John Forrest N/P) also permit trail bikes on Bibbulmun Track [*I assume he meant mountain bikes*; U.G.]
9	***Other***
	Trails need to be designed and continually developed by MTB'ers. They need to be a choice of long or short trails with loops and connecting sections.
	establish true mtb park, possibly forfeit some trails to walkers.
	important that safe trails are mapped and advertised so that all riders incl. those new to the sport can find suitable trails.
	there should be more dual slaloms and compressors
	For construction of trails it would be nice if Trailswest contacts the Mountain Bike Clubs for some consultation as our members are all keen to help out with areas and the building of trails.
	Can you make sure that there is a dual line in the middle of the track so that riders always stick to the left.
	Yes if new trails are made, please let me know, thank you
	Please sort out confusion over Kalamunda circuit/ Bib Track
	I have been on the hiking trails around Collie area & have never seen any hikers or walkers at all. The tracks are very overgrown and hard to see & I feel a controlled bike ride through these areas would be beneficial to all.
7	***More trails***
	more trails and trail access wanted
	we need more trail markers
	If I were to live in Moab, Utah, USA I could probably ride a different trail every week for the rest of my life, including the world famous Kokepelli trail.In WA we have the Winjan trail - big deal!
	More trails would be good.
	There needs to be a closer working relationship with CALM & the public so more DH trails can be available, that are not miles away. Downhillers are responsible racers. There are many mountain bike riders in Perth and the suburbs and we need places where we can ride and race our bikes. We have spent a lot of money to purchase and maintain our bikes (in many cases many thousands of dollars). But currently we have to ride in places which are a long way away. BMX riders get their own tracks that are local. Why can we not have a few areas in the local hills set aside for us so we can ride, race, practice + have fun. Surely out of the large amount of land that is in the Darling range there is some places that can be used by us.
	more local downhill tracks would be good. These only have to be 2-4 minutes ling and

	could be used for racing and/or practice, as DH is becoming very popular
	More tracks!!!
5	***Single track***
	need more single track
	most trails mtb's enjoy are originally single track walk trails;
	If more tracks get marked, make them single track, which can double as walk trails, but not too flat & straight (we are **mtb riders**). spread the trails, there are heaps in midland, lets see some in Armadale Hills and Freo
	I believe strongly when considering MTB trails there needs to be a distinction between the needs of the recreational rider and the enthusiast. The enthusiast seeks out single track not wide tracks or roads and more often than not, races. These riders seek challenging courses.
	When developing mountain bike trails there needs to be a distinction between recreational riders trails and experienced riders (enthusiasts) who require more difficult, challenging trails.
3	***Location***
	we need a trail from Balingup to Nannup and along the old railway on St Johns brook.
	would like to see some trails in forest that has not been logged/cleared previously!
3	***'Metro' trails***
	I would like to see a MTB trail within the central metro area. At present most riders can not get in any mid-week practice rides, apart from road riding.
	Please make trails close to Perth and Fremantle if possible. 51km is quite a hike for a trail especially when relying on your parents to drive you
	be nice to know of more "urban MTB TRAILS";
2	***Access***
	Restrictions to riding areas only promotes the area because it's restricted. Access to all trails would see an even spread of use and maximise enjoyment for all. If erosion is of concern - time restricted access would promote regrowth & better care of an area to have it available more often.
	From experience in Canada, if known trail access is restricted, illegal (often more interesting) trails will spring up with no control. - Resist the temptation to clear trails too much, bush walkers and mtn bikers prefer it that way. -
24	**Other**
	coming from Canberra Perth is despairingly flat; off-road riding only at races, 6 this year, soul-crushing.
	Mtb riders tend to be younger than walkers/other trail users;
	Also legislation to permit riders to not have to wear helmets on cycle tracks. I hate helmets and I hate having to wear one. I can understand why children have to wear them, but I don't think adults should be forced to wear them especially on a cycle track!! Can something be done about it?
	dislike day hikers (not enthusiasts); love old grannys that cheer you on as you ride by.
	single track kicks
	foes rule o.k.
	I find that the organisation of Mountain Bike races need to be much better than it is presently.
	MTB riding is good fun, but as always there are yahoos etc. who ruin it for the rest of us.
	outdoor activities should be encouraged not persecuted
	I believe that WA has to get its act together with mountain biking. The clubs are fine but I don't agree with all of CALMs ideas as they are not doing anything for the growing sport of mountain biking.
	It would be good to have links to the Bibbulmun Track page on the internet. Pictures of the trails + facilities would be most helpful in planning rides.
	love to ride Australia
	I like the Australian bush settings to ride in away from pollution and the noise of the city + vehicles and watching the changing seasons impacting on the bush.
	see you on the mountain bike trails
	Great sport & excellent family activity

	save old growth forests; save the whales
	to get as many people as possible to know how to ride a pushbike (any) to avoid car pollution
	Please do not consumerise trail riding! Keep our trails as unspoilt as possible.
	Mountain biking is a sport that can be beneficial to people's health and awareness of nature.
	I am currently not a mtb club member because I have been transferred to Manjimup but I am looking (since settled) to join the closest (Pinjarra) {previously with Nedlands-Claremont + continued involvement in the sport}
	WA needs bigger hills, preferably mountains for longer Downhilling
	I can't believe that walkers & horse riders believe that mtb riders 1. wreck trails, 2. spread dieback and they don't and 3. are all a bunch of hooligans with no respect or trail manners
	Mtb is mainly a winter sport in WA and other trail users do not emerge until weather is 21+C.
	Everlasting Downhill! with chainlift to get to the top!; Spring weather year round!
12	**Environmental damage**
	down hillers don't need a lot of land and we don't destroy the environment, unlike motor bikes + 4WD's.
	Horses and trail bikes cut up single track. Trails should be constructed to cause minimum erosion. Alternative routes for trails that are susceptible to erosion in summer or winter.
	MTB'rs DON'T cause A LOT of erosion, not half as much as horses or motorbikes of 4WD's - just check the tracks for prints and erosion… for yourself (if you're not out there how can you understand?
	mtb riders aware of env. & careful, except young ones
	mtb's don't create the probs most people believe they do, spurred on by unfriendly encounters with hikers etc.;
	since taking up mountain bike racing my family have become more aware of what the bush and nature offer and to respect with care.
	I think people underestimate how good mountain biking is. People think it damages the bush and wildlife but I say mind your own business. Mountain biking does minimal damage if you keep to the trails.
	Mountain biking should be strongly encouraged. It is low impact when well managed + encourages people to get to know, love and therefore protect natural ecology areas.
	I think that mountain bikes have a minimum impact on the environment (dieback) and authorities should look at the REAL causes of environmental problems rather than picking on a relatively harmless recreation activity by people who appreciate the environment
	The only places where trail damage of any significance occurs is on DH race courses. All other trails are generally smoothed out by walkers & XC riders & trail condition usually improves as a result of this. PS. I race DHG only & know few race courses there are & how small a problem trail damage from them really is.
	Mtb riders are looked upon as an extreme sport with extreme attitudes that don't consider risks associated with riding in sensitive areas. This is an old argument put forward by traditional trail users to close trails to Mtb riders. It is a completely unfounded argument. This can be seen in many other countries who have already gone down the path of banning mtb riders. Now trails are opened up and managed better than ever.
	Mtb should be able to be ridden in catchment areas - no noise, pollution, etc.;
10	**Questionnaire and survey**
	Congratulations for your interest & good luck!!
	I think the idea of Trailswest is great. About time the government showed an interest in someone other than walkers.
	more questionnaires like this
	good survey, great job
	Happy to help in any other way with your project (contact no provided)
	happy about survey; been a long time coming; hopefully helps everyone to get along with each other; thanks
	excellent idea for a study!

	Keep up the great work!
	Please distribute your results to all mountain bike clubs (including the Perth MTB Club), It will be interesting to read your findings. Other than that, thanks for allowing mountain bikers to participate in the survey.
	Have a nice day. Good luck with the survey.
10	**Information and education**
	And info where the tracks are and what tracks they are
	More publicity about cycle trails on and off road would be good.
	People want to ride, but are unsure of "proper" places to ride. There needs to be a "rider" education offering maps, brochures, etc., & other types of info readily available to the rider.
	People need to know where trails are that CAN be ridden on. Trails need to be clearly marked.
	There should be a booklet of maps for Mtbike trails in the surrounding hills of Perth. And other districts.
	Produce maps of tracks around Mundaring, Kalamunda + further south.
	education - education – education. Especially within our youth.
	Non-riders need to be informed about what MTB really is.
	rider training would be beneficial, prepared to donate time and knowledge
	not enough info on dieback risk areas
9	**Dieback**
	I think that if trails are in dieback affected areas there should be bike cleaning facilities with chlorine in the water for riders to wash their bikes before they leave.
	When I ride in dieback areas I encounter pigshooters, rally cars, 4WD's, wood collectors, bushwalkers and hashhouse runners. These are all give permission to enter restricted areas (and no they don't wash down!), why are mtb not allowed?
	Too many restrictions on mtb trails; re: dieback: logging of native woodland is a bigger problem
	I have often been told that we spread dieback on our tyres, but I fail to see what the difference is with hikers' boots, I'm sure they would spread it as well
	In regard to dieback CALM sets a poor example 95% of the time.
	Native animals/weather would spread more dieback than MTBers on trails!!
	MTB and dieback is overrated! Kangaroos would spread it more!;
	Please help us ride in the dieback areas legally because they rock and they could have hosing-down stations at the entrances. Most forests have ranger tracks used by hikers and even rally cars!
	PLUS I hardly believe my Mtb is a dieback risk transporter not when ALCOA deliberately infect areas so they are able to mine for aluminium. All trail users have the capacity to transporting dieback to single out MTB is unfair.
6	**Trail maintenance**
	More responsibility needs to be taken by MTB clubs who build tracks for races, to maintain these tracks after the races. This is especially relevant to downhill courses and downhill sections in XC races. Clubs should return after the races and repair and consolidate the tracks.
	people would respect trails more if trail maintenance committees involving all users were organised; involve all clubs, mtb and others.
	review markers regularly (trees can fall over etc.)
	Important to spend $ and time maintaining trails, not just building/construction.
	It would be nice to see some people get into action and start a volunteer trail maintanance programme.I would be happy to join as this could help prevent disease spreading.
	Initiate trail maintenance programs, you might be surprised.
6	**Multiple answers**
	Trials is good, ok. Most trail riders would respect reasonable rules and guidelines if more trails were open to mtb's.
	I believe that old railway routes should be converted into MTB trails and should be properly maintained. These should be widely publicised both nationally and internationally.

	need to push for access to the Bib Track. A properly conceived lobbying, concentrating on a code of conduct and the benefits to towns along the track (o/s mtb tourists etc.), could open up this much underused track to many more people who are not walkers.
	We all can share trails as long as everyone does their part and respects where they go. If we are supplied toilets, bins & drinking facilities then littering can be reduced & it promotes that area to tourists etc.)
	Bibbulmun should be open to MTB - I've ridden very consistently over many years very limited walkers - with track rules eg. bells or whistle to let walkers know we are coming rather than startling them, they wouldn't hate us so much. Dieback is a problem - education (wash downs). Bibbulmun 3 weeks walking? how many users - 1 week riding how many users - more potential.
	A code of etiquette which dictated the way trails were ridden in certain areas may be of benefit in conservation areas which may not be otherwise be ridden. Perhaps riders could receive accreditation from a course which would demonstrate the basic skills necessary to b=negotiate trails with lower impact and how to wash down tyres for dieback etc. Maybe a license fee to those who complete this.
6	**'No'**
4	**Code of Conduct**
	Plus: Please develop a standard warning for cyclists to use to get people out of the way & have the walkers understand what to do in the event that riders want to pass.
	code of conduct would be good for mtb 'image'.
	Produce a book for hikers, walkers, riders on Bush Code of Existence.
	Mountain biking is a valid recreational use of land but we must act responsibly. You see a lot of riders doing the wrong thing.
4	**Shared use**
	everyone has a right to be on existent trails;
	walkers don't like to share trails & don't know how much fun mtb is; tend to be unhappy bunch; mtb riders have live and let live attitude
	my experience over the world: in USA everyone is selfish-walkers/horse riders want the trails to themselves & bike riders are sometimes disrespectful to those people. In Europe- even on a walk trail-riders and walkers will pass considerately & smile & say hello- they are aware they have to share the world & everyone is happy
	Every road to have a cycle path or to share use of pavement with pedestrians.
1	**Safety**
	When out on the trails you should never go alone because it is vital for safety, eg. Accidents can be FATAL if alone. Must be with two or more people.