The assessment, monitoring and management of hiking trails: a case study from the Stirling Range National Park, Western Australia

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SUMMARY

Degradation of hiking trails is a recognised worldwide problem, but as of yet, no standard system for the assessment and monitoring of trail degradation has been established. The purpose of this study was to apply a trail problem assessment method, similar to that developed in the USA, to walking trails in an Australian national park, in order to assess the method's suitability as an international system for assessment and monitoring. The assessment method was also developed further to evaluate the effectiveness of trail maintenance. Results indicate that the method is well suited to a variety of trails, and provides an efficient system, however the method becomes more resource intensive when used for trails longer than 5 kilometres in length. The method provided detailed trail profiles describing selected environmental variables, degradation problems and maintenance. Assessment of constructed features revealed that efficient constructed features maintain good trail condition. Efficiency is achieved through the provision of sufficient numbers of constructed features and their regular upkeep.

Key words: Hiking trails, assessment, management monitoring, Western Australia

INTRODUCTION

Hiking impacts and degradation of trails is a recognised worldwide problem and presents as a significant management issue in many protected areas around the world. Trail usage results in various physical, biological and social impacts that degrade both trails and the surrounding environment. Physical impacts of trail use include soil compaction (Newsome *et al.* 2002), soil erosion (Leung and Marion 1999), track widening (Bayfield 1974; Leung and Marion 2000), increased bare ground (Cole and Spildie 1998), root exposure (Jewell and Hammitt 2000), wet or muddy tracks (Leung and Marion 2000), the creation of multiple tracks (Leung and Marion 2000) and disturbance of aquatic systems (Jewell and Hammitt 2000). Biological impacts such as fauna disturbance and vegetation damage, and social impacts including vandalism, litter, loss of wilderness values, unsafe travelling conditions and user conflicts on multi-use trails can also occur as a result of trail use (Cole and Spildie 1998; Deluca *et al.* 1998; Jewell and Hammitt 2000; Newsome *et al.* 2002).

Constructed features (eg. water bars and board walks) and continual upkeep of trails can minimise trail degradation (Burde and Renfro 1985; Marion and Leung 2001). Trail management includes educational and regulatory actions, as well as various management actions. Successful management is also dependent on formal systems of assessment that provide a sound basis for monitoring change. Such systems have been developed in the USA but have not been applied widely outside the US. Despite studies having been undertaken in the UK, Europe, USA and Australia (Bayfield 1973; Coleman 1977; Bratton *et al.* 1979; Sun and Walsh 1998; Leung and Marion 2000) there is, as yet, no international standard for assessing trail condition, Moreover, few studies have directly examined the influence of management on degradation.

The aim of this paper is to report on the application and usefulness of a Trail Problem Assessment Method (TPAM), developed in the USA by Leung and Marion (1999), and assess its suitability as an international system. We also developed the TPAM further in order to measure the impact that management maintenance actions have on trail degradation.

Case study: Stirling Range National Park, Western Australia

The Stirling Range National Park is located 330 km southeast of Perth and 75 km north of Albany in the south-west of Western Australia (Moon and Moon 2000). The park consists of two reserves, and covers a total area of 115 920 ha. (Figure 1). The Stirling Range National Park is managed by the Western Australian Department of Conservation and Land Management (CALM) for the Conservation Commission of Western Australia (Morphet 1996).

Records of park use prior to the 1960's are limited, although it is known that a local tourist association formed in the 1920's made efforts to construct roads in the area (Watson, 1993). Major road works occurred in the late 1960's when most of the current firebreaks and trails were established (Gillen and Watson 1993). Little is known about visitors to the park, although visitor numbers have increased over the years. Almost 42 000 cars were recorded in the Bluff Knoll car park in 1993,

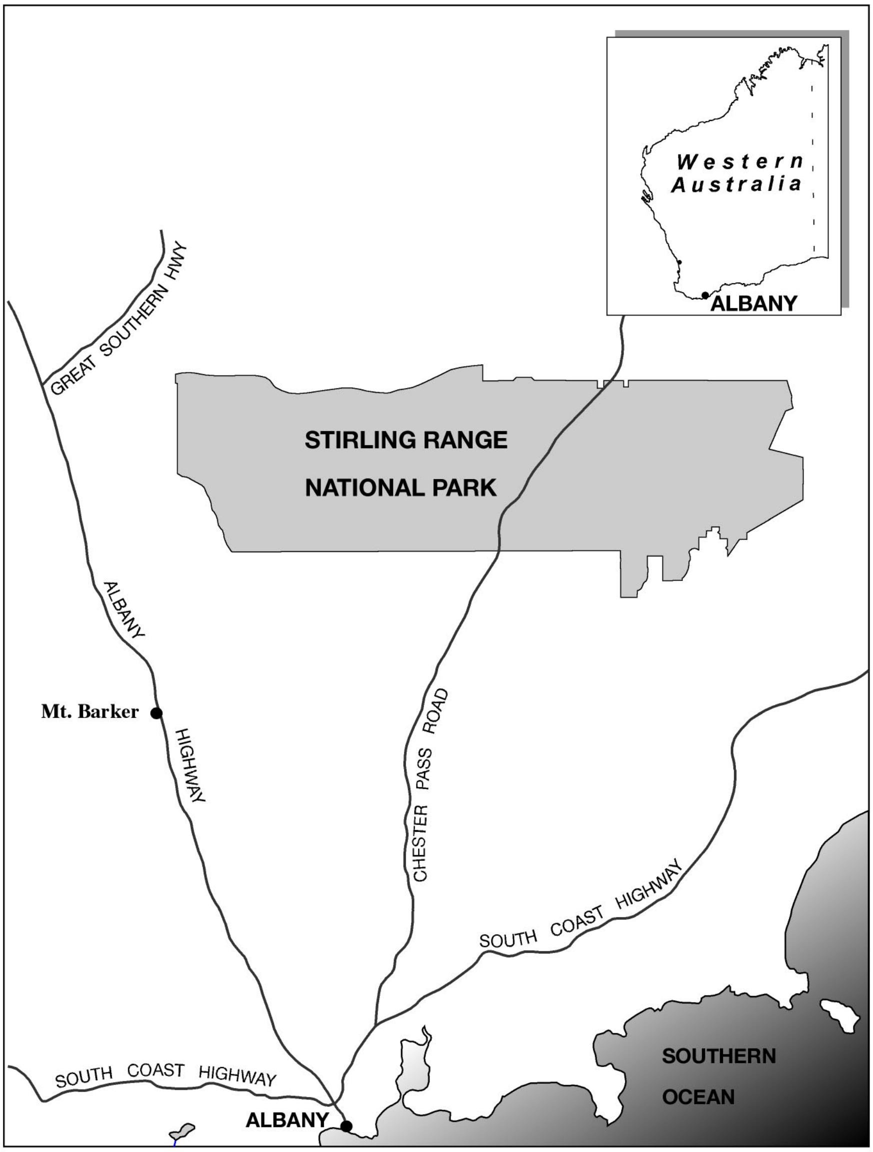

Figure 1. Map of the location of Stirling Range National Park, Western Australia.

and this figure rose to almost 50 000 in 2001 ([1]Harnett, pers. comm. 2002). In 1997–98, 90 000 people were estimated to have visited the Stirling Range National Park (CALM 1999). Exact visitor numbers walking various trails in the park are not known. However, the most popular trail is Bluff Knoll, which receives approximately 30 000 visitors per year (Bain, pers. comm. 2002).

There are currently ten formal trails to summits in the Stirling Range National Park, covering a total of 32.7 km. (Figure 2). The trails in the Stirling Range National Park are restricted to pedestrians. Horse riding, cycling and off-road vehicles are not permitted due to the risk of spreading dieback disease an accidentally introduced fungus, *Phytophthora cinnamomi*, which has been shown to kill a wide range of plant species (CALM 1999). However, under road traffic regulations, these forms of transport are all permitted on the public roads in the park.

There is currently no formal management strategy for the trails in the Stirling Range National Park. Two rangers oversee the park and are responsible for maintaining the trails. Monitoring consists of walking the trails and making a mental note of the problem areas, which are repaired at a later date ([1]Harnett, pers. comm. 2002). Bluff Knoll is monitored as often as once a week during periods of heavy visitation. Mt Hassell, Mt Talyuberlup and Mt Trio are only monitored once a year. Written records of monitoring are kept ([1]Harnett, pers. comm. 2002). Maintenance involves the repair of problem areas as noted by informal monitoring.

[1] Ranger in Charge, Stirling Range National Park, Department of Conservation and Land Management

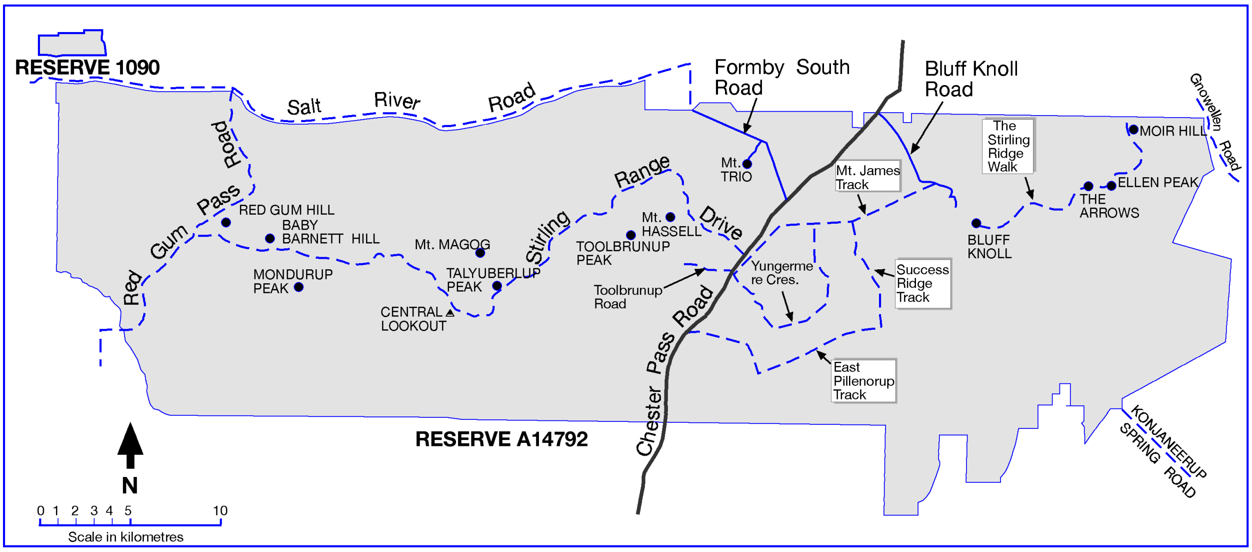

Figure 2. Location of footpaths in the Stirling Range National Park.

Research methods

Fieldwork was completed from 27 May to 14 June 2002. During this time, all the major recreational trails in the Stirling Range National Park were assessed to provide comprehensive baseline information on trail condition in the park. The trails in the park were evaluated by walking each trail from the summit to the start of the trail. This facilitated trail assessment by decreasing time taken to measure variables, as it was easier to walk uphill first and measure downhill, rather than to measure uphill. The total distance of each trail was measured by pushing a measuring wheel (100 cm circumference) along its length. Numerous variables categorised as descriptive variables, trail degradation indicators and constructed features were evaluated along the length of each trail (Table 1). Both point sampling and the trail problem assessment method (TPAM) were used to assess trail condition. It was decided due to time and resource constraints, and in order to provide an efficient and easy evaluation of the trails, that some variables were better suited to point sampling whilst the TPAM was more appropriate for other variables (Table 1).

Point sampling provided a fast, efficient and precise method of measuring three descriptive variables at intervals of 100 metres. Descriptive variables give an inventory of general footpath attributes and provide information for footpath planning and management (Monz 2000; Marion and Leung 2001). A database of current footpath condition can be built through the

TABLE 1

Variables assessed to evaluate trail condition in the Stirling Range National Park

POINT SAMPLING	RAPID PROBLEM ASSESSMENT METHOD		
DESCRIPTIVE VARIABLES	DESCRIPTIVE VARIABLES	DEGRADATION INDICATORS	CONSTRUCTED FEATURES
Trail width Slope Rockiness (% rock cover)	Soil texture	Erosion – E1: A segment of the trail that has been eroded 5 to 10 cm below the estimated original surface level. – E2: A segment of the trail that has been eroded 11 to 15 cm below the estimated original surface level. – E3: A segment of the trail that has been eroded 16 to 20 cm below the estimated original surface level. – E4: A segment of the trail that has been eroded more then 20 cm below the estimated original surface level. Excessive trail width Multiple trails Exposed roots	Constructed features – benches, board walks, bridges, boot cleaning stations, retaining walls, sand traps, signposts, stairways, water bars

evaluation of degradation indicators. Such indicators can be utilised to monitor footpaths for on-going deterioration. In particular the assessment of soil erosion provides a trail inventory that identifies problem areas. Measurement of erosion was started at 5 cm, as this is clear evidence that erosion has been initiated. Increases in 5 cm intervals as indicators of progressive severity were chosen to facilitate data collection. Excessive track width is taken as a segment of footpath that exceeds a width of 130 cm. Multiple trails reflect former off-road vehicle tracks or more commonly the creation of social trails that proliferate from the formal managed trail. Root exposure was measured as a segment where the top and sides of roots are visibly exposed. The depth of exposed root was recorded as the maximum depth measured from the top of an exposed root to the soil surface, perpendicular to the footpath surface.

Constructed features are an important management tool used to counteract footpath degradation. It is important to evaluate constructed features in order to provide information on existing or needed maintenance work on the path (Marion and Leung 2001). Constructed features were interpreted as an object constructed out of natural or artificial materials to maintain and manage the footpath, increase user comfort and/or provide information to footpath users. Although typically not considered as a construction feature that helps to reduce trail degradation 'boot cleaning stations' are included here because of their importance in the Australian context of helping to prevent wider ecosystem damage as a result of *Phytophthora* spores being moved via a trail network.

The data for individual trails were tabulated. Comparisons between descriptive variables, degradation indicators and constructed features were made through graphical representations. Data for all the trails were averaged and tabulated to enable comparisons between the trails.

RESULTS

Descriptive variables

The longest trail assessed was Bluff Knoll, although a longer trail, the Stirling Ridge walk extends from Bluff Knoll to a firebreak past Ellen Peak, covering a total distance of 17 km (Figure 2). Only 3 km of the Stirling

TABLE 2

Comparison of erosion recorded on the footpaths in the Stirling Range National Park

FOOTPATH	AVERAGE EROSION 1 (M/100M)	AVERAGE EROSION 2 (M/100M)	AVERAGE EROSION 3 (M/100M)	AVERAGE EROSION 4 (M/100M)	AVERAGE TOTAL EROSION (M/100M)
Baby Barnett Hill	15.4	0.0	0.0	0.0	15.4
Bluff Knoll	14.9	0.2	0.4	0.0	15.5
Central Lookout	15.6	0.0	0.0	0.0	15.6
Mt Hassell	14.8	1.6	0.0	0.0	16.4
Mt Magog	8.6	6.4	2.3	0.1	17.4
Mt Trio	0.7	0.0	0.0	0.0	0.7
Red Gum Hill	40.3	2.7	0.0	0.0	43
Stirling Range Walk	20.6	4.5	0.0	4.1	29.2
Talyuberlup	23.1	20.9	10.3	23.8	78.1
Toolbrunup	0.0	0.0	0,0	0.0	0.0

TABLE 3

Comparison of excessive width, footpath proliferation and root exposure recorded on the footpaths in the Stirling Range National Park

FOOTPATH	AVERAGE EXCESSIVE WIDTH (M/100M)	AVERAGE FOOTPATH PROLIFERATION (M/100M)	AVERAGE EXPOSED ROOTS (#/100M)	AVERAGE DEPTH OF EXPOSED ROOTS (CM)
Baby Barnett Hill	0.0	0.3	3.8	1.8
Bluff Knoll	0.3	0.5	6.1	3.0
Central Lookout	1.2	3.6	7.9	6.5
Mt Hassell	0.1	5.7	12.5	4.6
Mt Magog	0.0	32.3	6.9	4.2
Mt Trio	0.0	1.2	2.6	3.1
Red Gum Hill	0.0	0.0	5.0	2.0
Stirling Range Walk	0.2	13.9	9.9	2.9
Talyuberlup	6.4	2.8	24.7	9.4
Toolbrunup	0.6	1.8	6.0	7.3

Ridge walk was evaluated. The shortest trail was Central Lookout, at 390 metres. The steepest trail was Talyuberlup with an average slope of 39 degrees, followed closely by Toolbrunup (34 degrees) and Mt Hassell (33 degrees). Central Lookout had the gentlest average slope of 16 degrees. The average trail rockiness varied from 21 percent (Bluff Knoll) to 98 percent (Toolbrunup). Bluff Knoll was the widest trail, with an average width of 123 centimetres, whilst the narrowest trail was the Stirling Ridge walk (Ellen Peak section) at 50 centimetres.

A total of nine soil types were recorded on the trails. Clayey sand was the most common soil type, covering a total of 5.3 km of trail in the park. Other soil types Degradation indicators

Erosion E1 was the most common degradation problem on the trails (Table 2). The Talyuberlup trail was the most eroded trail in the park (Figure 3). Talyuberlup had the highest average erosion E4 (23.8 m/100 m), E3 (10.3 m/100 m) and E2 (20.9 m/100 m), as well as the highest total erosion (78.1 m/100 m). The Red Gum Hill trail was the second most eroded trail in the park (43 m/100 m) and had the highest erosion E1 (40.3 m/100 m). The least eroded trail was the Toolbrunup trail, which had no erosion (Figure 4). Exposed roots were also found on all the trails (Table 3), mainly occurring in conjunction with erosion. Talyuberlup had the highest number of exposed roots (353), whilst Mt Trio had the least amount (43).

Trail proliferation (Table 3) occurred on all trails except Red Gum Hill. There were 97 instances of trail proliferation in total, covering a total of 1.7 km. Mt Magog had the most trail proliferation in terms of metres (32.3 m/100 m), although the majority of the proliferation on Mt Magog was old vehicle tracks that were in the process of being rehabilitated. Central Lookout had the highest number of extra trails (1.5 extra trails/100 m). The Stirling Ridge walk had the second highest amount of trail proliferation (13.9 m/100 m), and the second highest number of extra trails (1.2 extra trails/100 m).

Excessive width (Table 3) was the least common problem in the Stirling Range National Park, occurring 25 times, but only covering a total distance of 0.1 km. Most trails recorded less than one percent of excessive width, with four trails recording no excessive width at all (Table 3). The Talyuberlup trail was most affected by excessive width (6.4 m/100 m).

Constructed features

The constructed features found on the trails are listed in Table 1. Most trails assessed had an average of less than six constructed features per 100 metres, although Baby Barnett Hill and Red Gum Hill had no constructed features (Table 4). Whilst Bluff Knoll had the highest total number of constructed features (1215), Mt Trio

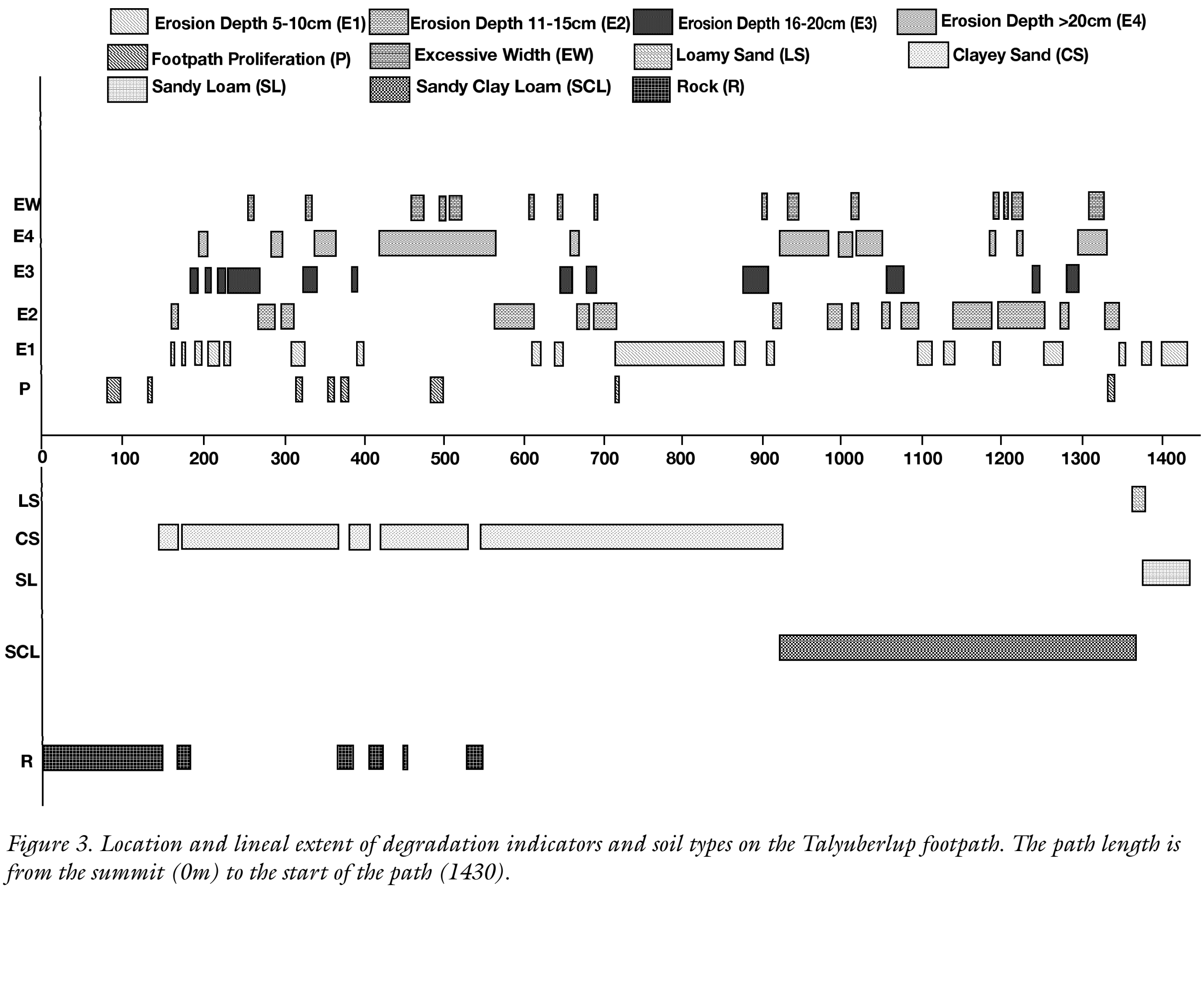

Figure 3. Location and lineal extent of degradation indicators and soil types on the Talyuberlup footpath. The path length is from the summit (0m) to the start of the path (1430).

had the most constructed features on average (43.7/100m). The Mt Trio trail also had the most features designed to assist in degradation control (725 boardwalks, bridges, retaining walls, sand traps, stairways and water bars). Mt Hassell had the most signposts (57), followed by Toolbrunup (53).

At least 79% of the constructed features found on each trail were in good condition (Table 4). The Toolbrunup trail had the highest percentage of constructed features in moderate condition (16.9%) whilst Talyuberlup (Figure 5) had the most constructed features in poor condition (13%). Despite the fact that the majority of constructed features in the park were in good condition, many were found to be either moderately effective or ineffective. For example, all of the constructed features on the Central Lookout trail were in good condition, but only 18.2% were very effective, with 54.5% being moderately effective and 22.8% being ineffective. The Talyuberlup trail had the highest percentage of ineffective features (Figure 6) (56.3%). Mt Trio and Bluff Knoll had the highest percentage of very effective constructed features (99.3% and 91% respectively).

Table 4

Comparison of the number, condition and effectiveness of constructed features recorded on the footpaths in the Stirling Range National Park

FOOTPATH	TOTAL NUMBER	FEATURES IN GOOD CONDITION (%/100)	FEATURES IN POOR CONDITION (%/100)	VERY EFFECTIVE FEATURES (%/100)	INEFFECTIVE FEATURES (%/100)
Baby Barnett Hill	0	0	0	0	0
Bluff Knoll	1215	96.3	0.7	91	1.4
Central Lookout	22	100	0	22.8	22.8
Mt Hassell	68	97	0	85.0	1.5
Mt Magog	179	83.8	5	76.2	6.0
Mt Trio	725	99.7	0	99.3	0
Red Gum Hill	0	0.0	0	0	0
Stirling Range Walk	29	98.7	0	77.8	0
Talyuberlup	23	87	13	31.2	56.3
Toolbrunup	54	79.2	5.7	80.8	9.2

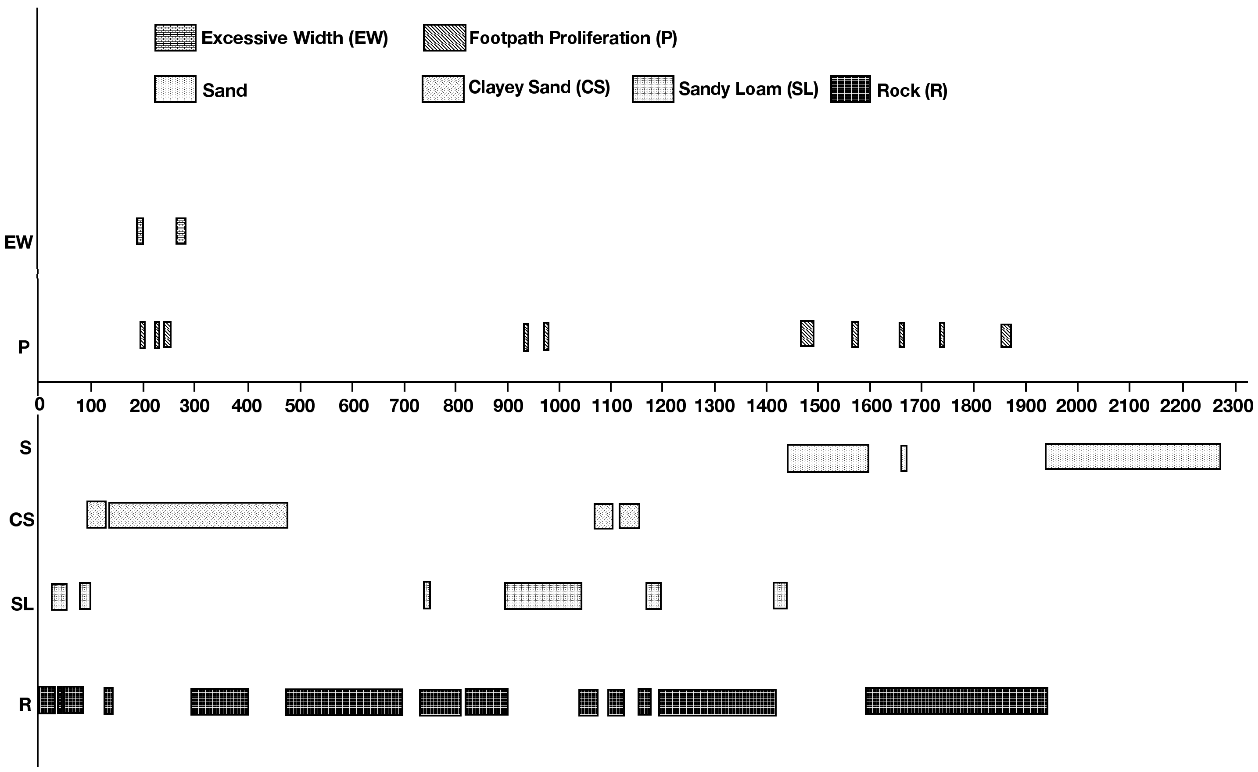

Figure 4. Location and lineal extent of degradation indicators and soil types on the Toolbrunup footpath. The path length is from the summit (0m) to the start of the path (2266m).

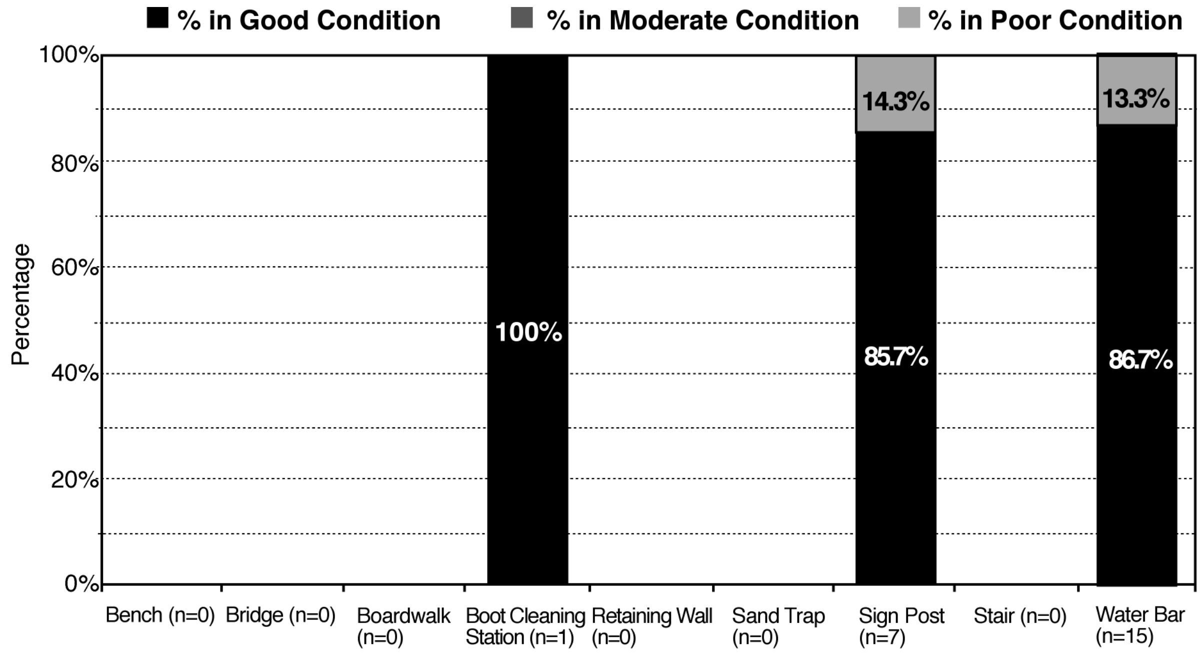

Figure 5. The percentage maintenance features on the Talyuberlup footpath classified as being in good condition, moderate condition and poor condition.

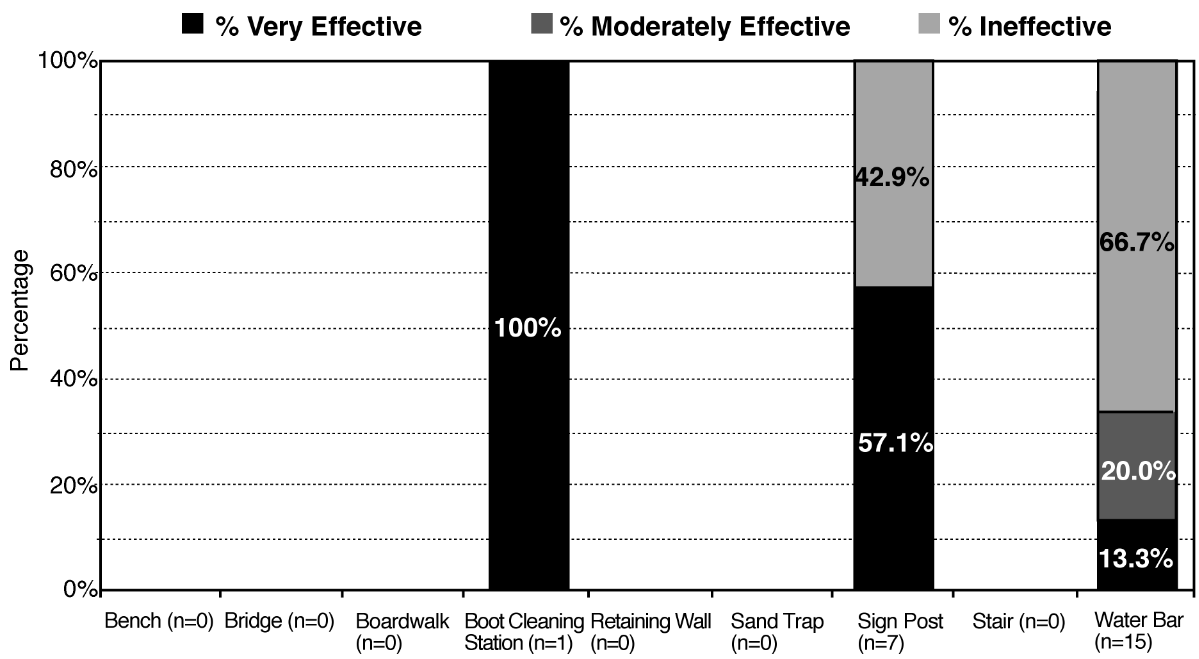

Figure 6. The percentage maintenance features on the Talyuberlup footpath classified as very effective, moderately effective and ineffective.

DISCUSSION

Degree of maintenance of constructed features in the Stirling Range National Park

The current levels of degradation on some of the trails, in particular the high percentage of erosion occurring on most trails may be due to a combination of historical factors such as poor trail location and the on-going use of user-developed trails (trail proliferation) which in some cases arose from old off-road vehicle tracks that had been used to access lower lying areas. The results also suggest that on some trails not enough effective constructed features have been installed or that regular maintenance has not been carried out to ensure maximum effectiveness of constructed features.

Regular trail maintenance should include the upkeep of constructed features, to ensure that they are in good condition and very effective. Some trails, such as Central Lookout and Talyuberlup had a high percentage of moderately effective or ineffective constructed features. This could be rectified by maintenance. For example, most of the water bars on the Central Lookout trail were moderately effective (54.8%) to ineffective (22.8%) because debris, namely gravel and small rocks, had built up around the water bars. Regular maintenance would keep water bars free of debris, making them more effective.

Ongoing trail maintenance is also very important in the Australian context in that it helps to control the spread of *Phytophthora cinnamomi*, the spores of which are spread through the movement of water through soil, and also through the movement of eroded soil. The further water or eroded soil moves, the further the spores can move. Infected upland areas can act as a source of spores that spread downhill as water is shed off trails and eroded soil moves downslope (see Newsome 2003). Ongoing maintenance can ensure that water flow along trails is minimised and that water is dispersed into specific drainage areas before it can build up to any appreciable volume. Such actions will help to prevent soil erosion and in doing so will reduce the wider spread of *P. cinnamomi*. The Bluff Knoll and Mt Trio trails were the only trails that had maintenance work done in 2002 ([2]Bains, pers. comm. 2002). Marion and Leung (2001) discuss the importance of trail management, including the installation and upkeep of adequate constructed features (Table 1), and highlight that these actions are vital to limiting trail degradation.

Condition of constructed features versus effectiveness of constructed features

Assessment of the constructed features on the trails in the park revealed that constructed features in good condition did not necessarily mean they were very effective. For example, 100% of the constructed features on Central Lookout were judged to be in good condition, yet only 18.2% were assessed as being very effective, while 54.5% were moderately effective and 22.8% were ineffective. There are two main reasons why these differences occur. Effectiveness of a constructed feature does not depend entirely on its condition, but rather on its placement and the total number of features. Placement of constructed features includes where they are placed in relation to environmental variables such as slope, how well features have been installed on the trail and how far apart they are placed from one another. For example, water bars placed at the base of Talyuberlup did little to prevent the severe erosion occurring on the slopes further uphill. The Mt Hassell trail had 6 water bars placed within a 50 metre segment at the base of the hill. The 50 metre segment containing the water bars on Mt Hassell was not eroded, suggesting that a sufficient number of water bars are present in that segment. However, further uphill, erosion was recorded on slopes that had no constructed features. The placement of different types of constructed features together, such as retaining walls, steps and water bars all working in conjunction with each other, can also improve the efficiency of individual structures.

It is also important to have sufficient constructed features on each trail. Most trails in the park averaged between 0.9 and 5.6 constructed features per 100 metres. Bluff Knoll and Mt Trio averaged 35.8 and 43.7 constructed features per 100 metres respectively, which contributes to the similarities between their condition and effectiveness. If enough constructed features are present, there will be less pressure on individual structures, and the combined effects of constructed features will increase their effectiveness. The Stirling Ridge walk (Ellen Peak), for example, had 20 steps and nine water bars within a 100 metre segment (1692 to 1792 metres from the summit), that was very steep (45 to 70 degrees). Despite the steps being very effective, and the water bars being very to moderately effective, erosion E4 occurred for most of the 100 metre section, and a 14 metre segment of erosion E2 was also recorded. The steps in this segment were made of large stones, and were judged as being very effective because they enabled trail users to climb the steep slope, and reinforced the soil immediately around each step. However, the steps and water bars were 2 to 18 metres apart, and erosion was present in the intervals between constructed features. More constructed features are required in this segment to control the erosion. A well constructed and maintained staircase, rather than individual steps placed far apart, as well as additional means of erosion control, e.g. water bars and retaining walls, would stabilise the slope and shed water off the trail, helping to control erosion in this segment.

The importance of trail maintenance

Without ongoing regular maintenance and upkeep of constructed features, trail conditions in the park will

[2] Assisting Ranger, Stirling Range National Park, Department of Conservation and Land Management

continue to deteriorate. Degraded trails detract from the aesthetics of the park, and make travel conditions difficult and unsafe. They also make it difficult to achieve the managerial goals of the park, such as developing and maintaining trails to appropriate standards to provide safe and enjoyable walking experiences, and implementing maintenance to arrest erosion and provide safe access (CALM 1999). The trails in the park are promoted as tourist attractions, and tourist facilities such as car parks and picnic areas provide access to trails, so it is important to maintain good trail condition. This can be achieved by adhering to trail management and monitoring programs.

Basis for a management and monitoring program

Once a trail inventory has been gathered and the trail condition assessed, it is important to monitor trails. Similar or even identical indicators as those used to assess trails can also be used as a monitoring system (Monz 2000). Monitoring involves methodical collection and analysis of data over time (Newsome *et al.* 2002), and is important in many ways. Firstly it identifies the impacts of hikers on trails and assesses the changes over time, thus describing any trends in trail condition and alerting managers to trail degradation (Burde and Renfro 1985; Hendee *et al.* 1990; Monz 2000). Secondly, monitoring systems can be used to assess the effectiveness of trail maintenance. Information gathered by monitoring trails can be utilised by managers to evaluate and update resource conditions and management programs (Monz 2000). Monitoring also provides important data that can be used in the planning and design of trails (Hendee *et al.* 1990).

Three main monitoring techniques have been developed to evaluate trails. These are permanent point surveys, sampling based rapid surveys and problem based rapid surveys. Each of these methods has advantages and disadvantages, and relays different information to managers of natural areas. Visitor surveys may also be used to monitor some aspects of trails, such as trail use, and provide qualitative and some quantitative data.

The interval sampling and problem assessment method employed in the Stirling Range National Park evaluated descriptive variables, degradation indicators and construction features to provide the baseline information on current trail condition. The same method can be used to monitor the trails, which would allow direct comparison to the data gathered in this preliminary assessment, thus providing information on changes in trail profiles and evaluation of trail maintenance and management programs. Some minor adjustments would need to be made to make the assessment method suitable for monitoring. For example, the descriptive variables (slope, rockiness, width, length, soil type) and shallow exposed roots would not need to be monitored unless trails are re-aligned, relocated or new trails are built. These were included in the preliminary assessment to describe the trail environments and to allow comparison of environmental controls with trail degradation. The descriptive variables are fairly constant (e.g. slope would not be expected to change much over time) and therefore it is not necessary to monitor them. Exposed roots were often found in segments with no erosion, due to the shallow soils found on the slopes in the park. Also, many of the exposed roots were mallee roots, which are naturally partially exposed. Most exposed roots found were uncovered to a depth of 1 to 5 cm, and did not create problems such as tripping hazards or increased travel difficulty. Roots exposed to a depth of 10 cm and over should be monitored because they were often found in conjunction with erosion, and have the potential to be hazardous to trail users. Monitoring the depth of root exposure can alert managers to increases in root exposure depth, which is indicative of continuing degradation.

The location and lineal extent of erosion, excessive width and trail proliferation should be monitored to alert trail managers to problem areas and to assess degradation trends over time. Constructed features used in the preliminary assessment should also be monitored. For example, initial assessment of a trail, using the problem assessment method, may find a 2 metre segment of erosion, starting 3 metres from the summit and finishing at 5 metres from the summit. The trail managers may take action, such as placing water bars at the start and finish of the erosion problem and backfilling the eroded section. Further monitoring of the trail, using the same method, will detect whether the 2 metre segment of erosion re-occurs after maintenance action has been taken, or whether maintenance has been effective and the segment remains rehabilitated. Monitoring will also provide information on the condition and effectiveness of any new water bars, alerting trail managers to any ongoing maintenance that may be required, such as clearing rock and debris from water bars or replacing wooden water bars after severe fires if they have been burnt and rendered ineffective.

Practical applications and limitations

The trail problem assessment method used in this study provided a simple and very efficient evaluation of trails in the Stirling Range National Park. Comprehensive profiles of trail condition can be obtained as indicated by the data derived from Toolbrunup (Figure 4) and Talyuberlup (Figure 3). Because it can be easily used in any environment, whether it be steep mountain trails or lowland trails, the technique appears to be well suited to international trail assessment. One of the main limitations to the approach taken here, however, is that although deemed especially suitable for trails 1–5 km in length it is not likely to be applicable in situations where much longer trail distances (>10 km) are involved. With much longer trail systems such levels of detail, such as overall trail profiles, would be much more resource intensive to acquire and managers are likely to choose a sampling based rapid survey technique (Marion and Leung 2001; Newsome *et al.* 2002).

Practical aspects of undertaking this work included the need to take care when using the measuring wheel in order to avoid inaccuracy. It is important to ensure that the measuring wheel does not bounce over rough terrain and that people do not walk backwards with it, as this can increase distances measured. The measuring wheel also needs to be kept in the middle of the trail. If the measuring wheel swings across the trail from side to side, the distance is again increased. Measuring wheel inaccuracy can be overcome by staff training.

At the local site level there was difficulty in defining the summit of some trails (e.g. Baby Barnett Hill, Bluff Knoll). This could be improved by providing discrete markers, such as metal pins set into the ground. The markers would then be used as the start of the measuring.

There was also some degree of subjectivity in the method in that personal judgment was needed to decide where degradation starts and finishes, and what condition/ effectiveness the constructed features are in. This can be improved through staff training, by using photographs to demonstrate examples of degradation indicators and constructed features, and through workshops designed to teach and improve measurement techniques.

A significant constraint in this study was the lack of information on visitor numbers and trail use in the park. Without this data, the influence of environmental controls on trail degradation cannot be fully understood. Visitor information is also very important for managerial decisions, such as prioritising trails, and choosing appropriate management and monitoring actions.

REFERENCES

Bayfield NG (1973) Use and deterioration of some Scottish hill paths. *Journal of Applied Ecology* **10**, 635–644.

Bratton SP, Hickler MG, Graves JH (1979) Trail erosion patterns in Great Smoky Mountains National Park. *Environmental Management* **3**, 431–445.

Burde JR, Renfro JR (1985) Use impacts on the Appalachian Trail, National Wilderness Research Conference, Fort Collins, CO, July 23–25.

CALM (1990) South coast region – regional management plan 1990–2000, Department of Conservation and Land Management, Perth, Western Australia.

CALM (1991) Policy statement no 18 – Recreation, Tourism and Visitor Services, Department of Conservation and Land Management, Perth, Western Australia.

CALM (1996) Stirling Range and Porongurup National Parks Draft Management Plan 1997, Department of Conservation and Land Management, Perth, Western Australia

CALM (1999) Stirling Range and Porongurup National Parks Management Plan 1999 – 2009. Department of Conservation and Land Management, Perth, Western Australia

Cole DN (1983) Assessing and Monitoring Backcountry Trail Conditions, USDA Forest Service, Intermountain Forest and Range Experiment Station Ogden, UT 84401, Research Paper **INT-303**

Cole DN, Spildie DR (1998) Hiker, horse and llama trampling effects on native vegetation in Montana, USA. *Journal of Environmental Management* **53**, 61–71.

Coleman RA (1977) Simple techniques for monitoring trail erosion in mountain areas of north-west England. *Environmental Conservation* **4**, 145–148.

Deluca TH, Freimund WA, Cole DN (1998) Influence of llamas, horses and hikers on soil erosion from established recreation trails in western Montana, USA. *Environmental Management* **22(2)**, 255–262.

Gillen K, Watson J (1993) Controlling *Phytophthora cinnamomi* in the mountains of south-western Australia. *Australian Ranger* **27**, 18–20.

Hendee JC, Stakey GH, Lucas RC (1990) *Wilderness Management*, North American Press, Colorado, USA

Jewell MC, Hammitt WE (2000) Assessing soil erosion on trails: A comparison of techniques. USDA Forest Service Proceedings RMRS-P-15-Vol-5

Leung Y, Marion J (1996) Trail degradation as influenced by environmental factors: A state-of-knowledge review. *Journal of Soil and Water Conservation*, **51(2)**,130–136.

Leung Y, Marion J (1999) Assessing trail conditions in protected areas: application of a problem-assessment method in the Great Smoky Mountains National Park, USA. *Environmental Conservation* **26(4)**, 270–279.

Leung Y, Marion J (2000) Recreation impacts and management in wilderness: A state-of-knowledge review. USDA Forest Service Proceedings RMRS-P-15-VOL-5, 2000.

*******Lloyd, M. (2002), Personal communication. District Parks Manager, Albany District, Department of Conservation and Land Management

Marion J, Leung L (2001) Trail resource impacts and an examination of alternative assessment techniques. *Journal of Park and Recreation Administration* **19(3)**, 17–37.

Moon R, Moon V (eds) (2000) *Discover Australia – National Parks*. Hema Maps Pty Ltd, Brisbane, Queensland.

Monz C (2000) Recreation resource assessment and monitoring techniques for mountain regions. In *Tourism and Development in Mountain Regions* (eds PM Godde, MF Price, FM Zimmermen), pp. CABI Publishing, Oxford.

Morphet AT (1996a) *Mountain Walks in the Stirling Range – Part 1*. Torridon Publications, Capel, Western Australia.

Newsome D (2003) The role of an accidentally introduced fungus in degrading the health of the Stirling Range National Park ecosystem in South Western Australia: status and prognosis. In *Managing for healthy ecosystems* (eds DJ Rapport, WL Lasley, DE Rolston, NO Nielsen, CO Qualset, AB Damania), pp. Lewis Publishers, Boca Raton, Florida, USA.

Newsome D, Moore SA, Dowling RK (2002) *Natural Area Tourism: Ecology, Impacts and Management.* Channel View Publications, Clevedon, UK.

Pearce-Higgins JW, Yalden DW (1997) The effect of resurfacing the Pennine Way on recreational use of blanket bog in the Peak District National Park, England, *Biological Conservation* **82**, 337–343.

Sun D, Liddle MJ (1993) A survey of trampling effects on vegetation and soil in eight tropical and subtropical sites, *Environmental Management* **17**, 497–510.

Sun D, Walsh D (1998) Review of studies on environmental impacts of recreation and tourism in Australia. *Journal of Environmental Management* **53**, 323–338.

Western Australian Tourism Commission (2002) Draft. Great Southern Tourism Development Plan 2002–2006, Perth, Western Australia

Wallin TR, Harden CP (1996) Estimating trail-related soil erosion in the humid tropics: Jatun Sacha, Ecuador and La Selva, Costa Rica. *Ambio* **25**, 517–522.

Watson J (1993) In *Mountains of Mystery. A natural history of the Stirling Ranges*, (eds C Thomson, G Hall, G Friend), p. 129. Department of Conservation and Land Management, Perth, Western Australia.

Whinam J, Chilcott N (1999) Impacts of trampling on alpine environments in central Tasmania. *Journal of Environmental Management* **57**, 205–220.

********Wills R, Kinnear J (1993) In *Mountains of Mystery. A natural history of the Stirling Ranges*, (eds C Thomson, G Hall, G Friend) Department of Conservation and Land Management, Perth, Western Australia.

Wilson JP, Seney JP (1994) Erosional impact of hikers, horses, motorcycles, and off-road bicycles on mountain trails in Montana, *Mountain Research and Development*, **14(1)**, 77–88.