CHAPTER IV. CHARACTERIZING BACKCOUNTRY CAMPING IMPACTS AND THEIR SPATIAL PATTERNS IN GREAT SMOKY MOUNTAINS NATIONAL PARK

Abstract

This study investigates resource impacts and spatial patterns of backcountry campsites in the Great Smoky Mountains National Park. Study objectives are to improve our understanding of the multivariate nature of camping impacts and their distribution patterns, and to aid in the formulation of effective backcountry camping management and monitoring strategies. Three hundred and eight campsites at designated backcountry campgrounds, and 69 additional unofficial campsites were assessed. Factor analysis of 195 established campsites on eight impact indicator variables revealed three dimensions of campsite impact: land disturbance, soil and groundcover damage, and tree-related damage. Each of these dimensions might be related to a common set of causes that requires targeted management strategies. Cluster analysis of factor scores yielded three distinctive backcountry campsite types that characterize both the intensity and areal extent of resource impacts. Spatial patterns and site attributes of these three campsite types are illustrated and discussed. The campsite impact typology developed in this study demonstrates that campsite impacts can be viewed holistically with the help of multivariate methods. Further research on the stability of the impact dimensions and the campsite typology is suggested.

Key Words: recreation impacts, backcountry campsites, multivariate methods, spatial patterns, Great Smoky Mountains National Park.
Introduction

Protected areas worldwide, such as national parks, nature reserves, and wilderness areas, are commonly established and managed to safeguard our natural and cultural heritage. Internal and external sources of human impact, including encroaching development, pollution, introduction of exotic species, and recreation or tourism visitation, increasingly threaten to compromise these purposes. Among these sources, recreation and tourism visitation present a perennial and growing management challenge to protected area managers. This is particularly true for national park managers as they are mandated to protect park resources while also providing appropriate recreational opportunities (NPS 1988). These dual mandates require managers to carefully manage visitation and any negative environmental effects or impacts. Various forms of resource impact have been described, including vegetation loss, soil exposure, compaction and erosion, tree and seedling damage, wildlife disturbance, and miscellaneous damage caused by depreciate behavior (Cole 1987, Hammitt and Cole 1987).

Backcountry camping, a primary outdoor and wilderness recreational activity, has the potential to generate substantial resource impacts due to the nature of the activity, such as high activity concentration and relatively long durations of stay. Although most camping impacts occur on and around campsites, their ecological disruptions may be locally intensive and extensive within popular destination areas (Marion and Cole 1996, Cole et al. 1997). As campsites serve as destinations and focal points for recreational activities, evidence of resource impacts on campsites can have a negative influence on the quality of recreation experiences (Roggenbuck et al. 1993). Hence, resource impacts on individual campsites,
coupled with the proliferation of campsites over time, may constitute a significant threat to the ecological and social values of parks.

Park managers have responded to camping impacts by implementing a variety of site and visitor management measures for reducing both per capita and total or cumulative impact. These measures include selection of resistant sites, site hardening, facility development, site maintenance, site closure and restoration, designated or dispersed site camping policies, use limits and rationing, and visitor information and education (Cole 1987, Marion et al. 1993). In order to select effective strategies park managers need objective and up-to-date information on the intensity, extent, and distribution patterns of different forms of camping impact. Such information is also a critical element for evaluating indicators and standards in management planning frameworks such as Limits of Acceptable Change (LAC) and Visitor Experience and Resource Protection (VERP) (Stankey et al. 1985, NPS 1997).

**Campsite Impact Assessment and Monitoring**

Campsite impact assessment and monitoring (CIAM) programs, when appropriately designed and implemented, can be responsive to a variety of management information needs. These programs have employed two different survey approaches (Cole 1989a, Marion 1991). Condition class rating systems are the earliest approach: surveyors simply determine which of several descriptive classes best characterizes a campsite’s condition. This approach is still commonly used, notwithstanding concerns regarding its subjectivity and imprecision. A multiple-indicator approach, on the other hand, yields more objective data on individual
impact indicators (e.g., campsite size, soil exposure), which may be aggregated to form summary impact indices for the purpose of characterizing conditions on individual or groups of campsites (Cole 1989a). This second approach may be applied using a system of discrete ratings, such as campsite size categories, or using actual measurements. Some programs combine both condition class and multiple-indicator systems to provide a more comprehensive coverage of information (Marion 1991).

The first issue examined in this paper is related to the limitations of the multiple-indicator CIAM approach. While this approach is designed to yield information that permits a comprehensive evaluation of campsite conditions, individual impact indicators are often evaluated separately with little account for the interrelationships among indicators and for the similarities among campsites. The use of numerous indicators in the multiple-indicator approach also probes the question of efficiency, and whether some indicators might be omitted to expedite field work without compromising CIAM objectives. The third limitation concerns the mathematical appropriateness of some summation methods in which campsite impact indices are constructed by averaging and adding ordinal-scale measurements (Schuster and Zuuring 1986).

Multivariate methods offer powerful tools to overcome these limitations by simultaneously analyzing the influence of various impact indicators, identifying dimensional structures and interrelationships among indicators, and providing objective aggregate characterizations of campsites based on their resource conditions. While multivariate approaches are common in recreation and environmental literature, their application in
assessing camping impacts is somewhat limited. An early application was conducted by Ditton et al. (1977) for campsites along the Rio Grande River in Big Bend National Park. They employed cluster analysis and principal components analysis to classify and characterize campsite conditions based on 15 environmental and impact indicators measured at an ordinal scale. Other published examples of multivariate application include multiple regression by James et al. (1979) and Marion and Merriam (1985), and principal components analysis-ordination by James et al. (1979) and Zabinski and Gannon (1997).

The second issue examined in this paper concerns the spatial patterns of camping impact. Most previous CIAM studies have been directed at investigating the nature and intensity of camping impacts, while evaluations of the spatial extent and distribution of campsites have been limited. Early studies on the spatial patterns of camping impacts have been reviewed by Hart (1982). Most of these early investigations, and to some extent recent studies (Cole 1992, Marion and Cole 1996), have focused on the intra-site variation in camping impact. Recognizing that the problem of campsite proliferation, or increasing number of campsites at a landscape scale is as serious as worsening conditions on established campsites, some recent studies have examined backcountry campsites with respect to their spatial extent and distribution (Stohlgren and Parsons 1992, Cole 1993, McEwen et al. 1996, Cole et al. 1997). These studies typically mapped the location of campsites and qualitatively examined their distribution patterns.
The primary goal of this study is therefore to improve our understanding of backcountry camping impacts from multivariate and spatial perspectives. Four specific objectives are:

1. To identify the dimensional structure of camping impact indicators,
2. To characterize camping impacts by developing a campsite typology based on the identified dimension structure,
3. To evaluate spatial patterns and environmental and use characteristics of the identified campsite typology, and
4. To provide management recommendations derived from the campsite typology.

**Study Area**

Great Smoky Mountains National Park (GSMNP), located in the southern Appalachian Mountains along the border of Tennessee and North Carolina, served as the study area (Figure 3.1, p.29). Its 209,000 hectares of park area comprise the main divide of the Great Smoky Mountains and numerous spur ridges and foothills. Due to the moist climate and large elevation change, GSMNP accommodates one of the most diverse flora and fauna in North America. Major vegetation communities include spruce-fir, northern hardwoods, xeric hardwoods and mesic hardwoods (Whittaker 1956).

Since its establishment in the 1930s, GSMNP has been one of the most visited national parks in the United States, reporting 9.2 million visits and about 96,000 overnight stays in 1992 (NPS 1994). Recreational resources and facilities in the 170,000 hectares of
backcountry zone have been subject to exceptionally high use pressure. Except for fire permit requirements, no restrictions were placed on backcountry camping until 1976, when the park faced ever-growing numbers of visitors and rapidly proliferating camping impacts (Bratton et al. 1978). All backcountry camping has since been restricted to about 87 designated backcountry campgrounds (DBC) and 18 shelters, each of which is marked on park maps and identified with a signpost. A self-registered permit is required for all backcountry overnight stays, with specific restrictions on group size (eight persons) and length of stay (three nights per campsite). Advance reservations for overnight stay are required for 15 rationed DBCs and all shelters.

In the vicinity of each DBC there are typically two to four individual campsites (maximum=12) connecting each other with visitor-created social trails. Individual campsites are generally not marked and no clear boundaries have been defined for each DBC, therefore visitors are not restricted from creating their own camping spots within a reasonable distance from the DBC signpost. Camping near shelters, however, is prohibited. Unofficial campsites developed by visitors outside these DBC zones are considered to be illegal.

Significant resource impacts at backcountry campsites and shelters have been documented by Bratton et al. (1978, 1982). They found that backcountry campsites were concentrated along the park's formal trails, at which camping disturbance to vegetation and soil was extensive. Illegal campsites were widespread and contributed significantly to the total area of camping disturbance, soil exposure, and number of fire pits parkwide (Bratton et al. 1978). Assessment results from a recent survey (Marion and Leung 1997), suggest that
there have been remarkable improvements in the reduction of campsite-related land
disturbance, especially around shelters. However, the problem associated with campsite
expansion and proliferation at DBCs is still substantial, likely due to the lack of specific
campsite designation at DBCs.

Methods

Field work for this study was conducted in the Summer of 1993. Legal campsites at
all but two DBCs were assessed. Illegal campsites were also located and assessed through
extensive searches along park trails, informal trails, and at potential locations advised by park
personnel. Overnight use statistics for the DBCs were obtained from the 1992-93 annual
statistics from self-registered backcountry permits (GSMNP 1992-1993), which likely
underestimate actual camping visitation. Reasonably reliable DBC use data was available only
for the rationed DBCs and the shelters.

Field assessment procedures were modified from Marion (1991). The location of each
identified legal or illegal campsite was marked on the corresponding 1:24,000 topographic
map, from which campsite elevations were obtained. Locational and environmental attributes,
including landform position, dominant tree species, distance to water source, and distance to
formal trail, were recorded. Use and managerial attributes, such as type of use and campsite
legality status, were collected from information provided by park personnel.

The boundaries and size of each campsite were determined using the variable transect
method (Marion 1991), by which a central permanent reference point and numerous boundary
points were flagged, with distance and azimuth from the reference point to each flag measured to derive campsite size. Measurement precision, which is important for monitoring purposes, was enhanced by assessing most impact indicators within the defined campsite boundary. A probable cost of this design was underestimating certain forms of impact, such as tree damage or cut trees, which also occur beyond campsite boundaries.

The overall condition on each campsite was rated using a five-point condition class scale based on ground vegetation and litter coverage (Marion 1995); class 1 sites are barely evident while class 5 sites have lost most vegetation and litter cover and soil erosion is evident. Campsites rated class 3 or above were assessed with additional measurements to provide more comprehensive information on their condition. The reduced data on condition class 1 and 2 sites prevented their inclusion in the multivariate analyses but they are grouped together as a distinct campsite type comprised of sites that have minimal vegetation disturbance and no exposed soil. This group of low impact campsites were added to the campsite typology identified from the multivariate analysis for profile description.

Groundcover vegetation and exposed soil on each condition class 3-5 campsite and on nearby undisturbed and environmentally-similar control areas were assessed using six cover classes (0-5%, 6-25%, 26-50%, 51-75%, 76-95%, 96-100%). Amount of groundcover vegetation loss on campsites was inferred from: (1) the absolute groundcover loss, defined as the mid-point difference in percent coverage between the campsite and its control, and (2) the area of vegetation loss, which was the product of absolute groundcover loss and campsite size.
A similar areal measure was also used for expressing the extent of exposed soil on each campsite.

Within campsite boundaries the number of occurrences were recorded for the following impact indicators: damaged trees (trees with obvious human-caused trunk mutilations), trees with exposed roots, tree stumps, fire sites (pits or rings), visitor-created social trails radiating from campsite boundaries, and intersite visibility (number of other campsites visible from the campsite being assessed).

Eight campsite impact indicators were selected for the multivariate analysis based on their ecological and managerial significance, commonness in previous CIAM studies, and their appropriate levels of measurement for multivariate procedures. Prior to the analyses, three outlier cases were removed and a logarithmic transformation was used to reduce skewness for the campsite size indicator. Percent measures (total number of on-site trees as the base) of damaged trees, tree with exposed roots, and tree stumps were chosen as they were not related to campsite size as count measures were. Campsites that had no trees on-site were excluded from the construction of the correlation matrix used in factor analysis.

A factor analysis (principal components extraction, varimax rotation) was used to identify the dimensional structure of the selected impact indicators. This analysis also served as a data pre-treatment procedure to eliminate multicollinearity among impact indicators and to derive composite factor scores for cluster analyses (Hair et al. 1995). Only factors with eigenvalues of greater than 1.0 were extracted. Eigenvalue scree plots were also used to aid in determining an appropriate number of factors.
A series of cluster analyses were performed using factor scores to classify campsites into types based on impact patterns. Both hierarchical and non-hierarchical clustering procedures were employed (Everett 1980). The first approximation was conducted using the hierarchical Ward's method (Griffith and Amrhein 1997). The cluster solution from this method was evaluated to suggest an approximate number of clusters. The second approximation involved use of the non-hierarchical K-Means clustering method with random initial seeds. This method was used because no hierarchical structure was assumed in the dataset and better groupings can be produced by allowing relocation of entities at later stages (Everett 1980). Several runs were performed using different numbers of clusters, as guided by the dendrogram generated in the first approximation. Final cluster centers obtained from the two approximations were compared for grouping consistency. The profile of clusters (campsite types) was also examined on different site and use attributes and aggregate impact measures. Campsites types were also mapped to discern their distribution patterns in space. One-way ANOVAs and Chi-square were used for testing the null hypothesis that site and use attributes are independent of campsite types.

Results and Discussion

A total of 377 backcountry campsites were identified and assessed in the survey, with a density of 0.2 campsites per km². Three hundred and eight campsites were located in close proximity to DBCs and therefore assigned as legal campsites. The number of individual campsites at a DBC range from 1 to 12. DBCs with high campsite numbers are concentrated
in the central portion of the park, as are most of the 69 illegal campsites located by survey staff (Figure 4.1). Constituting about 18% of the total number of backcountry campsites, these illegal campsites seem to be spatially associated with DBCs in many areas, perhaps serving as 'overflow' sites when DBC campsites are occupied. Some campers might also be psychologically displaced from legal campsites at DBCs due to undesirable resource and social conditions. The remaining illegal campsites are distributed singly away from DBCs, possibly indicating a spatial mismatch between DBCs and backcountry use patterns.

One hundred and ninety five campsites (176 legal and 19 illegal) rated condition class 3 or higher were included in the multivariate analyses. Another 141 campsites were rated class 1 and 2, characterized by little or no vegetation loss and no exposure of underlying mineral soil.

**Dimensional Structure of Camping Impacts**

The results of factor analysis are summarized in Table 4.1. The dimensional structure comprises three factors with eigenvalues of greater than 1.0, accounting for 58% of the total variance. Using similar principal components analysis, Ditton et al. (1977) and James et al. (1979) achieved similar levels of explained variance, although more indicators were included in these two studies.
Figure 4.1. Location of legal (designated) and illegal campsites in Great Smoky Mountains National Park.
Table 4.1. Results of factor analysis on eight indicators of backcountry camping impacts in Great Smoky Mountains National Park (N=195).

<table>
<thead>
<tr>
<th>Factor Name and Indicator</th>
<th>Factor Loadings $^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>1. Land disturbance</strong></td>
<td></td>
</tr>
<tr>
<td>Campsite Size (log scale) (ft$^2$)</td>
<td></td>
</tr>
<tr>
<td>Fire Sites (pits or rings) (#)</td>
<td></td>
</tr>
<tr>
<td>Visitor-created Social Trails (#)</td>
<td></td>
</tr>
<tr>
<td><strong>2. Soil and groundcover damage</strong></td>
<td></td>
</tr>
<tr>
<td>Trees with Exposed Roots (%)</td>
<td></td>
</tr>
<tr>
<td>Absolute Groundcover Loss (%)</td>
<td></td>
</tr>
<tr>
<td>Exposed Soil (%)</td>
<td></td>
</tr>
<tr>
<td><strong>3. Tree-related damage</strong></td>
<td></td>
</tr>
<tr>
<td>Tree Stumps (%)</td>
<td></td>
</tr>
<tr>
<td>Damaged Trees (%)</td>
<td></td>
</tr>
<tr>
<td>Eigenvalue</td>
<td>2.173</td>
</tr>
<tr>
<td>Variance Explained (Cumulative %)</td>
<td>27.2</td>
</tr>
</tbody>
</table>

$^1$ Principal components factor extraction with orthogonal varimax rotation. Factor loadings that are greater than 0.5 are in bold. Only factors that have an eigenvalue of greater than 1.0 were included.
The first factor, accounting for 27% of total variance, includes campsite size, fire sites, and social trails. This factor is named *Land Disturbance*, as the three indicators imply or contribute to the disturbance of land caused by camping. The areal extent of camping disturbance, campsite size, is a primary indicator related to use intensity and environmental fragility. The level of off-site disturbance and the potential for campsite expansion and proliferation may be inferred in part by the number of social trails radiating from a campsite. The number of fire sites is also indicative of the extent of land scarring and associated soil damage caused by campfires.

The second factor, accounting for 22% of the total variance, is named *Soil and Groundcover Damage*, since its constituent impact indicators are directly related to trampling loss of vegetation groundcover and concomitant soil exposure and erosion. The three indicators included in this factor are trees with exposed roots, absolute groundcover loss and exposed soil (Table 4.1).

The third factor, *Tree-Related Damage*, accounts for 13% of the total variance. This factor includes the percentage of on-site trees that are damaged (tree damage) and that are cut (stumps). Both of these impacts are linked to depreciative visitor behavior.

**Typology of Backcountry Camping Impacts**

A set of three clusters, or backcountry campsite types, were identified from the cluster analysis (Table 4.2). By studying the final cluster center of each campsite type, two aspects of impact, the intensity of impact (percentage measures) and the spatial extent of impact
Table 4.2. Results of cluster analysis: final cluster center (N=195).

<table>
<thead>
<tr>
<th>Factor Name</th>
<th>Cluster (Backcountry Campsite Type)</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(N=89)</td>
<td>(N=78)</td>
<td>(N=28)</td>
</tr>
<tr>
<td>Land disturbance</td>
<td></td>
<td>0.284 ²</td>
<td>0.265</td>
<td>2.033</td>
</tr>
<tr>
<td>Soil and groundcover damage</td>
<td></td>
<td>-0.590</td>
<td>1.097</td>
<td>-0.058</td>
</tr>
<tr>
<td>Tree-related damage</td>
<td></td>
<td>0.068</td>
<td>-0.261</td>
<td>0.202</td>
</tr>
</tbody>
</table>

¹ Cluster Names: 1 = Low-Impact Campsites (LIC); 2 = Intensively Impacted Campsites (IIC); 3 = Extensively Impacted Campsites (EIC).
² Mean factor scores.
(areal measures), emerged that distinguish one campsite type from another. These two impact aspects are therefore used to name and describe the campsite types.

Cluster 1 has low scores on the land disturbance factor, and the lowest scores on the soil and groundcover damage and tree-related damage factors. This cluster is named the **Low-Impact Campsite (LIC) Type**. Cluster 2 has the highest scores on soil and groundcover damage, but low scores on land disturbance and tree-related damage. This cluster is named the **Intensively-Impacted Campsite (IIC) Type**. Cluster 3 possesses the highest scores on land disturbance and tree-related damage, with intermediate scores on soil and groundcover damage. This cluster is named the **Extensively-Impacted Campsite (EIC) Type**. As mentioned, the 141 campsites rated condition class 1 and 2 were excluded from the cluster analysis, but they formed a distinguishable group due to their low levels of vegetation and soil disturbance as assessed using the Condition Class rating system. This group of campsites is therefore defined as the fourth campsite type, named **Minimally-Impacted Campsite (MIC) Type**, and included in the following discussion.

There are a number of similarities among the four campsite types with respect to environmental and use characteristics. The majority of campsites in each campsite type, for instance, are unrationed legal sites located near DBCs in forested footslope positions, which is the dominant biophysical setting in the park. On the other hand, differences among these four types are also evident. More profile descriptions and comparisons of the campsite types follow, with a summary in Table 4.3.
Table 4.3. Comparison of site attributes among four backcountry campsite types in Great Smoky Mountains National Park.

<table>
<thead>
<tr>
<th>Site Attribute</th>
<th>MIC (N=141)</th>
<th>LIC (N=89)</th>
<th>IIC (N=78)</th>
<th>EIC (N=28)</th>
<th>Signif.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Distance to Park Trails (m)</strong></td>
<td>42±4</td>
<td>34±5</td>
<td>32±6</td>
<td>18±4</td>
<td>0.08(A)</td>
</tr>
<tr>
<td><strong>Distance to Water ≤30 m (%)</strong></td>
<td>51</td>
<td>62</td>
<td>63</td>
<td>82</td>
<td>0.05(C)</td>
</tr>
<tr>
<td><strong>Elevation (m)</strong></td>
<td>879±28</td>
<td>805±34</td>
<td>934±30</td>
<td>768±39</td>
<td>0.02(A)</td>
</tr>
<tr>
<td><strong>Intersite Visibility (#)</strong></td>
<td>1.0±0.1</td>
<td>1.6±0.2</td>
<td>1.8±0.2</td>
<td>2.4±0.3</td>
<td>0.00(A)</td>
</tr>
<tr>
<td><strong>Canopy Cover &gt; 75% (%)</strong></td>
<td>61</td>
<td>65</td>
<td>39</td>
<td>56</td>
<td>0.00(C)</td>
</tr>
<tr>
<td><strong>Slope Position (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.10(C)</td>
</tr>
<tr>
<td>Footslope</td>
<td>57</td>
<td>67</td>
<td>56</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>Midslope</td>
<td>28</td>
<td>19</td>
<td>33</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Upslope</td>
<td>14</td>
<td>14</td>
<td>10</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Horse Use Permitted (%)</strong></td>
<td>61</td>
<td>62</td>
<td>57</td>
<td>70</td>
<td>0.69(C)</td>
</tr>
<tr>
<td><strong>Sites with no Trash (%)</strong></td>
<td>46</td>
<td>42</td>
<td>31</td>
<td>4</td>
<td>0.00(C)</td>
</tr>
</tbody>
</table>

1 Backcountry campsite type: MIC = Minimally Impacted Campsites (non-clustering group); LIC = Low-Impact Campsites; IIC = Intensively Impacted Campsites; EIC = Extensively Impacted Campsites.
2 Number of campsites.
3 Significance level for one-way ANOVA (A) (interval/ratio data) or Chi-square tests (C) (categorical data). Significance of < 0.05 is in bold.
4 Mean ± 1 standard error.
One hundred and forty-one campsites are included in the MIC Type (non-clustering group). Campsites of this type tend to be distributed in isolation, indicated by a low mean intersite visibility. They are also located farther from park trails but closer to streams and water sources (Table 4.3). These campsites are in excellent condition, although they could degrade to any of the other three types with more intensive use.

The LIC Type (Cluster 1) includes 89 campsites with low levels of impact for the three impact factors. Sixty-five percent of the campsites in this type are rated condition class 3. However, even on these low impact campsites, 61% of groundcover has been lost, exposing soil over 38% of the median campsite.

The IIC Type (Cluster 2) includes 63 campsites. This campsite type has intermediate land disturbance and the highest levels of soil and groundcover damage (Table 4.2). The smaller size of these campsites may be in part due to their more prevalent location at midslope topographic positions (Table 4.3) or to other factors that constrain campsite sizes, such as irregular topography, rocky ground, or dense vegetation. Intensive human activity within these limited usable areas creates a greater percentage loss of vegetative and organic litter cover but also limits their areal extent. Campsites located within steeper or irregular topography may also have an increased potential for problems with soil erosion.

Finally, the EIC Type (Cluster 3) consists of 28 campsites. They are characterized by high levels of land disturbance and tree-related damage, indicating that impacts are spatially extensive. However, campsites in this type are characterized by intermediate levels of soil and groundcover damage (Table 4.2). This contrasting pattern in the two impact aspects suggests
that camping activities and associated trampling forces may be dispersed over larger areas, likely due to the absence of topographic or vegetative barriers to campsite expansion. The high proportion of these campsites at footslope topographic positions appears to support this view (Table 4.3). Campsite expansion and proliferation are therefore the prime concern for this EIC Type.

Comparisons among the four campsite types can also be made for aggregate impacts by summing impact values for each campsite type (Figure 4.2). For instance, while the 177 MIC-Type campsites represent 37% of the total number of sites, their aggregate impacts are disproportionately low, particularly for damaged trees (3% of total sum) and total area of vegetation loss (10% of the sum). In contrast, 38% of all stumps are found on the 89 LIC-Type campsites, which represent only 26% of all sites. More disproportionate contributions to aggregate impacts are associated with the IIC-Type campsites, which constitute only 7% of all sites but account for 44% of all trees with exposed roots and 36% of the total area of vegetation loss (Figure 4.2). Similarly, while the EIC-Type campsites are few in number (8%), they contribute 30% of the total area of soil exposure, 29% of the total area of vegetation loss, and 27% of all trees with exposed roots.

Spatial Distribution Patterns of Backcountry Campsite Types

Spatial distribution of the four backcountry types is depicted in Figure 4.3. Four observations about the spatial patterns can be made based on this map. First, campsites of each type are widely distributed throughout the park area, while higher concentration of the
Figure 4.2. Relative contribution to the aggregate measures of resource impacts among four backcountry campsite types in Great Smoky Mountains National Park.
Figure 4.3. Distribution of four backcountry campsite types in Great Smoky Mountains National Park.
EIC-Type campsites can be found in the central and south portions of the park. Second, the majority of EIC-Type campsites seems to be spatially associated with greater number of campsites, regardless of the type. This association pattern further indicates an acute problem of campsite expansion and proliferation at these locations (Figure 4.3). Third, campsites that agglomerate together, typically at DBCs, appear to belong to differing types, possibly reflecting their different stages of development. For example, many MIC-Type campsites are located near IIC- and EIC-Type campsites at DBCs. These minimally-impacted campsites, most of which are illegal sites, possibly serve as overflow or displaced campsites as discussed earlier. Finally, this map provides a useful visualization of campsite impact pattern at a parkwide or landscape scale, facilitating the identification of problem areas and the allocation of campsite management efforts.

**Management Implications and Conclusions**

The purpose of this study was to characterize backcountry camping impacts from multivariate and spatial perspectives. The results demonstrate that multivariate techniques are useful for this purpose. Three dimensions of camping impact and four campsite types were identified. Spatial distribution patterns of these campsite types were also revealed by means of mapping. Such impact characterizations can facilitate interpretation and evaluation of camping impacts from a holistic perspective, instead of piecemeal evaluation of individual and sometimes interrelated impact indicators. Furthermore, by adopting standardized field
procedures such as Cole (1989a) or Marion (1991), data from different CIAM surveys may be compared with respect to impact dimensions and campsite types, contributing to a more comprehensive understanding of camping impacts. Future CIAM programs should try to ensure that data collected can meet the principal requirements for multivariate analyses. These include judicious selection of impact indicators, consideration of indicator measures, scale of measurement, and sampling scheme.

Three impact dimensions or factors were extracted from the factor analysis. Further work using data from other locations is needed to determine if the factor structure identified in this study is comparable across areas. If the factor structure is found to be generalizable, consideration can be given to reducing the number of interrelated indicators that measure common impact dimensions. Indicators that are loaded high on each factor, that can be measured with good precision, and that can be intervened managerially should then be selected as representative indicators. For example, the number of tree stumps might be preferred over number of damaged trees, both of which are represented by the same impact dimension. Tree stumps can be counted more quickly and with greater precision than number of damaged trees (Williams and Marion 1995). Where appropriate, omitting redundant indicators can reduce field time or permit measurements of other impact indicators not represented by the present factor structure, such as soil properties or vegetative composition.

One concern about using cluster analysis in campsite classification is that the campsite typology for one park may be different from another. Like factor analysis, additional studies are needed to determine the extent to which campsite typologies based on natural groupings
can be generalized, and what factors contribute to the uniqueness of a campsite typology. Measurements on individual indicators and the use of condition class systems can complement campsite typologies to facilitate an understanding of resource impact problems at broader scales, such as regional or parkwide comparisons.

From a management perspective, it may be more effective to formulate campsite management strategies based on campsite types than on characterizations of individual impact indicators. For example, strategies developed for controlling resource impacts on EIC- and IIC-Type campsites are likely to be different. EIC-Type campsites, characterized by their extensive disturbance and their agglomeration with other campsites, have a very high potential for expansion and proliferation. Controlling the spatial extent of impact, by designating specific camping spots or delineating site boundaries, might be the most effective form of management to limit degradation on these sites. In contrast, for IIC-Type campsites, the management priority might be on controlling soil erosion, with actions such as site maintenance or temporary closure for restoration and revegetation work (Marion and Sober 1987). Research indicates that use limits would be potentially effective in reducing impact on MIC- and LIC-Type campsites, as they are at an impact stage that is more responsive to changes in use (Cole 1987). The most lightly altered sites might also be closed, as recovery would proceed quickly and such sites may not be needed.

In summary, if camping impact management is to be successful, an improved understanding of impact patterns is indispensable. Sustained CIAM programs with standardized study designs, augmented by multivariate analysis and mapping, should
contribute to such an understanding and aid in the formulation of effective impact management strategies.