

Article

A Management Process for Improving the Resource and Social Sustainability of Camping: A Case Study in the US Desolation Wilderness

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Abstract

Protected area managers have long employed unregulated or dispersed camping policies that allow visitors to select and create campsites, frequently in flat areas where problems with campsite proliferation, expansion, severe resource impacts, social crowding, conflicts, and noise occur. This study fills a research gap by providing guidance based on recreation ecology studies and a US wilderness case study for evaluating and adopting a camping containment strategy in areas of higher use. Four efficient steps are described and illustrated involving campsite inventory, monitoring, and occupancy surveys, selection of preferred sustainable campsites, and implementation of a camping containment strategy and supporting practices. Case study findings are presented to illustrate the guidance and reveal the potential efficacy of implementing camping containment strategies that shift camping to preferred sustainable established or designated campsites as part of a visitor use adaptive management process. As demonstrated, such policies can accommodate heavy visitation with substantially reduced campsite numbers, aggregate area of camping impact, and an improved potential for higher quality social conditions.

Keywords: camping impact; sustainable camping management; recreation ecology; visitor use management; dispersed camping; wilderness management



Academic Editor: Hossein Azadi

Received: 24 September 2025

Revised: 8 November 2025

Accepted: 12 November 2025

Published: 16 November 2025

Citation: Marion, J.L.; Maretzki, N. A Management Process for Improving the Resource and Social Sustainability of Camping: A Case Study in the US Desolation Wilderness. *Land* **2025**, *14*, 2264. <https://doi.org/10.3390/land14112264>

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1. Introduction

Many United States (US) and international protected areas (PAs) have legislative mandates to provide for their “use and enjoyment” by the public while preserving their natural conditions “unimpaired” for the enjoyment of future generations. Tension and conflict exist between these competing objectives, with articles in the popular media questioning if US parks and wilderness are being “loved to death.” PA managers frequently must strive to achieve an appropriate balance between these legal mandates as they strive to manage visitor use to provide access and support high quality visitor experiences while avoiding or minimizing associated negative resource and social impacts.

In the US, professional planners from six federal agencies formed an Interagency Visitor Use Management Council to develop a comprehensive yet efficient Visitor Use Management (VUM) framework incorporating planning, decision-making, and adaptive management to maintain an acceptable and defensible balance between the dual recreation provision and resource protection objectives [1]. The VUM framework references a PA’s purpose, legislative, and agency guidance to prescribe desired resource and social

conditions, recreation opportunities, and visitor experiences. Indicators reflective of these management objectives and desired conditions are selected, and thresholds (standards) are identified to clarify the point at which conditions cross the threshold of acceptability. A permanent program of monitoring periodically assesses indicator conditions to alert managers if and where unacceptable conditions occur, triggering an evaluative adaptive management process to (1) identify the most effective corrective actions, (2) implement, and (3) evaluate, learn from, and apply additional actions if necessary to maintain the desired conditions in perpetuity [1,2].

Agencies that manage recreation lands have long recognized the need for developing recreation infrastructure components such as trails or day-use and overnight facilities to accommodate safe, low-impact visitation [3]. These facilities are developed to concentrate visitor activities and traffic on hardened surfaces, while protecting natural conditions in the surrounding terrain. As part of a visitor impact *Containment* strategy, managers generally have substantial control over the sustainable location and development of these facilities and the ability to employ designs, education, and regulation to attract and/or restrict visitor use to minimize both the “footprint” and severity of visitor impact [2]. For example, in US backcountry and wilderness settings nearly all managers have opted to purposefully design, construct, and maintain formal trail systems. In contrast, many have allowed visitors to select and create their own campsites in locations of their choosing [4]. Generally referred to as *Dispersed camping*, this strategy maximizes visitor freedom in these more remote areas, yet recreation ecology monitoring and research studies have consistently documented significant and substantial resource and social impacts when this strategy is employed at moderate to high levels of camping [5–9]. Visitors commonly select unsustainable camping locations in large flat areas where campsite expansion and proliferation problems manifest at higher use levels, frequently causing substantial and unacceptable levels of resource degradation and visitor crowding.

The implications of these recreation ecology studies are that PA managers can more substantially limit the aggregate extent and severity of camping impact *and* visitor crowding/conflict problems by adopting a containment strategy in moderate to high use areas. Like the management of trail systems, this requires managers to carefully select and develop a limited infrastructure of sustainable appropriately located campsites. Our study objectives were to develop an efficient standardized process by which PA managers can evaluate the efficacy of their camping management policies, based on minimizing campsite numbers and sizes and improving the selection and use of preferred sustainable campsites that minimize resource and social impacts. This process involves four steps: (1) a campsite survey to document campsite numbers, locations, resource conditions, and sustainability attributes, (2) a survey of campsite occupancy rates for a small sample of typical high use nights to document camping demand, (3) identification of a preferred set of sustainable appropriately located campsites, and (4) implementation or improvement of science-based camping containment or pure dispersal policies, with campsite closure and restoration of unnecessary/non-sustainable campsites. This process is illustrated through a study of the two most heavily used lake basins in the US Forest Service (USFS) Desolation Wilderness, Eldorado National Forest, located in northeastern California just west of Lake Tahoe.

2. Literature Review

It is unclear why US PA managers developed traditions for professionally designing, constructing, and maintaining trail systems while failing to adopt similar practices for managing camping. For example, the USFS and Bureau of Land Management have commonly employed a dispersed camping strategy allowing visitors to create or select campsites in locations of their choosing, sometimes with voluntary requests to avoid camping close

to water, other visitors, and formal trails [4,6,10]. Campsite monitoring surveys reveal that this type of strategy loses its efficacy in moderate to high use areas because visitors consistently create a surplus of unnecessary campsites, campsite proliferation problems that manifest most frequently in flat terrain near water or attraction features [9,11]. The creation of dense clusters of campsites in flat terrain permit a second significant chronic problem, campsite expansion, which often leads to the merging of adjacent campsites and substantially increases the areal extent of camping impact and degraded social conditions, impacts that are easily avoided or minimized under camping containment policies (e.g., established or designated site camping) [4,8,9,12]. The twin problems of campsite proliferation and expansion have long been a core challenge in agency management efforts to balance resource protection and recreation provision objectives [4]. As PA visitation expands, these challenges are increasingly causing managers to reconsider their past laissez-faire camping management policies in favor of more sustainable containment-oriented camping policies and practices [13].

2.1. Spatial Patterns of Camping Impact

PA managers seek to provide high-quality recreation experiences while limiting the areal extent of land degraded by visitor activities and the severity of various impacts (e.g., vegetation loss, exposure and loss of soil, damaged and cut trees). With respect to primitive camping in backcountry and wilderness settings, research reveals that the spatial extent and severity of impact are best minimized by limiting the number and sizes of campsites, while fostering high quality experiences is aided by spatially separating campers to avoid crowding, conflicts, and noise [14–16]. Unfortunately, PA visitors are inherently attracted to camping in the flattest available terrain near water and other attraction features, a natural tendency that exacerbates rather than minimizes the chronic problems of campsite proliferation and expansion, which too frequently create high-density clusters of campsites directly at odds with manager's core objectives.

Campsite monitoring surveys conducted in areas managed under unregulated or dispersed camping consistently document and illustrate the problems with these policies in moderate to high use areas. A study of high use destinations within Oregon's Three Sister's Wilderness documented substantial resource and social impacts [17]. For example, the popular Sunshine-Obsidian Falls area had exceptionally high densities and numbers of campsites ($N = 269$), with an aggregate area of impact of 20,444 m². According to visitor use data, 639 groups camped 1.9 nights/yr, representing 1214 camping nights/yr; dividing by 269 campsites reveals that the campsites average only 4.5 nights/site/yr [17]. The authors also surveyed visitors to evaluate perceptions of crowding and preferences for alternative management practices. Fifty-six percent of visitors to the Sunshine-Obsidian Falls area reported that the number of encounters with other visitors while camping detracted from their visit [17]. Visitor support for regulatory actions such as limiting use was low (10–28%) while their support for restricting camping to designated sites was high (44–85%). If managers designated the 60 most sustainable campsites, each site would still only receive 20 nights/yr, while the potential closure and restoration of 209 campsites would eliminate 15,884 m² of impact, a 78% reduction (based on a mean campsite size of 76 m²) [17]. Adequate separation between these sites would also aid in resolving social/experiential problems with visitor crowding, conflicts, and noise.

In Oregon's Eagle Cap Wilderness, managed under a dispersed camping strategy, Cole [11] found that most campsites were clustered in high densities in just two popular lake basins and that about 10 groups/night camped on 221 campsites, an occupancy rate of only 4.5% during the popular summer season. Visitors also routinely violated the requested camping setback distances from water and trails. Cole recommended that aggregate

camping disturbance be substantially reduced by concentrating use on a small subset of the existing campsites. However, this strategy was not adopted, and a later Eagle Cap survey documented further campsite proliferation, a 134% increase in campsite numbers in seven high use lake basins, with campsite densities exceeding two sites/ha and “many clusters of sites so dense that it is difficult to tell where one site ends, and another begins” [6]. In Montana and Idaho’s Lee Metcalf Wilderness, campsite proliferation increased site numbers 84% from 1972 to 1988, while in Montana’s Selway-Bitterroot Wilderness campsite numbers increased 53% from 1977 to 1989 [6]. Cole attributed these instances of campsite proliferation to “passive campsite management programs” or “management attempts to avoid over-crowding and overuse by dispersing use.”

Similar findings have been reported from camping impact studies conducted for US long distance trails that have largely been managed with dispersed camping policies. In a large representative study of campsites along the 3524 km Appalachian Trail (AT) in the eastern US, the median campsite size was 37 m², yet 25% of the campsites exceeded 93 m² and 13% qualified as mega-sites (campsites exceeding 185 m²) [8]. The study also documented numerous high-density mega-clusters of campsites (with >1858 m² of camping impact) created by visitors in popular areas with flat topography and water sources. The ten largest mega-clusters of AT campsites accounted for 30% of the total areal extent of camping impact in this representative survey, along with the most salient experiential problems of crowding, conflicts, and noise [8,9]. In a similar study of camping impacts and sustainable camping practices along the 4265 km Pacific Crest Trail (PCT) in the western US, campsite sizes averaged 71 m², yet mean sizes exceeded 93 m² for half of the individual study areas (18 of 36) and 8% qualified as mega-sites [9]. Mega-clusters of visitor-created campsites were also found, with one of the most degraded occurring at the Lower Twin Lake basin in Oregon’s Mt. Hood Wilderness. This basin had 19 campsites and 4620 m² of aggregate camping impact; the majority associated with a high-density area of merged campsites in flat terrain. Associated impacts included poor social conditions and 159 damaged trees, 82 stumps, and 96 trees with severely exposed roots [9].

In an evaluation of alternative wilderness camping policies, Cole [18] concluded that visitor dispersal ineffectively reduces the severity of impact while markedly increasing the total area of impact. He concluded that “unless campers could be directed to preexisting sites, visitor dispersal would increase the total area of degradation and distribute impact throughout a greater percentage of the wilderness area.” The solution is to concentrate camping on a limited number of highly used resistant campsites. He clarifies that this is not a “sacrifice site concept” because concentrating use effectively limits the aggregate “footprint” of impact, it would be more appropriate to equate the sacrifice site concept with the dispersed camping strategy in which less visited areas are sacrificed by accommodating use shifted there in efforts to improve conditions in a few heavily used areas, which research reveals are nearly always unsuccessful [18].

2.2. Science-Based Sustainable Camping Management Policies

Recreation ecology studies consistently document a sigmoidal relationship between amount of visitor trampling and the response of vegetation and soil impacts. While many vegetation types can support limited traffic for a night or two, additional use generally initiates a relatively rapid reduction in the height and cover of vegetation. As trampling increases, an inflection point is reached where additional trampling results in rapidly diminishing per capita resource impact (about 15 nights of camping in many US areas) [2]. At this level of use most vegetation cover has been lost in core campsite areas, though shady areas with broad-leafed herbs are substantially more sensitive and less resilient to trampling than sunny areas with grasses and sedges [19,20]. The use-impact relationship

becomes asymptotic above the inflection point, with resource impacts leveling off such that use levels could double or triple with diminishing increases in resource degradation.

The sigmoidal and asymptotic use-impact relationship has substantial implications for sustainable camping management policies. In low use areas, studies reveal that a pure form of visitor dispersal can be effective, such as directing visitors to camp just one night on herbs, a few nights on grasses, or many nights on exposed barren rock or soil (e.g., shoreline gravel/sand bars naturally devoid of plants) [21]. This *pure dispersal strategy* with a natural site camping option is viable only when vegetation impacts are minimal and fully recover within a year, and when visitors use locations that are not easily found and reused by other visitors [2,4,9,22].

In areas with intermediate to high use, studies reveal that a *containment strategy* is most optimal, with visitors encouraged to voluntarily camp on a limited number of preferred and sustainably selected “established sites,” or required to use only “designated sites” [2,4]. This strategy’s objective is to minimize the aggregate area of camping impact by: (1) selecting the smallest number of highly visited campsites needed to meet camping demand, and (2) sustainably selecting campsites best able to resist the traditional problems of campsite expansion and proliferation, generally due to surrounding sloping or rocky terrain [14]. When implemented, PA managers may be able to select enough sustainable campsites from existing campsites, but surveys can likely discover even more sustainable locations that could be developed as new campsites [4,13]. Managers can then close and restore unneeded and/or less sustainable campsites to reduce the aggregate area of camping impact.

Similar to the design and construction of sustainable side-hill trails, managers can design and construct sustainable *side-hill campsites* in sloping terrain or identify locations where sustainable campsites in rocky or uneven terrain can be developed [2,23]. Research indicates that side-hill campsites should be constructed in sloping terrain with grades that exceed 15%, where small flat spots for tents and cooking are created surrounded by steep side-slopes that inherently compel visitors to spatially concentrate their camping activities [14,23]. This practice provides a “permanent” solution derived from camper’s direct interactions with surrounding terrain, with minimal need for ongoing maintenance, education, regulation, or enforcement efforts. While some managers may oppose the purposeful construction impacts of developing sustainable side-hill campsites, the decision process is identical to the traditional design and construction of side-hill trails, widely recognized as being the most sustainable alignments. Sustainable formal trails avoid the greater impacts associated with duplicative and non-sustainable informal trail networks. As previously reviewed, monitoring surveys consistently document similar unacceptable and avoidable problems when visitors are permitted to create dense clusters of campsites in flat terrain that will forever expand and proliferate over time, along with substantially degraded experiential conditions [6,11,17].

Marion [24] collaborated with the Appalachian Trail Conservancy to identify and evaluate best management practices for the largest and most impacted camping locations on the AT, followed by a 16-year study on the efficacy of sustainable camping management actions taken to resolve camping impacts at Annapolis Rocks in Maryland, the worst of the investigated areas. In 2002, a containment strategy with designated site camping was applied and a large cluster of 19 campsites in flat terrain were closed and replaced by 14 constructed “side-hill” campsites in adjacent areas of sloping terrain. Like side-hill trails, these campsites were constructed using cut-and-fill excavation to form ideal tenting spots that attract and concentrate use, with surrounding sloping terrain compelling the spatial concentration of camping activities to the new “small footprint” campsites. The aggregate area of camping impact after 16 years was only 25% of the pre-treatment camping area of 4004 m² [23]. Greater success would likely have been achieved if all the side-hill

campsites had been in terrain with slopes exceeding 15% grade, shown more recently as the recommended minimum slope necessary to effectively constrain campsite expansion pressures [14]. The closure and restoration of original campsites was highly effective due to fencing and AT Ridgerunner presence, with no further use detected after 2004 and substantial vegetative recovery on all former sites by 2012.

2.3. Evaluating Campsite Sustainability and Visitor Preferences

Selecting or constructing sustainable campsites able to resist site expansion and proliferation pressures in locations and with attributes that both PA managers and visitors prefer is key to management success. If managers don't consider visitor's preferences when designing or expanding trail systems, visitors often "vote with their feet" to create new informal trails [25]. Similarly, managers should consider visitor campsite preferences for locations and attributes to ensure that selected campsites will be used and enjoyed by visitors and to minimize the creation of less desirable campsites or use of closed sites.

A study by Arredondo and others [14] reviewed the literature and conducted extensive regression modeling with the large AT campsite dataset to identify and rank the most influential sustainability factors affecting campsite size. Geographic Information System (GIS) terrain and slope analyses revealed that the proportion of a 10 m buffer around campsites that is steeply sloped (>15%) or that had substantial rugosity (rockiness or roughness) were significantly predictive of campsite size. For example, holding all variables constant, the model predicts that a campsite in flat terrain will be 127 m² while one 50% surrounded by steep slopes (>15%) will be 78 m², and a campsite 100% surrounded by steep slopes will be only 47 m² [14].

The PCT campsite study further developed and applied these findings to identify practices and indicators for selecting preferred sustainable campsites [9]. New GIS analytical protocols were developed to efficiently identify the best potential "naturally occurring" side-hill campsites in sloping terrain, those with some campsite-sized flat terrain surrounded by slopes greater than 15%. Ground-truthing verified the viability of this practice and that such sites within 100 m of trails could be easily converted into sustainable campsites. To evaluate existing or proposed new campsites, an efficient field-based predictive indicator is to walk site boundaries and tally all possible tenting spots within a 10 m external buffer, excluding prohibitively steep slopes and rocky/uneven terrain and *including* terrain obstructed by woody vegetation and downed logs (which could be removed by forest fires or visitors with woods tools) [9]. This simple tent pad count provides an excellent measure of a site's enduring resistance to expansion and the creation of new tenting spots or campsites in adjacent offsite areas.

Social scientists have conducted visitor surveys and observational studies to document the campsite preferences of backcountry and wilderness visitors [26–29]. Brunson and Shelby [30] developed a campsite choice model describing a hierarchy of campsite attributes that provide a basis for campsite selection. These include *necessity* attributes such as sufficient level ground available for tenting and proximity to water; *experience* attributes like site distance to other campsites or formal trails, scenic beauty, smooth well-drained tent sites, and lack of human noise; and *amenity* attributes including shade, a campfire ring, seating, nearby firewood, and few bothersome insects.

PA managers also have preferences for campsite locations and attributes, for example, campsite setbacks from waterbodies (generally 30–60 m) to protect water quality. Other considerations include the avoidance of sensitive or rare flora, fauna, and historic/cultural sites, or closed campsites [8]. Managers can proactively avoid problems with visitor crowding, conflicts and noise by selecting site locations that reflect desired social conditions (low to high density), using either inter-site distance or visibility indicators with other campsites

or formal trails. As previously noted, visitor surveys reveal that visitors prefer designated site camping policies over quotas that limit visitor access [17]. Finally, tort liability [9] and visitor safety from hazardous trees can be substantially reduced in comparison to dispersed camping policies by (1) shifting camping to sloping or rocky terrain that substantially constrains campsite numbers and sizes and thus potential numbers of proximate hazardous trees, (2) selecting campsites in more open grassy or shrubby areas, and (3) by advising visitors to avoid camping under or near dead or potentially hazardous trees.

3. Study Area

The study area was named the Desolation Valley Primitive Area in 1931 and designated as the Desolation Wilderness in 1969, a 258.8 km² wilderness area located in northeastern California. Its location bordering Lake Tahoe and just 300 km east of San Francisco make it accessible to over 120,000 visitors/year. The area is managed by the USFS Eldorado National Forest and Lake Tahoe Basin Management Unit. Elevation ranges from 1980 to 3043 m and comprises subalpine and alpine forest, granitic peaks, and glacially formed valleys and lakes. Primary forest species include red fir (*Abies magnifica*), lodgepole pine (*Pinus contorta*), western juniper (*Juniperus occidentalis*), and mountain hemlock (*Tsuga mertensiana*) trees. It also boasts a large variety of wildlife, including mule deer (*Odocoileus hemionus*) and black bears (*Ursus americanus*). Rainbow trout (*Oncorhynchus mykiss*) and brook trout (*Salvelinus fontinalis*) are the most common fish within its waters.

The popular PCT and Tahoe Rim Trail (TRT) pass through Desolation Wilderness for 35 km along the same alignment. Given its immense popularity as a hiking and backpacking destination with a national reputation, the USFS utilizes a permit system for overnight visitors with summertime quotas for 45 travel zones to limit and redistribute visitation. Overnight permits can be reserved online up to six months in advance for 70% of the daily quotas, with the balance available to “day-of” visitors at local USFS public contact facilities.

The Desolation Wilderness topography is diverse, with predominantly sloping mountainous terrain and sparsely forested slopes giving way to rocky and relatively barren glaciated rocky terrain with increasing elevation. Flat terrain is generally limited to approximately 130 lake basins, which attract most backpackers to camp on approximately 1180 campsites with an average size of 70 m² (providing an estimated aggregate area of camping impact of 82,600 m²) [31]. This study focuses on the two most popular lake basins within Desolation: Lake Aloha and Lake of the Woods, both are easily accessed via the combined PCT-TRT from the Echo Lake Trailhead.

3.1. Lake Aloha

Lake Aloha (LA) is the most accessible and heavily visited alpine lake basin (Figure 1) at an elevation of 2474 m, located in the shadow of Pyramid Peak, at 3043 m, the highest peak in the wilderness. Considering its proximity to a major trailhead and the PCT and TRT running through it, Aloha is regularly accessed by Desolation Wilderness day hikers, backpackers, and long-distance backpackers. The exceptionally rocky terrain in this lake basin limits the sizes of campsites (mean size of 46 m²), but campsite proliferation has been a chronic and significant problem, with USFS campsite monitoring surveys documenting 146 campsites and an aggregate area of campsite impact of 6680 m² [31]. The USFS employs a dispersed camping strategy for this lake basin, requesting visitors to select any location for camping that is greater than 30 m from the lake (40 of 52 campsites in this study violate this voluntary guidance). Our study area was restricted to the southern half of this lake basin due to its large size and numbers of campsites (Figure 1).

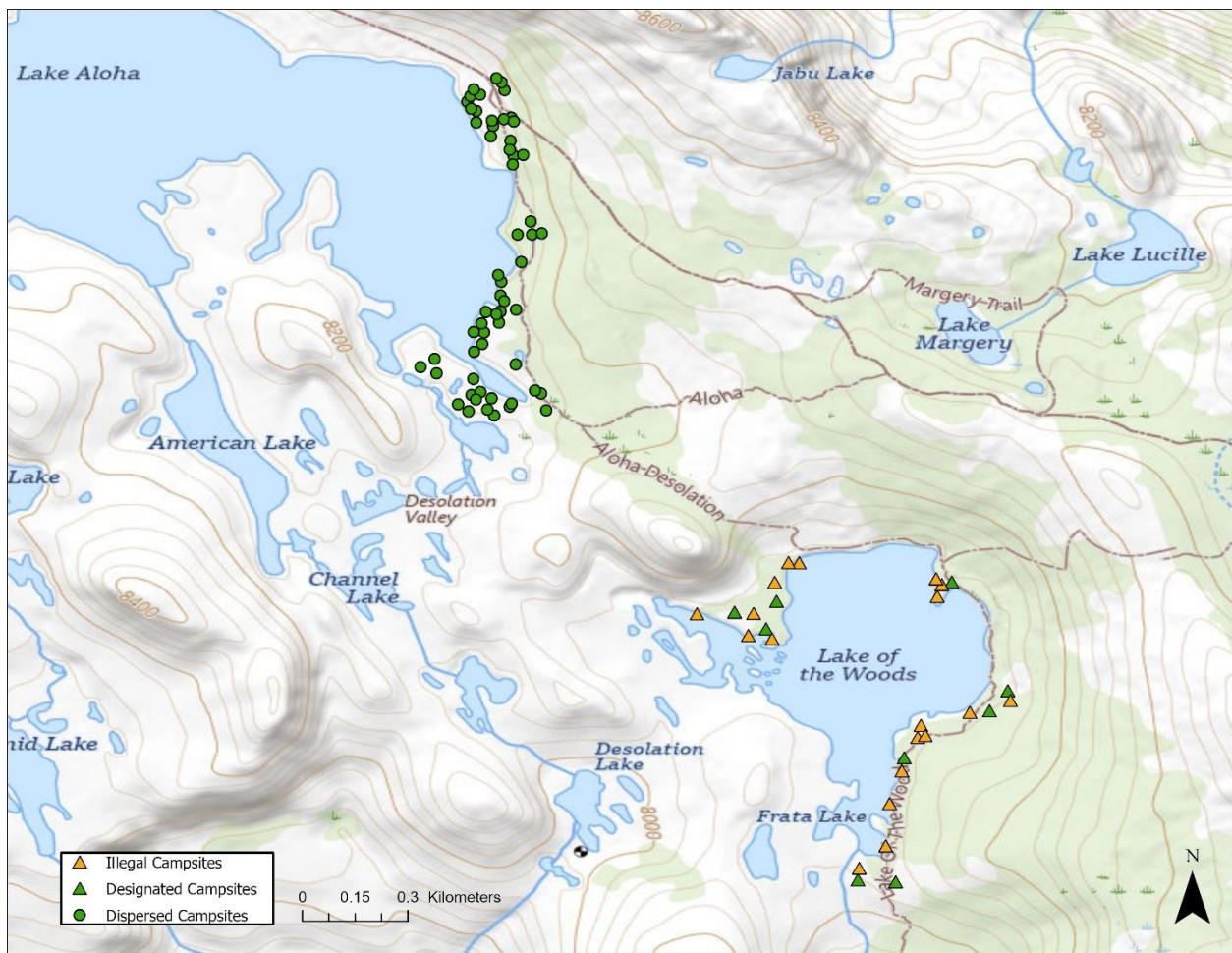


Figure 1. Study areas include the southern half of the Lake Aloha (LA) basin and the Lake of the Woods (LW) basin, located within the Desolation Wilderness of northeastern California.

3.2. Lake of the Woods

Lake of the Woods (LW) is a smaller but highly popular lake basin (Figure 1) located 1.5 km closer to the trailhead at an elevation of 1511 m, with terrain that is substantially less rocky and more forested. Due to its beauty, accessibility, and longtime popularity, camping (except on the west shoreline) is restricted by regulation to nine designated campsites. Both campsite expansion and illegal camping have been chronic problems in the flatter areas of this lake basin. Our monitoring survey conducted with USFS staff documented an additional 19 illegal campsites, and mean campsite size in the LW basin is 156 m² (3.4 times larger than LA campsites) with an aggregate area of camping impact of 4384 m² [31]. A large flat peninsula on the northwest shore of the LW basin includes 58% of the aggregate area of camping disturbance in this lake basin (Figure 1).

4. Methods

As described in the Introduction, our study objectives were to aid PA managers in evaluating and improving the efficacy of their campsite management policies based on recreation ecology science. The steps involved in this proposed VUM adaptive management evaluation process are outlined here to illustrate guidance as developed and applied to the Desolation Wilderness study areas.

4.1. Campsite Assessments

Step 1 is to conduct a census inventory and monitoring survey to document campsite numbers, locations, conditions, and attributes related to sustainability and manager and visitor preferences. Monitoring was conducted during the mid- to late-portion of the camping season to accurately characterize “typical” resource conditions and not off-season recovery or natural vegetation senescence. Investigators and USFS staff carefully searched for and surveyed all campsites within the LA and LW study areas, also consulting mapped campsites from prior monitoring surveys. Indicator protocols were those applied by the USFS combined with new campsite preference and sustainability indicators (described below). Campsites sometimes consist of several separate but proximate tenting and cooking sites so judgements were made to combine clusters that a single group would reasonably use. This common challenge explains our recommended focus on aggregate lake basin measures of camping impact rather than numbers and sizes of individual campsites, which are influenced by such arbitrary judgements.

Our survey found and assessed 52 dispersed campsites in the LA study area and 9 legal and 19 illegal campsites within the LW basin. These assessments generally required two staff approximately 15 min to apply to each campsite. We identified site boundaries by pronounced visually obvious changes in a combination of vegetation cover, vegetation height/disturbance, vegetation composition, and surface organic litter caused from trampling-intensive camping activities [14]. Global Positioning System (GPS) center points were collected for each campsite, and their sizes were measured using the geometric figure method, whereby the dimensions of one or more geometric figures were closely matched to campsite boundaries and measured to obtain their areas [9].

Within campsite boundaries, a percentage estimate of six cover classes (0–5%, 6–25%, 26–50%, 51–75%, 76–95%, 96–100%), was recorded for live vegetation groundcover and exposed soil lacking vegetation or organic litter cover. A percentage estimate of vegetation groundcover and exposed soil was also recorded for an adjacent offsite, environmentally similar control or reference area that lacked human disturbance [32]. Area of exposed soil was computed by multiplying the midpoint of the cover class for exposed soil by site size. Similarly, estimates of the area over which vegetation loss has occurred were computed by subtracting the midpoint values of onsite vegetation cover from offsite values and multiplying percent vegetation loss by site size.

Other campsite characteristics assessed included distance to the nearest other campsite, number of other campsites within view, distance to the nearest formal trail, site visibility from the trail, distance to water, number of obvious tenting spots, overstory tree canopy cover, and campsite expansion potential. Campsite expansion potential was the principal sustainability indicator, assessed by walking campsite boundaries and counting the number of potential 2-person tenting spots within a 9 m buffer, disregarding the presence of any herbaceous or woody vegetation and woody debris and movable rocks. This reflects permanent attributes like sloping terrain and rockiness, not woody vegetation or downed logs that visitors or a forest fire could remove. Flexibility in analyzing and applying these data is maximized by collecting counts and measures rather than categorical ratings. However, campsite functionality indicators were assessed as “+”, “ok”, or “–” and consulted during the final selection of preferred campsites, including ease of water access, scenic attractiveness, dead/hazard trees, cat-hole potential, and seating. Comprehensive indicator protocols can be found in Marion and others [9].

All field data were efficiently input and recorded in the field using a smartphone app, with data synched and uploaded to the “cloud” for safe storage and downloaded to a Microsoft 365 Excel file for error-checking and analyses. The app directly accesses the

phone's camera to capture, check, and retake images of each campsite, and permanently links and georeferences them to each campsite data record.

4.2. Campsite Occupancy Surveys

Step 2 is to assess camping demand for high but not peak use periods for each travel zone or management unit of interest to evaluate how many campsites are needed at each lake basin. This was accomplished through late- and early-day walking surveys to observe campsite occupancy rates for a small sample of nights. In some PAs this information may be available from collected permit data. Desolation Wilderness permit data only document visitation by trailhead so it was not possible to estimate overnight visitation within travel zones or lake basins. To increase fieldwork efficiency, we integrated the campsite monitoring and occupancy surveys for both lake basins on four high use weekends (5/6, 12/13, 26/27 August, and 5/6 September 2023).

Campsite occupancy was assessed by counting the number of groups and number and size of tents on every campsite (we did not approach or speak with campsite occupants). While one holiday weekend was included in our sample the weather was poor, so it resembled the other high-use weekends. Decisions on the supply of campsites should be based on typical high use periods because peak use can be substantially higher. Accommodating peak would require many campsites used only a few nights/year, an inefficient practice that unnecessarily increases the aggregate area of resource impact.

Campsite occupancy surveys were conducted on Saturday evenings at one lake basin within 1.5 h of sunset and at the other basin the following morning within 1.5 h of sunrise. This was important to capture long-distance backpackers who often spend nearly all daylight hours hiking. While a count of occupied campsites might be acceptable, we sought to estimate total overnight visitation by assessing tents and visitor numbers as one-person tents (1 visitor), two-person tents (2 visitors), and larger tents (3.5 visitors). While some two-person tents were occupied by one person, some of the larger tents were likely occupied by four or more visitors.

4.3. Selection of Preferred Sustainable Campsites

Step 3 is to evaluate campsite monitoring and occupancy data to determine and select an optimal subset of existing sustainable campsites, or to identify if more sustainable campsites are needed. A *Campsite Selection Index* (CSI) was developed and employed to select a preferred set of sustainable campsites from existing campsites. This index integrates three resource and two social indicators, each with four categories rated 1 (poor) to 4 (good).

Resource indicators included *Campsite expansion potential*, reflecting counts of potential offsite tenting spots ($\geq 6 = 1$, $4-5 = 2$, $2-3 = 3$, $0-1 = 4$); this indicator received a $2\times$ weighting, reflecting the added importance of shifting camping to locations that permanently constrain site expansion and proliferation. *Campsite size* (m^2) was included to penalize larger campsites, with categories calibrated for each lake basin due to their differing ranges in site size (LW: $>200 = 1$, $135-200 = 2$, $70-135 = 3$, $<70 = 4$; LA: $>70 = 1$, $47-70 = 2$, $23-46 = 3$, $<23 = 4$). *Proximity to water* (m) was included to protect water quality by favoring campsites located further from water ($\leq 15 = 1$, $15-30 = 2$, $31-61 = 3$, $>61 = 4$). The two social indicators were *Distance to nearest other campsite* (m): ($\leq 30 = 1$, $30-61 = 2$, $61-91 = 3$, $>91 = 4$), and *Distance to nearest formal trail* (m): ($\leq 30 = 1$, $30-61 = 2$, $61-91 = 3$, $>91 = 4$). Both indicators seek to redistribute camping away from other campsites and formal trails to enhance camping solitude and natural quiet. The CSI was computed by summing the scores for each indicator, with index values ranging from non-sustainable (CSI = 6) to highly sustainable (CSI = 24).

The CSI ratings provide a combined resource/social rank-ordering of all campsites for each travel zone or management unit of interest. PA managers may wish to consider

other indicators, weightings, or computational procedures or the use of separate resource and social indices. Regardless, the ratings can be consulted when selecting the number of preferred campsites needed to meet estimated campsite demand or desired campsite supply. Note that there may be an insufficient number and/or distribution of existing sustainable campsites, or some sustainable campsites may be undesirable because they are located too close to other sites, trails, waterbodies, or rare/sensitive flora, fauna, and cultural resources. These instances may require the use of less sustainable campsites or the construction of new highly sustainable side-hill or naturally occurring sites. Finally, a “ground-truthing” process to evaluate the acceptability of retaining each selected campsite is necessary, though campsites can be omitted or added at any time in the future.

4.4. Implementation

Step 4 is to implement improved camping containment policies, along with a program to close and restore some or all unnecessary or non-sustainable campsites. Once the appropriate number of campsites has been identified, PA managers could implement a voluntary Established Site Camping policy or a regulatory Designated Site Camping policy to promote or require their use. Campsite improvements could be made, including improvements to create desired numbers of ideal tenting spots, installation of site facilities such as anchored rock or metal fire sites (if permitted), and erosion control or hazard tree removal work. Actions to communicate and promote the new camping policies, aid visitors in finding the sustainable campsites, and low impact camping practices can also increase implementation success.

5. Results

5.1. Campsite Inventory and Monitoring Survey

Both study areas were thoroughly searched to find and assess all campsites. At LW 28 campsites were assessed, ranging in size from 14 to 729 m², with a mean of 157 m² and aggregate impact of 4384 m² (Table 1). Visitors are required to camp at one of 9 designated campsites at LW, but the survey also found 19 illegal campsites, so Table 1 distinguishes between the designated campsites (aggregate impact of 2863 m²) and illegal campsites (aggregate impact of 1521 m²).

Analyses and field observations (Figure 2) also revealed substantial differences in the sizes of LWs campsites based on their locations, including lake shoreline campsites, generally situated in sloping and/or rocky terrain (18 campsites with a mean size of 103 m² and aggregate impact of 1846 m²) versus campsites located on a flat peninsula on the northwest side of the lake (10 campsites with a mean size of 254 m² and aggregate impact of 2538 m²) (Figure 1). The flat peninsula terrain readily permits campsite expansion while the more sloping and rocky lake shore terrain constrains site expansion. Similarly, the mean area of exposed soil for the lake shoreline campsites (12 m²) is substantially less than mean area of exposed soil for the peninsula campsites (56 m²). Both legal and illegal campsites exhibit similar large ratios between lakeshore and peninsula areas for both site size and area of exposed soil (Table 1).

At LA, 52 campsites were assessed within the southern half of the lake basin, ranging in size from 9 to 354 m², with a mean of 53 m² and aggregate impact of 2745 m². The terrain throughout this lake basin is exceptionally uneven and rocky, which effectively constrains campsite expansion, as illustrated by comparing mean site size for LA (53 m²) to LW lakeshore (103 m²) and peninsula (254 m²) mean campsite sizes.



Figure 2. Campsite photos illustrating the typical LWs shoreline campsite, where topography and rockiness constrain site expansion (A), peninsula campsites where flat terrain permits site expansion and proliferation (B), and a closed/restored shoreline campsite (C), with an LA campsite where topography and exceptionally rocky terrain effectively constrain campsite expansion (D).

Table 1. Data for five areal measures of campsite impact for Lake of the Woods designated and illegal campsites situated around the lake and on a peninsula, and for Lake Aloha.

Impact Indicator	Lake of the Woods				Lake Aloha	
	Designated		Illegal		All	All
	Lake 6 Sites	Peninsula 3 Sites	Lake 12 Sites	Peninsula 7 Sites	28 Sites	52 Sites
Campsite size (m²)						
Mean/Median	185/160	585/570	61/72	112/117	157/108	53/33
Range	150/270	455/729	14–101	57–142	14–729	9–354
Sum	1109	1754	737	784	4384	2745
Vegetation loss (%)						
Mean/Median	73/73	48/73	55/73	60/61	60/73	51/61
Range	61–86	0–73	0–73	48–73	0–86	0–86
Vegetation loss (m²)						
Mean/Median	136/116	248/310	33	68	87/59	20/16
Range	109–231	0–330	0–70	29–103	0–413	0.6–60
Sum	813	743	397	479	2431	926

Table 1. *Cont.*

Impact Indicator	Lake of the Woods				Lake Aloha	
	Designated		Illegal		All 28 Sites	All 52 Sites
	Lake 6 Sites	Peninsula 3 Sites	Lake 12 Sites	Peninsula 7 Sites		
Exposed soil (%)						
Mean/Median	18/1	26/16	13/3	21/16	17/3	22/13
Range	0–88	0–63	0–63	0–61	0–88	0–73
Exposed soil (m²)						
Mean/Median	27/2	125/88	4/2	26/20	28/2	6/2
Range	0–132	0–287	0–25	0–71	0–287	0–28
Sum	162	375	53	184	774	317

The social settings and potential for solitude for campers and hikers is reflected by campsite intersite distances and visibility, and distance and visibility from the nearest formal trail (Table 2). At LW 9 (32%) of the campsites are located within 30.5 m of other campsites, with 12 (43%) between 30–61 m. In contrast, at LA 21 (40%) of the campsites are located within 30.5 m of other campsites, with 15 (29%) between 30–61 m, indicating somewhat closer spacing and less opportunities for solitude and natural quiet for LA campers (Table 2). Distance and visibility to formal trails is less concerning and data are more comparable between the two lake basins (Table 2).

Table 2. Frequency data for five campsite inventory indicators for Lake of the Woods designated and illegal campsites situated around the lake and on a peninsula, and for Lake Aloha.

Impact Indicator	Lake of the Woods				Lake Aloha	
	Designated		Illegal		All 28 Sites	All 52 Sites
	Lake 6 Sites	Peninsula 3 Sites	Lake 12 Sites	Peninsula 7 Sites		
Distance to other campsites (m)						
≤30	1	1	5	2	9	21
30–61	4	0	4	4	12	15
61–91	0	0	0	0	0	10
>91	1	2	3	1	7	6
Campsites in view (#)						
0	0	0	4	0	4	7
1	0	3	8	6	17	24
2–3	6	0	0	1	7	21
≥4	0	0	0	0	0	0
Distance to trail (m)						
≤30	3	0	5	0	8	18
30–61	2	0	4	0	6	7
61–91	1	0	3	0	4	5
>91	0	3	0	7	10	22
Visibility from trail						
Not	1	2	9	1	13	29
Partially	1	1	3	5	10	6
Highly	4	0	0	1	5	12
Bordering	0	0	0	0	0	5

Table 2. *Cont.*

Impact Indicator	Lake of the Woods				Lake Aloha	
	Designated		Illegal		All	All
	Lake 6 Sites	Peninsula 3 Sites	Lake 12 Sites	Peninsula 7 Sites	28 Sites	52 Sites
Distance to water (m)						
≤15	0	0	12	6	18	0
15–30	4	0	0	1	5	40
31–61	2	2	0	0	4	8
>61	0	1	0	0	1	4
Mean/Median	28/26	66/61	4/4	11/12	17/8	22/15
Range	18–42	46–91	2–6	3–17	2–91	2–76
Campsite expansion potential (# tent spots)						
0–1	0	0	5	1	6	21
2–3	0	0	4	0	4	24
4–5	0	0	3	1	4	6
≥6	6	3	0	5	14	1
Mean/Median	9/9	13/11	2/2	5/6	7/6	2/2
Range	7–11	7–20	0–6	1–7	0–20	0–8
Sum	57	38	24	38	157	107

While managers prohibit camping within 30 m of lakes and streams, 40 (77%) of LA campsites violate this regulation, and at LW 23 (82%) of campsites are in violation, including 44% of designated and 100% of illegal campsites (Table 2). Finally, campsite expansion potential, as indicated by the number of potential adjacent offsite tenting spots, was extremely high for LW designated campsites, with all having 6 or more possible tenting spots (Table 2). Similarly, 8 (80%) of the flat peninsula campsites had 6 or more potential offsite tenting spots compared to 6 (33%) of the lake shoreline campsites. Campsite expansion potential was substantially lower at LA, with only 1 campsite having 6 or more potential offsite spots and 6 (11%) of campsites having 4 possible offsite tenting spots. These values explain the corresponding similar differences in mean and aggregate campsite sizes for these groupings of campsites.

5.2. Campsite Occupancy Survey

Campsite occupancy surveys were conducted in both study areas to provide baseline estimates of visitor use on high but not peak-use weekends (Table 3). The LWs study area had 5 to 11 occupied campsites/night and 12 to 48 campers, with means of 9 campsites and 32 campers across the four surveyed weekends. Designated campsites received approximately twice as much use as the illegal sites, with means of 6 vs. 3 occupied campsites/night, and 22 vs. 10 campers/night, respectively. Visitation in the LA study area is much higher, with 11 to 21 occupied campsites/night and 43 to 65 campers, with means of 17 campsites and 55 campers.

Combining the data from the campsite inventory and occupancy surveys allows an examination of campsite proliferation rates. In the LW basin the occupancy data suggests a need for up to 11 campsites, yet 28 are present, indicating the creation of 17 unnecessary campsites (61% of all sites) during high (not peak) use weekends. These unnecessary campsites are attributable to visitors not complying with the LW lake basin's designated site camping regulations, with occupancy data suggesting there are too few designated campsites to accommodate camping demand during high use periods (visitors have created 19 illegal campsites, see Table 1). In the LA basin the occupancy data indicates a need for up to 21 campsites, yet 52 are present, indicating the creation of 31 unnecessary campsites

(60% of all sites) during high use weekends. These unnecessary campsites reflect “avoidable” camping impact, attributable to illegal camping and insufficient law enforcement in the LW basin, and to campsite proliferation and visitors who have the freedom to create new and unnecessary campsites under a dispersed camping strategy in the LA basin.

Table 3. Campsite occupancy survey results for Lake of the Woods and Lake Aloha based on counts of tents for four high use weekends.

Tents and Campers ¹	Survey Date				
	8/6	8/13	8/27	9/4	Mean
Lake of the Woods: Designated campsites					
1 (1)	0	3	4	2	
2 (2)	12	7	6	3	
3+ (3.5)	3	0	3	0	
Campers	35	17	27	8	22
Campsites	7	5	8	4	6
Lake of the Woods: Illegal campsites					
1 (1)	0	1	2	0	
2 (2)	1	3	4	0	
3+ (3.5)	3	0	1	1	
Campers	13	7	14	4	10
Campsites	4	2	2	1	3
Lake of the Woods: Totals					
Campers	48	24	41	12	32
Campsites	11	7	10	5	9
Lake Aloha					
1 (1)	4	7	8	4	
2 (2)	24	27	19	16	
3+ (3.5)	1	1	2	2	
Campers	56	65	53	43	55
Campsites	13	21	20	11	17

¹—Tents (campers): 1-person (1), 2-person (2), 3+ person (3.5).

5.3. Selection of Preferred Sustainable Campsites

The CSI index was calculated and applied separately to each lake basin, ranging from 7 to 19 for the LW basin and 12 to 20 for the LA lake basin; the best possible value is 24. The number of selected sustainable campsites were increased from the campsite occupancy survey minimum values to allow for uncertainty and increasing future use, though this would be a management decision. At LW 12 sites were selected with CSI ratings ranging from 15 to 19 and at LA 23 campsites were selected with CSI ratings ranging from 17 to 20. Table 4 reveals comparative data for resource and social indicators between the selected and omitted campsites for each lake basin. The “ground-truthing” step was omitted from this case study exercise as this requires additional field evaluations and judgements by PA managers.

The resource protection and social condition improvements of this proposed sustainable campsite management and selection process are illustrated in Table 4 data. A substantial reduction in the aggregate area of camping-associated visitor impact is the most substantial benefit, with 1351 m² of camping impact for the selected (retained) campsites in the two lake basins compared to 5983 m² of camping impact for the omitted campsites that could be closed and restored (Table 4). Thus, the aggregate area of camping impact for LW and LA would be reduced from 7334 m² to just 1351 m², an 82% reduction while continuing to accommodate existing or slightly higher camping use on only 18% of the current aggregate area of camping impact. These actions would also substantially reduce

mean campsite sizes (from 133 m² for the omitted sites to 39 m² for the selected sites). Perhaps of equal importance, the suggested actions would shift future camping to locations with a greatly reduced potential for campsite expansion and proliferation, as indicated by the campsite expansion potential indicator reductions (recall that this indicator received a 2× weighting in the CSI index). The selected LW campsites have an average of only 1.75 potential adjacent offsite tenting spots, compared to an average of 10 spots for the omitted campsites, while in the rockier LA basin the comparison is 1.2 vs. 2.8 potential tenting spots.

Table 4. Comparative results for resource and social indicators employed in the Campsite Selection Index for the LW and LA lake basin campsites.

Sustainability Indicator	Lake of the Woods		Lake Aloha	
	Selected 12 Sites	Omitted 16 Sites	Selected 23 Sites	Omitted 29 Sites
Campsite size (m²)				
Mean/Median	59/62	230/150	28/19	72/45
Range	14–101	82–729	9–95	11–354
Sum	705	3679	646	2304
Campsite expansion potential (# tent spots)				
0–1	6	0	16	7
2–3	4	0	6	17
4–5	2	1	1	4
≥6	0	15	0	1
Mean/Median	1.8/1.5	10/8	1.2/1	2.8/2.5
Range	0–5	4–20	0–5	0–8
Distance to water (m)				
≤15	12	5	16	7
15–30	0	5	2	7
31–61	0	5	5	11
>61	0	1	0	4
Mean/Median	11/10	92/60	42/20	98/100
Range	5–20	20–300	5–150	5–250
Distance to other campsites (m)				
≤30	3	6	3	13
30–61	6	6	7	10
61–91	0	0	8	4
>91	3	4	5	2
Distance to trail (m)				
≤30	3	5	0	13
30–61	4	2	1	6
61–91	3	1	3	3
>91	2	8	18	7

Mean and median values for the distance to water indicator are much lower for the selected than for the omitted campsites in both lake basins (Table 4). As noted in Section 6, this is at odds with management desires to protect water quality by separating campsites from shorelines to allow water runoff to be adequately filtered by soil, organic litter, and vegetation. This and other topics of concern must be evaluated during the ground-truthing process to remove and replace sustainable sites where needed. Based on the distance to other campsites and formal trail indicators, social conditions would also be substantially improved by using a substantially smaller subset of campsites and by their greater distances

to other campsites and formal trails. These improvements are much more pronounced for the LA basin than the LW basin.

6. Discussion

Protected areas must balance resource protection with the provision of recreation visitation, which necessarily entails the development and management of supporting infrastructure. In backcountry and wilderness settings, PA managers are increasingly discovering the need for and benefits of visitor containment strategies that concentrate intensive traffic on carefully located networks of sustainable trails and campsites [33]. Traditional dispersed camping policies have been consistently shown to lose their efficacy and viability when visitation reaches moderate levels and completely fail in popular high use settings [4,9,17,33]. In the eastern US, AT managers and volunteer stewards have been implementing a camping containment strategy based on recreation ecology studies that emphasize closing large mega-clusters of campsites in the most popular areas, generally located in flat terrain where site expansion and proliferation have long been chronic problems [8,13,14]. The most successful projects have shifted both campsites and formal trails to entirely avoid flat terrain, replacing them with more sustainable naturally occurring or constructed side-hill campsites in sloping, rocky, or uneven terrain that permanently and naturally constrain site expansion and proliferation, even in the absence of education, regulations, or enforcement. The selection of preferred well-distributed campsite locations also resolves salient social problems with reduced crowding, conflicts, and noise, and impacts to sensitive locations such as shorelines and areas with rare or sensitive flora/fauna and historical/cultural resources [34].

This study sought to provide guidance for PA managers seeking to evaluate and improve the sustainability of their camping management policies. A four-step process was developed and implemented at two high-use lake basins in the Desolation Wilderness. In Step 1, a campsite inventory and monitoring survey characterized camping supply, documenting campsite numbers, locations, conditions, and several resource protection and social problems. At LW the presence of 9 designated campsites (2863 m²) and 19 illegal campsites (1521 m²) suggested a failed containment strategy employing a designated site camping option (Table 1). Analyses also revealed salient locational deficiencies that allowed excessive campsite expansion, including 10 peninsula campsites in flat terrain (mean size of 254 m²) accounting for 2538 m² of camping impact compared to 18 shoreline campsites in sloping rocky terrain (mean size of 103 m²) accounting for 1846 m² of impact (Figure 1, Table 1).

LA campsite survey data revealed rockier terrain that effectively constrained site expansion (mean size of 53 m²) but allowed excessive campsite proliferation due to an ineffective dispersed camping strategy and very high use levels. LA visitors created excessive numbers of unnecessary campsites: 52 campsites in just the southern half of the lake basin, with an aggregate area of impact of 2745 m². Campsite inventory data also revealed a high potential for poor social conditions in the LA basin based on mapped campsite locations, with close distances and high intervisibility between campsites and formal trails (Table 2, Figure 1). A new campsite expansion potential indicator (Table 2) clearly demonstrated its ability to distinguish between areas of high and low campsite expansion potential, a salient consideration for selecting sustainable campsites [14].

In Step 2, efficient campsite occupancy surveys in the LW and LA basins were employed to characterize current camping demand, with all counts conducted within 1.5 h of sunset or sunrise on four high, but not peak-use, weekends. PA managers generally agree that infrastructure should be developed and managed for average high use given that peak use can reach more than double these levels. In the LW basin the occupancy

survey indicated that the nine designated campsites are a “bare minimum” number, and that visitors commonly use illegal sites even when some designated sites are unoccupied. This suggests confusion among visitors and insufficient enforcement regarding current designated site camping policies. In the LA basin, campsite occupancy data document a higher level of camping demand, with means of 17 occupied campsites within the southern half of the lake basin, which had 52 visitor-created campsites.

VUM and carrying capacity decision-making involve sustaining high quality visitation by balancing camping supply and demand while minimizing resource and social impacts. These two surveys, efficiently combined in this applied case study, yielded all data needed to evaluate resource and social camping impacts, support informative analyses, and suggest and evaluate corrective management options. For example, the traditional problems of site expansion and proliferation were both revealed and quantitatively described in the LW basin, as were site proliferation and high-density camping problems in the LA basin. Specifically, LA basin occupancy data suggested that 23 of 52 campsites are needed, with 29 unnecessary campsites of “avoidable impact.” Similarly, in the LW basin only 12 of 28 campsites are needed, allowing for the closure of 16 campsites. If these campsites were closed, the aggregate area of impact in the two lake basins would decline 82%, from 7334 m² to 1351 m², with no reduction in visitation and expected improvements in social conditions.

Monitoring data were used in Step 3 to develop and apply a weighted CSI to identify the most sustainable subset of campsites best able to resolve resource and social impacts. In both basins the selected campsites are considerably smaller in size and located in terrain that substantially and permanently reduces the threat of campsite expansion and proliferation. In the LW basin the CSI ratings suggested that the greatest reduction in camping impacts could be obtained by closing legal and illegal campsites on the flat peninsula along the northwest shoreline. In the LA basin the CSI ratings yielded substantial improvements in social conditions, substantially increasing distance to other sites and formal trails measures (Table 4).

We note that 63 of 80 (79%) of all campsites surveyed are less than 30 m from lakes so application of the CSI index was unable to resolve this problem. In some areas the rocky terrain and shorelines may yield little sediment in water runoff so this may be acceptable [10]. Those campsites that do pose a threat could be omitted and replaced by creating highly sustainable naturally occurring or constructed side-hill campsites in sloping or rocky terrain set back from lakes. However, Cole [35] describes how prohibiting shoreline camping has rarely resulted in substantial recovery of these sites while such policies contribute to campsite proliferation away from shorelines. Nevertheless, we identified numerous possible well-separated locations in a 30–60 m band from shorelines, particularly if managers employ side-hill campsites. Over 750 side-hill campsites have been developed within the AT corridor in the eastern US, including within wilderness, and a 16-year study demonstrated their efficacy in resolving both resource and social impacts [8,14,23,33,34].

While Step 4 has not yet been considered by the USFS, we suggest some actions for alternative or improved camping policies based on this study and the recreation ecology literature. The large flat peninsula at LW (Figure 1) could be closed by a sign placed along the main access trail where it departs northwest to the LA basin. Additional visits by volunteer or agency staff to inform and enforce the required designated site camping policy would also be beneficial. Several new side-hill campsites could be developed in sloping terrain along the eastern shoreline, set back from the lake and other campsites to address problems with crowding, conflicts, and noise [34].

Some PA managers believe that they assume greater tort liability when containment strategies encourage or require the use of established or designated campsites due to the

potential dangers of dead and hazardous trees. However, a review of this topic reveals that under the US Federal Tort Claims Act, the Discretionary Function exemption greatly reduces liability when agencies exercise discretion and make policy decisions based on such factors as research, budget realities, and agency goals and objectives [9]. Additionally, the “duty of care” to protect visitors from such dangers is exceptionally low in backcountry and wilderness settings due to the widespread effects of wildfires, insects, and other natural events that damage or kill large numbers of trees.

In the LA basin our data suggest that the greatest reduction in camping impacts can be obtained by closing about 31 unnecessary campsites that visitors have created over time. This study suggests that converting the dispersed camping strategy to a containment strategy with established or designated site camping offers the most effective options for balancing resource protection and recreation provision objectives. As illustrated by this case study, managers could implement voluntary established site camping by selecting the most preferred sustainable subset of campsites (approximately 21 sites in the southern half of the LA basin) and encouraging visitors to use only these sites while closing and assisting the recovery of non-selected sites. Alternately, a designated site camping policy could be employed.

To increase visitor compliance with using the selected sustainable campsites, managers could: (1) use triangular paint blazes to mark campsite access trails and campsite trees or posts, (2) list their coordinates on websites and in digital files for GPS units, and (3) include their locations on paper maps and phone apps used by visitors for navigation. Phone apps provide a beneficial and effective “new tool” for facilitating visitor navigation to established or designated campsites, and could clearly differentiate the closed campsites or zones, for example, by shading 30 m setbacks from shorelines or formal trails. A large and increasing number of backpackers now use these navigational phone apps and AT stewards have been working with app makers to include or exclude specific campsites for more than a decade. While some managers have concerns about advocating technology use in wilderness it is the visitors who choose to either adopt or forgo using such devices in wilderness [33].

Under a VUM adaptive management process, containment strategy actions such as those described above can be implemented and evaluated for their efficacy [2]. If educational and voluntary actions are found to be ineffective then more regulatory policies like designated site camping are justified. PA managers charged with balancing the trade-offs of protecting natural resources vs. providing high-quality recreation experiences must consider the loss of visitor freedom “costs” associated with regulatory policies. As previously noted, visitor surveys indicate a clear preference for policies like designated site camping that retain their access, before the imposition of even more regulatory restraints like trailhead quotas that prevent access above a specified level [17]. Given this finding, one questions why many US PA managers have widely applied dispersed camping policies shown to be ineffective at higher levels of use, and trailhead quotas that preclude use, in lieu of first adaptively applying containment strategies that employ established or designated site camping [4,6,9,17,33,35].

Limitations and Future Research

This study was designed as a case study to develop and apply guidance for PA managers to apply as part of VUM adaptive management programs. As such, no actual management actions were implemented, preventing the type of “before and after” measurements necessary to evaluate efficacy. Thus, some of our results reflect the potential estimated success of hypothetical actions. However, several longitudinal recreation ecology studies have evaluated and documented the success of implemented camping containment actions in resolving resource and social impacts [12,23,32,34].

Additional social science and recreational ecology research is needed to further clarify complex relationships and guide VUM adaptive management decision-making. In the social sciences, scientists can develop stated choice analysis surveys that compel visitors to make tradeoffs between competing management options [36]. Such analyses can clarify divergent opinions regarding their preferences for alternative management actions. Longitudinal recreation ecology studies are challenging to fund, though agency monitoring programs are beginning to yield datasets of sufficient quality to evaluate adaptively applied VUM management strategies and actions. While experimentally designed studies are generally preferred, VUM adaptive management programs operating in PAs are also worthy of academic attention and research [23].

7. Conclusions

While backcountry and wilderness managers have long designed, constructed, and maintained formal trail infrastructures, they have generally allowed visitors to select and create their own campsites. Recreation ecology research has consistently documented the resulting resource and social impacts associated with this *laissez faire* approach, such as the development of mega-sites and mega-clusters of campsites in large flat areas with associated social impact problems [8,9,35]. These impacts frequently reach unacceptable levels under conditions of moderate to heavy visitation. These research findings indicate a need to professionally manage sustainable camping infrastructures the same as trails. Purposefully shifting campsites and trails out of flat terrain into sloping/rocky terrain has emerged as the most effective and permanent solution to these problems, allowing environmental conditions to spatially constrain camping activity more easily and effectively than education or regulation and enforcement. This paper provides and illustrates such guidance through a case study in a high use wilderness along the PCT corridor. A four-step process involving campsite inventory, monitoring, and occupancy surveys combined with an evaluative component, and implementation of alternative camping management policies as part of an adaptive VUM process was illustrated.

Author Contributions: Conceptualization, J.L.M.; methodology, J.L.M.; investigation, J.L.M. and N.M.; formal analysis, J.L.M. and N.M.; resources, J.L.M.; data curation, J.L.M. and N.M.; writing J.L.M. and N.M.; project administration, J.L.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

Acknowledgments: We received excellent collaboration, fieldwork, and GIS assistance from the US Forest Service, Eldorado National Forest. Specifically, we extend our gratitude to wilderness staff Dustin Bell for providing information and assistance throughout the project, and Kelly Bessem for providing field assistance in conducting and sharing campsite inventory and monitoring survey data and volunteer assistance in creating our study area map.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

US	United States
PA	Protected Areas
VUM	Visitor Use Management
USFS	United States Forest Service

AT	Appalachian Trail
PCT	Pacific Crest Trail
GIS	Geographic Information System
GPS	Global Positioning System
TRT	Tahoe Rim Trail
LA	Lake Aloha
LW	Lake of the Woods
CSI	Campsite Selection Index

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