Journal of Outdoor Recreation and Tourism 9 (2015) 64–76

Contents lists available at ScienceDirect

Journal of Outdoor Recreation and Tourism

journal homepage: www.elsevier.com/locate/jort

A longitudinal multi-method study of recreational impacts in the Arthur Range, Tasmania, Australia

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ARTICLE INFO

Article history:
Received 16 January 2015
Received in revised form
27 March 2015
Accepted 27 March 2015

Keywords:
Recreational impacts
Monitoring
Walking tracks (trails)
Campsites
Land management
Tasmania

ABSTRACT

Longitudinal studies of recreational impacts can be valuable for identifying long-term trends and for assessing the long-term effectiveness of management measures designed to mitigate impacts. Several types of impact relating to recreational walking were monitored periodically in the remote and rugged Arthur Range, Tasmania, utilising a variety of techniques over a 20-year period starting in 1994. The first twelve years of the study coincided with the implementation of several management measures in the range including extensive 'hardening' of some tracks (trails) and campsites, local track realignments and closures, and the installation of signs encouraging walkers to 'fan out' on some track-free sections of the range. The monitoring programme provided information on the effectiveness of these measures and on trends in the condition of unimproved tracks, routes and campsites. The installation of camping platforms and associated infrastructure halted deterioration and facilitated recovery at several major campsites, although the recovery of devegetated sites was slow. 'Fanning out' forestalled track development in some parts of the range but proved ineffective even as a short-term measure on steep, confined terrain. Active deterioration continued on many unimproved track sections and campsites. Further management inputs are required if recreational impacts in the range are to be sustainable.

MANAGEMENT IMPLICATIONS

This study demonstrates the value of longitudinal monitoring programs for describing both the severity and extent of recreational impacts and the effectiveness of management measures. However, the situation in the Arthur Range exemplifies much of the 'real world' where, despite an abundance of data, changing policies and limited management resources have stalled efforts to achieve sustainable recreation management.

Findings of the study include:

- On unimproved track sections, absolute impacts are lower but rates of change proportionally greater in many lower-use areas (consistent with the widely-reported finding that the impact-use relationship is curvilinear).
- The installation of camping platforms, hardened tracks, toilets and other infrastructure at major campsites arrested and in some cases actually reversed campsite impacts, broad-scale trampling impacts and ad hoc track development at several of those campsites.
- Some recovery of closed or disused impacted campsites occurred, but recovery was minimal or extremely slow on alpine sites that had lost most of their original vegetation cover.
- The implementation of a 'fan out' (dispersal) policy in selected areas met with varying success, failing to halt track development even in the short term on steep, confined sites, but proving successful on open sites with low vegetation.

1. Introduction

Many of the world's natural areas are managed primarily to preserve their natural condition while providing opportunities for nature-based recreational activities such as hiking and camping

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http://dx.doi.org/10.1016/j.jort.2015.03.005
2213-0780/

(Dudley, 2008). These objectives can conflict since recreational activities are often associated with impacts such as vegetation loss and soil erosion that degrade natural values (Cole, 1993). Consequently, managers often need to implement measures such as educating visitors and stabilising walking tracks to limit recreational impacts (Park, Manning, Marion, Lawson & Jacobi, 2008). For such measures to be effective and to optimise their effectiveness, monitoring is required so that managers can be informed about usage patterns, determine the location, severity and extent of biophysical and other impacts (Eagles, McCool & Haynes, 2002; Hadwen, Hill & Pickering, 2007; Tanner and Nickas, 2007), and assess the effectiveness of management measures (Leverington, Costa, Pavese & Hockings, 2010; Newsome, Moore & Dowling, 2013). Ideally, monitoring should be ongoing continuously, so managers stay informed about current conditions, be aware of long-term trends and adjust management measures to take account of changing conditions (Boyers, Fincher & van Wagtendonk, 2000; Hockings, Stolton, Leverington, Dudley & Courrau, 2006). Long term recreation impact monitoring programs are rare internationally; this is one of the reasons there are so few rigorous assessments of management effectiveness worldwide (Cole, Foti & Brown, 2008).

The past half-century has seen a dramatic increase in the extent of protected areas around the world, a development that reflects increasing awareness of environmental issues including anthropogenic threats to the natural environment (Dudley, 2008). The same period has witnessed a huge increase in the popularity of nature-based recreation activities (Balmford, Beresford, Green, Naidoo & Walpole, 2009). Since the early 1970s a substantial body of the literature has emerged in the field of recreational-impact research (Leung & Marion, 2000; Cole, 2004; Manning, 2011; Newsome et al., 2013), exploring topics such as the mechanisms of track deterioration and the effectiveness of educational programs in modifying walker behaviour. A range of techniques has been developed to monitor usage patterns and recreational impacts (e.g. Leung & Marion, 2000), and studies have been undertaken into the effectiveness of management measures such as signage (Park et al., 2008).

1.1. Nature and mechanics of recreational impacts

Numerous researchers have studied the biophysical effects of recreational trampling and camping in natural settings (Pescott & Stewart, 2014; Cole, 2004). Impacts typically include damage to and loss of vegetation, changes in species composition, soil compaction, erosion, and the development and deterioration of defined walking corridors (i.e. tracks or trails) and campsites (Cole, 2004). Post-impact recovery is often slow, particularly in alpine environments (Leung & Marion, 2000). The relationship between recreation use and impact has often been described as curvilinear, with low usage causing disproportionately high impacts (Hammit & Cole, 1998). For example, in some Tasmanian environments prolonged and sustained damage can result from as few as 100 walker passes (Whinam & Chilcott, 2003). However, the use-impact relationship can take other forms, and some studies have described a sigmoidal relationship (Monz, Pickering & Hadwen, 2013).

Walking tracks (trails) are generally subject to ongoing physical deterioration unless they are designed sustainably (which generally requires low gradients, with trails more closely aligned to contours rather than fall lines) or are located on self-maintaining substrates that resist erosion (Leung & Marion, 2000); otherwise artificial stabilisation or 'hardening' is required to avoid deterioration. The deterioration of unimproved walking tracks (generally visitor-created trails on which no stabilisation or hardening works have been undertaken) poses a serious management problem in many natural areas worldwide (op. cit.), especially as soil loss is generally considered irreversible (Olive & Marion, 2009). In addition to the obvious environmental impacts associated with gullying, track widening, quagmire development and track braiding or duplication, they can at the same time adversely affect the recreational experience of walkers (Lynn & Brown, 2003) and generally run counter to the management objectives of protected areas.

The factors that predispose unimproved tracks to degradation have been well studied, with key factors being gradient, track alignment relative to topography, drainage and substrate characteristics (e.g. Leung & Marion, 1996, 2000; Dixon, Hawes & McPherson, 2004; Morrocco & Ballantyne, 2007; Olive & Marion, 2009). Campsite impacts such as vegetation trampling and loss and site expansion, which typically develop rapidly and recover slowly, have also been studied extensively (Cole 2004). Campsite conditions are particularly important for the visitor experience because visitors are strongly influenced by what they find at campsites (Flood, 2003).

1.2. Monitoring techniques

A wide range of techniques has been described for measuring and monitoring recreational impacts in wild settings (e.g., Monz, 2000; Marion & Leung, 2001). They include sampling-based track surveys, the assessment of permanently marked sampling plots, and assigning condition-class ratings to campsites. Similarly, a range of techniques has been described for monitoring visitor numbers and itineraries (Cessford & Muhar, 2003). The choice of techniques for a particular situation depends on a range of factors including the type and accuracy of information required by managers, the efficiency with which information can be obtained and the resources available for monitoring. Practical considerations are also important; for example, the practicality of taking measurements at sites subject to extreme weather conditions was a consideration in our study (see Section 4).

1.3. Management options

A variety of management techniques has been developed to mitigate recreational impacts (Leung & Marion, 2000). They include hardening tracks and campsites, redirecting visitation through regulation or education, modifying visitor behaviour, and modifying visitor expectations. Each technique has its advantages and limitations, and the choice of technique(s) to address a particular impact will depend on a range of factors including cost, likely effectiveness and the impact of the technique on recreational values. For example, track hardening can locally solve the problems of track widening and erosion, but it can also increase the artificiality of recreation settings and is often expensive (Olive & Marion, 2009). It may also have unintended side effects such as attracting increased visitation to fragile areas.

Education programs are a light-handed recreation management practice and are generally viewed favourably by visitors (Manning, 2011). Studies of the effectiveness of education compared with other management actions have shown varied results (Manning, 2011; Newsome et al., 2013), and an educational approach alone is unlikely to solve impact problems in the short term (Cole, 1995). Nevertheless, user education is important in impact management because it can support other more direct actions (Newsome et al., 2013).

2. The study area

The Arthur Range lies in the remote southwest wilderness region of Tasmania, Australia's island state (Fig. 1). This region is

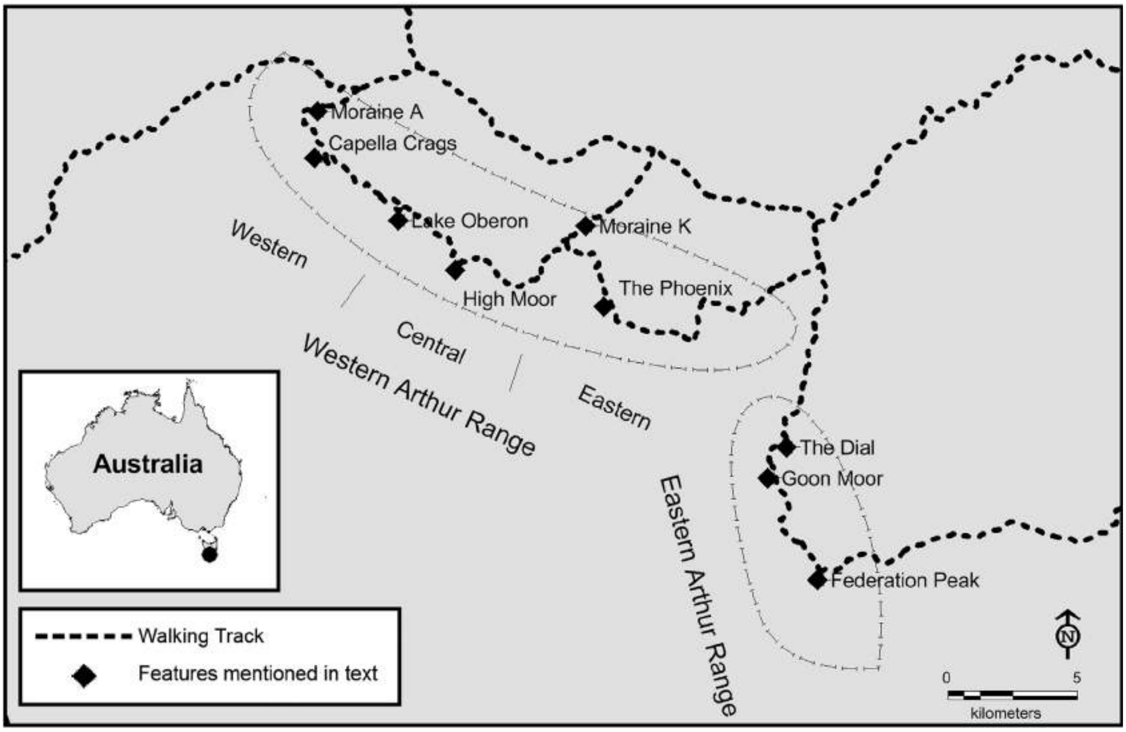

Fig. 1. Location of the Arthur Range, Tasmania, Australia.

Photo 1. The Arthur Range. Much of the walking route traverses close to the skyline of this rugged range.

part of the Tasmanian Wilderness World Heritage Area (TWWHA) and is managed by Tasmania's Parks and Wildlife Service (PWS). The topography of the range is rugged and dramatic due to Pleistocene glaciation, and many summits exceed 1000 m elevation (Photo 1). The flora and fauna of the range have links to the ancient super-continent Gondwana, and aspects of the landscape, vegetation and fauna make a significant contribution to the values of the TWWHA (Smith & Banks, 1993; Sharples, 2003; Balmer, Whinam, Kelman, Kirkpatrick & Lazarus, 2004). Like much of the TWWHA, the Arthur Range is moderately to highly susceptible to trampling damage owing to the region's high rainfall and the prevalence of steep slopes, fragile vegetation and poorly-drained soils (Dixon et al., 2004; Whinam & Chilcott, 2003). The rugged topography has confined recreational use to narrow corridors throughout much of the range, and sites suitable for camping are similarly highly localised. The eastern and western sections of the range are separated by a low pass.

3. Recreational history and management context

3.1. Recreational history

The Arthur Range is widely regarded as one of the most rewarding and challenging bushwalking destinations in Australia (Chapman, 2008). Owing to its remoteness and ruggedness major peaks in the range were not climbed until the mid-twentieth century, and the first traverse of the Western Arthur Range was not completed until 1960. The Western Arthur Range traverse is 37 km in length and the route through the Eastern Arthur Range about 15 km. In both cases, plains and foothills must be traversed to access the ranges so a visit to either part of the range typically entails a week-long expedition. Annual visitation peaked at up to 700 walkers per annum in the late 1990s and is currently about 500 walkers, although far fewer walkers access the more remote parts of the range. While visitation has never been very high,

Photo 2. Severe track erosion was evident in parts of the Arthur Range by the late 1980s and has increased substantially since.

significant impacts have developed owing to the low resistance and resilience of the environment to trampling (see Section 2). A well-worn, trampled route existed through much of the Eastern and Western Arthur Ranges by 1980. This route was visitor-created and mostly poorly sited in terms of long-term stability. By the late 1980s, substantial damage was already occurring on some track sections and campsites (Photo 2).

3.2. Management pre 1993

The Arthur Range received little direct management prior to the 1990s. In the late 1970s a state-wide ban on aerial food drops for bushwalkers in national parks substantially reduced litter at former airdrop sites in the range. In 1985 the PWS launched a state-wide 'Minimal Impact Bushwalking' (MIB) educational campaign, disseminated through printed materials and by ranger staff in strategic areas, and in the late 1980s campfires were banned throughout the Arthur Range (and subsequently most of the TWWHA). Together, these measures greatly reduced litter and faecal waste impacts at campsites in the range, and virtually eliminated campfire use (O'Loughlin, 1997). The education campaign continued through the 1990s but due to declining resources was effectively discontinued by the end of the decade.

3.3. Management post 1993

In the early 1990s the PWS undertook an inventory of track conditions and recreational impacts throughout the TWWHA, and prepared a comprehensive walking track management strategy for the region (PWS, 1994). The strategy recommended a range of management measures including an extensive works programme, a track classification scheme, ongoing walker education, and the establishment of a TWWHA-wide recreational-impact monitoring programme (the Arthur Range component of which is described in this paper). In the Arthur Range, where extensive erosion and environmental degradation were documented but the terrain and environmental considerations limit options for relocating impacted sites, a containment approach was considered the most practical management option for the most impacted areas. The strategy recommended the hardening of major campsites (Photos 3 & 7) and strategic track sections, priority erosion control works (intended to be followed up by intensive track hardening), the installation of toilets and in some cases water collection systems at major campsites, local track realignments and closures, and signage to inform users about management actions and preferred behaviour. The prescriptive track classification system (PWS 2014) provides a framework for determining acceptable levels of impacts such as extent of track development, track width and campsite condition.

Photo 3. Camping platforms and associated infrastructure were constructed at a number of seriously-impacted sites between 1994 and 2002.

Photo 4. Sign advising walkers to "fan-out" to minimise trampling impacts when traversing a still-trackless section of alpine moorland in the Eastern Arthur Range.

Rationing visitation was also recommended by the 1994 strategy but was and remains politically unacceptable and so has not been seriously pursued as a management option during the period of this study. Following publication of the strategy the PWS convened a stakeholder consultation group that made recommendations on recreational management issues in the Arthur Range and elsewhere (BATR, 2004).

Since the 1990s a fan-out (dispersal) strategy has been promoted at a number of alpine moorland localitions in the Arthur Range, with the goal to disperse walker trampling and minimise the risk that permanent tracks would develop (Photo 4). In many instances, the primary intent of this approach has been to forestall track development and major vegetation loss until more intensive hardening could be carried out.

Works in the range were generally expensive and time-consuming, often requiring helicopters and the development of new skill sets (e.g. stone work). It is estimated that more than A$1.5 million (in 2014 terms) had been spent by 2006. Despite this investment, 84% of the route through the Western Arthur Range and 70% of the Eastern Arthur Range remain unimproved with much of the track and campsite network subject to serious and ongoing problems.

4. Monitoring methods

A range of methods was developed and implemented to monitor the condition and rates of change of tracks, campsites and selected track-free areas throughout the Arthur Range (and elsewhere in the TWWHA). Conditions in the Arthur Range were monitored periodically from 1994 to 2014, with revisits occurring at two or three-yearly intervals (less frequently in the Eastern Arthur Range). Some pre-1994 data on track and campsite conditions were also available thanks to early monitoring trials and observations by ranger staff.

Track conditions and rates of change were monitored with two techniques. Both techniques were developed primarily to measure conditions on unimproved tracks because the majority of tracks in the TWWHA were in an unimproved condition, the deterioration of unimproved tracks was of greatest concern, and it was assumed that track widening and erosion effectively ceased once tracks were intensively hardened. The latter assumption is supported by extensive observation although it has not been quantitatively verified. Note, however, that the clustered-transect technique described below was used to measure impacts on some track sections where intermittent steps and drainage works had been installed (see Section 5.2.3).

4.1. Distance sampling

A distance-based sampling technique involved recording categorical measurements of various impact parameters (the same as those developed for the clustered-transect technique; see Section 4.2) at regular spatial intervals along a track, and calculating the proportion of track subject to specified categorical ranges of impact value (Hawes, Candy & Dixon, 2006). The method is designed to characterise track condition over extended sections (i.e. kilometres). Environmental data was also recorded to determine the track *Type* at each sample point (a classification based on environmental and siting factors; broadly speaking, the higher the *Type* number the less stable the track; Dixon et al., 2004). This technique was applied in the Western Arthur Range only, as a substantial proportion of the Eastern Arthur Range had been hardened by the time the technique was developed. Data were recorded at 50 m intervals using a weather-proof Trimble Juno GPS-enabled personal digital assistant running GBM Mobile software. The standard deviation of the proportion estimates was given by the following formula:

$$\mathrm{SD}(P) = \sqrt{(P * (1-P)/N)}$$

where P is the estimated proportion and N is the number of sampling points. This quantity has its maximum at $P=0.5$ (50%); for example if $P=0.5$ and $N=100$, $\mathrm{SD}(P)=0.05$ or 5%.

4.2. The clustered-transect technique

A clustered-transect monitoring technique measures track-impact indicators at permanently marked and widely dispersed sites, each site comprising 10 transects located at two-metre intervals (Dixon et al., 2004). Sites were classified by *Type* (see Section 4.1). The majority of sites were selected at random locations on unimproved sections of track, although a small number were established on sections where intermittent steps and/or drains had been installed. (Data from the latter were excluded from analyses that required unbiased data.) Measurements were taken of the three variables *Depth* (the maximum depth of the track profile relative to a telescopic rod extended between the edges of the profile), *Width Free of Vegetation* and *Total Width* (of all ground visibly impacted by trampling). Repeat measurements can reliably ($p<0.05$) detect depth and width changes of approximately 2 cm and 5 cm, respectively. The number of clustered-transect sites in the Arthur Range has fluctuated over the monitoring period due to the loss of some sites when tracks were hardened and the installation of some more recent sites. There are currently 30 active monitoring sites in the combined western-central region of the Western Arthur Range, 17 sites in the eastern region and 14 active sites in the Eastern Arthur Range.

4.3. Incipient and informal tracks

The number, location and extent of incipient and informal tracks on side routes and around camping areas were initially assessed by inspecting large scale (1:5000) aerial photographs of selected sites. The aerial photographs were taken in 1995–1996 and repeated for some areas in 2000, after which funding to undertake such monitoring was unavailable (Google Earth imagery has the potential to be similarly useful but is not yet available at sufficient resolution for the Arthur Range study area). Ground inspections were undertaken with a GPS unit to check and calibrate the findings of the aerial monitoring system and to monitor track development in areas where high vegetation rendered aerial identification of incipient tracks impractical. The use of this GPS-based approach was continued post-2000 to monitor track development in selected areas.

4.4. Fan-out monitoring

The fan-out monitoring technique was designed to monitor track development and broad-scale trampling impacts in areas of open terrain considered at risk of such impacts, particularly areas where walkers were encouraged to fan out (but walkers were typically encouraged to remain within a corridor some dozens of metres wide, due to local topographic constraints) in an effort to prevent track development. The technique requires measuring relocatable transects oriented perpendicular to the direction in which it is assumed likely that most people walk. Each square metre along these transects is assigned one of three categorical impact values (see caption for Fig. 6), and the proportions of each transect in the three impact categories are calculated. Trials have indicated that proportion estimates over a typical 50-m transect are accurate to within 10%. There are 10 such transects at two locations in the Western Arthur Range, and 15 transects at four locations in the Eastern Arthur Range.

Marion and Wimpey (2011) describe a Line Transect Survey technique which is similar to the above method. They also describe other techniques for monitoring informal trail development that, with similar time investment, may provide better information on more indicators.

4.5. Campsites

The campsite monitoring technique is a condition class system (Frissell, 1978; Marion, 1991) consisting of several statements linked to a code that describes increasing levels of campsite impact. Class 0 campsites are barely distinguishable whereas class 5 campsites comprise bare soil or rock with obvious soil erosion. The main limitation of the condition class system is that the evaluator is simultaneously examining multiple impact factors, which may not co-vary (Monz & Twardock, 2010). However, the main aim was to inventory all campsites (currently 66 campsites in the Western Arthur range and 31 campsites in the Eastern Arthur

Range) in order to identify any new impacts (Cole, 2004), and the method allowed direct comparison with data collected before 1994. Most campsites were also photographed from a relocatable point during each visit.

4.6. Summary

The techniques described above are all simple to use and can be undertaken fairly quickly, an important consideration in the Arthur Range where working conditions can be extreme. The techniques need to be undertaken by trained and experienced operators to optimise precision and minimise bias. For example, application of the fan-out monitoring technique requires measurements by staff who have had experience in identifying signs of trampling impacts and visually estimating areas of vegetated ground to within a few per cent. For the current study, the authors themselves undertook all the monitoring for the 20-year duration of the project.

4.7. Visitation levels

The only sources of information on visitation levels in the Arthur Range were log books in which visitors could choose to register at the start and/or end of their walk. These have been in place on all access routes since the 1980s and, despite their limitations, provided useful data on visitor numbers and itineraries (Rundle, 2002; B. Knowles, pers. comm.).

Table 1
Proportions of the main traverse of the Western Arthur Range that exceeded acceptable limits for selected monitoring indicators, as specified by the track classification (see Section 3.3). *N* indicates the number of points sampled using the distance-sampling method (see Section 4.1). The differences between the values shown in italics are statistically significant ($p < 0.05$).

Western Arthur Range	2004	2007	2014
Western region, *N*=91			
Maximum depth (*D*) > 25 cm		19%	24%
Total width (WT) > 100 cm (T2 track class prescription)		*44%*	*34%*
Central region, *N*=369			
Maximum depth (*D*) > 25 cm		23%	21%
Total width (WT) > 75 cm (T3 track class prescription)		*26%*	*39%*
Eastern region, *N*=277			
Maximum depth (*D*) > 25 cm	8%	10%	10%
Total width (WT) > 50 cm (T4 track class prescription)	*27%*	30%	*33%*

5. Results

5.1. Usage trends

Annual visitation to both the Eastern and Western Arthur Ranges increased rapidly in the 1980s, peaked in the 1990s and has declined slightly since then. Total visitation to the Eastern Arthur Range in recent years (2011–2012) is a little under 250 visitors per year, with many visitors traversing only part of the range. The Western Arthur Range can be effectively divided into three regions (Fig. 1), the western and most popular region (between the Moraine A and Lake Oberon) currently (i.e, 2013–2014) receiving just under 500 visitors per year, the central region (between Lake Oberon and Moraine K) receiving around 230 walkers annually, and the eastern region (between Moraine K and Lake Rosanne) now receiving only about 75 walkers annually. Visitation to the more remote central and eastern regions has declined since the 1990s, and the average trip length of visitors to the range has decreased from 7 nights (early 1990s) to 5 nights (2010–2012).

5.2. Track conditions

5.2.1. Distance sampling (Western Arthur Range only)

As noted previously, acceptable limits for impact parameters such as track width and depth are broadly specified by a track classification scheme (PWS, 2014). The classification assigned to the main traverse in the central region of the Western Arthur Range is slightly lower than that for the western region, implying a lower standard of track development, and the classification in the eastern region is lower again (maximum prescribed widths vary from 0.5 to 1 m through the range). Over one third of the main traverse exceeded the maximum width prescribed by the relevant track classification, the worst result (39%) occurring in the mostly unimproved central region (see Table 1). The proportion of track that exceeded the specified width standard increased from 26% to 39% between 2007 and 2014 in the 18.5 km central region, and from 27% to 33% between 2004 and 2014 in the 13.9 km of the eastern region. In the high-use western region the proportion of over-width track declined from 44% to 34% between 2007 and

Photo 5. Track erosion and widening on southern slope of The Phoenix, in the low-use eastern region of the Western Arthur Range; 1994 (left), 2014 (right).

2014, probably due to recovery of peripheral trampled vegetation following track hardening. The cited changes are all significant at $p < 0.05$.

Based on track *Type* (Dixon et al., 2004; Hawes, Dixon and Ling, 2013), up to 56% of the unimproved sections of the main traverse route were assessed to be highly susceptible to erosion. By 2014 heavy erosion (depth > 25 cm) had occurred on up to a quarter of the trails in the more heavily used western and central regions of the range, but only on 10% of the eastern region. However, no significant changes in the extent of

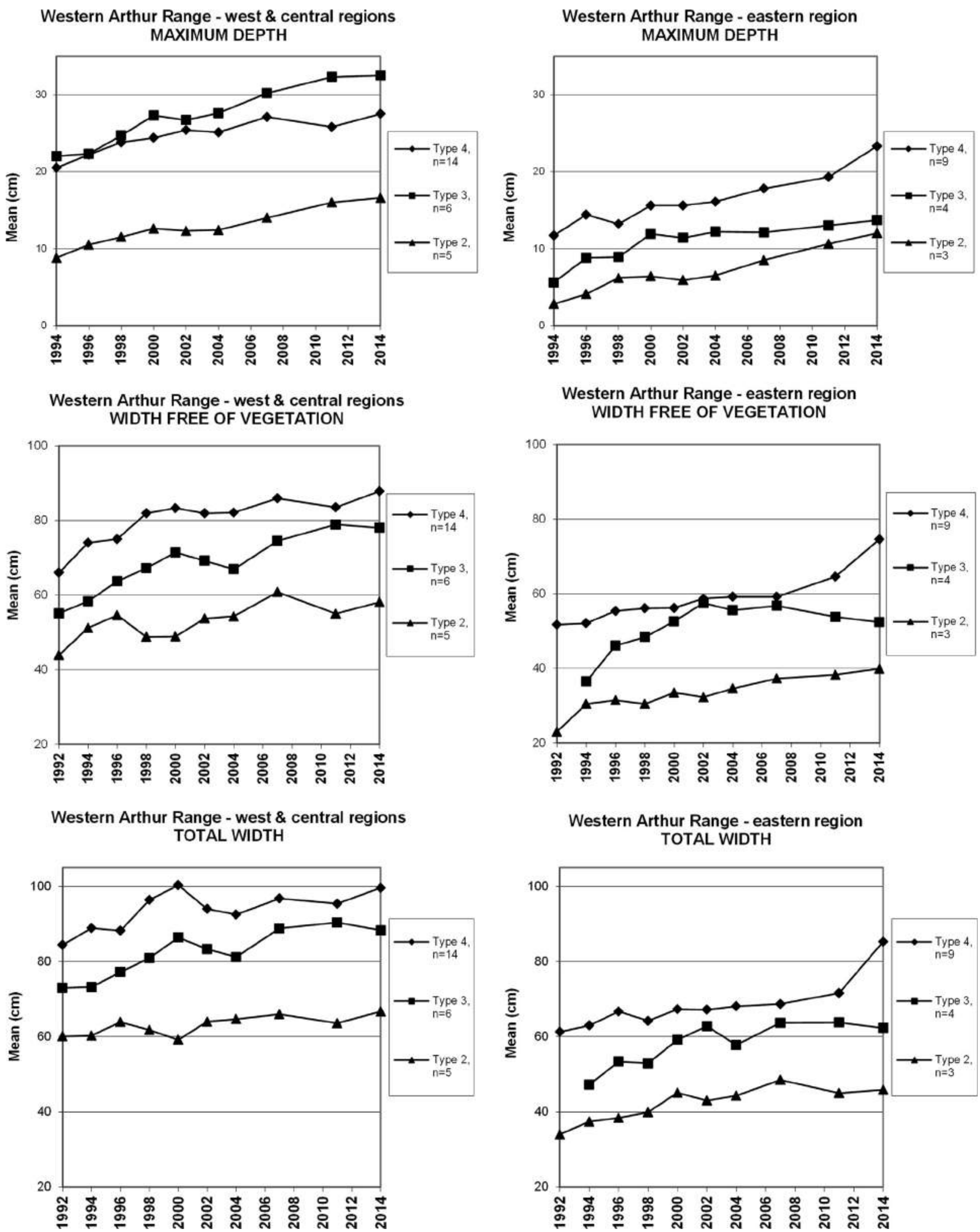

Fig. 2. Changes in impact parameters at clustered-transect monitoring locations in the Western Arthur Range. Types are a method of describing a site's susceptibility to erosion or widening; sites were classified by Type based on environmental and siting factors (see Section 4.2).

excessively deep track were observed in any region between 2007 and 2014.

5.2.2. Fixed monitoring locations

The fixed clustered-transect monitoring locations in the Western Arthur Range showed a mean increase in all impact monitoring parameters for all track *Types* (Dixon et al., 2004) over the 20 year monitoring period (1994–2014). Mean depth increases of the order of 50–100% occurred for all track *Types* across the range. Mean width increases were broadly similar in the higher-use western-central region of the range and the low-use eastern region, and hence greater relative to initial values in the eastern region; up to 40% since 1994. This observation is consistent with the widely-recognised curvilinear relationship between usage and impacts, low usage typically causing relatively high levels of impact. Graphs of these impacts are shown in Fig. 2. Owing to the scarcity of remaining fixed monitoring locations in the western region (track hardening between 1994 and 2006 rendered several monitoring locations obsolete), results for the western and central regions have been combined.

Dramatic deterioration in indicator measures occurred at many locations, notably on steep sections in the central region and in some alpine moorland areas. For example, a depth increase from 25 cm to more than 55 cm occurred at a location in the rugged Beggary area in the central region of the range, and from 5 cm to 20 cm at a location on The Phoenix in the eastern region. This latter location also displayed a total width increase from 41 cm to almost 85 cm, at a nearby location, the indicator *Width Free of Vegetation* increased from 66 cm to 104 cm, both indicating active track formation in this low-use alpine area (Photo 5). These impacts can be directly attributed to trampling, as only limited water flow occurs at these locations.

Overall impacts on the eastern region of the range were significantly lower than for the western and central regions. However, as noted above, rates of change were proportionally greater (relative to current values) in this less-trafficked part of the range.

Due in part to extensive track hardening in the Eastern Arthur Range, much of main route traversing the range is now quite resilient. During the period 1994–2000 significant net increases in one or more of the monitoring parameters were recorded at 14 of the 16 unbiased monitoring locations located throughout the range. All three parameters increased at seven locations, while an improvement was recorded (in *Total Width*) at only one location. Since 2002, data from the few locations that remain on non-hardened sections of track in the range have indicated that ongoing deterioration is occurring in several areas.

5.2.3. Priority erosion control (PEC) monitoring locations

PEC, comprising installation of drainage and some steps, was undertaken during the 1990s in parts of the Arthur Range in an attempt to retard active track degradation until more intensive stabilisation could be undertaken (see Section 3.3). Seven clustered-transect monitoring locations have been established in these localities. Differences in environmental conditions preclude rigorous comparison with unimproved (non-PEC) localities. Nevertheless, it is noteworthy that four PEC monitoring locations have displayed no significant change since installation 15–20 years ago, despite ongoing use of the tracks. Some resurgent erosion at two other locations since 2009 can probably be attributed to lack of maintenance as the drains installed at these locations are now clogged with gravel.

5.2.4. Closed tracks

During the mid-1990s, a number of track sections were closed or their use was discouraged by other means (where routes were duplicated or tracks realigned) as part of a broader management strategy for the Arthur Range (see Section 3.3). Seven clustered-transect monitoring locations have been established in these localities. While some of these tracks were heavily eroded (and, in most cases, no rehabilitation work was undertaken), no significant additional erosion occurred at six monitoring locations during the period 1994–2004.

5.3. Track development on routes

The extent of incipient track development (Photo 6) was assessed on 11 separate Route-classified (PWS, 2014) side routes in the Western Arthur Range (with a total length or more than 16 km) and four such routes in the Eastern Arthur Range (total 1.5 km). Most of the development was considered acceptable, either because it occupied $<25\%$ of the extent of the relevant route or because the impacts were historical and appeared to be either static or declining.

Traversing all side-routes was time-consuming, and hence impractical in addition to undertaking all the other monitoring tasks described in this paper. Hence, many side-routes have only been inspected once in order to ascertain if their condition was acceptable, as noted above. Some more accessible routes have been inspected multiple times and little change in the extent of track development has been noted (e.g., 71% of the 577 m Procyon Peak side route comprised an incipient track in 2014, similar to the 70% estimate in 2000). However, a clustered-transect monitoring location (see Section 4.2) on the short side route to The Dial indicated active track development (increasing *Width Free of Vegetation*) at this location despite no apparent change in the overall extent of track development on the route.

5.4. Campsite conditions

In the Western Arthur Range, the late 1990s saw hardening of many popular campsites (12 sites at four camping nodes were hardened; Photo 3) but also measurable deterioration of some unimproved campsites, most within the western and central regions of the range. Post-2000 campsite deterioration has also occurred, mostly on unimproved sites within the low use eastern region of the range: eight of the 66 recorded campsites have deteriorated (increased condition class by at least 1 or notably expanded) since 2000. At least five new campsites have also appeared, some in the low-use eastern region of the range (the uncertainty due to the possibility some sites may have been missed during earlier surveys).

Hardening of 11 campsites at four camping nodes in the Eastern Arthur Range, completed by the early 2000s, reduced the number

Photo 6. Incipient track on alpine moorland, Eastern Arthur Range.


Photo 7. High Moor campsite, in Western Arthur Range, before (1995) and after (2002) installation of camping platforms.

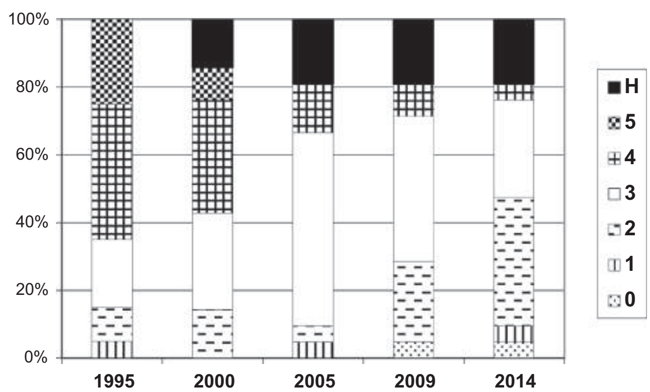

Fig. 3. Proportion of 21 campsites in the Eastern Arthur Range in each condition class over time. Campsite condition ranges from near-pristine (class 0) to mostly-bare and seriously-eroded (class 5); H indicates that the site has been hardened (see Photo 3).

of very seriously impacted campsites (because tent platforms were constructed over them in many cases; see Photo 7). There has been a concomitant reduction in the proportion of moderately-impacted sites (see Fig. 3), probably due to slow recovery of disused sites with the capacity to recover and perhaps also due to reduced usage (see Section 5.1).

At camping nodes where some campsites have been hardened, many unimproved sites have improved (see above) and/or display evidence of disuse (e.g. undisturbed leaf litter cover, moss or lichen growth). These findings confirm that construction of tent platforms at many major alpine campsites, mostly during the 1990s, successfully focussed camping pressure and so constrained or limited impacts.

The stakeholder consultation group referred to in Section 3.3 proposed standards for the condition class of unimproved campsites additional to those derived from the track classification system (BATR, 2004; PWS, 2014). While the standards were not formally adopted, it is instructive to utilise them to report on campsite conditions in the Arthur Range.

- In the western and central regions of the Western Arthur Range, the condition of 10 campsites within major camping nodes is unacceptable (seriously-impacted class 4 or 5), with three comprising in-use campsites. Seven minor campsites elsewhere in the western-central region are class 3 and so exceed the standard for the track. In the low-use eastern region of the Western Arthur Range, the condition of five campsites, all at major camping nodes, are unacceptable.
- In the Eastern Arthur Range, the condition of all major campsites is acceptable but seven minor campsites are class 3 and so exceed the standard for the track. In all cases, these are historic impacts which are not escalating and most of the class 3 sites are now closed or abandoned.

Photographic records indicate that revegetation of closed or abandoned alpine campsites in the Arthur Ranges has been very slow (Photo 8), often with no visible change evident for at least ten years. Unpublished quantitative data from High Moor supports this observation (J. Whinam, pers. comm.). Campsites that were seriously eroded previously and now show little remnant soil, or which had become completely denuded of vegetation while retaining full organic soil cover, have displayed only minor revegetation after some twenty years (and most of this has visibly commenced in the last five years). Sites that retained organic soil and at least a patchy vegetation cover when they were closed have fared slightly better. Attempts at assisting revegetation by the laying of jute matting appear to have slightly improved outcomes, at least where the disturbed area was of limited extent.

5.5. Off-track trampling impacts in the vicinity of campsites

Construction of camping platforms and hardened access tracks at major camping areas has generally reduced the extent of broad-scale trampling in the vicinity of these campsites, although a remnant informal track network remains in many cases.

For example, at High Moor, 517 m of incipient or informal track is still apparent within an area of less than two hectares (Fig. 4), 12 years after construction of a hardened campsite and visible improvement of the closed campsites. Aerial photography clearly shows the pre-hardening network of incipient tracks but no recent photography is available to allow for a direct comparison.

At Lake Oberon, three of the four fan-out monitoring transects (see Section 4.4) located on moorland that was traversed to access now-disused campsites recorded a 20–30% increase in non-impacted terrain during the three years of 1995–1998 subsequent to construction of hardened campsites. The condition of these transects has been largely stable since 2000.

Changes in ground condition over time are best illustrated by combining the results for all fan-out monitoring transects in a particular area. For example, Fig. 5 illustrates the total percentages of the Lake Oberon transects in each of the three condition categories, on eight sampling dates for the period 1995–2014. The total length of transects in the area was 141 m. The results show an initial decrease and subsequent stabilisation of the

Photo 8. Alpine campsite in Western Arthur Range with minimal revegetation 19 years after site closure; 1995 (left) vs 2014 (right).

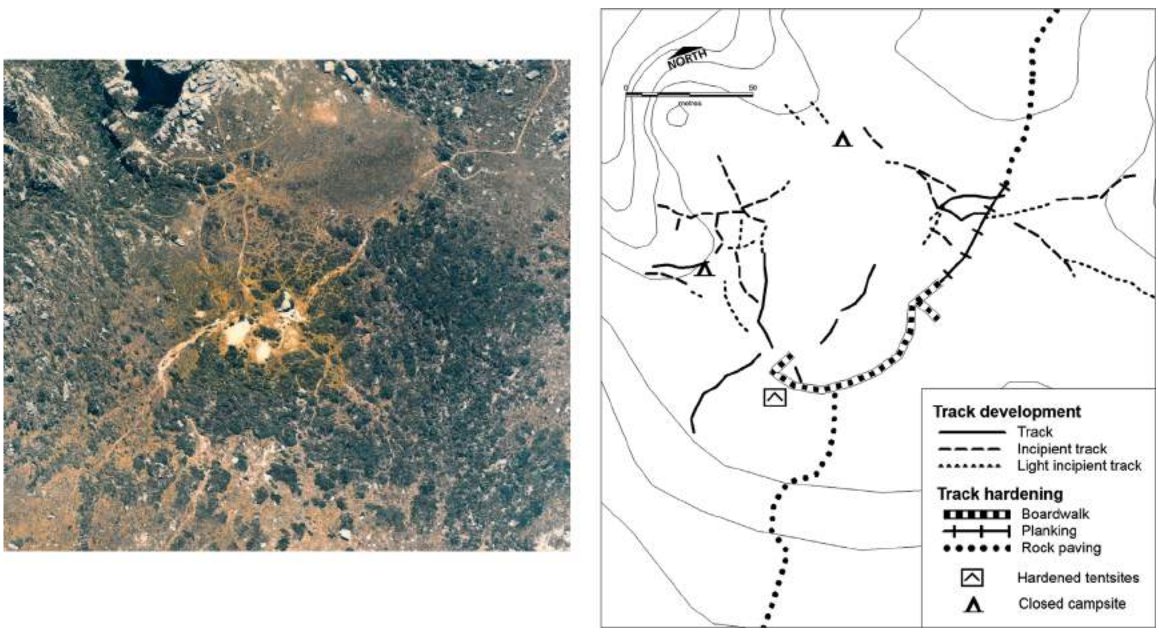

Fig. 4. Incipient track network around High Moor campsite, Western Arthur Range; 1995 aerial photo (left) vs. 2014 on-ground mapping (right).

percentages of moderately and heavily impacted ground following the hardening of campsites at Lake Oberon.

5.6. Off-track trampling impacts on fan-out sites

The fan-out strategy described in Section 3.3 has proven successful in several areas. For example, Fig. 6 shows the results of recent (2014) on-ground mapping of incipient pads at Goon Moor, on the main walking route through the Eastern Arthur Range. Here, a 160 m section of alpine moorland where fanning-out has been promoted has remained free of track development.

As described in Section 5.5, changes in ground condition over time are best illustrated by combining the results for all fan-out monitoring transects in a particular area. For example, Fig. 7 shows the results for Goon Moor, on seven sampling dates during the period 1995–2009. The total length of transects in the area was 121 m. Here, impacts remained constant over the monitoring period within the bounds of statistical uncertainty. By contrast, Fig. 8 shows the results for a site in the Capella Crags area from six transects with a combined length of 229 m. The chart shows a

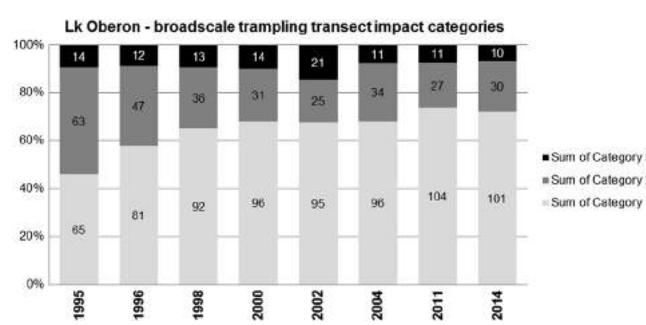

Fig. 5. Changes in broad-scale trampling impacts in the vicinity of Lake Oberon campsite, Western Arthur Range; the chart summarises data from four separate transects with a combined length of 141 m. Category 1 = 95–100% vegetation cover and no sign of trampling impact; Category 2 = 75–95% vegetation OR 95–100% vegetation and definite sign of trampling impact; Category 3 = less than 75% vegetation cover.

progressive increase in the percentage of moderately and heavily impacted ground. Here, the fanning-out regime was abandoned in 2002 in favour of hardening a defined track.

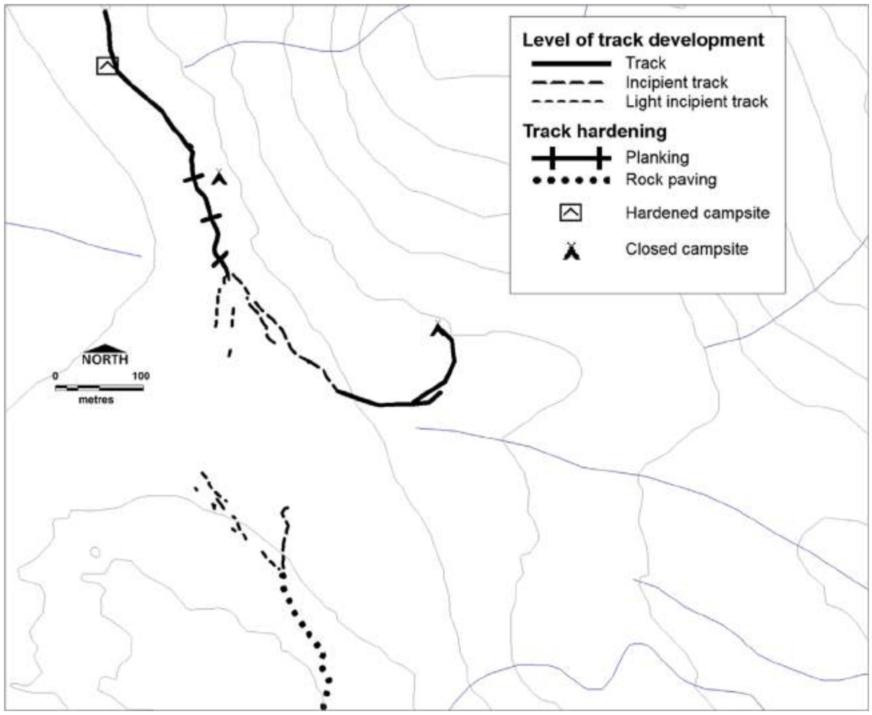

Fig. 6. Tracks and incipient tracks at Goon Moor, on the main walking route through the Eastern Arthur Range; a 160 m section of alpine moorland where fanning-out has been promoted remains free of track development. The curved track descending to the east accesses a now-closed campsite. Mapped on-ground in 2014.

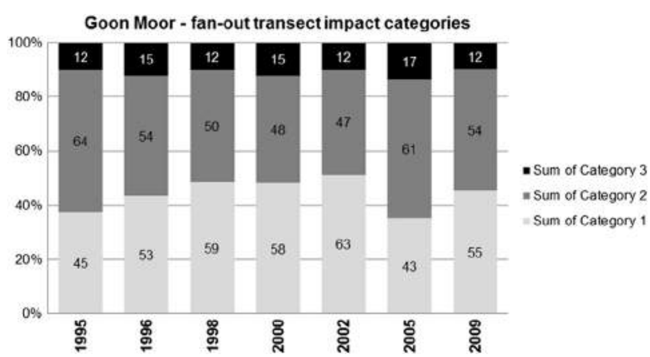

Fig. 7. Changes in broad-scale trampling impacts in the Goon Moor fan-out area, Eastern Arthur Range; the chart summarises data from four separate transects with a combined length of 121 m. Impact categories are shown in Fig. 6.

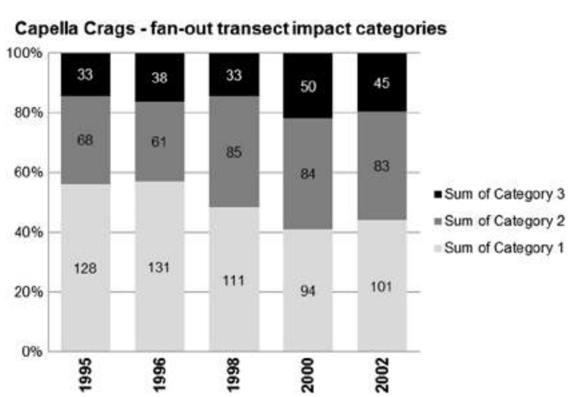

Fig. 8. Changes in broad-scale trampling impacts in the Capella Crags fan-out area, Western Arthur Range; the chart summarises data from six separate transects with a combined length of 229 m. Impact categories are shown in Fig. 6.

5.7. Other observations

In some walking areas of the TWWHA evidence for resurgent campfire use appears since the Minimal Impact Bushwalking (MIB) education campaign (see Section 3.2) has been downgraded, and particularly since the cessation of regular on-ground presence of ranger staff. In the Arthur Range, no evidence of recent campfire use was recorded during late 1990s campsite surveys but two campfire sites were noted during 2001–2005 surveys.

Probably due to the MIB campaign, the presence of litter and faecal waste in the vicinity of campsites declined to such an extent that it was no longer recorded during campsite surveys after the mid-1990s. Improved faecal waste management was supported by the installation of basic fly-out toilets at five major campsites in the Arthur Range during 1994–2000.

6. Discussion and conclusions

6.1. General findings

Cole (2006) argues that recreation impact monitoring is too often "lost in the gulf between science and management", that is, considered uninteresting by scientists and unimportant by managers. (As noted by Cole, a widespread view among managers is that common sense and experience is enough.) In this respect the study described herein is unusual especially given its duration and its use of a variety of techniques to monitor on- and off-track impacts as well as campsites and visitation. Moreover the study coincided with the implementation of a range of management measures in the Arthur Range intended to address a range of visitor-created impacts, allowing the effectiveness of these measures to be assessed over an extended period. Our main findings were as follows:

1. Visitation levels to the range declined slightly over the 20-year monitoring period, but appear to have stabilised in recent years

(There has been no rationing of visitation – see Section 3.3 – hence the decline in visitation has occurred for other reasons).
2. Impacts on unimproved track sections increased substantially in many locations over the monitoring period, with impacts on much of the track network violating the standards associated with the track classifications. Track erosion is of particular concern because soil loss is irreversible, although the vegetation damage associated with track widening is also a major concern given the extremely slow recovery times (and no guarantee that recovery will occur). Absolute impacts were lower but rates of change were proportionally greater in the lower-use parts of the range, an observation that confirms the widely-reported finding that the impact-use relationship is curvilinear.
3. The installation of camping platforms, hardened tracks, toilets and other infrastructure at major campsites, arrested and in some cases actually reversed campsite impacts, broad-scale trampling impacts, and ad hoc track development at several of those campsites. In most cases, hardening or stabilisation works were undertaken on pre-existing impacted sites or alignments (see Section 3.3). The installation of toilets also largely eliminated the incidence of faecal waste.
4. Despite the above-mentioned site hardening, the Arthur Range still contains many unimproved campsites which remain in use. Impacts at many of these sites exceed acceptable standards.
5. Photographic monitoring provided evidence of some recovery of closed or disused impacted campsites. However, recovery was minimal or extremely slow on alpine sites that had lost most of their original vegetation cover.
6. The implementation of a 'fan-out' policy in selected areas (where it was initially deemed feasible to disperse visitors sufficiently so as to prevent tracks developing or trampling impacts escalating) met with varying success, failing to halt track development in the short term on steep, confined sites, but proving successful over the monitoring period on open sites with low vegetation.
7. The 'Minimal Impact Bushwalking' campaign was effective in eliminating campfires and litter in the range during the 1990s and early 2000s. However, campfires began to reappear when the campaign was no longer actively promoted.
8. There was some (limited) evidence that priority erosion control (PEC) measures, involving the installation of basic drainage and dispersed steps (as distinct from full-scale hardening), were effective in arresting track deterioration.

6.2. Modelling the impact/time relationship

As we have described elsewhere (Dixon et al., 2004), data from the TWWHA track monitoring programme has allowed the impact/time relationship for walking tracks to be modelled as an exponential curve, with the curve parameters varying according to track *Type* (see Section 4.1) and usage level. The monitoring study from which this model was derived focussed primarily on established tracks and did not attempt to model in detail the initial phase of track development before vegetation cover is lost. A separate study utilising experimental trampling trials (Whinam & Chilcott, 2003), also conducted in the Arthur Range, examined this initial phase and broadly identified thresholds corresponding to the levels of trampling at which track development and long-term vegetation damage occur in different types of environment. That study indicated that, if visitation remains sufficiently low, vegetation may remain intact indefinitely; in this case the impact/time curve would not be exponential since impacts would approach an asymptote.

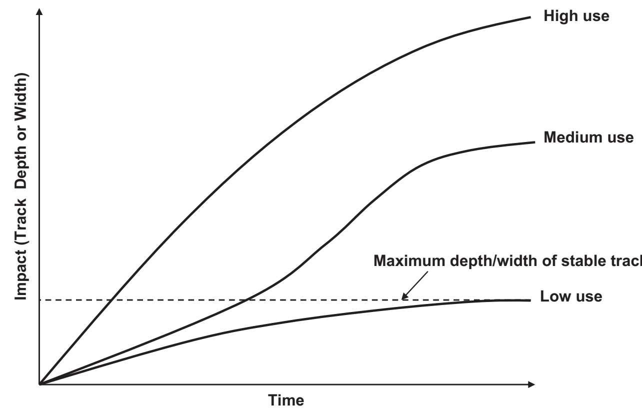

Fig. 9. Inferred impact/time curves for different use levels.

Based on these findings it is reasonable to infer that the impact/time curve for track development can be modelled in different ways depending on the level of visitation involved (see Fig. 9). For high visitation the curve is exponential, as just noted. For sufficiently low visitation the curve is asymptotic, with the track impact indicator *Total Width* (for example) increasing towards, but never exceeding, an upper limit (a similar curve would apply to track *Depth*, with the increase associated with initial soil compaction; by contrast, *Width Free of Vegetation* might remain constant and possibly zero). The curve for medium visitation will lie somewhere between these. It may be sigmoidal, with *Depth* (for example) increasingly slowly until vegetation cover is lost, accelerating during the early bare-ground stage, and then gradually levelling off. There is scope for further research to test this hypothesis.

These findings, albeit somewhat speculative, have clear implications for the longer term management of routes on which full-blown tracks (with their potential for erosion and widening issues) have not yet developed. In particular, evidence is starting to mount to limit visitation the levels below which extensive vegetation loss will occur.

6.3. Conclusions for management

The monitoring programme described in this paper highlights the value of the management measures implemented in the Arthur Range during the period 1993–2006, and identifies the extent, severity and rate of deterioration of impacts in unimproved parts of the track and campsite system. The data obtained provide a sound basis for identifying areas of concern and for assigning priorities to future management.

Notwithstanding the successes noted in Section 6.1, the management measures implemented in the range to date fall far short of what would be necessary to stabilise impacts throughout the range. The ruggedness of the terrain, limited re-route options and high per-metre cost of track work have constrained the ability of managers to address the problems in a holistic way, rationing visitation has not been a management option (see Section 3.3), and the problem has been compounded by the refocussing of agency priorities on front-country after the early 2000s. As a result deterioration is continuing unchecked throughout many parts of the range, PEC works have not been followed up with intensive hardening, and existing infrastructure has been inadequately maintained.

Many authors have argued for long term monitoring of human impacts, and we concur. Nevertheless the situation in the Arthur Range exemplifies much of the 'real world' where, despite an abundance of data, changing policies and limited management resources have stalled efforts to achieve sustainable recreation management.

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