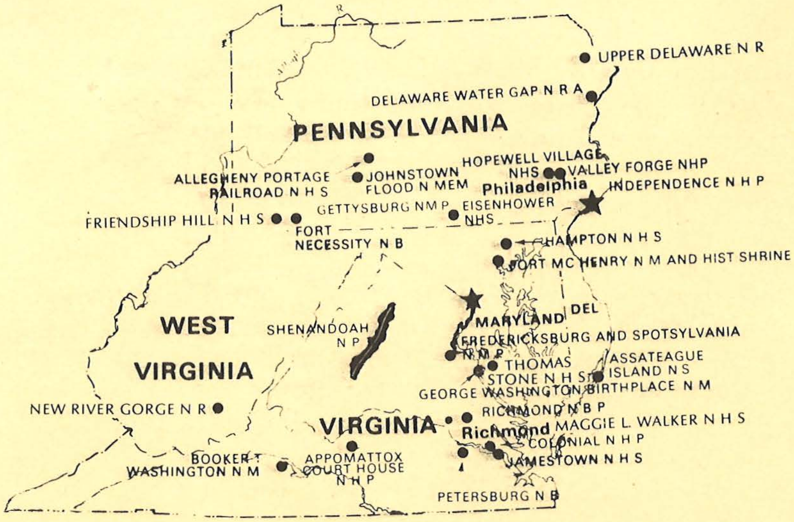

MID-ATLANTIC REGION

RESEARCH/RESOURCES MANAGEMENT REPORT

APPROPRIATE RIVER RECREATION USE STUDY
MAR - 28

Ecological Impacts on Recreation Sites at Upper Delaware Scenic and Recreational River, Pennsylvania-New York

U.S. DEPARTMENT OF THE INTERIOR

NATIONAL PARK SERVICE

MID-ATLANTIC REGIONAL OFFICE
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FINAL REPORT

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EXECUTIVE SUMMARY

Concern over increasing recreational use along the Delaware River and impacts to resources managed by the National Park Service prompted this study of impacts on recreation sites. No information on the number, distribution or condition of recreation sites along the Upper Delaware Scenic and Recreational River (UPDE) was available. Camping along the river is permitted in privately operated campgrounds and in several areas of state public lands which are not officially designated as camping areas. Trespass camping and recreational use on private lands without the owner's permission does occur and is considered a major problem by many of the area's residents.

This study was initiated to provide information on recreation site distribution and condition. Specific objectives were to: (1) estimate how much change due to recreational use has occurred on a sample of 10 recreation sites along the Upper Delaware; (2) assess the relationship between amount of impact and amount of use (based on a concurrent study in neighboring Delaware Water Gap National Recreation Area); and (3) compare levels of impact on recreation sites located close to the river (lowland) with those on sites set back from the river (upland), (also based on a concurrent study conducted at Delaware Water Gap National Recreation Area). At the same time, all impacted sites (excluding commercial campgrounds) and accesses within the UPDE boundaries were inventoried, using rapid estimation

procedures.

The type and magnitude of impacts was given perspective through comparison with impacts on recreation sites at New River Gorge National River (NERI) and the Delaware Water Gap National Recreation Area (DEWA). These areas were being studied during the same summer, using identical measurement procedures. Impact levels were also compared with those in some remote wilderness areas in the central and western United States.

Amount of impact was estimated by comparing conditions on recreation sites with those on neighboring undisturbed controls, representative of the recreation site as it would be if no use had occurred. All but two of the parameters we examined--exposure of rock and soil moisture level--differed significantly between recreation sites and controls.

The recreation sites we examined were typically 177 m^2 in size, with a central devegetated area of 87 m^2. Trash was abundant on most sites (typically enough to almost half fill a 33-gallon trash bag) and improperly disposed human waste was evident on most sites. Typically, only 54% of the tree reproduction had been eliminated on recreation sites, much less than has been lost on recreation sites examined elsewhere. Median loss of groundcover vegetation was 76%. Because organic matter is removed by yearly floods, mineral soil is exposed once vegetation is removed. Although mineral soil is not exposed on most control sites, it is exposed over 8% of a typical recreation site.

Damage to overstory trees was severe. Typically, all trees showed some evidence of damage and on many trees this damage was extensive. In addition, on the median site, 11% of the trees had been felled.

Impacts to the mineral soil were also evident, but not severe. Organic horizons were naturally absent on one-half of the recreation sites. On those sites with organic horizons, they were severely disturbed by recreational use. Despite the fact that there was often no organic horizon to cushion mineral soils from trampling stress, soil compaction levels are only moderate. Bulk density was typically 1.15 g/cm^3 on recreation sites, 0.23 g/cm^3 higher than on controls.

Recreation sites at UPDE are generally less highly impacted than sites at NERI and DEWA. Compared with sites at NERI, UPDE sites are smaller and have less disturbed shoreline; felling of trees is less pronounced. Compared with recreation sites at DEWA, UPDE sites have more trash and exposed human waste. UPDE sites have more damage to standing trees than either area, but tree reproduction is more abundant and vegetation loss and mineral soil exposure has been less pronounced. Compared with backcountry areas in the western and central United States, amount of impact appears to be roughly comparable. Only mineral soil exposure is unusually high on UPDE sites. This is largely a result of removal of organic horizons by flooding. When vegetation is killed by trampling, nothing but mineral soil is left.

Differences in impact related to differing amounts of use (low or high) and geographic orientation (upland or lowland) may be inferred from the research at DEWA. Frequently used recreation sites (40-70 nights/year) at DEWA are more highly impacted than infrequently used sites (3-10 nights/year). They are larger, have experienced more tree damage, loss of tree reproduction and groundcover alteration, and their soils are more compacted. However, even the infrequently used recreation sites have experienced pronounced impact. For example, although the median vegetation loss on high use sites was 89%, the median loss on low use sites was 68%. The difference in amount of impact, between high and low use sites, is small compared with the difference in amount of use these sites receive. We expect that similar relationships exist for the recreation sites at UPDE.

The only sizeable difference between upland and lowland recreation sites at DEWA was the much greater area of disturbance and devegetation on upland sites. For example, the median lowland site (172 m^2) was smaller than the smallest upland site (177 m^2). Lowlands have rough terrain and thick vegetation, conditions that inhibit recreation site expansion. These constraints to expansion are lacking on upland sites.

Impacts on UPDE recreation sites and the relationships between amount of impact and both amount of use and environmental characteristics are not very different from those reported elsewhere. The most unusual characteristic of UPDE recreation sites, large exposures of mineral soil, result from removal of organic horizons by floods and a moderately fragile groundcover vegetation that is readily removed by trampling.

Wherever vegetation is removed, mineral soil is exposed. Therefore, contrary to the hypothesis that these environments might be particularly tolerant of recreation use (given their favorable growing conditions compared to many western wilderness areas, for example) they are somewhat more fragile. Although the visual impacts of severe groundcover alterations are obvious, impacts to the mineral soil are only moderate.

The implications of these results to the management of recreational use are not clear. The majority of the lands along the river are privately owned and most of the camping and recreational use of these lands is considered trespass use. It is clear that this trespass use results in considerable alteration of the environment in localized areas. Although UPDE recreation sites are only moderately impacted, compared with recreation sites elsewhere, recreation site conditions are very different from those in undisturbed places.

Additional efforts to inform visitors concerning the private ownership of riverbank lands and appropriate locations for camping and other recreational activities are necessary. Some visitors may knowingly trespass on private lands in order to camp along the river and to avoid crowded or noisy campgrounds. Only one or two commercial campgrounds currently provides these kinds of opportunities. Finally, some canoe liveries only permit visitors who rent canoes from them to use their campgrounds. Such restrictions may encourage trespass camping when visitors are unable to find or reach lands where camping is permitted.

The highest priority in recreation site management, beyond the trespass issue, should be to develop a low-impact educational program. Trash, exposed human waste and toilet paper and damaged trees are common and unnecessary. Visitors should be taught a behavioral code in which littering, improperly disposing of human waste and damaging trees are deemed inappropriate. This might be accomplished by working through the canoe liveries to distribute minimum impact pamphlets and/or information on river maps to all visitors.

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INTRODUCTION

Increasing recreation use and the impacts of recreation use and management on neighboring communities has spurred considerable interest and concern about three units administered by the Mid-Atlantic Region of the National Park Service. These units--the Upper Delaware Scenic and Recreational River (UPDE), the Delaware Water Gap National Recreation Area (DEWA), and the New River Gorge National River (NERI)--are the focus of a series of studies being conducted under a cooperative agreement between the Mid-Atlantic Region and the U.S. Forest Service's North Central Forest Experiment Station River Recreation Management Research Unit.

The primary goal of this research is to help ensure that these river segments are appropriately managed to provide for and to protect the recreational, natural, and cultural resources and values for which they were established. More specific research questions have been asked, in an attempt to contribute to appropriate management. These questions and associated studies have been divided into environmental, user, community and managerial components. This report describes the results of a study of the environmental effects of recreational use at UPDE and compares impacts at UPDE with those found at NERI and DEWA.

The main objective of this study was to estimate how much ecological impact has occurred on a sample of trespass recreation sites along the Delaware River. A secondary objective was to evaluate differences in impacts on heavily and lightly used recreation sites, as well as between sites located close to the river and sites located on higher benches. This field work was done at DEWA because (1) the Park Service owns the land upon which the sites are located, and (2) suitable sample sites could be found in more different environments and use levels there. Due to their close proximity, results from DEWA should be largely applicable to sites at UPDE.

By understanding the nature of the impacts occurring on recreation sites, management will have an improved perspective on the severity and distribution of ecological impact problems. By understanding the importance of differences in amount of use in influencing the nature and severity of impacts, management will be better able to evaluate the potential of use limitation or distribution strategies for mitigating problems. By understanding the importance of differences in location in influencing the nature and severity of impacts, management can determine where best to locate sites. Finally, such work should improve systems for monitoring impacts, increasing management's ability to identify and react to problems and to evaluate the success of actions taken to mitigate problems.

PREVIOUS RESEARCH

This research builds on previous work on recreational impacts; however, it is unique in several important ways. There have been numerous descriptive studies of recreational impacts and some of these have examined how various factors influence amount of impact. Little of this work has been done either along rivers or in the eastern United States; very little work (perhaps none) has been done in environments as resilient (able to recover) as those at UPDE. Moreover, impacts caused by the types of recreationists that use these areas have seldom been studied. Most previous studies have examined impact either on campgrounds or picnic areas that are readily accessible by car, or on campsites in remote backcountry areas. Most impacts in the study areas are caused by users that arrive by boat, on day or short overnight trips.

We addressed three basic questions in this research project. The following discussion reviews previous research relevant to these questions, how the current project builds on previous work, and how it provides new information.

1. How much and what types of impact have occurred on recreation sites? World-wide, the number of studies relevant to this question exceeds 100. In the study area, we will be confining our research to areas of concentrated day or overnight use. About 50-60 studies describe impacts on such sites. We are aware of 12 studies that have been conducted on such sites in the eastern United States. Four were studies of backcountry sites in Great Smoky Mountains National Park (Bratton et al. 1978, Saunders 1979), the Adirondack Mountains (Rechlin 1973) and islands off the Maine coast (Leonard et al. 1983). Six examined long-established picnic and/or camping areas, accessible by car, in New Hampshire (LaPage 1962), Rhode Island (Brown et al. 1977), Connecticut (Lutz 1945), New York (Echelberger 1971), South Carolina (Dunn et al. 1980) and the

southern Appalachians (Ripley 1962). The other two examined a newly-opened car campground in Pennsylvania (LaPage 1967) and one-time use of a site in New York (Bogucki et al. 1975).

Very few studies of impacts along rivers have ever been conducted. Outside of the arid West, the only example is a study of impacts on the Ozark National Scenic Riverways in Missouri (Sutton 1976, Marnell et al. 1978). Thus little information, of even a descriptive nature, is available for riparian sites similar to those along the Delaware River. There is certainly reason to believe that impacts there might be quite different from those described in more mountainous, higher elevation areas, particularly those in the West. This research builds on earlier work by collecting data that can be compared to impact data collected elsewhere. This allows us to compare impact problems in UPDE with those found elsewhere. This, along with similar studies at NERI and DEWA, provides the first detailed analysis of problems and opportunities that are unique to riparian environments in the eastern United States.

<u>2. How do impacts vary with the amount of use sites receive?</u> Quite a few studies have examined the relationship between impact and amount of use. Generally, these studies have found that, above relatively low use thresholds, amount of use does not explain much of the variability in amount of impact (see, for example, Cole and Fichtler 1983, Marion and Merriam 1985). Most of these studies have been conducted in relatively fragile environments, however, where such a relationship is to be expected. The only study of this relationship in the more

resilient environments of the East suggested that use thresholds are much higher (Dunn et al. 1980). Even on the more fragile islands off the Maine coast, experimental trampling suggested that vegetation is relatively resistant to damage (Leonard et al. 1985). Results of the study at DEWA are included here because results are largely applicable at UPDE and they provide further perspective on this relationship in an environment that is very different from those studied before. The nature of the use/impact relationship has important management implications, particularly related to the appropriateness of use concentration and dispersal. Some of the management implications of research elsewhere might be challenged by results obtained from a close examination of resilient environments.

3. How do impacts vary between different environments? A number of impact studies have found substantial differences in amount of impact between different environments. Variation in environmental durability is particularly obvious in experimental trampling studies undertaken in different vegetation types. For example, studies have found that certain vegetation types can tolerate more than ten times as much use as other types before losing 50% of their vegetation cover (Cole 1985a). In the East, Ripley (1962), Bratton et al. (1978), and Dunn et. al. (1980) all report differences in the susceptibility of different environments to impact. Understanding such differences can be useful to management programs that attempt to locate facilities or direct users to particularly durable sites. Since little is known about the relative durability of many eastern

environments, particularly those along rivers, this study--conducted at DEWA--will advance our knowledge of the importance of location along rivers in the East.

STUDY SITES

The Upper Delaware Scenic and Recreational River includes 73 miles of river along the New York and Pennsylvania border. The river valley is rural, with paved roads and a railroad track paralleling much of the river's length. There were approximately 163,000 recreational visits in 1986. Most use is day use in canoes, but about 35% of visitors camp overnight, either in outfitter campgrounds or on predominantly private lands at undeveloped user-selected sites along the river.

In the entire study we examined 55 sites, each paired with an undisturbed control plot. Ten 10 recreation sites were examined at UPDE, in addition to 29 sites at DEWA, and 16 at NERI. Differences in the number of study sites reflect different levels of stratification in each area.

At NERI, 8 high use sites used primarily by local fishermen were compared with 8 high use sites used primarily as picnic sites by whitewater outfitters. This stratification was selected because of management concern with these two particular uses and because they are the dominant site uses in the study area.

No comparisons were made at UPDE; 10 sites were located in a variety of use and environmental situations. In addition, fishing access sites and major day use and camping areas were also inventoried for the entire river segment.

At DEWA, sites were stratified according to amount of use and location--either lowland or upland. Lowland sites are close to the waters edge and are frequently flooded; upland sites are located on higher benches and are not frequently flooded. Eleven of the most frequently used recreation sites at DEWA were compared with 11 sites that are among the most infrequently used third of sites. These high and low use sites were paired on the basis of environmental similarity so an equal number of upland and lowland sites were sampled. For the location stratification, nine high use upland sites were compared with a comparable number of high use lowland sites. Use levels were estimated in categories of low, moderate and high, on the basis of observation, judgement of river managers, and limited data. Low use sites are thought to receive between 3 and 10 nights of use/year and high use sites are thought to receive between 40 and 70 nights of use/year. Moderate use sites were not examined.

FIELD AND LABORATORY METHODS

We attempted to ensure that the methods used were comparable to those used elsewhere. This allows use to improve our perspective on the general applicability of research results and to assess the severity of impact at UPDE on the basis of comparison with other areas. Therefore, we replicated, as closely as possible, the study methods used in the Eagle Cap Wilderness, Oregon (Cole 1982), the Bob Marshall Wilderness, Montana (Cole 1983), and the Boundary Waters Canoe Area Wilderness, Minnesota (Marion 1984).

Each of the ten study sites consisted of both a recreation site and a neighboring undisturbed control site. The control was environmentally similar to the recreation site, selected to be an example of what the site would be like if it had not been used for recreational purposes. Recreational impacts were estimated by comparing conditions on recreation sites with those on controls.

Recreation Site Measurements

At each site we located a center point in a position which allowed the entire site to be measured. From this center point we established 16 linear transects in the following directions: N, NNE, NE, ENE, E, ESE, SE, SSE, S, SSW, SW, WSW, W, WNW, NW, and NNW. Along each transect, we measured the distance to the first significant amount of vegetation and to the edge of the apparently-disturbed part of the site. These measurements defined the devegetated central core of the site, as well as the entire disturbed site. We calculated the area of both the site and the devegetated core by plotting intercepts along each transect on scaled maps, connecting these intercepts with straight lines and measuring the area of the resultant polygon with a polar planimeter. The area of any "islands" of undisturbed vegetation were excluded from all subsequent measurements.

Damage was assessed for trees, defined as individuals taller than 140 cm (4.5 ft). Saplings (0-2 cm dbh) were distinguished from larger trees. We counted the number of individuals in each of these size classes within the recreation site, noting species and whether the tree was live, dead but standing, or a stump. Excluding stumps we assigned each individual to one of the following tree damage categories: **none** (no tree damage other than from obviously natural causes); **slight** (nails, nail holes, small branches cut off or broken, small superficial trunk scars); **moderate** (large branches cut off or broken, trunk scars and mutilations that may be numerous but do not total more than 1 ft^2 of area; or **severe** (trunk scars that total more than 1 ft^2 or complete girdling of the tree).

We attempted a similar categorization with root exposure, but quickly discovered that we could not consistently distinguish between recreation-related exposure and exposure for other reasons, particularly flooding. Therefore, we reluctantly abandoned the root exposure, convinced that it was a significant impact in some places but unable to quantify the extent of the problem.

Within the recreation site area, we also counted the number of tree stems at least one-half year old but less than 140 cm (4.5 ft) tall. We recorded each individual by species and distinguished between seedlings (those individuals less than 30 cm--1 ft tall) and larger reproduction (those individuals between 30 and 140 cm--1 and 4.5 ft tall). We did not count reproduction in untrampled islands excluded from the recreation site area.

For the entire recreation site we estimated the percent cover of each of the following six groundcover categories: **dense groundcover vegetation** (ground where vegetation cover less than 0.5 m in height is 50-100% in a 1 m^2 quadrat); **sparse groundcover vegetation** (ground where vegetation cover less than 0.5 m in height is 5-50% in a 1 m^2 quadrat); **exposed root area** (non-vegetated--<5% cover --ground where tree roots are exposed, as well as the immediately adjacent areas between); **litter** (non-vegetated ground, without exposed roots, that is generally covered with organic horizons); **exposed rock** (ground not covered with vegetation, litter or exposed roots, but with exposed rock); **exposed soil** (ground not covered with vegetation, litter, exposed roots, or rock). All these categories are mutually exclusive; so the percentages totaled about 100%. Cover was estimated in 10% coverage classes between 10 and 100% and to the closest percent where cover was 10% or less. The midpoint of each coverage class was used as an estimate of cover. This method of assessing groundcover replicated the technique utilized by Marion (1984).

To replicate the techniques of Cole (1982, 1983), quadrats were located along 4 linear transects originating at each center point. The azimuth of the first transect was randomly selected (from random numbers between 1 and 90). The azimuth of each subsequent transect was 90 degrees greater than the previous transect.

The number of quadrats established along each transect was roughly proportional to the relative length of each transect.

On most sites 15-20 quadrats were placed, representing approximately a 10% sample of the average site. Smaller sites had fewer quadrats.

This sampling scheme was decided upon for the following reasons: (1) the systematic sample with a random start combines the advantages of a well-distributed, uniform sample of the entire recreation site and an adequate measure of the standard error of measurements; and (2) quadrats are particularly efficient in terms of sampling intensity per unit of time invested.

Within each of the quadrats we estimated the percent cover of understory vegetation, exposed mineral soil, exposed rock, and tree trunks and roots. We also estimated the cover of litter, whether under vegetation or not. Finally we estimated the cover of each vascular plant species, and of mosses and lichens, each as a group.

Within each quadrat we also measured the depth of the surface organic horizons (down to mineral soil)--where more than this year's leaf fall remains. Then we took two penetration resistance readings in the quadrat with a pocket soil penetrometer. Where organic horizons were present, readings were taken at the top of the mineral soil, after organic horizons were removed.

In addition, we noted whether or not the quadrat was located primarily in the devegetated core. This enables us to compare results with those of Stohlgren (1982) and Cole (1985b), who distinguished between impacts on the core and peripheral parts of the recreation site. We also noted the presence of any vascular plant species, mosses or lichens found on the recreation site but not in the quadrats. This permits a more reasonable comparison of species richness on recreation sites and controls.

On each site we collected eight soil samples with a core sampler. Four were taken adjacent to the quadrats closest to the center point on each transect. The other four were taken randomly in peripheral parts of the site. In addition to representing the range of conditions on the site, this allows comparison between site center and perimeter (as Stohlgren 1982 and Cole 1985b did) and permits comparison to Cole's (1982) and Marion's (1984) results, in which only the center of the site was sampled.

Following extraction each soil sample was placed in a labeled plastic bag that could be sealed. In the laboratory moist soil samples were weighed and then dried in a 110 degree Centigrade oven for a day. They were weighed again and passed through a 12.5 mm sieve to remove stones. Stone-free bulk density was calculated by dividing the weight of the stone-free dry soil by the volume of the extracted core (minus the volume of stones). The dry soil weight was subtracted from the wet soil weight to obtain the weight of the moisture. Gravimetric moisture (%) was calculated by dividing moisture weight by the dry soil weight; volumetric moisture (g/cm^3 was calculated by dividing moisture weight by the volume of the extracted core.

The final procedure involved looking for improperly-disposed human waste and trash within a 50 m radius of the site center. The number of waste disposal sites were counted, as was the number of trash bags (33 gallon size) of trash (recorded to the nearest 0.1 bag).

Control Measurements

Controls were established as close to recreation sites as possible. Once selected, we established a center point. Controls were circular with a total area of 30 m^2, a size decided upon after determining appropriate "minimal areas" based on species area curves.

Within the control we estimated the percent cover of each of the six mutually exclusive groundcover categories we estimated on the site. We also estimated, for the entire control, percent cover of total understory vegetation, exposed mineral soil, exposed rock, and tree trunks and roots, as was done on recreation site quadrats. We also estimated the cover of litter, whether under vegetation or not and the cover of each vascular plant species, and of mosses and lichens, each as a group. As before we estimated cover in 10% classes from 10 to 100% and to the nearest percent if 10% or less and used the midpoint of each class as an estimate of coverage.

We took 20 regularly-distributed measurements of surface organic horizon thickness and 40 regularly-distributed measurements of penetration resistance. We collected four soil samples, with the core extractor, usually one-half way between the center and perimeter of the control, along four transects at right angles to each other. Bulk density and moisture content were calculated as on the recreation site.

Finally we counted all tree reproduction, by species and in the two size classes used on recreation sites. This was done in a 50 m^2 circle that extended 1 m beyond the control.

DATA ANALYSIS

Beyond the calculation of simple descriptive statistics such as means, medians and percentages, three synthetic indexes were calculated and tree reproduction was expressed on a density (per hectare) basis. One index was for tree damage. It was calculated as follows:

Tree Damage Index = ((# of trees in no damage category) + (2 * # of trees in slight damage category) + (3 * # of trees in moderate damage category) + (4 * # of trees in severe damage category))/ total number of trees excluding stumps.

The other two indexes are for differences in the groundcover species composition of recreation sites and controls. The first index, floristic dissimilarity, utilizes data on the relative cover of each species in the quadrats and controls. It was calculated as follows:

$$\text{Floristic Dissimilarity} = 0.5 \sum_{i=1}^{n} |p_{1i} - p_{2i}|,$$

where p_{1i} is the relative cover of a given species on the control and p_{2i} is the mean relative cover of the same species on the recreation site, and n is the total number of species.

The second index, Sorensen's dissimilarity is based solely on the presence of species on the recreation site (either in the quadrats or not) and controls. It was calculated as follows:

$$\text{Sorensen's Dissimilarity} = (1 - [2C/A+B]) \times 100 ,$$

where A is the number of species on the recreation site, B is the number of species on the control and C is the number of species on both the recreation site and the control.

Camp area, devegetated core area, amount of human waste and trash, tree damage and floristic dissimilarity provide measures of impact on each site. Other measures require comparison to controls. Both absolute and relative differences (Cole 1982) were calculated as estimates of recreation site impact. Absolute difference is the difference between recreation site and control conditions. Relative difference is absolute difference expressed as a percent of control conditions. Absolute difference was considered the most appropriate estimate of amount of impact except where differences between controls were substantial in relation to differences between recreation sites and controls.

With only a few exceptions, data were not normally-distributed and, therefore did not meet the requisite assumptions for use of parametric statistics. Consequently, we rely heavily on non-parametric statistics. We do often report means and standard errors, however.

Medians, ranges, means, and standard errors were calculated for each impact parameter, for all sites. The null hypothesis that recreation sites are identical to controls was tested with parametric paired t-tests and non-parametric Wilcoxon matched-pairs, signed-ranks tests. The test used depended upon whether or not data met the assumptions for parametric tests. A significance level of 0.05 was used. Where applicable, similar tests were used to test the null hypothesis that recreation site cores are identical to recreation site peripheries.

Medians, ranges, means, and standard errors were calculated for each river segment--NERI, DEWA and UPDE. The null hypothesis that there were no differences between areas was tested with parametric and non-parametric analysis of variance tests and multiple comparisons. This was done to provide some perspective on how impacts compare to those present elsewhere.

Medians, ranges, means, and standard errors were calculated for both high and low use sites at DEWA. The null hypothesis that there are no differences between types of use was tested with parametric t-tests and non-parametric Mann-Whitney tests.

Medians, ranges, means and standard deviations were calculated for both upland and lowland sites at DEWA. The null hypothesis that there are no differences between environments was tested with parametric t-tests and non-parametric Mann-Whitney tests.

AMOUNT OF CHANGE ON RECREATION SITES

Size of Disturbances, Trash and Waste

The disturbed area of the recreation sites examined varied from 45 to 283 m^2, with a median area of 177 m^2 (table 1). This area consists of a largely devegetated central core surrounded by a less heavily impacted zone. The median area of

Table 1. Selected characteristics of recreation sites along the Upper Delaware Scenic and Recreational River.

Statistic	Disturbed Area	Devegetated Area	Shoreline Disturbance	Trash Bags	Human Waste Sites
	-----square meters-----		---meters---	-number-	--number--
Median	177	87	10	0.4	1.5
Range	45-283	0-172	0-17	0.2-2.5	0-17

Table 2. Differences between river segments for selected recreation site characteristics.

Impact Parameter	River Segment NERI N=16	DEWA N=29	UPDE N=10	Signif.[1]
	------------median------------			
Disturbed Area (m^2)	286	184	177	.149*
Devegetated Area (m^2)	118	90	87	.572
Shoreline Disturbance (m)	20a	7b	10b	.004
Trash Bags (#)	0.8a	0.1b	0.4a	.000
Human Waste Sites (#)	1.0	0.5	1.5	.186

[1] Significance was tested with Kruskall-Wallis analysis of variance tests or, for those denoted by an asterisk, with parametric analysis of variance. Probabilities >0.05 are not significant. Values in the same row followed by the same letter (or no letter) are not significantly different.

the devegetated core was 87 m^2, although it varied between 0 and 172 m^2. Disturbance was also evident along the riverbank where parties disembark from their boats or fished. The median distance of shoreline that was disturbed was 10 m, although it reached 17 m on one site.

These recreation sites are neither unusually large nor small for recreation sites that are not accessible by automobile. Most of these sites are similar in size to recreation sites at DEWA, but none of them are as large as the largest DEWA sites (731 m^2). They are substantially smaller than recreation sites at NERI (table 2). They tend to be slightly smaller than sites in such backcountry areas as the Eagle Cap Wilderness, Oregon (median of 193 m^2), the Bob Marshall Wilderness, Montana (216 m^2) and the Boundary Waters Canoe Area, Minnesota (220 m^2). The size of the devegetated core is comparable to that at DEWA (median of 90 m^2) and Eagle Cap (87 m^2), smaller than NERI (118 m^2) and larger than Bob Marshall (14 m^2) and Grand Canyon (32 m^2) sites.

Shoreline disturbance is slightly more extensive than at DEWA but much less extensive than at NERI.

Trash is a problem on UPDE sites. The median amount was 0.4 trash bags and one site had 2.5 bags (table 1). This is considerably less than was found on sites at NERI (median of 0.8 bags) but more than at DEWA (0.1 bags), where recreation sites are cleaned up every week by river rangers. The UPDE does sponsor trash collection along the river but collections are not as frequent as at DEWA. Although quantification is lacking, it is our opinion that trash is considerably more abundant than in such backcountry areas as the Eagle Cap, Bob Marshall, Grand Canyon and Boundary Waters Canoe Area.

The median number of recreation sites where human waste was improperly disposed was 1.5; one recreation site had 17 human waste sites. Although differences are not statistically significant, this is a larger problem at UPDE than at NERI (median of 1.0 sites) or DEWA (0.5 sites). This reflects, in large part, the presence of composting toilets at several of the more popular recreation sites at DEWA and the less frequent overnight use at sites at NERI.

Tree Damage

Tree damage is widespread on the recreation sites (table 3). On the median site 12 trees, 100% of the standing trees, have been damaged by recreationists. Much of this damage is severe, consisting of extensive scarring of boles. This is reflected in a relatively high median tree damage index of 2.8. The median number of dead standing trees was 0, although on one site 14% of the standing trees were dead. In addition to damage to standing trees, a median of 11% of all trees on the site had been felled. On the worst site, 4 trees had been felled. Using the median site as a typical example, of 13 trees on the site, 2 had been felled; 3 standing trees were severely damaged (either girdled or with trunk scars that exceed 1 ft^2), 3 trees were moderately damaged (these have large broken branches or trunk scars that total less than 1 ft^2), 5 were slightly damaged and

Table 3. Tree damage on recreation sites along the Upper Delaware Scenic and Recreational River.

Statistic	Damaged Trees		Standing Dead Trees	Felled Trees	Tree Damage Index
	-number-	------------percent------------			
Median	12	100	0	11	2.8
Range	1-19	33-100	0-14	0-67	1.3-4.0

Table 4. Relative density of tree species and amount of damage on recreation sites.

Tree Species	Frequency of Occurrence	Relative Density[1]	Tree Damage Index[2]
	-number of sites-	-percent-	
Pinus strobus	6	17	2.7
Quercus velutina	5	14	2.3
Acer rubrum	3	14	3.2
Tilia americana	3	9	2.7
Carpinus caroliniana	2	8	
Acer saccharum	4	7	
Betula lutea	2	5	
Acer saccharinum	3	4	
Fraxinus americana	3	3	
Fraxinus pennsylvanica	1	3	
Cornus florida	1	2	
Nyssa sylvatica	1	2	
Prunus americana	2	2	
Populus grandidentata	1	2	
Carya spp.	1	1	
Prunus spp.	1	1	
Liriodendron tulipifera	1	1	
Hamamelis virginiana	1	1	
Fagus grandifolia	1	1	
Betula lenta	1	1	
Quercus palustris	1	1	

[1] Relative density expresses a species' density as a proportion of all trees on UPDE recreation sites.

[2] The tree damage index was only calculated for tree species with at least 10 individuals.

none were undamaged.

Table 4 lists tree species in the order of their relative density on UPDE recreation sites. Diversity is relatively high. The five most abundant species, *Pinus strobus* (white pine), *Quercus velutina* (black oak), *Acer rubrum* (red maple), *Tilia americana* (basswood) and *Carpinus caroliniana* (American hornbeam) account for 62% of the trees on recreation sites. Seventeen other species were present on the ten recreation sites. This can be compared with the total of 17 tree species found on 29 recreation sites at DEWA. We calculated tree damage index for the more abundant species. *Acer rubrum* trees were more frequently and seriously damaged than the typical species (median tree damage index was 2.8); *Quercus velutina* were less frequently and severely damaged.

Damage to standing trees has been substantially greater than at NERI or DEWA. This is expressed most succinctly in the tree damage index which has a median of 2.8 at UPDE, 2.2 at DEWA and 1.9 at NERI (table 5). On the other hand, tree felling is less common than at either of the other two areas. These results can be compared most readily with those for Boundary Waters sites, where the proportion of damaged standing trees (96%) and tree damage index (2.7) were comparable to UPDE recreation sites. Both the number (3.3 trees/site) and proportion (27%) of felled trees were substantially higher on Boundary Waters sites, however.

Table 5. Differences between river segments for tree damage on recreation sites.

Impact Parameter	River Segment NERI N=16	DEWA N=29	UPDE N=10	Signif.[1]
	--------median--------			
Damaged Trees (#)	8	9	12	.792
Damaged Trees (%)	73	81	100	.055
Standing Dead Trees (%)	0	0	0	.344
Felled Trees (%)	35a	18b	11b	.012*
Tree Damage Index	1.9a	2.2a	2.8b	.002*

[1] Significance was tested with Kruskall-Wallis analysis of variance tests or, for those denoted by an asterisk, with parametric analysis of variance. Probabilities >0.05 are not significant. Values in the same row followed by the same letter (or no letter) are not significantly different.

Table 6. Tree reproduction and groundcover characteristics on recreation sites along the Upper Delaware Scenic and Recreational River.

Statistic	Seedlings	Vegetation	Soil Exposure	Rocks	Trees/ Roots	Organic Litter[1]
	-stems/ha-	----------percent----------				
Recreation Sites						
Median	936	23	48	0	0.5	40
Range	117-4000	3-88	0-74	0-28	0-4	14-80
Control						
Median	2900	95	0	0	0	95
Range	200-11800	75-95	0	0-15	0	65-95
Median Difference						
Absolute	-1361	-71	48	0	0.5	-51
Relative (%)	-54	-76		0		-58
Significance[2]	.007	.003	.004*	.068	.043	.022

[1] Values are for the five sites that had an organic horizon.

[2] Significance was tested with Wilcoxon matched-pairs, signed-ranks tests or, for those denoted by an asterisk, with paired t-tests. Probabilities <0.05 are not significant.

Tree Reproduction

The median amount of tree reproduction (stems less than 140 cm tall) was 12 stems/recreation site. This represents a density of 936 stems/ha (table 6). By comparing this with the median density of 2900 stems/ha on controls, the median relative difference between recreation site and control was -54%. This allows us to estimate that 54% of the tree reproduction on the site has been lost as a result of recreational use.

Table 7 lists tree species in order of their abundance, in reproductive size classes, on recreation sites. Diversity is high, but many of the species were found on only a few sites. Several of the more abundant species in the overstory were not reproducing on many sites. For example, *Pinus strobus* was present in the overstory of six recreation sites, but it was reproducing on only one site. The fact that it was reproducing on a recreation site and not a control suggests that this lack of reproduction is not related to camping impacts. The most widespread *and* abundantly reproducing species were *Acer rubrum*, *Prunus* spp. (cherry), *Hamamelis virginiana* (witch hazel) and *Carya* spp. (hickory). The relatively high survival rate on these recreation sites is reflected in the fact that some of these species were growing more densely on recreation sites than on controls. It is unlikely that this represents a positive response to trampling. More likely it reflects the choice of controls that were not truly representative of undisturbed conditions, a problem that is exacerbated by the relatively small sample size.

Table 7. Differences between recreation sites and controls in the density of reproduction by different tree species.

Tree Species	Frequency of Occurrence		Mean Density[1]		Relative Density[2]		Resistance Index[3]
	Site	Cont.	Site	Cont.	Site	Cont.	
	---number---		--no./ha--		--percent--		
Fagus grandifolia	1	1	1295	1000	18	3	
Acer rubrum	6	2	278	143	14	3	4.67
Prunus spp.	3	4	253	1840	8	27	0.30
Hamamelis virginiana	2	2	203	200	8	2	4.00
Nyssa sylvatica	1	1	2886	200	6	1	
Carya spp.	3	2	208	250	4	3	1.33
Fraxinus americana	2	3	173	1400	4	12	
Quercus velutina	3	3	94	550	3	6	
Tilia americana	1	1	378	200	3	1	
Cornus florida	2	2	75	1067	2	9	
Carpinus caroliniana	3	1	186	133	2	1	
Prunus americana	2	0	137	0	2	0	
Liriodendron tulipifera	3	2	71	133	1	1	
Robinia pseudoacacia	2	1	107	67	1	1	
Acer saccharum	1	3	50	200	1	2	
Quercus prinus	1	3	56	164	+	2	
Juniperus communis	1	0	222	0	+	0	
Betula nigra	1	0	55	0	+	0	
Pinus strobus	1	0	99	0	+	0	
Gleditsia triacanthos	0	2	0	400	0	2	
Acer spicatum	0	2	0	200	0	1	
Sassafras albidum	0	1	0	2400	0	7	
Acer saccharinum	0	1	0	600	0	2	
Quercus rubra	0	1	0	200	0	1	
Fraxinus pennsylvanica	0	1	0	2000	0	6	
Morus alba	0	1	0	200	0	1	
Quercus palustris	0	1	0	200	0	1	

[1] Means are for all sites (either recreation site, control or both) on which the species was found--not all 10 sites.

[2] Relative density expresses a given species' density as a proportion of all tree reproduction on UPDE recreation sites and controls. A + indicates a relative density of < 1%.

3 The resistance index, only calculated for those species found on > 3 sites, is relative density of the recreation site divided by relative density of the control. Species with an index greater than 1.00 survive on recreation sites more often than the average species; species with an index of less than 1.00 survive less frequently on recreation sites.

By dividing the relative density of a species on recreation sites by its density on controls, we calculated a resistance index for the more widespread species. Of these, *Acer rubrum* and *Hamamelis virginiana* survive four times as frequently on recreation sites as the typical species; in contrast, *Prunus* spp. are reproducing less than one-third as frequently as normal on recreation sites.

The loss of tree reproduction on UPDE recreation sites is the least drastic loss reported in the literature. UPDE sites retain a seedling density 3 times greater than that on DEWA sites and 9 times greater than that on NERI sites (table 8). In those areas, and most others from which data have been reported, more than 90% of seedlings have typically been lost on recreation sites.

Groundcover

Several means of evaluating changes in groundcover were used. The figures reported in table 6 are based on quadrat measurements. Most controls were completely covered with vegetation; mineral soil, rocks and roots were seldom exposed. The groundcover of recreation sites was quite different. Median vegetation cover was only 23%, representing a loss of 76% of the vegetation on undisturbed controls. This loss of vegetation resulted in exposure of mineral soil and occasionally rocks and roots. (Although we did not distinguish between tree trunk and root cover, because there is no reason for tree cover to increase on recreation sites, we are interpreting an increase as an increase in root exposure; this interpretation agrees with our observations). Mineral soil exposure increased from a median of 0% on controls to 48% on recreation sites. Rock exposure increased from control to recreation site in only a few cases. Root exposure increased from control to recreation site on one-half of the cases and although the size of this increase was small, it was consistant enough to be statistically significant. Finally, on the 5 recreation sites that had an organic horizon, the median litter cover was only 40%, compared with 95% cover on the control--a reduction of almost 60% on the median site.

These groundcover changes are quite similar to those found on sites at DEWA and NERI (table 8). In both those places, the only pronounced changes were loss of most vegetation, a large increase in mineral soil exposure and substantial reductions in litter cover on the few sites with an organic horizon. The only statistically significant differences between recreation sites in the three areas were higher rock and root and tree coverages and greater increases in root and tree cover at NERI than at DEWA. These differences amount to only a few percent cover and are of little managerial significance. Although differences between the three areas were not sizeable or consistent enough to be statistically significant, vegetation loss and mineral soil exposure were typically less pronounced on UPDE recreation sites than on NERI or DEWA sites.

These results are directly comparable to those for the Eagle Cap and Bob Marshall. The median loss of vegetation on UPDE recreation sites (76%) is less than that found on Eagle Cap

Table 8. Differences between river segments for tree reproduction and groundcover characteristics.

Impact Parameter	NERI N=16	DEWA N=29	UPDE N=10	Signif.[2]
	River Segment			
	------------median------------			
Seedlings (stems/ha)	106a	314ab	936b	.008
relative difference (%)	-92a	-95a	-54b	.013
Vegetation Cover (%)	5.5	6.0	23.0	.062
relative difference (%)	-94	-89	-76	.062
Soil Exposure (%)	77	73	48	.056*
absolute difference (%)	70	71	48	.091*
Rock Cover (%)	3.0a	0b	0b	.000
absolute difference (%)	0	0	0	.137
Tree and Root Cover (%)	2.0a	0b	0.5ab	.002
absolute difference (%)	2.0a	0b	0.5ab	.004
Organic Litter Cover[1] (%)	53	47	40	.600
relative difference (%)	-44	-39	-58	.831

[1] Values for those sites with an organic horizon (1 at NERI, 13 at DEWA, 5 at UPDE).

[2] Significance was tested with Kruskall-Wallis analysis of variance tests or, for those denoted by an asterisk, with parametric analysis of variance. Probabilities >0.05 are not significant. Values in the same row followed by the same letter (or no letter) are not significantly different.

sites (87%), but more than the loss on Bob Marshall sites (66%). The median increase in mineral soil exposure (48%) is much greater than that reported for the Eagle Cap (25%) or the Bob Marshall (7%).

Slightly different results are derived from the measures of groundcover based on single estimates for the entire site, but these results are comparable to those obtained in the Boundary Waters. Using these figures, controls were completely covered with dense vegetation. On recreation sites, total vegetation decreased 70%; median dense vegetation cover was 5% and sparse cover was 20%. Median mineral soil exposure was 40% and on most recreation sites no rock or roots were exposed. In comparison, Boundary Waters sites had more vegetation (median cover of 36%, with a loss of 62%), much less mineral soil exposure (median cover of 10%, a 10% increase), but a more pronounced increase in rock exposure (median cover of 12%, with an increase of 11%).

These results suggest that the groundcover on UPDE recreation sites has been somewhat less severely disturbed than that on NERI or DEWA sites; however, disturbance has been comparable or greater than that reported in backcountry areas in the West and Midwest.

Vegetation Composition

The composition of the groundcover vegetation on recreation sites was quite different from that found on undisturbed control plots. The median floristic dissimilarity was 64% (table 9). This figure, which is based on the coverage of constituent

Table 9. Differences between recreation sites and controls in the species composition of groundcover vegetation along the Upper Delaware Scenic and Recreational River.

Statistic	Floristic Dissimilarity[1]	Sorensen's Dissimilarity[2]	Species Richness[3]	
			Site	Control
	--------------percent	--------------	--no. of	species-
Median	64	57	19	18
Range	30-97	37-66	10-30	7-25

[1] Floristic dissimilarity is a measure of the difference in species composition between recreation and controls, based on the coverage of each species. See text for a formula.

[2] Sorensen's dissimilarity is a measure of difference in species composition based on presence of species. See text for a formula.

[3] Species richness is simply the number of species on recreation sites or controls. Recreation sites and controls were not significantly different (paired t-test; $p < 0.05$).

species, can vary between 0 (no difference in composition) and 100% (no species in common), although two samples of the same vegetation type will usually have a dissimilarity value of 25-40%. This difference is much less than the median of 80% found on both DEWA and NERI sites. It is also much lower than the compositional change on Boundary Waters sites (88%) and is comparable to that on Eagle Cap (59%) and Bob Marshall (63%) sites. Sorensen's dissimilarity, an index based on the presence or absence of species, had a median of 57%, a value between that for NERI (64%) and DEWA (52%) sites. Species richness, the number of species on sites, did not differ between recreation sites and controls.

Much of the change in composition is accounted for by changes in the relative abundance of shrubs, graminoids (grasses and sedges), and forbs (herbaceous plants other than graminoids). On controls, forbs are much more abundant than graminoids and shrubs comprise about 4% of the cover (table 10). On recreation sites, however, graminoids predominate and shrubs are usually absent. Mosses increase in importance on many recreation sites. A similar shift in relative importance toward graminoids on recreation sites was found on DEWA sites and almost everywhere it has been examined (NERI is a notable exception). It results from the graminoid growth form generally being more resistant to trampling than other forms.

The most common species on recreation sites is a non-native grass--*Poa pratensis* (Kentucky bluegrass). This plant is highly resistant to trampling and was also the most abundant species on

Table 10. Relative cover of growth froms on recreation sites and controls at Upper Delaware Scenic and Recreational River.

Growth form	Recreation Sites Median	Recreation Sites Range	Control sites Median	Control sites Range	Significance level[1]
	--------percent--------				
Graminoids	53	14-78	38	0-55	.007
Forbs	23	12-84	60	17-89	.000
Mosses	3	0-36	0	0-9	.001
Shrubs	0	0-5	4	0-26	.018
Tree seedlings	1	0-8	1	0-8	.407

[1]Significance was tested with the Wilcoxon matched-pairs, signed-ranks test.

recreation sites at DEWA, as well as in the Bob Marshall and Eagle Cap. We found 12 non-native species on these sites. The proportion of cover contributed by non-native species increases from 3% on controls to 23% on recreation sites. This compares with a relative cover, for non-native species, of 22% on NERI sites and 44% on DEWA sites.

The species that are most resistant to trampling are grasses, sedges, non-native forbs and mosses (table 11). The common species that declined the most on UPDE recreation sites were Aster divaricatus (white wood aster), Parthenocissus quinquefolia (Virginia creeper) and Athyrium felix-femina (lady fern). Species that were common on undisturbed controls but virtually absent on recreation sites are listed in table 12. Table 13 lists species that are neither particularly resistant not susceptible to trampling. A list of all species found on recreation sites and controls is in the appendix.

Soils

One-half of the recreation sites we examined had organic horizons. On these sites, the median thickness of the organic horizon was 0.5 cm; typically organic horizons on recreation sites were only 50% as thick as those on controls (table 14). Compaction of the mineral soil resulted in higher penetration resistance and bulk density on the recreation sites compared to controls. The median penetration resistance on the recreation sites was 2.1 kg/cm^2, an increase of 1.9 kg/cm^2 over controls. The median bulk density on the sites was 1.15

Table 11. Frequency, mean cover and mean relative cover of common species that are particularly resistant on 10 recreation sites and controls along the Upper Delaware Scenic and Recreational River.[1]

Species	Frequency		Mean Cover		Mean Relative Cover	
	Site	Control	Site	Control	Site	Control
	----number----		------------percent----------------			
Grasses/Sedges						
Carex davisii	3	4	3.1	0.8	5.5	0.5
Carex virescens	2	1	0.8	0.5	2.6	0.4
*Poa pratensis	4	0	4.9	9	24.1	0
Forbs						
*Glecoma hederacea	5	0	0.7	0	2.1	0
Oxalis stricta	4	2	0.5	0.2	0.7	0.2
*Stellaria media	5	0	0.3	0	1.0	0
*Trifolium repens	4	0	0.2	0	0.9	0
Mosses	6	5	3.5	4.2	10.6	2.6

[1] Frequency is the number of campsites or controls on which the species was found. Mean cover was based on all 10 sites, regardless of frequency. Mean relative cover is the proportion of all cover accounted for by a given species. * denotes a non-native species.

Table 12. Frequency, mean cover and mean relative cover of common species that are particularly susceptible on 10 recreation sites and controls along the Upper Delaware Scenic and Recreational River.[1]

Species	Frequency		Mean Cover		Mean Relative Cover	
	Site	Control	Site	Control	Site	Control
	----number----		------------percent------------			
Ferns and Allies						
Equisetum sp.	1	2	+	0.2	+	0.1
Grasses						
Elymus sp.	2	1	0.2	4.5	0.5	2.7
Panicum sp.	3	4	0.3	5.2	0.5	3.4
Forbs						
Eupatorium rugosum	1	3	0.1	5.1	0.4	4.3
Impatiens sp.	2	4	0.1	2.2	0.7	1.3
Lysimachia ciliata	1	6	+	0.6	+	0.4
Solidago gigantea	0	4	0	2.8	0	1.5
Solidago sp.	1	2	0.1	0.8	0.1	0.5
Triosteum perfoliatum	0	3	0	0.3	0	0.2
Vines						
Amphicarpa bracteata	0	4	0	0.5	0	0.4
Parthenocissus quinquefolia	7	8	0.3	14.0	4.5	10.5
Rhus radicans	0	4	0	3.2	0	3.4
Smilax herbacea	1	4	+	0.8	+	0.5
Shrubs						
*Berberis thunbergii	3	0	1.0	0	0	0.7
Rosa palustris	1	2	+	1.2	+	0.6

[1] Frequency is the number of recreation sites or controls on which the species was found. Mean cover was based on all 10 sites, regardless of frequency. Mean relative cover is the proportion of all cover accounted for by a given species. + indicates a trace of cover. * denotes a non-native species.

Table 13. Frequency, mean cover and mean relative cover of common species that are neither resistant nor susceptible on 10 recreation sites and controls along the Upper Delaware Scenic and Recreational River.[1]

Species	Frequency		Mean Cover		Mean Relative Cover	
	Site	Control	Site	Control	Site	Control
	----number----		------------percent-------------			
Ferns and Allies						
Athyrium felix-femina	1	4	0.9	14.2	7.4	10.9
Grasses/Sedges						
Agrostis sp.	2	1	0.3	3.5	1.3	2.1
Bromus sp.	1	4	0.2	0.8	1.5	0.5
Carex bromoides	3	5	3.4	9.5	4.4	5.8
Panicum sp.	1	4	1.6	5.4	2.8	3.0
Poa sp.	5	3	1.9	10.5	5.2	6.7
Sphenopholis nitida	1	2	0.2	5.8	2.2	3.0
Forbs						
*Alliaria officinalis	2	3	0.3	1.7	0.6	1.1
Aster divaricatus	5	4	3.7	18.5	8.2	12.4
Maianthemum canadense	3	4	0.1	3.2	1.9	1.7
Potentilla simplex	1	3	0.5	0.9	0.8	0.5

[1] Frequency is the number of recreation sites or controls on which the species was found. Mean cover was based on all 10 sites, regardless of frequency. Mean relative cover is the proportion of all cover accounted for by a given species. * denotes a non-native species.

g/cm^3, an increase of 0.23 g/cm^3 over controls.

Comparison of these soil impacts with those found elsewhere suggest that soil impact levels at UPDE are neither unusually high nor unusually low. Compaction levels, both penetration resistance and bulk density, are lower on UPDE recreation sites than on NERI or DEWA sites, but such measures are also lower on UPDE controls; increases in compaction (difference between recreation site and control) are not significantly different from that on sites in the other areas (table 15). Penetration resistance was higher on recreation sites in the Boundary Waters (3.7 kg/cm^2) and Bob Marshall (3.1 kg/cm^2), although increases over controls range from somewhat higher to much less there (2.4 and 0.9 kg/cm^2, respectively) and on Grand Canyon sites (2.0 kg/cm^2). Bulk density was much higher on recreation sites in the Boundary Waters (1.3 g/cm^3) and Grand Canyon (1.60 g/cm^3), but the difference between recreation sites and controls was only slightly higher, 0.3 and 0.24 g/cm^3, respectively. However, on Eagle Cap recreation sites both bulk density (0.95 g/cm^3) and the increase over controls (0.11 g/cm^3) were less than on UPDE sites.

The final parameters we examined were moisture levels on recreation sites compared with those on controls. Gravimetric moisture (the weight of water as a percentage of the weight of dry soil) was generally less on recreation sites than controls, while volumetric moisture (the weight of water in a given volume of soil) was often higher on recreation sites (table 14). Neither difference was statistically significant. Although

Table 14. Soil characteristics on recreation sites and controls along the Upper Delaware Scenic and Recreational River.

Statistic	Organic Thickness[1]	Penetration Resistance	Bulk Density	Gravimetric Moisture	Volumetric Moisture
	---cm---	-kg/cm^2-	-g/cm^3-	-percent-	-g/cm^3-
Recreation Site					
Median	0.5	2.1	1.15	21	23
Range	0.1-1.3	0.7-3.5	0.87-1.34	8-40	11-34
Control					
Median	0.6	0.3	0.91	26	20
Range	0.1-2.7	0-0.7	0.50-1.28	5-69	7-34
Median Difference					
Absolute	-0.3	1.9	0.23	-2	2
Relative (%)	-50	363	26	-11	13
Significance[2]	.034	.000*	.001*	.214	.266

[1] Values are for the five sites that had an organic horizon.

[2] Significance was tested with Wilcoxon matched-pairs, signed-ranks tests or, for those denoted by an asterisk, with paired t-tests. Probabilities <0.05 are not significant.

Table 15. Differences between river segments for soil characteristics.

Impact Parameter	NERI N=16	DEWA N=29	UPDE N=10	Signif.[2]
	----------median----------			
Organic thickness[1] (cm)	0.4	0.4	0.5	.948
absolute difference (cm)	-0.9	-1.1	-0.3	.700
Penetration Resistance (kg/cm^2)	2.3a	2.9b	2.1a	.002*
absolute difference (kg/cm^2)	1.8	2.5	1.9	.074*
Bulk Density (g/cm^3)	1.24a	1.26a	1.15b	.004*
absolute difference (g/cm^3)	0.18	0.16	0.23	.898*
Gravimetric Moisture (%)	16	14	21	.066
absolute difference (%)	2.0	-2.0	-1.5	.526
Volumetric Moisture (g/cm^3)	19	18	23	.083*
absolute difference (g/cm^3)	4.0	0	2.0	.298*

[1] Values for those sites with an organic horizon (1 at NERI, 13 at DEWA, 5 at UPDE).

[2] Significance was tested with Kruskall-Wallis analysis of variance tests or, for those denoted by an asterisk, with parametric analysis of variance. Probabilities >0.05 are not significant. Values in the same row followed by the same letter (or no letter) are not significantly different.

these responses are divergent, it is clear that recreational use is not adversely affecting soil moisture levels. For comparison, gravimetric moisture levels were less than 4% on Grand Canyon recreation sites, where a statistically significant reduction of 21% in comparison to controls was also recorded. On Boundary Waters sites, gravimetric moisture levels on recreation sites (15.8%) were somewhat lower than those at UPDE and were slightly lower than levels on controls.

Summary

In sum, then, all but three of the parameters we examined differed significantly between recreation sites and controls. These three parameters, for which there was no indication of recreational impact, were rock exposure and the two measures of soil moisture content. The increase in root exposure was statistically significant but not large; other impacts were quite pronounced.

These sites were generally less highly impacted than recreation sites at NERI and DEWA, although they were more highly impacted in some ways. Compared with sites at NERI, UPDE recreation sites are smaller and have less disturbed shoreline; felling of trees is less pronounced, but damage to standing trees is greater. Tree reproduction is more abundant and vegetation loss and mineral soil exposure has been less pronounced. Compared with recreation sites at DEWA, UPDE sites have more trash, more human waste and more damage of standing trees. Tree reproduction is more abundant and vegetation loss and mineral soil exposure has been less pronounced. Penetration resistance and bulk density is less but increases in compaction are not significantly less. (Note from tables 4 and 8 that several of these differences, while pronounced, are not statistically significant). Compared with the backcountry areas in the West and Midwest, examined with comparable methods, amount of impact appears to be roughly comparable. The only pronounced difference is in mineral soil exposure, which is unusually high on UPDE sites. This partially reflects the fact that the majority of sites have no organic horizons, because they are removed by annual floods. Therefore, when vegetation is killed by trampling nothing but mineral soil is left. Mineral soil exposure is also unusually pronounced on those sites with organic horizons, however. Perhaps compared with coniferous litter, hardwood litter is more readily broken up and eroded away by campers. Legg and Schneider (1977) report a tendency, on some recreation sites in northern Michigan, for litter cover to decline more rapidly under hardwoods than under conifers. Soil impacts, however, which one might theorize would be high due to the scarcity of organic litter, are generally comparable to those experienced elsewhere.

DIFFERENCES BETWEEN THE CORE AND PERIPHERY OF RECREATION SITES

On most recreation sites disturbance is greatest at the center of the site and decreases as one moves from there to peripheral parts of the site and then to relatively undisturbed areas beyond the site. Our approach has been to characterize the average condition of the entire site, out to where disturbance is not visually evident. Stohlgren (1986) has pointed out that such an approach underestimates the amount of impact on the central core of the site and overestimates the amount of impact on peripheral parts of the site. He suggests dividing the disturbance gradient into two categories--core and periphery. While we recognize the existence of this gradient, there are no sharp boundaries along this gradient that allow us to define a non-arbitrary number of categories; therefore, for our purposes we prefer to use the entire site--rather than subunits within the site--as the descriptive unit.

However, to compare our results to those of Stohlgren, we attempted to distinguish core quadrats from periphery quadrats. Because this distinction was made primarily on the basis of amount of vegetation, it is not surprising to find that vegetation was less abundant and mineral soil was more abundant on core quadrats than on periphery quadrats (table 16). Site cores are mostly mineral soil (median of 62%), while peripheral parts of the site still retain a median 33% vegetation cover. Differences in litter cover were not pronounced. Organic horizon thickness and penetration resistance were also measured on both core and periphery quadrats. Organic horizons were thinner on the core and penetration resistances were higher; however, neither difference was significant. Core bulk densities were significantly higher than peripheral densities. Differences in moisture level were not significant, although gravimetric moisture was lower on the core than either the

Table 16. Differences in groundcover and soil conditions between the core and periphery of recreation sites and controls along the Upper Delaware Scenic and Recreational River.[1]

Impact Parameter	Recreation Site: Core	Recreation Site: Periphery	Control Site
	median		
Vegetation Cover (%)	5a	33b	95c
Soil Exposure* (%)	62a	21b	0c
Rock Cover (%)	0a	0ab	0b
Tree and Root Cover (%)	0a	0ab	0b
Organic Litter Cover[2] (%)	42a	45a	95b
Organic Thickness[2] (cm)	0.6a	0.4ab	0.6b
Penetration Resistance* (kg/cm^2)	2.3a	1.4b	0.3c
Bulk Density* (g/cm^3)	1.22a	1.05b	0.91c
Gravimetric Moisture (%)	18	26	26
Volumetric Moisture* (g/cm^3)	21	24	20

[1] Significance was tested with Wilcoxon matched-pairs, signed-ranks tests or, for those parameters denoted with an asterisk, paired t-tests. Values in the same row followed by the same letter (or no letter) are not significantly different ($p=0.05$).

[2] Values are for the five sites that had an organic horizon.

periphery or controls, which had comparable levels.

As Stohlgren found for subalpine recreation sites in Sequoia National Park, there is a gradient of increasing vegetation loss and mineral soil exposure that can be recognized and sampled in a stratified manner. The parts of the site with more vegetation also had soils with levels of compaction that averaged almost twice those of periphery soils. We also found some evidence, as Stohlgren did, that moisture levels were lower on cores, but differences were not substantial. We compared core characteristics with control characteristics to see how differences compare with those between average site and control characteristics. Although core-control differences were often greater, the statistical significance of differences (or lack thereof) were no different. Similarly, the statistical significance of differences between lowland and upland sites and between high and low use sites at DEWA (described in the following sections) were no different whether core or average site values were compared with controls. This establishes the validity of using average site conditions for comparative purposes, as long as we remember that some parts of some sites are much more highly impacted than the average values suggest.

DIFFERENCES BETWEEN HIGH AND LOW USE RECREATION SITES

A number of factors may account for the differences between levels of impacts measured on UPDE recreation sites and those reported elsewhere. Among the important factors are amount and type of use and environmental characteristics. To provide some perspective on these factors we compared impacts on some of the most frequently used recreation sites at DEWA with those on some of the more infrequently used sites. We feel that these results would also be generally applicable to sites at UPDE because environmental characteristics and types of use are comparable.

It is clear from table 17 that the areal measures of impact are higher on high use sites at DEWA. The median high use site is three times the size of the median low use site; the median devegetated area is four times larger on high use sites than on low use sites. Shoreline disturbance, which is absent on most low use sites is typically about 10 m on high use sites. The amount of trash left on sites is similar--probably reflecting the regular ranger cleanup of sites, but human waste is significantly more common on high use sites.

Tree damage is also more pronounced on the high use sites (table 18). This is expressed most succinctly in the tree damage index which was 2.8 on high use sites and 2.1 on low use sites. On most high use sites, all of the trees have experienced at least slight damage. Typically high use sites had 11 damaged trees, compared to 3 on low use sites. Felled trees were also more common on high use sites, although the difference was not statistically significant. Typically, 26% of the trees on high use sites had been felled, while only 8% of the trees on low use sites had been felled.

The extent of seedling loss is highly variable. Although this variability renders differences between high and low use

Table 17. Differences between high and low use campsites at Delaware Water Gap National Recreation Area for selected characteristics.

Statistic	Disturbed Area	Devegetated Area	Shoreline Disturbance	Trash Bags	Human Waste Sites
	-----square meters-----		--meters--	------number------	
High Use Sites (N=11)					
Median	288	165	10	0.1	1
Range	91-547	14-451	0-30	0.1-0.6	0-12
Low Use Sites (N=11)					
Median	90	43	0	0.1	0
Range	51-282	18-270	0-8	0.1-0.5	0-11
Significance[1]	.004*	.006	.002	.405	.045

[1] Significance was tested with Mann-Whitney tests or, for those denoted by an asterisk, with t-tests. Probabilities >0.05 are not significant.

Table 18. Differences in tree damage between high and low use campsites at Delaware Water Gap National Recreation Area.

Statistic	Damaged Trees		Standing Dead Trees	Felled Trees	Tree Damage Index
	number	-----------percent-----------			
High Use Sites (N=11)					
Median	11	100	0	26	2.8
Range	0-27	76-100	0-3	0-50	1.9-3.5
Low Use Sites (N=11)					
Median	3	71	0	8	2.1
Range	1-15	25-100	0-14	0-50	1.3-2.7
Significance[1]	.030	.026	.500	.129	.003*

[1] Significance was tested with Mann-Whitney tests or, for those denoted by an asterisk, with t-tests. Probabilities >0.05 are not significant.

sites non-significant, it is clear that most high use sites have lost virtually all tree reproduction, while a substantial amount of reproduction survives on low use sites (table 19). For example, the least impacted high use site lost 90% of its reproduction, while the median low use site lost only 76%. Given the high seedling densities that commonly occur (median of 6000 stems/ha on controls), if one-quarter of these seedlings typically survive camping, then recruitment of overstory trees should be substantially less troublesome than on high use sites--as long as recreationists do not chop them down as saplings.

Groundcover differences are also dramatic. Median values for high use sites are 5% vegetation cover, 74% mineral soil exposure and 24% litter cover; on low use sites median values are 16% for vegetation, 44% for mineral soil and 64% for litter. These values express the differences in groundcover impact more dramatically than those in table 19. Typically, high use sites lost 89% of their vegetation, significantly more than the median 68% lost on low use sites. The median increase in mineral soil exposure of 74% on high use sites is much greater than the median increase of 44% on low use sites, although the difference is not statistically significant. (Increases in mineral soil exposure, based on the single estimates of cover for the entire site--rather than on quadrats, were significantly higher on high use sites). Although differences are not sizeable, root exposure is also significantly more pronounced on high use sites.

Table 19. Differences from controls in tree reproduction and groundcover characteristics between high and low use campsites at Delaware Water Gap National Recreation Area.

Statistic	Seedlings	Vegetation	Organic Litter[1]	Soil Exposure	Rock	Trees/ Roots
	-------relative difference-------			--absolute difference--		
	---percent---					
High Use Sites (N=11)						
Median	-96	-89	-39	74	0	0
Range	-100- -90	-99- -34	-90-140	33-87	0	0-2
Low Use Sites (N=11)						
Median	-76	-68	-33	44	0	0
Range	-100-400	-96- -42	-55- -27	22-90	0-1	0-1
Significance[2]	065	.050	.228	.125*	.159	.025

[1] Values are for those with an organic horizon (5 high and 3 low use sites).

[2] Significance was tested with Mann-Whitney tests or, for those denoted by an asterisk, with t-tests. Probabilities >0.05 are not significant.

Changes in species composition were considerably more pronounced on high use sites than on low use sites (table 20). The high floristic dissimilarity values on DEWA sites are primarily a result of the dramatic changes that have occurred on high use sites, which have a median dissimilarity of 90%.

Some of the soil impacts are more pronounced on high use sites, while others are not (table 21). The median increase in penetration resistance is about 50% higher on high use sites--2.9 kg/cm^2 compared to 1.9 kg/cm^2, a statistically significant difference. The median increase in bulk density is also about 50% higher on high use sites--0.23 g/cm^3 compared to 0.16 g/cm^3, but this difference is not statistically significant. Differences in moisture level were neither large nor significant and the median decrease in organic horizon thickness was actually greater on low use sites.

In sum, high use sites are substantially more severely impacted than the low use sites. They are larger, have experienced more tree damage, loss of tree reproduction and groundcover alteration, and their soils are more compacted. While these high use sites are clearly highly impacted, the low use sites have also experienced pronounced impact. Conditions on low use sites are more similar to those on high use sites than to those on controls, despite the fact that use levels on high use times are undoubtedly many times greater than those on low use sites.

Table 20. Changes in groundcover species composition on high and low use campsites at Delaware Water Gap National Recreation Area.

Statistic	Floristic Dissimilarity[1]	Sorensen's Dissimilarity[2]	Species Richness[3]	
			Camp	Control
	-----------percent------------		-no. of species-	
High Use Sites (N=11)				
Median	90	55	11	14
Range	23-97	30-91	7-26	7-20
Low Use Sites (N=11)				
Median	55	44	12	11
Range	31-93	25-62	7-19	7-18
Significance[4]	.030	.050	.347	.657

[1] Floristic dissimilarity is a measure of the difference in composition between campsites and controls, based on the coverage of each species. See text for a formula.

[2] Sorensen's dissimilarity is a similar measure based on species presence. See text for a formula.

[3] Species richness is the number of species on campsite or control. Neither campsite/control pair are significantly different (paired t-test; $p < 0.05$).

[4] Significance of differences between high and low use campsites was tested with Mann-Whitney tests or, in the case of species richness, with t-tests; probabilities >0.05 are not statistically significant.

Table 21. Differences from controls in soil characteristics between high and low use campsites at Delaware Water Gap National Recreation Area.

Statistic	Organic Thickness[1]	Penetration Resistance	Bulk Density	Gravimetric Moisture	Volumetric Moisture
	---absolute difference---				
	--cm--	-kg/cm²-	-g/cm³-	-percent-	-g/cm³-
High Use Sites (N=11)					
Median	-0.5	2.9	0.23	-2	1
Range	-2.0-0	1.0-3.7	0.01-0.63	-21-4	-10-6
Low Use Sites (N=11)					
Median	-1.1	1.9	0.16	-2	-2
Range	-1.3- -0.7	0.7-2.7	0.01-0.31	-8-3	-7-3
Significance[2]	.365	.004*	.106*	.597	.416*

[1] Values are for those with an organic horizon (5 high and 3 low use sites).

[2] Significance was tested with Mann-Whitney tests or, for those denoted by an asterisk, with t-tests. Probabilities >0.05 are not significant.

DIFFERENCES BETWEEN UPLAND AND LOWLAND RECREATION SITES

Certain tree species, groundcover vegetation and soil types are more susceptible to being damaged than others. Because all recreation sites are located close to the river, under a closed tree canopy, environmental variability is relatively limited. One major difference, however, is that certain sites located close to the river are flooded on an annual basis; other sites are located on higher benches that are rarely, if ever, flooded. Lowland recreation sites were compared with upland recreation sites at DEWA. Again we feel that results are roughly applicable to UPDE.

Lowland sites were located less than 5 m above and 25 m from the level of the river in summer; upland sites were located more than 5 m above and 17 m from the river. Eighty-five percent of the overstory trees on lowland sites were *Acer saccharinum* and *A. saccharum*, with *A. saccharinum* being most abundant. On upland sites, *A. saccharum* is more abundant and these two species comprise 70 percent of the trees. *Carya* spp. and *Betula nigra* are the most abundant associates on upland sites. The most abundant groundcover species on lowland control sites were *Eupatorium rugosum*, *Glecoma hederacea* and *Leersia virginica*; associates particularly characteristic of lowland sites included *Elymus* sp., *Polygonum persicaria*, *Impatiens* sp., *Boehmeria cylindrica* and *Matteuccia struthiopteris*. The most abundant groundcover species on upland control sites were *Carex bromoides*, *Glecoma hederacea* and *Polyugonum virginicum*; characteristic associates included *Carex davisii*, *Viola* sp., *Aster divaricatus* and *Berberis thunbergii*.

From table 22, the most obvious difference is the larger area of disturbance on upland recreation sites. The disturbed area of the median lowland site (172 m^2) is less than the area of the smallest upland site; the median disturbed area for upland sites is 409 m^2. The median devegetated area is also higher on upland sites (308 m^2) than lowland sites (90 m^2); as the ranges indicate, however, upland sites do not always have more devegetated area and, consequently, upland and lowland sites are not significantly different. The large size of upland sites results from the abundance of flat terrain, without thick, tall vegetation, underneath a dense tree canopy. These characteristics provide little resistance to recreation site expansion, in contrast to the more hummocky topography and dense tangle of vegetation commonly found on lowland sites.

Shoreline disturbance, however, is more widespread on lowland sites (table 22). In this case the median disturbance on lowland sites (13 m) is greater than the maximum for upland sites; the median for upland sites was 8 m. Landing substrates for upland sites were mostly cobbly, while most landing substrates for lowland sites were sandy. The sandy landings are used as beaches for activities other than loading and unloading boats. This may cause more widespread disturbance. The vegetation growing in sand and finer-textured soils may also be more susceptible to disturbance than that growing among cobbles.

There were no sizeable differences in the cleanliness of upland and lowland sites. Trash was minimal--median of 0.1 bags on both upland and lowland sites. There was a median of 1

Table 22. Differences between lowland and upland campsites at Delaware Water Gap National Recreation Area for selected characteristics.

Statistic	Disturbed Area	Devegetated Area	Shoreline Disturbance	Trash Bags	Human Waste Sites
	-----square meters-----		--meters--	------number------	
Lowland Sites (N=9)					
Median	172	90	13	0.1	1.0
Range	80-538	14-534	3-30	0.1-0.6	0-12
Upland Sites (N=9)					
Median	409	308	8	0.1	1.0
Range	177-731	0-696	0-12	0.1-3.0	0-8
Significance[1]	.022*	.453	.042	.811	.391

[1] Significance was tested with Mann-Whitney tests or, for those denoted by an asterisk, with t-tests. Probabilities >0.05 are not significant.

improperly-disposed human waste site on both upland and lowland sites.

There is no clear distinction between locations in the prevalence of tree damage (table 23). Upland sites have more damaged trees--a median of 24 trees, as opposed to 10 damaged trees on lowland sites; however, they also have more undamaged trees. Consequently, a smaller proportion of trees have been damaged on upland sites and the tree damage index is lower--a median of 2.1 as opposed to 2.8 on lowland sites. Therefore, depending upon whether the number or proportion of damaged trees is considered the most appropriate indicator of impact, either upland or lowland sites can be considered to have more tree damage. The proportion of dead trees and of felled trees does not differ between upland and lowland sites.

None of the differences in tree reproduction or groundcover conditions are statistically significant (table 24). Essentially all tree reproduction is lost on both lowland (median of 97%) and upland recreation sites (92%). Most vegetation is lost on sites in both locations, although some of the lowland sites retained a majority of their cover. Median losses were 98% on upland sites and 87% on lowland sites. Lowland sites have their litter removed by annual floods. Consequently, when vegetation is removed, mineral soil is exposed immediately. This explains the greater amount of mineral soil exposure on lowland sites (median of 76%) as opposed to upland sites (51%). More upland sites also have tree and root cover than lowland sites. The median lowland site has

Table 23. Differences in tree damage between lowland and upland campsites at Delaware Water Gap National Recreation Area.

Statistic	Damaged	Trees	Standing Dead Trees	Felled Trees	Tree Damage Index
	number	-----------percent-----------			
Lowland Sites (N=9)					
Median	10	100	0	23	2.8
Range	0-27	29-100	0-14	0-50	1.6-3.5
Upland Sites (N=9)					
Median	24	76	0	21	2.1
Range	7-30	47-100	0-3	6-53	1.8-3.0
Significance[1]	.027	.027	.718	.923	.034*

[1] Significance was tested with Mann-Whitney tests or, for those denoted by an asterisk, with t-tests. Probabilities >0.05 are not significant.

Table 24. Differences from controls in tree reproduction and ground-cover characteristics between lowland and upland campsites at Delaware Water Gap National Recreation Area.

Statistic	Seedlings	Vegetation	Organic Litter[1]	Soil Exposure	Rock	Trees/ Roots
	-------relative difference------			--absolute difference--		
	--------------------------percent--------------------------					
Lowland Sites (N=9)						
Median	-97	-87	-56	76	0	0
Range	-100- -95	-100- -34	-56	36-87	0	0-2
Upland Sites (N=9)						
Median	-92	-98	-39	51	0	1
Range	-100- -90	-100- -85	-90-140	21-84	0	0-2
Significance[2]	.247	.091	na	.100*	.100	.077

[1] Values are for those with an organic horizon (1 lowland and 9 upland sites).

[2] Significance was tested with Mann-Whitney tests or, for those denoted by an asterisk, with t-tests. Probabilities >0.05 are not significant.

a vegetation cover of 13%, mineral soil cover of 78% and <1% cover of rock, tree and root or organic litter. The median upland site has a vegetation cover of only 1%, mineral soil cover of 51%, tree and root cover of 1% and organic litter cover of 47%. Again, the nature of impacts in each location differ, but neither location is clearly more heavily impacted than the other.

The magnitude of changes in vegetation composition is not clearly greater in either location (table 25). Although floristic dissimilarity is greater on lowland sites, this difference is not significant. Median Sorensen's dissimilarity values are virtually identical. Although species richness is less on upland recreation sites, this is merely a reflection of the differences in undisturbed conditions. Upland environments have fewer species per unit area than lowland sites, but they are generally neither more resistant nor more fragile.

None of the differences in soil impact are statistically significant (table 26). The medians and ranges suggest that increases in soil compaction on lowland sites are frequently higher than those on lowland sites. However, bulk densities on upland controls are also higher than on lowland controls. There is little difference in the penetration resistance or bulk density of upland and lowland sites. Moisture levels and changes in levels also do not differ greatly between lowland and upland sites.

In sum, the only substantial and important difference between upland and lowland recreation sites at DEWA is the greater size

Table 25. Changes in groundcover species composition on lowland and upland campsites at Delaware Water Gap National Recreation Area.

Statistic	Floristic Dissimilarity[1]	Sorensen's Dissimilarity[2]	Species Richness[3]	
			Camp	Control
	------------percent-------------		--no. of species--	
Lowland Sites (N=9)				
Median	90	53	14	14
Range	41-97	30-91	7-26	7-20
Upland Sites (N=9)				
Median	79	54	8	7
Range	23-100	33-100	2-20	1-17
Significance[4]	.426	.791	.028	.112

[1] Floristic dissimilarity is a measure of the difference in composition between campsites and controls, based on the coverage of each species. See text for a formula.

[2] Sorensen's dissimilarity is a similar measure based on species presence. See text for a formula.

[3] Species richness is the number of species on campsite or control. Neither campsite/control pair are significantly different (paired t-test; $p < 0.05$).

[4] Significance of differences between lowland and upland sites was tested with Mann-Whitney tests or, in the case of species richness, with t-tests; probabilities >0.05 are not statistically significant.

Table 26. Differences in soil characteristics between lowland and upland campsites at Delaware Water Gap National Recreation Area.

Statistic	Organic Thickness[1]	Penetration Resistance	Bulk Density	Gravimetric Moisture	Volumetric Moisture
	absolute difference				
	--cm--	-kg/cm^2-	-g/cm^3-	-percent-	-g/cm^3-
Lowland Sites (N=9)					
Median	-0.5	2.9	0.23	-2	1
Range	-0.5	2.4-3.7	0.09-0.63	-21-3	-10-6
Upland Sites (N=9)					
Median	-1.1	2.5	0.08	1	3
Range	-2.0-0	1.0-3.4	-0.08-0.50	-3-10	-4-9
Significance[2]	na	.139*	.155*	.155	.102*

[1] Values are for those with an organic horizon (1 lowland and 9 upland sites).

[2] Significance was tested with Mann-Whitney tests or, for those denoted by an asterisk, with t-tests. Probabilities >0.05 are not significant.

of upland sites. This lack of difference is surprising given the pronounced differences in vegetation, organic matter cover and cycling and natural disturbance regime of these two locations. The difference in area is a result of the roughness of the terrain and the density of vegetation. A similar result was found on recreation sites in the Grand Canyon (Cole 1985b), where the only difference between vegetation types was in area of disturbance. As at DEWA, a large area was typical of types without rough terrain and dense, tough vegetation that is difficult to flatten or remove.

DISCUSSION AND CONCLUSIONS

At the start of this report we asked three questions: (1) specifically what impacts have occurred on UPDE recreation sites and more generally how do impacts on riparian sites in the East compare to those found elsewhere, (2) what differences are there between frequently and infrequently used sites, and (3) what differences in amount of impact are there between upland and lowland sites along the river?

Our results suggest that impacts on UPDE recreation sites are quite similar to those found elsewhere. The same types of impact occur and magnitudes of impact on UPDE sites are comparable to those on sites in many other areas. The only impact that is unusually pronounced on UPDE sites is exposure of mineral soil. On recreation sites, the median soil exposure is 48%, while controls typically have no soil exposure; only sites at NERI and DEWA have comparable or higher levels of soil exposure. This large amount of soil exposure results primarily from the removal of organic matter by floods. Without organic horizons, mineral soil is exposed as soon as vegetation is eliminated. However, even those recreation sites with permanent organic horizons experience unusually pronounced soil exposure. Although soil exposure is extreme, impacts to the mineral soil are not.

Vegetation loss on recreation sites is moderate compared to other areas, although vegetation loss at both NERI and DEWA was much higher. Both amount of use and vegetational resistance may have contributed to the lesser vegetation loss on UPDE sites, compared with DEWA and NERI sites. Graminoids, which are usually particularly resistant to trampling (Cole 1985a), are more abundant on UPDE sites. This may have contributed to less severe groundcover loss.

Despite a lack of use data, these sites appear to not be used very frequently, compared with many of those at DEWA and NERI. Recent efforts to inform visitors that much of the land is privately owned may be effectively reducing the use of these recreation sites. Low use may also contribute to higher survival of vegetation on these sites. The fact that loss of seedlings is also unusually low on UPDE sites (in this case, lower than has been reported on recreation sites anywhere else) suggests that amount of use and trampling is probably more important than vegetational resistance in explaining survival rates for groundcover vegetation and tree seedlings.

In contrast to very low and moderate levels of seedling loss and groundcover loss, respectively, tree damage has been quite high. Damage to standing trees has been much greater than at NERI or DEWA and the tree damage index is even higher than on Boundary Waters sites, where tree damage has always been a problem. Felling of trees, however, is not pronounced. For some reason, campers at UPDE, like their counterparts further west, frequently hack and carve on trees, a behavioral norm that is less pronounced at DEWA and NERI.

Trash and improper disposal of human waste are also serious problems on UPDE recreation sites. The severity of these problems also relate to behavioral norms. They can be solved through increasing public awareness of the problems and appropriate behaviors and then attempting to make this behavior the norm.

The relationship between amount of impact and amount of use on DEWA sites is similar to that found in other studies (Cole 1982, 1985b, Marion 1984). Impacts are greater on high use sites; high use sites are larger, have experienced more tree damage, loss of tree reproduction and groundcover alteration, and their soils are more compacted. However, impact levels on low use sites are also high. The difference in impact level, between high and low use sites, is small in comparison to the difference in amount of use these sites receive.

These results suggest that at the Upper Delaware all use of these trespass sites must be eliminated before conditions can be expected to improve significantly or return to natural. Furthermore, if opportunities for primitive camping along the river are considered in the future by commercial ventures or government agencies this research suggests that use should be permitted only at designated sites and that impacts will be minimized by confining use to as few sites as possible.

The only sizeable difference in impact between upland and lowland sites at DEWA was the much larger area of disturbance and devegetation on upland sites. As was found on recreation sites in Grand Canyon, sites without rough terrain or vegetation lack barriers to site expansion. Given the fragility of the vegetation, this results in pronounced disturbance of a large area. This suggests that roughness of terrain and vegetation should be a major consideration when selecting durable recreation sites. Obviously some flat ground is necessary for a recreation site, but the ideal site will have just enough flat ground, within a local environment that inhibits further expansion.

Again, these results have important management implications only if opportunities for primitive camping along the river are being considered. Results indicate that site size can be limited by locating sites in lowlands, where rough terrain and dense vegetation inhibit site expansion.

The implications of these results for management are not clear, given the fact that most of the land along the river is privately owned and any camping on these lands without the landowners permission is trespass use. The results of this study do indicate that the environmental effects of this trespass use are substantial. Recreation sites have been highly altered in comparison to the surrounding environment, although generally less severely than sites at NERI and DEWA.

Moderate to high levels of impact should be expected wherever intensive recreational use occurs along the Delaware River. Although recovery from impact may be rapid (this appears to be the case and we are documenting recovery rates on recently-closed recreation sites at DEWA), the highly fragile groundcover will be disturbed as long as use continues.

Aside from the general problem of trespass use, we feel that the most serious problems on recreation sites result from inappropriate behavior, particularly littering, improper disposal of human waste and damage to standing trees. Trash, exposed human waste and toilet paper and damaged trees are common and unnecessary. Recreationists can be taught to avoid causing these impacts. Clearly an educational campaign dealing with these behaviors, as well as the issue of their trespass use on private lands, is a high priority.

Although all recreation site impacts may be inappropriate, given that they occur on private land, current levels of impact are not severe. Rapid recovery would probably occur on most sites if use could be eliminated or curtailed.

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APPENDIX: PLANT SPECIES LIST[1]

UPPER DELAWARE SCENIC AND RECREATIONAL RIVER

TREES

Acer rubrum L. Red Maple
Acer saccharinum L. Silver Maple
Acer saccharum Marsh. Sugar Maple
Acer spicatum Lam. Mountain Maple
Betula nigra L. River Birch
Carya ovata (Mill.) K. Koch. Shagbark Hickory
Carya tomentosa (Poir.) Nutt. Mockernut Hickory
Cornus florida L. Flowering Dogwood
Fagus grandifolia Ehrh. Beech
Fraxinus americana L. White Ash
Fraxinus pennsylvanica Marsh. Green Ash
Gleditsia tricanthos L. Honey Locust
Juniperus virginiana L. Red Cedar
Liriodendron Tulipifera L. Yellow Poplar
Morus alba L. White Mulberry
Nyssa sylvatica Marsh. Black Gum
Ostrya virginiana (Mill.) K. Kosh. Hop-hornbeam
Pinus Strobus L. White Pine
Prunus americana Marsh. Wild Plum
Prunus pensylvanica L. f. Pin-cherry
Prunus serotina Ehrh. Black Cherry
Quercus borealis Michx. f. Northern Red Oak
Quercus palustris Muenchh. Pin Oak
Quercus Prinus L. Chestnut Oak
Quercus velutina Lam. Black Oak
Robinia Pseudoacacia L. Black Locust
Sassafras albidum (Nutt.) Nees. Sassafras
Tilia americana L. Basswood

SHRUBS

Berberis Thunbergii DC. Barberry [Exotic]
Hamamelis virginiana L. Witch Hazel
Ilex vomitoria Ait. Yaupon
Rhamnus Frangula L. Alder Buckthorn [Exotic]
Rosa asicularis Lindl. Wild Rose
Rosa palustris Marsh. Swamp Rose
Rubus occidentalis L. Black Raspberry
Vaccinium angustifolium Ait. Blueberry

HERBS

Achillea Millefolium L. Yarrow [Exotic]
Alliaria officinalis Andrz. Garlic Mustard
Aralia nudicaulis L. Wild Sarsaparilla
Arisaema triphyllum (L.) Schott. Jack-in-the-Pulpit
Aster divaricatus L. White Wood Aster
Boehmeria cylindrica (L.) Sw. False Nettle
Equisetum spp. Horsetails

1 - nomenclature follows Gleason, H.A. and A. Cronquist, 1963. Manual of Vascular Plants of Northeastern United States and Adjacent Canada. D. Van Nostrand Co., New York.

Eupatorium rugosum Houtt. White Snakeroot
Fragaria virginiana Duchesne. Strawberry
Galium Aparine L. Cleavers
Galium pilosum Ait. Hairy Bedstraw
Galium triflorum Michx. Fragrant Bedstraw
Geum canadense Jacq. Avens
Geum macrophyllum Willd. Avens
Glecoma hederacea L. Ground Ivy [Exotic]
Helianthus decapetalus L. Wild Sunflower
Hesperis matronalis L. Dame's Rocket [Exotic]
Hypericum mutilum L. St. John's Wort
Impatiens spp. Touch-me-not; Jewel-weed
Lobelia inflata L. Indian Tobacco
Lycopus virginicus L. Water Horehound
Lysimachia ciliata L. Fringed Loostrife
Maianthemum canadense Desf. Wild Lily-of-the-Valley
Monarda fistulosa L. Wild Bergamot
Oxalis stricta L. Wood Sorrel
Plantago major L. Plantain [Exotic]
Podophyllum peltatum L. May Apple
Polygonum pensylvanicum L. Knotweed
Polygonum Persicaria L. Knotweed [Exotic]
Polygonum sagittatum L. Knotweed
Polygonum scandens L. False Buckwheat
Polygonum virginianum L. Knotweed
Potentilla simplex Michx. Cinquefoil
Prenanthes Serpentaria Pursh. Lions-foot
Prunella vulgaris L. Self-heal
Rhus radicans L. Poison Ivy
Solidago gigantea Ait. Goldenrod
Solidago spp. Goldenrod
Stellaria media (L.) Cyrill. Chickweed [Exotic]
Taraxacum officinale Weber. Dandelion [Exotic]
Trifolium repens L. White Clover [Exotic]
Triosteum perfoliatum L. Feverwort
Viola spp. Violets
Zizia aurea (L.) Koch. Early Meadow Parsnip

GRASSES/SEDGES

Agrostis spp. Bent-grass
Arrhenatherum elatius (L.) Mert. & Koch. Oat Grass [Exotic]
Bromus spp. Grass
Carex bromoides Schk. Sedge
Carex Davisii Schw. & Torr. Sedge
Carex Grayii Carey. Sedge
Carex virescens Muhl. Sedge
Elymus spp. Grass
Juncus spp. Rush
Leersia virginica Willd. White Grass
Panicum spp. Grass
Poa pratensis L. Kentucky Bluegrass [Exotic]
Sphenopholis nitida (Biehler) Scribn. Grass

FERNS

Athyrium Felix-femina (L.) Roth. Lady Fern
Osmunda Claytoniana L. Interrupted Fern
Onoclea sensibilis L. Sensitive Fern

VINES

Amphicarpa bracteata (L.) Fern. Wild Peanut
Clematis virginiana L. Virgin's Bower
Parthenocissus quinquefolia (L.) Planch. Virginia Creeper
Smilax herbacea L. Greenbrier
Vitis rupestris Scheele. Sugar Grape