Assessment on and Perception of Visitors' Environmental Impacts of Nature Tourism: A Case Study of Zhangjiajie National Forest Park, China

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This paper examines trampling impacts on vegetation and soil as well as visitors' perception of these impacts in Zhangjiajie National Forest Park, China. Results indicate that visitor usage is proportionate to trampling impacts, with the two most used trails–Yellowstone Village Trail and Gold Whip Stream Trail–having the highest values in Soil Impact Index (SII) and highest rate of scarred trees. Vegetation and soil near 'Treasure Box for Celestial Books' are the most impacted with the Impact Vegetational Index (IVI) being 87.50% and SII being 2.27, respectively. This spot has the highest level of unacceptability. However, visitors' perceptions of the impacts on their hiking satisfaction are not always consistent with the actual physical deterioration. The unacceptability level for 'Gold Whip Crag' was much higher than 'The General Rock' despite the latter having higher IVI values than the former. It is argued that visitors' perceptions of recreation impacts could be influenced by the interaction of IVI, SII, and the size of the area impacted. Other factors such as visual sensitivity and social elements could also have an effect on visitors' judgements. Finally, this paper proposes management strategies for improving the park's visitor and environmental management.

Introduction

Over the past two decades, national parks and other protected areas have become popular destinations for nature tourism and ecotourism, both of which are rapidly becoming important components of the international tourism industry. According to the World Tourism Organisation (WTO, 1998, in International Ecotourism Society, 2002), ecotourism generated revenue of some US $20

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billion a year and, in combination with nature tourism, contributed to 20% of global international travel. It has also been argued that ecotourism, at least in terms of its economic revenues, can contribute to the conservation of park resources. However, any form of tourism can have negative impacts on the resources on which tourism activities depend. Inevitably, the scale of such nature tourism and ecotourism will lead to the disturbance of, or damage to, park resources (Deng *et al.*, 2002; Leung & Marion, 2000), which in turn can affect the visitors' experience (Marion & Leung, 2001). In fact, the destruction of these environments could have a greater influence on the quality of visitor experiences than the presence of large numbers of other visitors (Kuss *et al.*, 1990). Thus, examination of visitors' impacts on the environment as well as visitors' perceptions of resource destruction has become one of the major areas of research in our field.

Arguably, tourism and environmental protection can be seen as two sides of the same coin. Eagles *et al.* (2002: xv) state that, 'protected areas need tourism, and tourism needs protected areas . . . tourism is always a critical component to consider in the establishment and management of protected areas'. This relationship is particularly true in China where the three main types of protected areas (i.e. nature reserves, scenic areas, and forest parks), especially those at the national level (some of them are equivalents of national parks, i.e. Zhangjiajie National Forest Park) have become increasingly popular destinations for ecotourism and nature tourism, both domestic and international. As expected, this development has affected the establishment and management of protected areas in China.

It is also widely recognised, however, that visitor overuse and the supplementary development of facilities and services in national parks and protected areas are the main threats to the ecological integrity of these environments (Rollins & Robinson, 2002; Swinnerton, 1999). In the case of Chinese nature reserves, for example, according to a survey conducted by China's Man and Biosphere Commission in 1994, 'almost all of China's nature reserves were under the heavy pressures of population and resource overuse' (Zhu *et al.*, 1996: 179). Similarly, in a recent study Nianyong and Zhuge (2001) found that 82% of China's reserves have pursued tourism activities and, as a result, the protected objectives in 22% of the reserves were impaired while tourist resources had deteriorated in 11% of the reserves.

Despite the above, very few studies have been conducted in China on the impact tourism has on the natural environment. In order to begin to address this research gap, the authors conducted a comprehensive study of tourism and visitors' impacts on vegetation, soil, water, air, wildlife, landscape, and air ions in China's first national park, Zhangjiajie National Forest Park. As part of this research programme, this paper describes visitors' trampling impacts on vegetation and soil in the park as well as how visitors perceive the actual impacts at selected sites. Based on these findings, practical implications for managing Zhangjiajie National Forest Park and other parks and protected areas in China are put forth.

Related Literature

Although very few studies have been conducted in China, a number of non-Chinese studies have examined recreational impacts on five ecosystem elements, namely vegetation, soil, water, air, and wildlife. These studies indicate

that the impacts of visitors and their activities on physical and biological environments are complex, multidimensional, and dynamic. Thus, for the purposes of this study, a brief review of literature on types of trail assessment methods, visitors' impacts on trail resources, specifically soil and vegetation, and visitors' perceptions of actual trampling impacts, follows.

Types of trail assessment methods

Basically, trails are where recreational activities are performed (Marion & Leung, 2001). Consequently, recreational impacts on vegetation, soil, or wildlife are most likely to occur in or along trails, especially those that are unsurfaced (Leung & Marion, 1999; Marion & Leung, 2001). Assessing and monitoring the conditions and situations of these visitor-concentrated sites is essential for both the protection of recreational resources and the provision of quality recreational experiences. To this end, a number of rapid-assessment methods on trail evaluation have been developed, which can generally be classified into three approaches (Leung & Marion, 2000), including the: (1) reconnaissance approach (condition classes vs. photo appraisal), (2) sampling-based approach (point sampling vs. point-quadrat sampling), and (3) census-based approach (sectional evaluation vs. problem assessment).

The reconnaissance approach either employs condition classes, where descriptive classes are defined and assigned to trails or segments, or photo appraisal, where trails are identified and evaluated from aerial photographs (Leung & Marion, 2000; Marion, 1991). With the sampling-based approach, point sampling evaluates trail conditions from measurements performed on a series of points along a trail, whereas point-quadrat sampling assesses trail conditions based on a series of quadrats along a trail (Leung & Marion, 2000). Both points and quadrats can be determined either at a fixed interval along a trail or in accordance with various strata such as level of use or vegetation type (Marion & Leung, 2001). In contrast with the sampling scheme discussed above, an impacted area could also be evaluated purposively (Hammitt & Cole, 1998) if pronounced erosion or damage has already occurred. One advantage of purposive sampling is that it can be more efficient in locating samples in comparison with random or systematical samplings (Hammitt & Cole, 1998). Finally, the census-based approach either uses sectional evaluation, where measurements are made to assess the entire trail sections, or problem assessment, where continuous assessments record every occurrence of predefined impact problems (Marion & Leung, 2001).

The choice of approach is largely dependent upon the study's purpose and the trail's situation. Generally, the reconnaissance approach provides an overall description of a trail and it is followed by either the sampling-based approach or the census-based approach. However, each approach can also be used either separately or in an integrative fashion. Regardless of which approach is chosen, however, each approach has its own advantages and disadvantages (see Hammitt & Cole, 1998; Leung & Marion, 2000; Marion & Leung, 2001 for a detailed discussion of both).

Visitors' impacts on vegetation

In order to measure visitors' impacts on vegetation, three sets of impact parameters have been proposed, each of which measures the amount of

vegetation, vegetation composition, and tree conditions (Hammitt & Cole, 1998). The most commonly used parameter for measuring the amount of vegetation is vegetation cover (e.g. Cole, 1981). The other two parameters are density and biomass (e.g. Sun, 1990; Sun & Liddle, 1993), although the latter is seldom used because it is destructive and time-consuming (Hammitt & Cole, 1998). The second set of parameters measures cover for individual species, species diversity, and frequency. Plant height and forms, growth forms (e.g. Cole, 1987; Sun & Liddle, 1993), floristic dissimilarity index (e.g. Cole, 1978; Cole & Fichtler 1983; Liu, 1992, 1996), and index of vegetational impact (e.g. Liu, 1996) are commonly used. Tree condition is measured by documenting the percentage, number, or density of trees afflicted by damage such as root exposure or scarring (Hammitt & Cole, 1998).

Finally, the impacts of trampling or other related activities on vegetation are multifaceted. Generally, vegetation can be affected in terms of germination and establishment of new plants, physiology and morphology, growth, viability, reproduction and regeneration, and invasion of new species.

Impacts on soil

Soil and vegetation are very susceptible to trampling and vehicle uses. As a consequence, the impact outdoor recreation activities have on soil and vegetation has received a great deal of attention from researchers (Hammitt & Cole, 1998). Various soil characteristics have been studied, including organic matter, profile truncation, compaction, macroporosity and infiltration, soil moisture, and soil erosion. Manning (1979, in Hammitt & Cole, 1998) viewed visitors' trampling impact on soil in terms of a seven-step cycle. This cycle involves a reduction or removal of the leaf litter and humus layers, a reduction in organic matter, a reduction in macroporosity, a reduction in air and water permeability, a reduction in water infiltration rate, an increase in water runoff, and an increase in soil erosion.

Visitors' perception on environmental impacts

As mentioned earlier, environmental degradation can influence the quality of visitor experiences. However, it is not well understood how visitors perceive their impacts on the environment. In addition, findings from past studies are not consistent in terms of acceptability or unacceptability as well as levels of satisfaction relating to the impacts from the visitors' perspective. Generally, visitors appear to be more sensitive to impacts such as litter, tree damage, and badly exposed tree roots (Leung & Marion, 2000). According to Hammitt and Cole (1998: 10), visitors' judgements about whether an impact is good or bad are largely dependent upon 'the type(s) of recreation an area is managed to offer, the objectives of various user groups, and the objectives of resource management'.

Furthermore, the same level of destruction may be seen differently by an outdoor recreationist depending on the type of setting he or she is in. For example, visitors in wilderness areas may be more sensitive to evidence left behind by previous users than visitors in more developed areas (Hammitt & Cole, 1998). Leung and Marion (2000: 26) concur, stating that 'in remote areas, the discovery of even a single trail or campsite can diminish opportunities for solitude'.

But even among those who pursue the same activity there may be different perceptions on the degradation of natural environments depending upon the

visitor's recognition of the impact and the impact's form. Lee (1975, in Hammitt & Cole, 1998), for example, found that enjoyment of backcountry campers was influenced more by litter than by other impacts. Similarly, Roggenbuck *et al.* (1993, in Leung & Marion, 2000) reported that littering and human damage to campsite trees were among the most highly rated indicators affecting the quality of wilderness experiences. Additionally, Hollenhorst and Gardner (1994, in Leung & Marion, 2000) indicated that visitors rated ground vegetation loss and bare ground at campsites as two important determinants of their satisfaction in wilderness. In contrast, though, Knudson and Curry (1981) examined campsite users' opinions about ground cover conditions and found that there is no relationship between actual destruction of ground cover and its influence on users' satisfaction; rather, most users are more satisfied with less ground cover (recognising, however, that there is a point beyond which such change becomes unacceptable). Finally, comparable findings have also been reported by Shelby *et al.* (1988) in regard to the acceptability of fire rings and bare ground related to camping use. As indicated here, the majority of such studies have been conducted with respect to camping use; few studies have actually examined the 'correlation of visitor trail impact perceptions with actual trail conditions as characterised by a trail condition assessment' (Marion & Leung, 2001: 34).

Conclusion

In conclusion, this section has provided a brief review of the literature on trail assessment methods, visitors' impacts on trail resources, and visitors' perception of actual trampling impacts. In the next section, these topics are examined in terms of China's Zhangjiajie National Forest Park.

Methods

Study area

Zhangjiajie National Forest Park, established in 1982, is China's first national park. It is also the main component of the Wulinyuan Scenic Area, a United Nations Educational, Scientific, and Cultural Organisation (UNESCO) world natural heritage site. The park is located in the north-west of Hunan province, southern China, between 29 17′–29 21′N and 110 24′–110 28′E (Figure 1). The park is 32 km from the city of Zhangjiajie and is approximately 4810 hectares in size.

Zhangjiajie National Forest Park can be accessed by paved roads. There is a well-developed visitor village stretching out along both sides of the road leading to the park's main entrance. Facilities in the village consist mainly of the park office, a grocery market, hotels, hospitals, cinema theatres, and local residences. The permanent population of the village is about 2500 people, 1100 of whom are park staff. Recreational access in the park is facilitated by a network of nearly 53 km of slate paved trails, including the Yellowstone Village, Gold Whip Stream, Kidney Stockade, Shadao Ravine, Pipa Stream, and Yuanjiajie trails. These trails offer visitors the opportunity to view nearby scenery as well as distant vistas. Currently, walking/sightseeing is the main recreational activity along the trails. Among the six trails, Yellowstone Village and Gold Whip Stream are the most

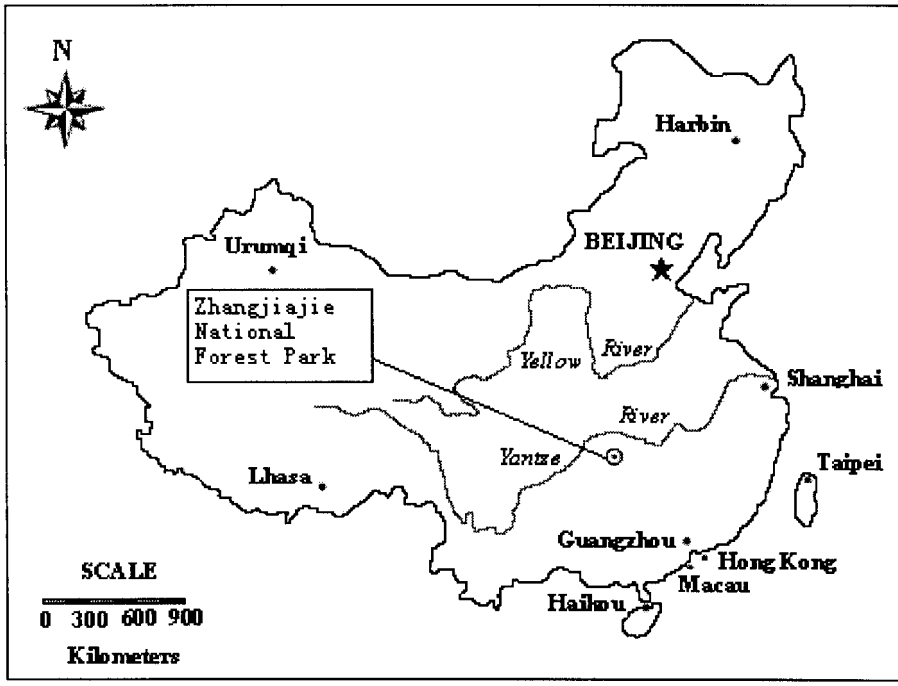

Figure 1 Geographical location of Zhangjiajie National Forest Park

used (Shi, 2000; Wu *et al.*, 1992), due to their access to some of the best scenery and most scenic spots in the park.

Over the past two decades, the impacts of tourism development on the quality of the park in terms of air pollution, water contamination, and plant pollution have been studied (e.g. Huang, 1990). In contrast, little research has examined visitors' trampling of vegetation and soil, which in turn may have negative impacts on visitors' recreational/tourism experience. Because previous research findings have not consistently supported this relationship, however, additional studies are clearly called for. Thus, in this study the impacts on vegetation and soil as well as visitors' perceptions of their impacts in Zhangjiajie National Forest Park are investigated.

Procedures

There are four major study designs employed in recreation ecology studies (Cole, 1987, in Leung & Marion, 2000): (1) descriptive surveys of recreation sites, (2) comparisons of used and unused sites, (3) before-and-after natural experiments, and (4) before-and-after simulated experiments. According to Cole (1995, in Leung & Marion, 2000), of these four study designs the first two are most commonly used for trail and campsite condition assessments. In this study the second design is used to assess trail conditions in the park (although not the assessment of scarred trees, which is discussed separately below).

Due to the spatial limitations on recreation activities, the major activity in the Zhangjiajie National Forest Park is walking/sightseeing along the slate-paved

trails. Therefore, soil and vegetation in the areas along the two sides of trails are the most vulnerable to trampling. In view of this, these two factors are the main consideration of this paper.

Based on the two lead authors' past experience with and knowledge of the park, soil in the park was visually impacted more seriously than vegetation. In terms of vegetation, as most of the accessible areas are covered by mature trees with planted Chinese fir being the dominant species, the main effects are scars on trees and trampling on ground vegetation. Whereas tree scarring was a relatively widespread form of depreciative behaviour in the park, ground vegetation affected by trampling was largely concentrated to several sites. Taking into consideration the study's purpose and the actual conditions of the six trails, four evaluation approaches were used to assess different aspects of vegetation and soil. First, a rapid assessment approach – reconnaissance approach (condition class) – was employed, where recreational impacts along all six trails were identified and classified into five classes (Marion, 1991: 36). Second, a census-based approach was used to assess the patterns and size of soil-impacted sites, where all impacted sites that were individually equal to or greater than 0.5 m^2 in size were measured. Third, a purposive sampling approach was adopted to determine the assessment location of impacted sites, where vegetation and soil change were assessed. A total of 29 soil-impacted sites were purposively selected from those sites that had been identified as class 3, 4, and 5. Vegetation sampling sites were limited to three sites with two along Yellowstone Village Trail (one near the scenic spot 'Treasure Box for the Celestial Books' and the other near the scenic spot 'General Rock') and one along Gold Whip Stream Trail (near the scenic spot 'Gold Whip Crag'). These three sites were relatively large and included the most visually impacted areas in the park. Three of the 29 soil-impacted sites were each located in these three vegetation sampling sites, thereby allowing the examination of impacted soil and vegetation as a single entity when asking visitors to evaluate the effect these impacts had on their hiking satisfaction.

Finally, because the condition class approach does not classify scarred trees, a systematic quadrat sampling approach was employed. During the reconnaissance survey it was discovered that scarred trees were less likely to be found in the segment near the main entrance of a trail. Instead, scarred trees were more likely to be found from near the middle to the end of a trail, and that the scarring frequency was more or less evenly distributed along this segment. Therefore, a systematic quadrat sampling approach was employed, with four 10 m by 10 m samples along each trail; one in the middle, one between the main entrance and the middle, one at the end, and one between the middle and the end. The location of these samples was based on the relative distance of scenic spots marked on the park's guiding maps. Because the subjects are mature trees, the sample size used here was larger than the 1 m by 1 m or 4 m by 4 m samples typically used in ground cover estimation (see Liddle, 1997).

Measurements

Measurement of vegetation

Three of the scenic spots described above were selected to measure the impacts of visitors' trampling. These spots are 'Gold Whip Crag' (GWC) in the middle of

Gold Whip Stream Trail, and 'General Rock' (GR) and 'Treasure Box for Celestial Books' (TBCB) along the Yellowstone Village Trail. In addition, three largely undisturbed 'control' areas that are 50 m away from the impacted sites were identified. These three control areas all had similar slopes to their corresponding recreational sites. The size of a given impacted area was calculated using the geometric figure method (Marion, 1991). Each control site's size was the same as its corresponding impacted site and, for ease of measurement, each control site was either square or rectangular in shape.

The following factors in both control areas and impacted sites were examined: dominant species, age (three levels: young, middle, and mature), number of species, average height, average diameter at breast height, abundance (measured by numbers for trees, cover percentage for ground cover and shrubs), and seedlings.

Three indexes, namely Cover Reduction (CR; Cole, 1981), Floristic Dissimilarity (FD; Cole, 1978) and Index of Vegetational Impact (IVI; Liu, 1996) were calculated. CR is calculated as follows:

$$CR = [(C_2 - C_1)/C_2]*100\% \quad (1)$$

Where C_2 and C_1 are the vegetation cover percentages in control sites and impacted sites, respectively. FD is calculated based on the following formula:

$$FD = 0.5\Sigma \mid P_{i1} - P_{i2} \mid \quad i = 1 \sim n \quad (2)$$

P_{i1} and P_{i2} are the amount of species i in a control site and in an impacted site, respectively, and n is the number of species. The value of FD can vary between 0 and 100%, where 0 means that an impacted site and its control site are identical in terms of the species and their relative abundance; a value of 100% means that the two sites have no species in common (Hammitt & Cole, 1998). IVI is calculated based on CR and FD:

$$IVI = (CR + FD)/2 \quad (3)$$

Measurement of scars

Trees along each trail in the park have been scarred to some extent. Past scars increase in size with the growth of the trees and turn black in colour over time. At each site the number and species of damaged and undamaged trees were counted. For damaged trees, characteristics such as height, diameter at breast height, roughness of bark, distance from trail, number of cuts, and the direction and height of cuts were examined and measured. A framework was developed for determining the extent of scars, roughness of barks, the directions to trail, and the age of scars. The standards used were: (1) degree of scars: light (cuts less than or equal to 50), moderate (cuts between 51 and 100), and severe (cuts more than or equal to 100); (2) roughness of barks: smooth, intermediate, and rough; (3) directions to trail: oblique, straight against, and back against; and (4) age of scars: early (equal to or more than 15 years), medium (between 5 years and 14 years), and recent (less than or equal to 5 years).

Measurement of soils

Four attributes, including the pattern, number, size, maximum length and width of impacted sites were measured along the six trails, while soil moisture

and compaction were measured at the 29 selected impacted sites. The size of a given impacted site was also determined using the geometric figure method (Marion, 1991). Soil moisture (SM) was calculated using the following formula:

$$SM = [(W_1 - W_2)/W_1] * 100\% \quad (4)$$

W_1 and W_2 refer to the mass of a sampled soil before and after being oven dry, respectively. Compaction was measured using Yamanaka's soil hardness tester (Zhuang & Nan, 1978, in Shi, 2000). The penetration resistance indicated by this penetrometer is measured by distance. Higher values indicate increased compaction. Penetrometers are commonly used in the recreation field instead of bulk density as the soil compaction indicator (Hammitt & Cole, 1998; Liddle, 1997).

To accurately determine effects, a gradient sample was used. That is, soil moisture and compaction were measured within 1 m, 2 m, and 3 m of a trail. A control site was located 8 metres away from a trail (three control sites were located in their respective vegetation control sites).

Measurement of visitors' perception on impacts

Visitors' perceptions of impacts on ground vegetation and soil were measured by asking visitors if the impacts were acceptable or not acceptable in terms of their effect on satisfaction when walking/sightseeing along the trails. In order to determine if there was a gap between actual and perceived impacts, visitors passing along the above-mentioned three scenic spots were interviewed between 8–15 July 1997. A face-to-face interview was carried out at each of the three spots. Respondents were asked to answer the question: 'In terms of the trampling impacts on vegetation and soil, do you think those impacts are acceptable or unacceptable in terms of your satisfaction?' In addition, respondents' age, sex, and education were recorded.

Results

Impacts on vegetation

Impacts by trampling on vegetation are listed in Table 1. The impacted area in size is 12.0 m^2, 4.0 m^2, and 100.0 m^2 for GWC, GR, and TBCB, respectively. As showed in this table, disturbed areas were impacted considerably compared with the corresponding control areas in terms of number of species, average height, average diameter, density, and seedlings. For instance, for TBCB, there was only one species in the impacted site, with no ground cover and shrubs, while there were 35 species in the control area. Similarly, for GR, there were no ground cover and shrubs in the used area compared with 17 species in the corresponding control area.

Based on the results in Table 1, CR, FD, and IVI were each calculated. The calculation of FD is not without problems, however, for at least three reasons. First, herbaceous plants and shrubs are the main factors that influence the percentage of ground cover, and it is a time-consuming and often difficult process to identify and measure the magnitude of a herbaceous species. Second, from the perspective of visitors, an area with diversified species may mean something more than a single species, especially a herbaceous one. And third, the

Table 1 Impacts by visitors' trampling on vegetation

Scenic spots		*Types*	*Dominant species*	*Number of Species*	*Average height (m)*	*Average diameter (m)*	*Density*[1]	*Seedlings*[2]
Gold Whip Crag	Used (12.0 m^2)	Trees	–	1	4.5	8.0	1	0(0)
		Shrubs	–	5	3.0	1.5	15%	–
		Ground cover	–	8	0.1	–	10%	–
	Control (12.0 m^2)	Trees	Chinese fir	1	16.0	15.0	3	3(0)
		Shrubs	–	11	4.0	2.5	75%	–
		Ground cover	–	13	0.5	–	98%	–
General Rock	Used (4.0 m^2)	Trees	Chinese fir	1	17.0	18.0	2	0(0)
		Shrubs	–	–	–	–	0.0	–
		Ground cover	–	–	–	–	0.0	–
	Control (4.0 m^2)	Trees	Chinese fir	1	17.0	20.0	4	2(0)
		Shrubs	–	5	1.8	1.5	20%	–
		Ground cover	–	12	0.3	–	95%	–
Treasure Box for Celestial Books	Used (100.0 m^2)	Trees	Chinese fir	1	10.0	17.0	21	0(0)
		Shrubs	–	–	–	–	–	–
		Ground cover	–	–	–	–	–	–
	Control (100.0 m^2)	Trees	Chinese fir	1	12.0	21.0	24	62(5)
		Shrubs	–	13	1.0	2.5	30%	–
		Ground cover	–	21	0.6	–	100%	–

1 Cover percentage was used to represent density for shrub and ground cover.
2 Number before bracket stands for number of fir shoots, while number within brackets stands for seedlings of other species including the fir.

calculation that was used did not account for regeneration. To this end, the authors proposed a modified calculation as follows:

$$FD = \sum_{i=1}^{4} W_i \, |P'_{i1} - P'_{i2}| \, P'_{i2} * 100\% \tag{5}$$

In this modified calculation, trees, shrubs, herbaceous plants and regeneration species are weighed with weightings being 0.4, 0.3, 0.2, and 0.1, respectively (Liddle, 1973, in Liddle, 1997: 78; Wynn & Loucks, 1975, in Liddle, 1997: 75), W_i refers to the weightings while P'_{i1} and P'_{i2} are the number of species in a control site and an impacted site, respectively.

Based on equation 3, IVI calculated for the three impacted sites are 59.4%, 75.0% and 87.5% for GWC, GR, and TBCB, respectively. The results indicate that vegetation around TBCB was the most seriously impacted by trampling. The least impacted area was GWC, with GR being in between.

Damaged trees

An examination of 24 sampling sites among the six trails found that a total of 112 trees were scarred to some extent. Among the 29 species represented, species featuring smooth bark such as *Machilus ichangensis*, *Acer fabri*, *Machilus*

lichyanensis, *Ilex maeroxarpa*, *Cornus controversa*, *Pinus taiwanensis*, *Cinnamomum appelianum*, and *Fagus longipetiolata* were the most damaged. Of the small number of scarred trees featuring coarse bark, most were species such as *Acer davidii*, *Choerospodias axillaris*, *Castanea fargesii*, *Castanea henryi*, *Cunninghamia lanceolata*, *Cyclocarya paliurus*, *Cryptomeria fortunei*, and *Sorbus alnifolia.*

Trees along the two sides of Gold Whip Stream were scarred at a rate of up to 40%, the highest of all six trails. The scarring rate for Yellowstone Village was 27.6%. Damage to the trees along the Yuanjiajie trail was the lowest with the scarring rate being 9.3%. Frequently, trees with diameters larger than 8 cm were scarred. Furthermore, scarred trees were most likely to be found at readily accessible places. For example, trees less than 1 m from trails appeared the most prone to scarring, while trees located more than this distance away from trails were seldom damaged.

Most of the scars occurred on the side of the trees that faced the trails while no scars were found on the back side of the trees. Scars on the side oblique to trails fell in between. Most scars were located around the breast height ranging from 1.2 to 1.6 m, and most of the examined trees were moderately scarred with between 50 and 100 cuts. Relatively, trees with cuts less than 50 or more than 100 accounted for only a small proportion of the overall total. Additionally, 50% of scarred trees were cut early (i.e. equal to or more than 15 years old), while fewer cuts were recent (i.e. less than or equal to 5 years). On the one hand, this finding could be due to the lack of unscarred trees along the trails, while, on the other hand, it could also be due to visitors' increased awareness of the need to protect park resources.

A correlation analysis indicated that the level of cuts was significantly related to the roughness of tree barks ($p < .001$) and the distance from the trails ($p < .001$). The more smooth a tree was, or the closer a tree was to the trails, the more seriously the tree was scarred. In view of this finding, it was suggested that trees with rough, rather than smooth, barks be planted along the trails so that cuts can be reduced.

Impacts on soils

Impacted patterns

Previous studies have found that visitor activities tend to concentrate on trails/routes and rest places/destination areas in which nodes and linkages resulting from intense trampling are formed (Manning, 1979, in Hammitt & Cole, 1998). According to Manning (1979, in Hammitt & Cole, 1998), nodes of impact occur at destination areas such as the table and firepit locations at a campsite, scenic overlooks and the like; and linkages developed along the routes between nodes. Based on an overall reconnaissance of the soil trampling situation, it was found that several types of nodes and linkages have taken place (see Shi, 2000 for a graphical description of these impacted patterns), where nodes often occurred near scenic spots or rest places in the shape of irregular polygons, while linkages were most likely to occur within 3 m of the trails. It was also found that there were a total of 99 nodes and linkages across all six trails. The total impacted areas were 1721.5 m^2 with an average of 14.7 m^2. Yellowstone Village Trail and Gold Whip Stream Trail, the two most popular trails, were the most impacted with their total impacted areas being 641.0 m^2 and 462.0 m^2, respectively.

Soil moisture and compaction

The average value of soil moisture measured along each trail consistently increased with the distance away from each trail. In terms of all six trails, the average values in the 1 m and 2 m sites were 11.97% and 14.26%, respectively, which are 37.13% and 25.11% less than the control sites. Compared to the other five trails, Yellowstone Village had the lowest values in the 1 m (10.57%) and 2 m (12.74%) sites. In terms of penetration resistence, the consistent finding across all six trails is that the closer a site is to the trail, the greater the value is. In terms of the average value measured 1 metre away from each trail, Yellowstone Village had the highest value of 34.21 across all six trails, which was 24.13%, 182.73%, and 203.01% more than the values measured in the 2 m, 3 m, and control sites, respectively.

The effects of recreational use on soil moisture are complex. Factors such as soil compaction, texture, organic content, density of forest cover, and exposure to sun and wind can influence the capacity of soil to hold water. It is not unusual to find that soil moisture is reduced as compaction increases, which leads to the reduction of infiltration and the amount of water available to the soil (Feng & Bao, 1999; Settergren & Cole, 1970). However, for the sandy loam soil, compaction can increase the amount of capillary pore space and the moisture-holding capacity of the soil (Hammitt & Cole, 1998). In the case of Zhangjiajie National Forest Park, because most of the areas were dominated by light sandy clay, soil moisture was reduced as a result of compaction by trampling.

Composite index

There are many factors that affect these two soil attributes. However, the consistent increase in these attributes on the two most used trails suggests that visitors' use plays a key role. Because all soil factors do not react to trampling the same way, ideally more than one indicator should be used to examine the effect visitors have on soil. Because no existing models incorporate these two factors, however, this paper proposes the following composite index:

$$\mathrm{SII} = \sum_{i=1}^{3} W_i \sum_{j-1}^{2} \frac{|N_{ij} - N_{0j}|}{N_{0j}} \tag{5}$$

In the above, SII refers to the soil impact index, with the greater the SII value indicating the more impacted the soil is. N_{ij} refers to the value of j attribute (i.e. soil moisture, or compaction) of the soil in a sample site that is $_i$ meter away from a trail; N_{0j} refers to the value of j attribute of the soil in a control site. $_i$ refers to the weight of gradient values measured in used sites.

Because the closer a site is to a trail the more likely it is that it will be impacted by trampling, the values measured in 1 m, 2 m, and 3 m are weighed by 0.5, 0.3, and 0.2, respectively (ref: Liddle, 1973, in Liddle, 1997: 78; Wynn & Loucks, 1975, in Liddle, 1997: 75). Based on the formula, the averaged SII calculated for each trail is 1.79 for Yellowstone Village, 1.59 for Gold Whip Stream, 1.57 for Kidney Stockade, 1.47 for Pipa Stream, 1.29 for Shadao Ravine, and 1.32 for Yuanjiajie, respectively.

The seriousness of impacts, in terms of SII, is proportionate to visitor use. The most used trails, Yellowstone Village and Gold Whip Stream, had the highest SII

values, 1.79 and 1.59, respectively. The less used Shadao Ravine had the lowest SII value (1.32). In addition to these average SII values for each trail, the SII values for the three impacted sites were also calculated, with 2.23 for GWC, 2.12 for GR, and 2.27 for TBCB, respectively. It is not surprising to find that these values were greater than those of their respective trails because, it should be remembered, these three sites were selected because they were visually the most impacted.

Based on the above, TBCB was the most seriously physically impacted site in terms of IVI and SII; while GR and GWC ranked second and third in terms of IVI, and third and second in terms of SII. Generally, soil impacts are less likely to influence visitors' visual satisfaction, while 'vegetation is the most readily evident to users' (Hammitt & Cole, 1998: 49). Therefore, it is anticipated that visitors will perceive the impacts on TBCB most unacceptable, followed by GR and 'GWC.'

Visitors' perceptions of impacted areas

In order to understand visitors' perceptions of trampling impact, 814 visitors who passed the three scenic spots were approached. Of the 683 (83.9%) individuals who were willing to participate, 210, 153, and 320 were interviewed in GWC, GR, and TBCB, respectively. In total, 194 (28.4%) visitors viewed the impacts as acceptable while 489 (71.6%) considered the impacts unacceptable. Visitors' perceptions of impacts on the GWC and TBCB were similar, with a majority viewing impacts as being unacceptable (77.14% and 84.69% for GWC and TBCB, respectively). In contrast, only 36.6% of respondents passing the GR considered the impacts as being unacceptable while 63.4% viewed the impacts as being acceptable. It is worth noting that impacts on GR were perceived to be more acceptable by a majority of visitors than GWC, despite the fact that GWC had a higher IVI than GR.

In order to try to understand the relationships between acceptability/unacceptability and variables such as sex, age, education, impacted sites, IVI, and SII, logistical regression was performed using SPSS 11. Logistical regression is particularly suitable to this study because: (1) the dependent variable is dichotomous; (2) the purpose is to predict the presence or absence of a phenomenon; this is, the acceptability or unacceptability of trampling impacts on visitors' tourism satisfaction; and (3) the independent variables are a mix of nominal, ratio, and dichotomous variables. Block entry of variables was used to estimate the relationship model. As redundancies among impacted sites, IVI and SII were detected; IVI and SII cannot be included together with impacted sites in one model. Therefore, these variables were regressed separately on acceptability/unacceptability. Acceptability and unacceptability were coded 0 and 1 respectively.

As reported in Table 2, the relationship between acceptability/unacceptability and both sex and age is not significant ($p > .05$). In contrast, education is significantly related to acceptability/unacceptability ($p < .001$), with the higher a visitor's level of education, the more he or she is likely to consider the impacts as unacceptable. Table 2 also reports visitors' perceptions of trampling impacts on their satisfaction varied significantly among the three sites, with TBCB being viewed as the most unacceptable ($p < .001$), followed by GWC ($p < .001$). As GC is the reference category in the regression, therefore, 'GR' was the least unacceptable (or, alternatively, the most acceptable) site.

Table 2 Logistical regression analyses for visitors' perceptions of environmental impacts

Variables	*B*	*Standard error*	*Wald*	*Sig.*	*Exp (B)*	*Coded variables*
Sex	0.073	0.19	0.15	0.70	1.08	Female: 0 Male: 1
Age	0.14	0.13	1.20	0.27	1.15	20–35: 1; 36–45: 2 46 and over: 3
Education	0.67	0.19	12.25	0.00	1.96	Below undergraduate: 1 Undergraduate or over: 2
GWC	1.75	0.24	53.83	0.00	5.76	GWC: 1; GR: 0; TBCB: 0
TBCB	2.30	0.23	97.27	0.00	9.95	TBCB: 1; GWC: 0; GR: 0
Constant	–1.15	0.30	14.29	0.00	0.32	

Table 3 Logistical regression analyses for relationship between visitors' perceptions of environmental impacts and the actual impacts caused by them

Variables	*B*	*Standard error*	*Wald*	*Sig.*	*Exp (B)*
IVI	–2.63	0.84	0.098	0.75	0.77
SII	15.54	1.56	99.42	0.00	5599078.2
Constant	–33.89	3.38	100.45	0.00	

In order to understand the relationship between visitors' perceptions of impacts and the actual impacts as measured by SII and IVI, SII and IVI together with other variables (e.g. sex, age, and education) were regressed on the dependent variable. Because the parameters for sex, age, and education remained the same as in Table 2, they are not included in Table 3. As shown in this table, IVI was negatively related to visitors' perceptions, but this relationship was not significant ($p > .05$). In contrast, SII was significantly and positively related to visitors' perceptions ($p < .001$). This result suggests that vegetation damage as measured by IVI does not appear to be the determining factor in terms of its effect on visitors' perceptions; rather, impact on soil as measured by SII was the main cause.

Because impacts of trampling on vegetation and soil are concomitant, and visitors' perceptions of a given site could be subject to the interaction of the size of the impacted site and physical destruction as measured by IVI and SII, two interactive variables – IVI* SII and IVI*SII*SIZE – were regressed against the dependent variable. As shown in Table 4, the effect of the interaction of IVI and SII on visitors' perceptions is significant and negative ($p < .001$). However, the effect of the interaction of IVI, SII, and the size of an impacted site is significantly and positively related to visitors' perceptions ($p < .001$), suggesting therefore that the size of impacted sites plays an essential part in influencing visitors' perceptions of

Table 4 Logistical regression analyses for the relationship between visitors' perceptions of impacts and the interactive factors

Variables	*B*	*Standard error*	*Wald*	*Sig.*	*Exp (B)*	*Coded variables*
IVISII	–5.74	0.82	49.45	0.00	0.003	IVISII: IVI*SII
IVISIISIZE	0.024	0.003	89.82	0.00	1.02	IVISIISIZE: IVI*SII*SIZE
Constant	7.83	1.18	43.85	0.00	2504.35	

whether or not the impacts are acceptable. This finding is generally consistent with the actual impacts of the sites. For instance, TBCB with the biggest impacted size and the highest IVI and SII was perceived by respondents as being the most unacceptable, while GWC with the middle SII and middle size ranked second, although its IVI is the lowest. Finally, GC with the lowest SII and smallest size ranked last in terms of its unacceptability, although its IVI value is between that of other two sites.

Discussion and Conclusion

As most of the trails in Zhangjiajie National Forest Park are at the bottom of valleys, visitors are limited spatially to walking along the trails. Consequently, the impacts of visitors' trampling on vegetation and soil are not equal everywhere. Most of the impacts occurred along trails with nodes formed in open spaces and linkages formed along the trails. In terms of soil impacted by trampling, the total disturbed area only represents 0.0036% of the park's total area, indicating that the effect trampling impact has on the park's environment is relatively small. This finding is consistent with several studies carried out in the United States. For example, disturbed areas at the heavily visited Great Smoky Mountains National Park represent only 0.05% of the park's total acreage (Marion & Leung, 1997, in Leung & Marion, 2000). For less visited campsites, this number is much smaller. For instance, a study conducted by Leung and Marion (1995, in Leung & Marion, 2000) in Virginia's Jefferson National Forest revealed that disturbed areas as a result of camping account for only 0.0007 to 0.015% of the wilderness.

The lower value in soil moisture and the higher value in penetration persistence as measured along the six trails, especially along the heavily used trail of Yellowstone Village, are also consistent with previous findings. For example, in terms of compaction measured by penetrometer readings, Cole (1983) found that penetration resistance increased by 71% on campsites in Bob Marshall Wilderness, 89% in the Rattlesnake, 139% in the Mission Mountains, and 220% in the Boundary Waters Canoe Area (in Hammitt & Cole, 1998).

Previous studies have also found that recreation impacts are proportionately related to visitor use – and this study is no exception. For instance, the total disturbed area for the two most heavily used trails, Yellowstone Village Trail and Gold Whip Stream Trail, is 1103.0 m^2, accounting for 64.1% of all disturbed area. Likewise, disturbance on soil as measured by SII was the most serious in the Yellowstone Village Trail followed by the Gold Whip Stream Trail. It was also

found that trees along Gold Whip Stream Trail are scarred at a rate of up to 40%, the highest of all six trails, followed by Yellowstone Village Trail with a scarring rate of 27.6%. Potentially, the high scarring rate along the Gold Whip Stream Trail could be due to the easier access visitors have to trees along this trail, the most level of all of the park's trails.

Although recreation impacts on the park do not appear to be serious, they may still have a negative effect on visitors' recreational experiences as these impacts were largely localised and concentrated on the most used trails. Leung and Marion (2000: 25) state that the location and concentration of recreation impacts 'can harm rare or endangered species, damage sensitive resources or diminish ecosystem health'. Likewise, visitors' recreational experience could also be influenced by recreation impacts that are localised and concentrated. In the case of this study, for example, it was found that visitors' recreational satisfaction has been largely and negatively influenced by recreation impacts, as demonstrated by the three most disturbed sites. However, visitors' perceptions of recreation impacts on their recreational satisfaction were not consistent across the three sites, suggesting that higher disturbance of vegetation does not necessarily lead to higher dissatisfaction, as has been suggested previously by Hammitt and Cole (1998: 49). Furthermore, it seems that visitors' responses to vegetation impacts were inconsistent with some previous studies that indicated that there was no relationship between visitors' satisfaction and actual vegetation destruction (e.g. Knudson & Curry, 1981), and that visitors tended to be more satisfied with less ground cover (e.g. Shelby *et al.*, 1988). Although this explanation is consistent with the actual vegetation destruction on GR, which had the highest IVI value whilst having the lowest unacceptability, it is largely contradictory to the actual vegetation destruction as measured by IVI in GWC and TBCB. Thus, it seems that there are other factors that influence visitors' judgements. One such factor could be the size of the impacted sites, which suggests that visitors' perceptions of recreation impacts at a given site reflect vegetation, soil, and size of the impacted area, with the last variable potentially being the most important.

Other factors that were not included in the regression analyses are visual sensitivity, social elements, and relative spatial locations. All these factors may have indirect or interactive effects on visitors' perceptions of recreational impacts on their sightseeing satisfaction. For instance, the low level of dissatisfaction on the site nearby GR could be due to the location of the site which is about 15 m away from the spot, and its visual impact is relatively low; while for the TBCB, the sampling site was between it and the 'Ethnic Wooden Pavilion' and visitors had to pass by it on their way to the top of Yellowstone Village. Thus, its visual impact is much greater. Moreover, there are a large number of souvenir sellers standing by the two sides of the trail ready to intercept visitors and, possibly, this may add to the higher level of unacceptability at this location. Finally, the sampling site around GWC is very close to the trail and it provides a broad viewing angle. Though the level of trampling impact is lower than GR, the unacceptable level is likely to be higher than the latter because of its greater visual sensitivity. This explanation seems consistent with Hammitt and Cole's (1998: 11) statement that 'recreationists, as a whole, seem to be more concerned with impacts that decrease the functional use of a site'. In conclusion, visitors' perceptions of recreation impacts were not determined by a single factor; rather, it is a combination of

factors such as vegetation, soil, size, visual sensitiveness, spatial locations, and social elements that influence visitors' judgements about whether or not recreation impacts are acceptable.

It should also be noted that socio-demographic factors could have an effect on visitors' perceptions of recreation impacts. As reported earlier, although sex and age did not significantly affect visitors' perceptions, education was significantly and positively related to visitors' perceptions, with visitors who had higher education levels being more likely to view recreation impacts as being unacceptable. Although it may be tempting to try to link this finding with studies that suggest that people who are highly educated are more likely to be environmentally concerned than people who have lower education levels (e.g. Dietz *et al.*, 1998; Fransson & Garling, 1999), it should be noted that other studies have found that levels of environmental concern are evenly distributed across education levels (Gooch, 1995; Jones & Cater, 1994). Moreover, the purpose of this study was to examine how visitors perceived the recreation impacts on their recreational satisfaction, not on the environment itself. Thus, caution appears warranted when attempting to make this linkage.

There are, of course, limitations associated with this study. First, visitors were asked about their perceptions of impacts and their effect on their satisfaction at only three sites. If more sites were selected, logistical regression analyses could prove to be both more valid and explanatory. Second, scarred trees were not included in the satisfaction analyses. Third, ground cover change at an impacted site, as measured by IVI, is relative to its control site. Therefore, even if the values measured varied among different impacted sites, the actual impacts on these sites could be similar. For example, recreation impacts on vegetation could be the same at GR and TBCB if the density of shrubs and ground cover for these two sites were zero, while IVI is 75.5% for the former and 87.5% for the latter. Because it remains unclear if visitors perceive recreation impacts in reference to the surrounding setting, results based on IVI may be open to question. In view of this as well as the potential interactions among the independent variables, qualitative analyses may be more appropriate and should be considered in future studies.

Having noted these limitations, this study still has practical implications. For example, it is essential that vegetation along both sides of a trail be effectively managed. From an ecological perspective, not doing so could lead to damaged vegetation and the overtrampling of soil along trails, which in turn could lead to the formation of valleys and the promotion of runoff. As a result, the base of the paved trails can be affected and may eventually be destroyed. This has already happened at some sites in the park. To this end, the monitoring and management of visitors' impact along trails must be increased. The following measures are, therefore, suggested:

(1) Set up temporary fences to keep visitors out of those sites that have been seriously impacted so that these areas can either recover naturally or by intentional planting.
(2) More attention should be paid to the management of stakeholders around scenic spots. In one case it was found that visitors were constantly being approached by souvenir sellers and it seems likely that this commercial activity

has led to crowding and, consequently, the trampling of soil and vegetation as well higher levels of visitor dissatisfaction.

(3) Environmental education has been shown to affect visitors' environmental concern and, therefore, it is an essential component of ecotourism. Unfortunately, like many other forest parks, environmental education has not yet been made part of park management in China. Thus, as the first national forest park in China, Zhangjiajie should take the lead in this regard.

(4) One alternative approach that can be used to mitigate the impact visitors have on overused trails is to channel them to less visited areas. Historically, Yellowstone Village and Gold Whip Stream are the most frequently visited trails while other trails in the park have been used much less frequently. For example, in a survey conducted in 1997 it was found that only 10 of 3039 users (0.33%) visited Kidney Stockade during a peak-season day. This finding also holds true for Shadao Ravine and Yuanjiajie trails, possibly due to them being less attractive and more physically demanding. However, another reason for this lesser use may be that the park's current marketing and guiding arrangement places greater emphasis on the Yellowstone Village and Gold Whip Stream trails. In order to increase the use of less used trails and mitigate the pressure on overused trails, the park should alter its marketing strategy while, at the same time, improving accessibility to, and the popularity of, less frequently visited trails.

In conclusion, this study has examined trampling impacts on vegetation and soil as well as visitors' perception of these impacts in Zhangjiajie National Forest Park, China. In doing so, it is hoped that this paper provides insight into these issues in a Chinese protected area specifically, and that it also contributes to research on ecotourism and recreational impacts generally.

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