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DISSERTATION

VISITOR CAPACITIES IN PROTECTED AREAS: A BIOPHYSICAL AND A CONCEPTUAL APPROACH

Submitted by

Christopher A. Monz

Natural Resource Recreation and Tourism Department

In partial fulfillment of the requirements

for the Degree of Doctor of Philosophy

Colorado State University

Fort Collins, Colorado

Summer 2001

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COLORADO STATE UNIVERSITY

April 13, 2001

WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY CHRISTOPHER A. MONZ ENTITLED VISITOR CAPACITIES IN PROTECTED AREAS: A BIOPHYSICAL AND A CONCEPTUAL APPROACH BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY.

Committee of Graduate Work

Advisor

Department Head

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ABSTRACT OF DISSERTATION

VISITOR CAPACITIES IN PROTECTED AREAS: A BIOPHYSICAL AND A CONCEPTUAL APPROACH

Two manuscripts are presented that examine the issue of visitor capacities in protected areas from different approaches. The first paper entitled "The response of arctic tundra plant communities to human trampling disturbance" examines the tolerance of tussock and dryas tundra communities to simulated dispersed recreation use over a four-year period. Treatments of 25, 75, 200 and 500 trampling passes were applied to 0.75m^2 vegetation plots approximately at the time of peak seasonal aboveground plant biomass. Plots where low and moderate levels of trampling were applied returned to pre-disturbance conditions by four years after trampling, but impact was still evident in plots subjected to high levels of disturbance. These results suggest that with adequate visitor management, these tundra communities can tolerate low to moderate numbers of visitors with minimal long-term observable resource impact.

The second paper entitled "The principles of visitor capacity in parks and protected areas" identifies a set of principles that can provide additional guidance for managers in the decision process for setting visitor capacities in parks and protected areas. These principles are a synthesis of related sets of principles such as those proposed for ethical land use, outdoor recreation, and

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ecosystem management and the consensus on this issue from an intensive work session sponsored by the Federal Interagency Task Force on Visitor Capacity on Public Lands. It is proposed that these principles will be of significant assistance to managers in the effort to make visitor capacity decisions that are comprehensive, defensible and appropriate in protected areas.

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This work is dedicated to my wife, Elizabeth Wyatt Lutsk, for her never-ending support and enthusiasm. Wyatt is my constant companion, both at home and in the many wild places we have visited, in work and play.

I have had many mentors over the years who taught me the practice of science and inspired me to strive to do my best. I thank Christa Schwintzer, John Tjepkema, Ted Elliott, Bill Hunt, Vern Cole, David Valentine, David Cole, Mary Arthur and Hon Ho for their confidence in my ability to attain the highest level of academic achievement. Throughout my studies, my graduate committee of Don Rodriguez, George Wallace and David Swift have not only been of great help and advice, but have also been good friends. My advisor, Glenn Haas deserves special thanks for always encouraging me to "think outside the box" and for his many hours of effort on my behalf. Glenn always treated me as a colleague, which has been a great compliment.

I have had the great fortune of experiencing the wonder of wild places with many friends over the last 25 years. These experiences inspired me to choose a career in natural resources and more importantly, I am a far richer person because of all of those days in the mountains. In these regards, I thank my partners on countless expeditions, climbs, paddles, skis and hikes: Mike Sawicky, Jim Luckner, Matt Taladay, Bill Ewing, Rich Perch, Chuck Liff, Patty Matteson, Dave Bangert, Paul Twardock, Doug Mason, Ron Kellermueller and Ivan

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Rezucha. I especially thank my friend and colleague, the late Thom Scheuer, for teaching me the craft of land stewardship and instilling in me the spirit of conservation. Most of all, I thank my parents who took me on my first camping trips and supported my outdoor pursuits and my career choices, no matter how unconventional they seemed at times.

Finally, I conclude with some wisdom from the poet Robert Frost. In these words I have found much inspiration in my life and work.

> *I shall be telling this with a sigh*
> *Somewhere ages and ages hence:*
> *Two roads diverged in a wood and I–*
> *I took the one less traveled by,*
> *And that has made all the difference.*

Christopher A Monz
Bellvue, Colorado
April, 2001

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TABLE OF CONTENTS

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CHAPTER I

Dissertation Overview

The structure of this dissertation diverges somewhat from the form traditionally followed, so a brief explanation is in order for the reader. Two separate manuscripts for publication are presented in Chapters II and III, with overall conclusions and synthesis in Chapter IV. Being in manuscript form for journal submission, these chapters are therefore more concise than otherwise found in a standard dissertation. The two manuscript format follows the requirements specified by the Natural Resource Recreation and Tourism Department and by the Graduate School, Colorado State University.

Although the general focus of my work is on visitor capacity in parks and protected areas, I have chosen to examine this issue from two fairly disparate approaches. Chapter II is a biophysical, experimental approach that reflects my background in ecology and strong interest in the interface between field research and management. Chapter III reflects my desire to utilize the knowledge gained from research to assist land managers in making better decisions. The following provides a brief description of each chapter and perspectives on how they relate to the overall theme of this work.

Chapter II

The findings of four years of fieldwork on recreational trampling of arctic tundra vegetation are presented in Chapter II. This project was initiated in the

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summer of 1994 while I was the Research Scientist for the National Outdoor Leadership School and continued in the field through August of 1998. The paper examines the tolerance of two co-dominant vegetation types common to areas of northern Alaska to simulated, dispersed recreation use. This approach provides specific biophysical information for land managers who desire to allow dispersed hiking and camping while maintaining a high degree of resource protection. Experimental studies of this kind can provide an accurate picture of the use- impact relationship in specific ecosystems and are therefore an important basis for capacity decisions, particularly where pristine conditions are desired.

Chapter III

A discussion of the fundamental guiding principles of visitor capacity decisions in parks and protected areas is presented in Chapter III. Ideas for this work originated with my participation at the 1999 Congress on Resource and Recreation Capacity and were furthered by the discussions and feedback at the Federal Interagency Task Force on Visitor Capacity on Public Lands Workshop in December of 2000. This paper is the result of an extensive literature review, an analysis of current, related sets of principles, and a synthesis of the input of over 70 land management professionals on this topic. It is proposed that these principles will improve upon and work in concert with current framework approaches, and therefore assist managers in making better visitor capacity decisions on public lands.

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Chapter IV

The final chapter presents some overall observations and conclusions from this multi-dimensional effort to advance visitor capacity management. This paper comments on the history of visitor capacity, the current issues and concerns from a scientific and managerial perspective and offers some suggestions as to the important "research gaps" for future work.

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CHAPTER II

Introduction

Managers of parks and protected areas worldwide are often faced with the challenge of maintaining a high level of resource protection while simultaneously offering ample recreation opportunities for visitors. These challenges come at a time when backcountry recreation is increasingly popular. A recent analysis of recreation use trends in wilderness areas in the US shows that visitation has steadily increased during the period 1965-1996, with total use increasing nearly sixfold (Cole, 1996). Similar trends in visitation and associated resource impacts have been reported in protected areas worldwide, including the European Alps, Indian Himalayas, Nepal and Patagonia (Denniston, 1995). Given these marked increases, it has been suggested recently that recreation and tourism activities could surpass the resource extractive economy as the single largest threat to the conservation of protected areas (Denniston, 1995).

The overall trend of increased visitation can be exacerbated by the development of more convenient access to a protected area, a phenomenon over which land managers often have little influence. In Alaska, access to many of the northern national parks and protected areas was previously limited to air transportation. This has recently changed with the opening to the public of the Dalton Highway along the northern extent of the Alaska pipeline, substantially

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improving access to the region, and increasing the potential for recreational disturbance. (Paul Salvator, personal communication).

Historically, the Alaskan Arctic remained relatively undisturbed by humans until the initiation of petroleum exploration in the 1940's (Walker, et al., 1987). Since that time studies have been conducted on the impacts of oil field development (Oechel 1989; Walker, et al. 1986), disturbance-induced thawing of permafrost soils (Truett and Kertell, 1992) and the consequences of vehicle trails in summer (e.g., Bliss and Wein, 1972) and in winter (Felix et al., 1992; Emers et al., 1995; Emers and Jorgensen 1997). Similar studies of human-induced disturbance have been conducted in the Canadian High Arctic (Forbes, 1992a & b; Kevan et al., 1995). Other disturbances, such as the effects of sand and dust on tundra adjacent to gravel roads have also been examined in Alaska (Auerbach et al., 1997) and in Siberia (Forbes, 1995).

With the exception of work in the Canadian High Arctic (Forbes 1992a; Kevan et al., 1995) there is little specific information on the ability of arctic tundra ecosystems to tolerate off-trail, dispersed recreation use and few studies on trampling disturbance in the Alaskan north. In an unpublished report, Reid and Schreiner (1985) investigated the consequences of low levels of trampling applied throughout the summer to three vegetation types in Denali National Park. The alpine community in this study, dominated by *Dryas octopetala*, was found to be relatively durable to human use. This implies that directing visitors to these areas and away from other vegetation types could be a viable management strategy for maintaining relatively undisturbed conditions. Information of this kind on the relative tolerance of ecosystems to human trampling disturbance is essential in these situations, where land managers are seeking to provide opportunities for

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dispersed recreation while preserving the "natural" or "pristine" character of an area. (Hammitt and Cole 1998).

Experimental trampling of groundcover vegetation has often been utilized to assess the tolerance of vegetation communities to human use. Since Wagar (1964) first proposed this approach, many soil-plant communities worldwide have been examined. These include, for example, mountain and riparian vegetation in the United States (Cole 1993; Monz et al., 2000), heath communities in Scotland (Bayfield 1979), sub-arctic and alpine areas in Canada (Gnieser, 2000), and sub-arctic vegetation in Finland (Tolvanen et al., 2000). A standard methodology, developed by Cole and Bayfield (1993), has been utilized in several of these studies and allows comparisons to be made across different ecosystem types (e.g., Cole 1995 a & b).

The objective of this project was to investigate the consequences of human trampling on two common vegetation types in arctic Alaska: the dryas dwarf shrub tundra and the cotton grass tussock tundra. Controlled levels of trampling were applied to the plant communities and initial responses and subsequent re-growth were measured. This information is important for several reasons. First, these tundra communities are geographically widespread in Alaskan protected areas where recreation use is prevalent, both in the arctic and in sub-arctic areas at higher elevations. Second, management objectives emphasize the protection of their pristine character, devoid of permanent trails or campsites (e.g., Gates of the Arctic General Management Plan, 1986). And finally, backcountry travelers will undoubtedly travel and camp on these communities, particularly the dryas tundra, which offers comfortable hiking and camping in an otherwise challenging environment. This specific information on the tolerance of these

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ecosystems to recreational disturbance will provide guidance to managers in future visitor capacity decisions and in the further development appropriate minimum impact visitor practices.

Methods

Study Site and Plant Communities

The study area was located in the Bureau of Land Management (BLM) managed "utility corridor" which is accessible from the Dalton Highway (Alaska pipeline haul road) near the Galbraith Lake Camp (68°27'N 149°30'W). This area is in the northeastern foothills of the Brooks Range and lies approximately 15km south of the Toolik Lake research station. Though Gabraith Lake was a work camp during the construction of the oil pipeline, the experimental plots were located approximately 1.5km from the old work site (vacant since 1978) and 3km from the pipeline haul road in an area of no known or observable disturbance. Recreational use is increasing at this location as it is one of the few spots along the northern Dalton Highway where visitors can drive some distance off the highway and camp. It also provides one of the few easily accessible hiking points into Gates of the Arctic National Park and Preserve (Paul Salvator, personal communication).

Vegetation in the study area is similar to many tundra communities found in the region, and consists of two primary types; dryas tundra dominated by the mat-forming shrub *Dryas octopetala* (mountain avens) and a moist tussock tundra dominated by *Eriophorum angustifolium* (tall cotton-grass) and other graminoids. Across much of arctic Alaska, *Dryas* typically occupies sites along river corridors

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that are high and flat with well drained, stony soils while *Eriophorum* is common to the lower-lying areas on poorly drained, acidic soils with shallow permafrost (Viereck, et al., 1992). This paper follows the nomenclature of Viereck, et al. (1992) in that plant communities are referred to with common names (i.e., dryas tundra), whereas scientific names following Hultén (1968 and 1973) are used for individual plant species.

Experimental procedures

Trampling

Experimental design for the trampling treatments follows the standard protocols described by Cole and Bayfield (1993). Four replicates of experimental trampling lanes (1.5m x 0.5m) were established in each of the two vegetation types and arranged in a randomized complete block design. Lanes were selected within blocks on the basis of suitability of application of trampling and homogeneity of the vegetation and treatments were randomly assigned. Each replicate block consisted of five lanes; control (untreated), 25, 75, 200 and 500 trampling passes. A pass is a one way walk conducted at a natural gait along the lane by a person weighing 60-75 kg and wearing a lug sole boot. Treatments were applied once during the early summer at a time approximating maximum seasonal aboveground plant biomass. For examinations of the overall ability of vegetation to tolerate recreational use, application of trampling at one time has been shown to be equally as effective as multiple treatments throughout the season. (Bayfield 1979; Cole 1985).

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Trampling response variables

Standard indices of trampling effects (Cole and Bayfield 1993) were recorded in each lane in one 30 x 50 cm subplot. Measurements consisted of 1) visual estimates of canopy coverage of each vascular plant species (only green material) and of mosses and lichens; 2) visual estimates of the cover of bare ground, which included mineral soil, organic material and plant litter; and 3) determinations of vegetation height, using a point quadrat frame with five pins five cm apart within the width of the subplot, for a total of 50 pin drops. Every effort was made to standardize and calibrate ocular cover estimates by using 100 random pin drops per subplot as a baseline in initial trial runs, and then basing final ocular estimates on these results. Soil compaction was estimated using a pocket soil penetrometer (Forestry Suppliers, Inc. Jackson, MS 39284-8397 USA) with two random measurements per subplot. Measurements were performed approximately ten days after trampling to asses initial resistance to trampling (referred to hereafter as "immediately after") and repeated one year and four years after to evaluate recovery (resilience). All measurements were taken at a similar time during the growing season. Lanes were rated as to the extent of resemblance to a recognizable trail (1= "no discernable path"; 2 = "some evidence of a trail"; 3 = "trail formation obvious") after four years of recovery.

Soil analysis

After two growing seasons, soils were sampled to a depth of 10 cm in lanes of high trampling intensity (500 passes in dry and 200 in moist tundra) and

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in control plots. This was accomplished by excavation of a small area in the dry tundra with a trowel and by using an Oakfield style slotted sampler in the moist tundra. Depth accuracy in the moist tundra was problematic due to high amounts of organic material in surface horizons and resulting compaction. Soils were kept cold after sampling and frozen immediately after transport from the field site until analysis was performed. In the dryas tundra, the surface organic horizon was separated from the mineral horizon. Total Kjeldahl nitrogen (TKN) and 2M KCL extractable NH_4^+ and NO_3^- were determined on soils from both sites by standard laboratory techniques (Soils Analytical Laboratory, Montana State University, Bozeman, MT USA).

Data analysis

For the trampling results, analysis follows the suggested protocols of Cole and Bayfield (1993) where a primary response variable for each vegetation type is relative cover. This is a measure of the proportion of the original vegetation that survives trampling and is adjusted for changes occurring on control plots over the same time period. It is determined in each plot by summing all of the individual species to obtain total plant cover and then calculating relative cover as:

$$\frac{\text{Surviving cover on trampled subplots}}{\text{initial cover on trampled subplots}} \times \text{cf} \times 100\%$$

Where:

$$\text{cf} = \frac{\text{initial cover on control subplots}}{\text{surviving cover on control subplots}}$$

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Relative cover was also calculated for a few common species to examine individual species responses. Relative height of the vegetation was calculated by summing the heights and dividing by the number of values greater than zero and then substituting the mean height values in the formula given above for relative cover. Calculations of resistance and resilience indices follow the procedures outlined by Cole (1995a). Species richness was calculated by counting the total number of individual plant species in each measurement subplot.

Many multivariate approaches have been identified in the literature to assess changes in plant communities as a consequence of disturbance or environmental factors (e.g., Gauch 1982; McCune and Mefford 1999). Here, a principal components analysis (PCA) on the species cover data followed by analysis of variance (ANOVA) on the factor scores was employed. This technique has the advantage of being a relatively straightforward approach that allows treatment differences to be tested statistically. The PCA-ANOVA was used on the species cover data for each of the three post-trampling sampling times within both tundra communities. A standard varimax orthogonal rotation was performed on the factors derived in the PCA. All statistical tests throughout this study were performed using SPSS software version 6.1.1 for the Macintosh (SPSS, Inc., Chicago, IL, USA.).

Results

At the initiation of the experimental work the pre-trampling species abundance for experimental plots in both sites (Table 1) was assessed. The plots are typical of the dryas and tussock tundra found in the region (Viereck, et al., 1992).

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In terms of initial resistance, low to moderate levels of trampling disturbance (25-75 passes) had little effect on the dryas tundra (Fig. 1a). Higher levels of trampling resulted in significant decreases in relative cover, with the highest level of trampling (500 passes) leaving only 19% relative cover remaining. In tussock tundra (Fig. 1b), substantial vegetation loss occurred with only 75 passes and the highest level of trampling resulted in only 10% cover remaining. Both vegetation types demonstrated a substantial ability to recover (resilience), but at the high level of disturbance, recovery was not complete in either pant community even after four years. For example, relative cover for the 500 pass level was 77% in the dryas tundra and 78% for the tussock tundra, indicating that recovery was not complete in these plots. Immediately after trampling, relative height of the dryas tundra was largely unaffected by trampling, while the high level of trampling resulted in only approximately 40% relative height in the tussock community (Fig. 2). Both vegetation types exhibited an increased height after recovery at all levels of trampling.

In both vegetation types, analysis on only the most abundant individual species was possible due to overall cover and frequency in plots (Table 2). In the dryas tundra, *Dryas octopetala* was moderately resistant, with 58% relative cover remaining after 200 passes. Recovery was substantial after one year and nearly complete after four years, but loss due to trampling remained at the higher disturbance levels. At moderate and high levels of trampling, lichens did not fully recover even four years after disturbance. In the tussock tundra, after a significant initial decline in cover due to trampling, *Eriophorum angustifolium* rebounded substantially after one year, but reduced cover was still observable at the 500 pass level even after four years. Mosses were initially sensitive to

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moderate and high levels of trampling with recovery being complete after four years in all treatments except the 500 pass level. Visual ratings of the degree of trail formation after four years or recovery revealed no observable trail formation in the dryas tundra, but in the tussock community, trail formation was greater at the 500 pass level (M = 3.0) compared to control plots (M = 1.0, F= 24.25, P < .0001).

Immediately after trampling the percent bare ground increased significantly in the dryas tundra at the 200 and 500 pass level, but there was no significant increase in soil penetration resistance (an index of surface soil compaction) (Table 3). A similar trend was observed in the tussock community in terms of bare ground, but soils were more susceptible to compaction, with just 75 passes showing a significant increase in penetration resistance compared to the control plots. In both communities, no significant differences in bare ground or penetration resistance were observed after 4 years of recovery. At this time, bare ground estimates on all plots approximated pre-disturbance levels. Interestingly, despite the observable changes in the soil and plant communities, soil nitrogen (NH_4^+, NO_3^- and TKN) did not differ significantly in comparisons of control and highly disturbed plots after one year of recovery (Table 5).

Overall plant species composition seemed to be relatively unaffected by trampling as examined by the PCA-ANOVA approach since few statistically significant differences were found (Table 6). In addition, observations of the plots over the course of the experiment suggested that little if any replacement of species occurred.

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Discussion

Although there is a significant literature on the resistance and resilience of plant communities (e.g., Cole 1993, Monz 2000, and others) and this information has been synthesized across ecosystem types (Cole 1995 a & b), site-specific information on the response of plant communities to human disturbance is desirable for management decisions. This specific information is particularly useful for land managers developing use regulations, visitor capacities and educational practices. Applied trampling studies do not exactly mimic disturbance from actual visitor use, but do provide an effective means for examining the responses to recreational disturbance while controlling or evaluating the influence of extraneous variables. This approach can therefore provide an index by which to base visitor use and capacity management decisions (Cole and Bayfield 1993).

The degree to which a plant community can support human use is a combination of its ability to resist the initial disturbance of trampling and its subsequent capacity for re-growth. The property of withstanding initial disturbance is most often referred to as resistance (Cole and Bayfield 1993; Sun and Liddle 1991) though Grime (1979) called this property inertia. In this experiment, resistance was determined by measuring plant properties approximately ten days after the applied trampling. A post-disturbance waiting period is needed before assessing resistance to accurately discern viable plant tissue from damaged material.

Resilience has been used commonly in the literature (Grime 1979; Cole and Bayfield 1993) to describe the ability of an ecosystem to recover from

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disturbance. Here, resilience was assessed by comparing the relative cover after disturbance with the relative cover after one and four years of recovery. Tolerance is another useful measure employed by Cole (1988), Cole and Trull (1992) and Cole and Bayfield (1993), that characterizes the ability of vegetation to both resist and recover from disturbance. Tolerance was assessed in this study by comparing vegetation cover after one and four years of recovery with the initial pre- disturbance cover.

The results presented here indicate that the dry tundra is more resistant to trampling than the tussock community, though only slightly so (Table 4). Both communities exhibit approximately a 50% cover loss with 200 passes and the dryas tundra has an overall mean relative cover (across the 0-500 passes) of 64.3% compared to 58.2% in the tussock tundra. Modeling work by Cole (1995b) suggests that resistance to trampling is largely a function of plant stature and whether the plants were graminoids, forbs or shrubs. Matted graminoids were found to be highly resistant, while erect forbs the least. *Dryas* is a unique shrub that forms dense low growing mats in most areas, and our results indicate that it is of moderate resistance. The tussock community, composed of erect graminoids is also of moderate resistance as compared to the results reported from of a wide range of vegetation communities (Cole 1993)

Both communities demonstrate a substantial resilience, especially the tussock community, which shows nearly full recovery one year after disturbance. Rapid recovery of graminoids in tussock communities has been previously observed (Emers et al., 1995 and Chapin and Shaver, 1981) as a consequence of the disturbance of the surface organic layers and the release of nutrients following disturbance. Our results indicate modest stimulation of growth in

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tussock tundra after one year with moderate levels of disturbance (e.g., 75 passes), followed by a return to conditions more closely approximating pre-disturbance levels at four years. Interestingly, at the 500 pass level, there was little change in relative cover after the initial re-growth, and cover did not return to pre-disturbance levels after four years (Fig. 1). Soil nitrogen showed no apparent trends, however, in comparisons of control and highly disturbed plots after one year of recovery (Table 5). This could be the consequence of a greater demand for the available nitrogen on the part of the plants in these plots, a topic requiring further research. The dryas tundra recovered more slowly at trampling intensities of 200 passes and above (Fig. 1). In contrast to the lower trampling intensities, the 500 pass level did not recover completely, with just 77% relative cover even after four years.

The results of this study contrast somewhat with the work of Reid and Schriener (1985) in that the previous work found dryas tundra to be of low resistance and high resilience. Direct comparisons of the two studies are difficult due to methodological differences, particularly in the timing and application of trampling treatments. However, the overall conclusion, that the dryas tundra can tolerate a moderate amount of dispersed use, is similar in the two studies.

Since *Dryas octopetala* has a low, mat-forming growth form, relative height (Fig. 2) of the vegetation was largely unaffected by trampling. It was, however, difficult to obtain accurate assessments of height in the field by standard methods, so measurement error may have confounded any subtle changes. In the tussock tundra, vegetation height was significantly reduced with 500 passes immediately after trampling (Fig. 2). Due to the morphology of this vegetation type (collectively tall graminoids in the 30 cm range), plants can be easily

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flattened by intensive human use. This may not be an important management consequence, given the degree of resiliency we observed. However, it could be problematic since areas of disturbance may become visually obvious to visitors. Disturbed areas could attract more use and reach levels of disturbance exceeding the ability of the ecosystem to recover.

Cole (1995a) in an analysis of the relative cover- trampling intensity curves of 18 vegetation types, concludes that the most durable vegetation types were not necessarily those with the highest initial resistance, but rather ones with a high tolerance for a complete cycle of disturbance and recovery. Also, many vegetation types have thresholds of vulnerability, beyond which complete recovery is at best very slow, and in some cases impossible. In general, both of the tundra communities and most of the individual species examined were able to recover to pre-disturbance conditions in all treatments except the 500 pass level. If disturbance is maintained at or below the 200 pass threshold, recovery is possible, even as quickly as one or two growing seasons.

It appears from this study that there is little effect on plant composition as a consequence of the applied trampling (table 6), though it is possible that these effects are very subtle, and our statistical and sampling methods not sufficiently sensitive. Moreover, standard protocols for trampling studies were followed (Cole and Bayfield 1993) where mosses and lichens are not identified by species. Some research indicated that these species may be important indicators of disturbance in these ecosystems (Forbs 1992a). It is also possible that additional cycles of disturbance and recovery over several years would result in plant community level changes as has been demonstrated in other research (Liddle, 1997).

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In many protected areas in Alaska, management plans call for the maintenance of resource conditions with as little observable human impact as possible, that is, without the formation of permanent trails and campsites (e.g., Gates of the Arctic, 1986). A dispersal camping strategy, where total use is limited but visitors are free to choose places to camp is typically used to accomplish this management objective (Leung and Marion, 2000). This strategy contrasts with a containment strategy, where visitors are required to travel on existing trails and camp in designated or existing campsites. Visitor dispersal as a management tool is generally useful where light visitation occurs. Dispersal strategies have proven problematic in some areas of moderate to high visitation resulting in greater overall impact compared to containment strategies in similar environments (Leung and Marion 2000). Given the tolerance observed to moderate disturbance in these tundra communities, effective dispersal of use seems possible, but only if use remains below threshold levels and if visitors are proficient in minimum-impact camping. Observations at Denali National Park, an area where dispersal strategies for backcountry camping have been utilized for some time, suggest that dispersal can be effective in similar tundra ecosystems (Leung and Marion 2000, Marion personal communication).

This work provides a basis to develop prescriptive visitor management strategies for these tundra communities. However, this information is limited by several factors, including the length of the study, the limited application of trampling treatments and the limited geographic scope. The work does provide a very useful and accurate index of the responses of these communities and by combining this information with monitoring and assessment programs and active visitor management, the maintenance of pristine conditions in many areas

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may be possible. It is especially important to manage and monitor the dryas tundra carefully, since visitors are often attracted to these areas which offer dry, level campsites and easier hiking than the tussock community.

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Table 1. Initial frequency and mean percent cover of all species in both tundra vegetation types. Standard errors are shown for all species with mean cover greater than 1 percent. "+" indicates relative cover less than 1%

	Vegetation type			
	Dryas Tundra		Tussock Tundra	
Species	Freq.	Cover	Freq.	Cover
Dryas octopetala subsp. *octopetala* var. *octopetala*	100	33±1.8	3	+
Vaccinium uliginosum subsp. *microphyllum*	8	+		
Androsace chamaejasme subsp. *Lehmanniana*	2	+		
Astragalus umbellatus	33	+		
Carex spp	83	+	31	+
Minuartia artica	2	+		
Geum glaciale	29	+		
Hierochloe alpina	27	+		
lichens	100	28±1.1	81	1
mosses	90	2	100	16±1.4
Oxytropis nigrescens subsp. *bryophilia*	69	1		
Pedicularis spp	27	+	13	+
Polygonum bistorta subsp. *plumosum*	63	+	59	+
Rhododendron lapponicum	21	+	22	+
Salix rotundifolia	23	+		
Salix reticulata subsp. *reticulata*	52	2	94	5 ± 0.9
Silene acaulis subsp. *acaulis*	15	+		
Vaccinium vitis-idaea	2	+		
Salix lanata subsp. *Richardsonii*			6	+
Ledum palustre			69	1
Cassiope tetragona subsp. *tetragona*			19	+
Dryas integrifolia subsp. *integrifolia*			97	6±0.8
Eriophorum angustifolium subsp. *subarticum*			100	7±0.8
Eriophorum spp			22	1±1.7
Arctostaphylos rubra			31	1

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Table 2. Relative cover[1] of abundant species after trampling and after one and four years of recovery.

	After trampling				After one year of recovery				After four years of recovery			
	Number of passes				Number of passes				Number of passes			
	25	75	200	500	25	75	200	500	25	75	200	500
Dryas Tundra												
Dryas octopetala	73	83	58	14	100	116	95	82	100	112	89	98
lichens	104	89	42	20	100	83	61	25	98	103	55	35
Tussock Tundra												
Eriophorum angustifolium	100	90	35	9	131	96	92	44	98	89	92	77
Dryas integrifolia	112	63	16	7	112	117	52	39	101	79	60	32
mosses	96	100	55	12	86	109	121	70	103	97	106	64

[1] Relative cover is the proportion of original cover that survives trampling, adjusted for changes on control plots. Relative covers were calculated following Cole and Bayfield (1993). This procedure reduces the variation between replications by calculating mean pre- and post-treatment cover estimates on all replications and then calculating relative cover from these means. As such, confidence intervals cannot be calculated.

Table 3. Exposure of bare ground, changes in soil compaction and species richness due to trampling. [1]

Treatment	After trampling			After one year recovery			After four years of recovery		
	Bare ground (%)	Soil penetration resistance (kg/cm^2)	Species Richness	Bare ground (%)	Soil penetration resistance (kg/cm^2)	Species Richness	Bare ground (%)	Soil penetration resistance (kg/cm^2)	Species Richness
Dryas tundra									
control	35 ± 2.9 a	.69 ± .2 a	9 ± 1.3 a	37.5 ± 2.5 a	.6 ± .3 a	9.8 ± 1.4 a	30.0 ± 4.1 a	1.3 ± 1.3 a	11 ± 1.5 a
25 passes	40 ± 4.1 a	.8 ± .2 a	8.5 ± .7 a	36 ± 12.4 a	.8 ± .3 a	10 ± .7 a	37.5 ± 4.8 a	2.5 ± 1.4 a	11.5 ± .9 a
75 passes	42.5 ± 4.8 a	.8 ± .2 a	8.5 1 .3 a	47.5 ± 2.5 a	.8 ± .3 a	9.3 ± .5 a	40.0 ± 5.8 a	2.0 ± 1.2 a	10.5 ± .3 a
200 passes	67.5 ± 7.5 b	1.6 ± .3 a	8.8 ± 1 a	53 ± 4.8 a	1.1 ± .3 a	8.8 ± .3 a	40.0 ± 7.8 a	1.5 ± 1.2 a	9.8 ± .8 a
500 passes	87.5 ± 2.5 b	1.6 ± .3 a	6.3 ± .6 a	65 ± 6.4 a	1.8 ± .9 a	9 ± .7 a	35.0 ± 5.0 a	2.8 ± 1.3 a	10.3 ± .8 a
Tussock tundra									
control	62.5 ± 4.8 a	.5 ± .1 a	7 ± 1 a	52.5 ± 4.8 ab	.5 ± .1 a	8.8 ± 1 a	60 ± 4.1 a	0.1 ± 0 a	9 ± 1.3 a
25 passes	65 ± 8.7 a	.9 ± .3 a	7.8 ± .5 a	55 ± 2.9 ab	1.1 ± .3 ab	10.3 ± 1 a	67.5 ± 6.3 a	.3 ± .1 a	9.8 ± 1 a
75 passes	70 ± 4.1 a	1.9 ± .3 ab	7.5 ± .5 a	42.5 ± 2.5 a	1.2 ± .3 ab	10.3 ± .8 a	62.5 ± 2.5 a	.4 ± .2 a	10.5 ± 1 a
200 passes	85 ± 5 ab	2.9 ± .3 b	6.5 ± .5 a	52.5 ± 2.5 ab	2.1 ± .3 b	9.3 ± .8 a	62.5 ± 9.5 a	.5 ± .2 a	9 ± .8 a
500 passes	97.5 ± 2.5 b	3.0 ± .3 b	7.8 ± .8 a	65 ± 6.5 b	2.3 ± .3 b	8.8 ± 1.7 a	65.0 ± 11.8 a	.3 ± .1 a	8.8 ± 1.4 a

[1] Values are means ± SE. Means not followed by the same letter are significantly different using the Scheffe test at $\alpha = 0.05$.

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Table 4. Indices of resistance, resilience, and tolerance for the two vegetation types.[1]

	Dryas Tundra	Tussock Tundra
Resistance		
Minimum number of passes that cause approximately a 50% cover loss	200 (48% Loss)	200 (55% Loss)
Mean relative cover after 0-500 passes	64.3	58.2
Resilience		
Mean increase in cover one year after 0-500 passes, as a percent of the damage caused by trampling	69.6	105.1
Mean increase in cover four years after 0-500 passes, as a percent of the damage caused by trampling	75.8	86.7
Tolerance		
Maximum number of passes that leave at least 75% relative cover one year after trampling	200	> 500
Mean relative cover one year after 0-500 passes	89.2	102.1
Maximum number of passes that leave at least 75% relative cover four years after trampling	500	> 500
Mean relative cover four years after 0-500 passes	91.4	94.4

[1] Calculations follow Cole and Bayfield (1993)

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Table 5. Soil nitrogen in highly disturbed plots after one year of recovery.

	NH4 (mg kg^{-1})	NO3 (mg kg^{-1})	TKN (%N)
Tussock Tundra			
Control	11.5 ± 2.3	0.13 ± 0.2	2.4 ± 0.1
500 Passes	12.8 ± 2.3	0.45 ± 0.2	2.3 ± 0.1
Dryas Tundra Organic Horizon			
Control	3.8 ± 2.5	1.2 ± .8	1.3 ± 0.2
500 Passes	8.1 ± 2.5	1.0 ± .8	1.2 ± 0.2
Dryas Tundra Mineral Horizon			
Control	2.7 ± 0.9	1.8 ± 0.8	0.7 ± 0.2
500 Passes	3.5 ± 0.9	1.2 ± 0.8	0.6 ± 0.2

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Table 6. Results of principal components-analysis of variance (PCA-ANOVA) procedure on plant communities.[1]

Analysis	Immediately after trampling			After one year of recovery			After four years of recovery		
Dryas tundra	MS	F	*p*	MS	F	*p*	MS	F	*p*
Factor 1 by trampling treatment	.802	.762	.566	1.62	1.96	.153	1.78	2.24	.112
Factor 2 by trampling treatment	8.27	2.06	0.058	.476	.417	*.793*	2.22	3.31	.039
% variation explained by factors 1 and 2	36.8			31.5			34.4		
Tussock Tundra	MS	F	*p*	MS	F	*p*	MS	F	*p*
Factor 1 by trampling treatment	.147	.119	.974	.147	.120	.974	.856	.826	.528
Factor 2 by trampling treatment	.821	.783	.553	.821	.783	.554	1.09	1.12	.386
% variation explained by factors 1 and 2	35.0			35.0			35.0		

[1] A PCA was performed on species cover data for each of the two plant communities at each sampling time. ANOVA was used to test for treatment differences on the factor scores of the first two components determined in the PCA.

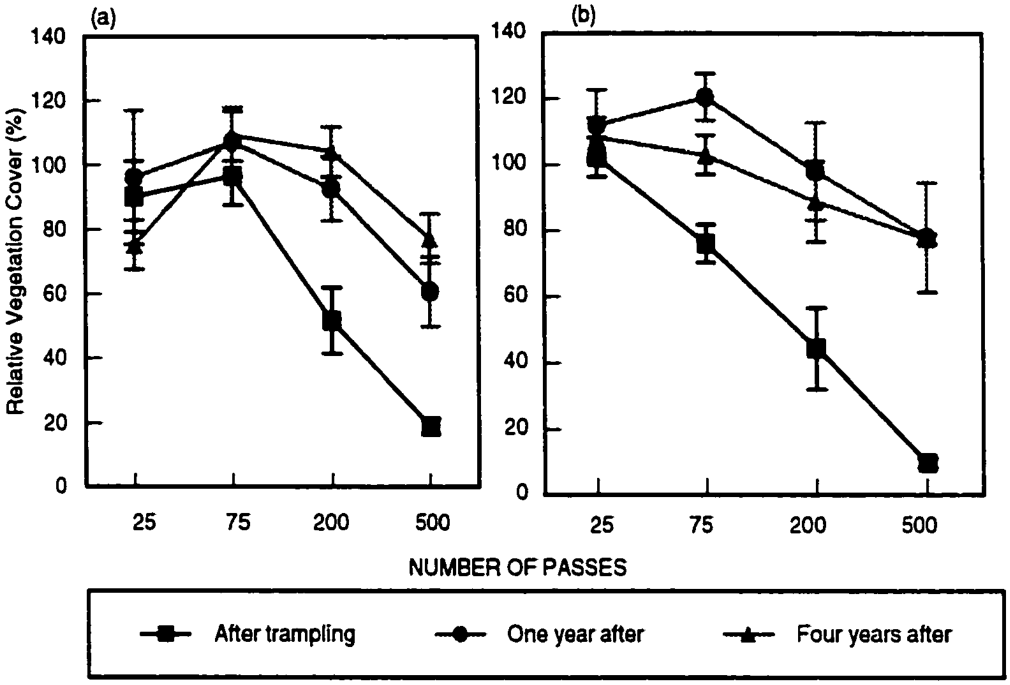

Figure 1. The relationship between vegetation cover and trampling intensity in the a) dryas tundra and b) tussock tundra communities. Error bars are ± one standard error.

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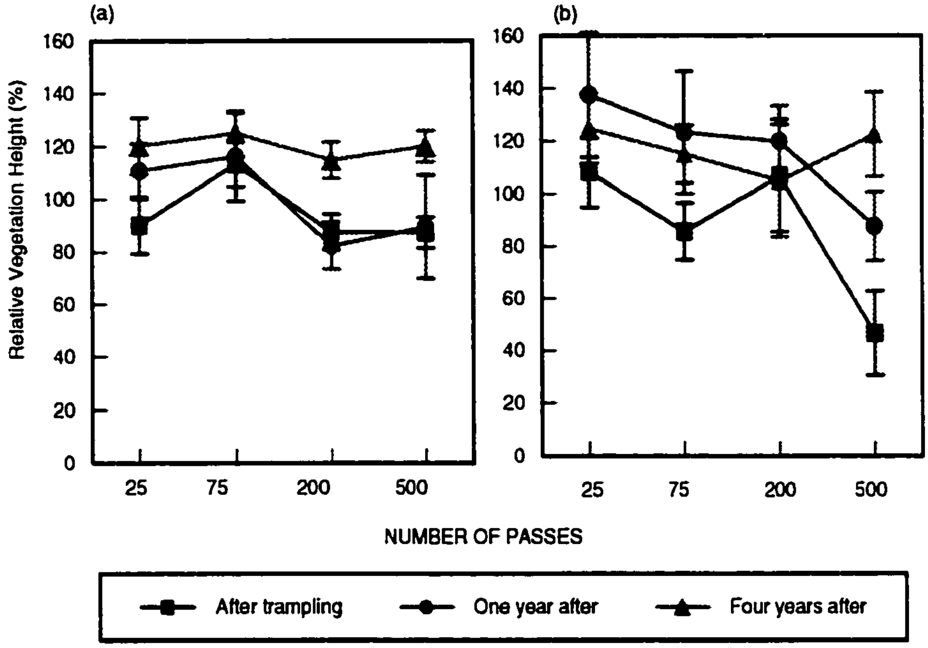

Figure 2. The relationship betwen vegetation height and trampling intensity the a) dryas tundra and b) tussock tundra vegetation types. Error bars are ± one standard error.

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CHAPTER 3

Introduction

The idea that public lands have a finite capacity for visitor use is not new. The concept of visitor capacity in recreation science has over a 40-year history of development, originating in the carrying capacity principle from range management (Stoddart et al., 1943). Although the planning processes developed over the last 15 years have diverged from setting numeric visitor capacities, making appropriate and defensible visitor capacity decisions continues to be a priority for land managers for several reasons. First, the available planning frameworks are complex, costly and highly dependent on monitoring. Managers of protected areas often cite these reasons for the limited application of these approaches (Brown 2001). Second, increases in demand for visitor opportunities on public lands continue to be challenging for managers. Concomitant difficulties in determining when use levels exceed the available supply of visitor services complicate the problem (Haas 2000). Last, there are circumstances when numeric visitor capacities have been determined to be useful and desirable (Stankey and McCool 1992; Haas 2001, Appendix I) and yet little guidance exists for managers to embark on a process to arrive at these decisions. As such, there is a continued call for the further development of tools designed to meet these ongoing management needs.

This paper follows the conceptual model of visitor capacity as proposed by Haas (2000), i.e., that there exists a finite supply of recreation opportunities across the range of parks and protected areas. This supply is influenced by such factors as the institutional foundation (e.g., Organic Act), public demand, the

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managing agency's capabilities and the suitability of the type and levels of use based on natural and cultural resource attributes. Conceptually, visitor capacity is reached when the demand for visitor opportunities outpaces the available supply. Therefore, visitor capacity can be defined as a prescribed number and type of visitor use that an area can accommodate. Although information about use-impact relationships can play a substantial role in informing any capacity process, capacity decisions are complex land-use allocation decisions. As such, individual liberties are limited in order to assure the sustainability of resource conditions and visitor experiences (Wagar 1964; Stankey et al., 1985, Stankey et al., 1990, Haas 2000). This is inherently an ethical process with decision challenges similar to those posed by issues of development, housing, flood control, and open space designation (Beatley, 1994). Capacities are an accepted practice in many aspects of land use planning and it logically follows that some elements of these processes would be transferable to visitor capacity decisions (Haas 2000).

A clarification of the professional principles involved in the decision making process is an important evolution of the visitor capacity concept and can provide guidance in this decision process. Principles often reflect the basic values, philosophy, and perspectives on which the practitioners of an established profession must rely. They serve as the code of conduct for making decisions and taking action and most importantly, they help participants understand and meaningfully contribute to a planning process. Principle- based approaches to guide management decisions are common in land management (Table 1) but the established principles do not directly address visitor capacity decision needs.

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By utilizing a process based on accepted principles, managers can be assured that a capacity decision designed to meet resource, social, and managerial objectives is acceptable, equitable and defensible. Moreover, the Administrative Procedures Act (1946:60 Stat. 237, 5 U.S.C.A.) established a legal standard that decisions must be principled and reasoned; that is, arbitrary decisions are in violation of federal law. Professional principles help managers meet this responsibility.

The proposed principles of visitor capacity decision making are not intended as a replacement of the current framework approaches (e.g., Limits of Acceptable Change [LAC] and others). Instead, the principles can act in concert with planning approaches when a numerical capacity is determined to be useful or desirable. These principles are unique in that they are intended specifically to guide visitor capacity decisions and do not serve the broader planning and management aspects, which currently have well-developed protocols. Although the appropriateness of setting visitor capacities in many settings remains a controversial issue (e.g., Stakey and McCool 1992), recent thinking suggests that capacities may be more applicable than previous framework approaches allowed (Haas 2001; Appendix I). It should also be emphasized that visitor capacity decision processes have evolved considerably from the "carrying capacity" concept that dominated early thinking in this field, and these differences have been clarified (Haas 2001; Appendix II). While the visitor capacity principles we propose are broadly applicable to a variety of land management jurisdictions, they are largely derived from values present in the United States and may need modification to be useful to managers in other cultural settings.

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Methodology

The overwhelming interest and participation at the 1999 Congress on Recreation and Resource Capacity (Lundquist and Haas 1999) demonstrated that managers are continuing to struggle with visitor capacity decisions. We utilized the conference as a general scoping process on the entire capacity issue, and followed with an extensive review of the pertinent literature. Our goal was to develop new ideas on visitor capacity using the literature and the managerial issues and concerns as a starting point. In developing the ideas for the principles we also reviewed the National Environmental Policy Act (P.L. 90-190), the National Park Service Organic Act (1916) and the National Forest Management Act (P.L. 94-588) to examine the legislative basis for visitor capacity decisions.

An initial synthesis of these ideas was presented at the Interagency Capacity Task Force Workshop in December 2000, which was attended by over 70 participants representing a wide range of agencies and interest groups. Participants at that workshop were divided into small working groups, and facilitators recorded all salient comments and feedback. An initial synthesis of comments into principles was presented to the entire group for comment and modification on the last day of the workshop, and subsequent changes were based on an analysis of the written information from the work sessions provided by the facilitators.

The Principles of Visitor Capacity

1) All public lands and facilities have a visitor capacity whether explicitly stated or not stated at all.

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Early conceptual investigations into the visitor capacity issue postulated that all lands have a finite capacity for visitation beyond which quality recreation experiences diminish (Wagar 1964). Since that time, considerable empirical examinations of the use- impact relationship have verified this assertion, both from an ecological perspective (Hammitt and Cole 1998) and a visitor experience perspective (Manning 1999). In addition, there is a reasonable limit to what management can accomplish in engineering sites and facilities to increase overall visitor capacity while maintaining an appropriate and high quality visitor experience.

It therefore logically follows that all public lands have a finite visitor capacity, reached when social, managerial or ecological thresholds are surpassed. Management can sometimes explicitly state a capacity, such as a finite number of backcountry permits issued per zone per day, or imply a capacity, such as the number of parking spaces at a trailhead. In cases where there is no explicit or implicit capacity, one exists, but is yet to be defined.

2) A capacity helps to sustain the integrity of natural and cultural resources, and the important recreational and nonrecreational benefits they afford to local, regional, and national publics.

Central to the mission of most land management agencies is the conservation of fundamental natural, cultural, and scenic resources. Through proper management of visitors, impacts to resources can be minimized (Hammitt and Cole 1998). Visitor capacities are one element of a comprehensive strategy of sustainable use that should be integrated with other management strategies such

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as visitor education, law enforcement, seasonal closures, etc. Capacities are prescriptive in nature in that they are based on desired future conditions of a protected area or particular zone in an area.

3) Setting a visitor capacity is a complex decision that requires sound professional judgment, principled and reasoned analysis, acceptance of some uncertainty, and the best available scientific and monitoring information.

Science can contribute to making informed decisions regarding the many aspects of managing protected areas: visitor preferences, crowding, resource tolerance thresholds, effectiveness of management actions, to name a few. Where science is lacking, it may be necessary to make decisions using professional judgment and elements of existing planning processes in an effort to establish capacity guidelines before management challenges arise. Wagar (1964) initially suggested this approach, and managers have mentioned the need to set capacities in advance, subject to modification, as new information becomes available (Brown 2001). In these cases, researchable questions should be identified and examined as part of the overall process.

4) A visitor capacity decision is made by a responsible official as part of a public planning process and may benefit from the thoroughness and legal sufficiency afforded by a NEPA-compliant planning process.

A capacity decision is a component of the overall planning process for any park or protected area. The National Environmental Policy Act (NEPA) serves as one of the main legal and procedural bases for any planning process and it

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should be followed for capacity decisions as well. NEPA is well established, exhaustive, inclusive (Eccleston 1999) and encompasses many of the larger scale considerations needed in the capacity process. Other legislation, such as the agency's Organic Act or enabling legislation, administrative laws and case law also provides legal guidance.

Approaches modeled after NEPA are commonplace and well established in the planning processes of the US Federal Land Management Agencies. For example, public participation, interdisciplinary perspectives, promoting harmony and understanding between people and the environment are all NEPA goals (Philips and Randolph 2000) and are also fundamental aspects in the planning processes.

5) A visitor capacity quantifies the supply of available visitor opportunities that an area can accommodate, and may also address the allocation of opportunities across the variety of affected visitors, i.e., recreationists, commercial operators, educational programs, scientists, and others.

The prescribed amount of visitation that an area can accommodate, or supply, is a function of the ecological, social and managerial environments (Manning 1999; Wagar 1964). In a capacity decision process, the ultimate goal is to quantify the available supply as accurately as possible. This is difficult in some cases, such as a dispersed recreation area with no facilities and low use. It is, however, quite possible and commonplace in many cases, such as camping along a river corridor, where only a finite number of possible sites exist and a finite number of individuals can be accommodated at a given time. Initial estimates

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can be subject to change based on new knowledge, information, and techniques. Moreover, available recreation supply must be balanced with other important protected area values, e.g., resource protection, experience values, purpose, etc.

Visitor capacities also may address the allocation of opportunities across visitor types. Visitor uses can sometimes conflict and certain uses can have different social or ecological consequences. The specific needs of commercial, educational, or research organizations should be accommodated in capacity decisions as these activities are recognized as legitimate uses of public land.

6) A visitor capacity decision considers the larger regional system of visitor opportunities affecting the particular area of recreation concern.

Management actions in one protected area have spillover effects in other areas regionally and even nationally. Decisions must be made with agencies at local, state, national or even international levels for all areas most likely affected. Capacity decisions must consider the larger ecological, social, economic, and cultural systems that they may affect.

7) A capacity provides clarity for focused dialogue and analysis of consequences across the proposed management alternatives under consideration in a planning process.

The process of arriving at a capacity decision should involve all stakeholders sharing responsibility in managing public land. The alternatives in a planning process will ultimately lead to varying functional capacities, and each alternative can have varying consequences for stakeholder groups and managers.

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Managing for a particular capacity is also influenced by allocation decisions, and these decisions need to involve all potentially affected stakeholder groups.

8) A capacity decision should use a sliding-scale rule, whereby the level of analysis is commensurate with the potential consequence of the decision.

High use areas and areas with particularly sensitive ecological and cultural resources are likely to require extensive planning, research, and monitoring to determine capacities. Areas with little visitor use and few sensitive resources may benefit from an established capacity based on sound professional judgment, principles, and public review but may not require extensive research and monitoring efforts initially. Management must be adaptive, and the capacity planning needs of a particular area are subject to modification as the resource, social, and managerial conditions change. In addition, areas where use is currently low can benefit from a visitor capacity as changes in technology, visitor activities and preferences, and overall demand can occur quickly.

9) Visitor use approaching a capacity triggers consideration of a full range of reasonable management responses and serves as a signal for action for managers, permittees, the general public and all stakeholders.

Capacities can be looked at as managerial "lines in the sand", indicators that visitor use is approaching maximum sustainable levels. Depending on the circumstances, capacities can be hard or soft lines. Where clear resource, social, or managerial constraints exist, capacities define the maximum allowable number, triggering a management action. Where the constraints are not as clear,

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capacities should still prompt an examination of potential management responses, but may not result in an immediate action.

Visitor use approaching or surpassing capacity should be a call to action on the part of all stakeholders as part of the shared responsibility of management. Stakeholder groups can potentially modify the type, location, frequency, and amount of use in order to assist managers in their efforts to maintain sustainable levels.

Management should follow a series of pre-identified steps along the minimum-tool approach. Each initial management action can then be evaluated and the next level of action applied if needed. Often times, combined approaches are best, for example minimum-impact education combined with backcountry permits in wilderness.

10) A visitor capacity decision needs to be adaptive to new science, information, uses, technology, trends, conditions, and other important circumstances.

Adaptive management, which is loosely defined as learning by doing, is receiving a growing recognition in land management (Thom 2000). Planners and managers can utilize information from monitoring to assess management policies systematically and as new science and information becomes available, management actions can be further refined. It is possible, perhaps even likely, that certain visitor capacities will have a high degree of uncertainty. Adaptive management will be particularly useful here, as new and more accurate information becomes available. In addition, the complex circumstances of visitor

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management are continually in flux and a capacity decision process needs to be robust to accommodate this dynamic nature.

11) The effectiveness of a visitor capacity depends on an adequate program of monitoring that is commensurate with the potential consequences, risk, or uncertainty at hand.

Monitoring is essential for any management strategy to be successful. It is particularly important in a visitor capacity process, because capacity decisions are inherently multi-dimensional, involving social, environmental, and managerial factors. Adequate information and the elucidation of causal relationships are essential to the decision process.

It is reasonable for the amount, type, and frequency of monitoring strategies to vary depending on the circumstances. For example, in areas of high visitation where a significant potential for resource or visitor experience impact exists, monitoring should be frequent and extensive. On the other hand, in situations of low visitor use, less sensitive resources, etc., monitoring strategies may not require as much rigor. Regardless, monitoring information is important and applicable to nearly every visitor management situation.

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Table 1. Examples of principle-based approaches considered in the development of the Principles of Visitor Capacity Decision Making[1]

NEPA goals[2]	Themes of VERP, LAC, ROS, etc.[3]	Outdoor recreation[4]	Wilderness Management[5]	Ethical Land Use[6]
• Encourage productive and enjoyable harmony between humans and the environment	• Recreation settings are defined as a combination of biological social and managerial conditions that give value to a place	• Outdoor recreation considered within a theefold framework of concerns: natural, social and management environments	• Manage wilderness as one extreme on the environmental modification spectrum	• Ethical land use seeks to promote the greatest quantity of social benefits or welfare
• Promote efforts that will prevent or eliminate damage to the environment	• Focus on recreation setting as this is the primary component of the rec. opportunity that managers can influence	• Substantial diversity in outdoor recreation	• Manage wilderness as a composite resource, not as separate parts	• Land use policy should promote social and economic justice in society
• Enrich our understanding of ecological systems and natural resources	• Recognition that it is important to provide a diversity of rec. and educational opportunities	• Diversity is needed in outdoor recreation opportunities	• Manage wilderness and sites within, under a non-degradation concept	• Land-use policy should prevent or minimize harms to people and the environment
• Enhance long-term productivity of resources and the environment	• Establishment of clear measurable management objectives	• Explicit objectives are needed to guide management	• Manage human influences, a key to wilderness protection	• Land- use policy must protect land use rights due every individual
• Encorporate environmental considerations early in policy making and planning	• Interdisciplinary planning teams	• Recreation management should be applied thoughtfully and deliberately	• Manage wilderness to produce human values and benefits	• Protect and conserve the natural environment, both for humans and other forms of life
• Elevate environmental considerations to full partnership with technical and economic factors	• Recognition that two goals may be in conflict, i.e. visitor use and maintaining natural conditions (LAC)	• Outdoor recreation is most apporpriately defined in terms of motivations an benefits	• Favor wilderness-dependent activities	• Protect landscapes and resources which may enrich the lives of future generations
• Utilize a systematic interdisciplinary approach to decision making	• Ongoing monitoring and evaluation	• Quality can be defined as the degree to which opportunities provide experiences	• Guide management with written plans that state objectives for specific areas	• Tolerate a diversity of life-styles and assist individuals in pursuing their own life plans

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Table 1 continued.

NEPA goals[2]	Themes of VERP, LAC, ROS, etc.[3]	Outdoor recreation[4]	Wilderness Management[5]	Ethical Land Use[6]
• Monitor and evaluate activities to protect the environment	• A focus on management of human induced change	• Satisfaction is a multifaceted concept	• Set carrying capacities as necessary to prevent unnatural change	• Avoid paternalism and replacing and individuals view of acceptable risk with society's.
• Identify and mitigate unavoidable impacts	• A need for sound biophysical and social science information	• Interrelationships exist among outdoor recreation issues	• Focus management on threatened sites and damaging activities	• Public land-use authorities must keep the promises that they make
• Provide the public with relevant information early in the planning process		• A concerted effort is needed to obtain systematic and objective information from visitors	• Apply only the minimum regulations or tools necessary to achieve wilderness area objectives	• Use and development of land is a privilege not a right
• Encourage public involvement in decision making		• Opportunities should be managed for identifiable segments of the visitor population	• Involve the public as a key to the acceptance and success of wilderness management	• No political jurisdiction is free-standing; obligations exist to other jurisdictions, particularly those adjacent
• Ensure that unquantified environmental values and amenities are considered		• A variety of practices are available for managing outdoor recreation	• Monitor wilderness conditions and experience opportunities	Land-use policy must be formulated through a fair and equitable political process.
			• Manage wilderness in coordination with management of adjacent lands	

[1] Not organized for a comparison across principle sets in this table

Sources: [2]Philips and Randolph 2000; [3]Nilson and Tayler 1997; [4]Manning 1999; [5]Hendee 1990; [6] Beatley 1994.

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CHAPTER IV

Introduction

This study is an effort to further the body of knowledge regarding visitor capacities in the management of protected areas. Multidimensional by nature, capacity decisions often require a fundamental understanding of complex biophysical and sociological phenomena. Chapters II and III provide new knowledge on this subject from a site specific-biophysical and a decision process perspective, respectively. It is hoped that these approaches will provide managers with an example of the kinds of processes that could be considered in the complex effort of managing visitors appropriately.

In light of the experience gained from conducting this research, this concluding chapter provides a historical context of the issue of visitor capacity and some overall conclusions and future directions in terms of researchable questions and management needs.

A brief history of visitor capacity

The visitor capacity concept is often traced back to the work of Sumner (1942) in the High Sierras of California where he called for a restriction of use to within an area's "carrying capacity" or "recreational saturation point". By that time, the carrying capacity concept had been firmly established in ecology and range science. Classic studies throughout the early and mid 1900's on the Kaibab Plateau in Arizona (Rasmussen 1941) had demonstrated the resource-level

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consequences of deer population pressure exceeding the available supply of browse. It is likely that these observations influenced early thinking on visitor capacities and focused attention on natural resource limitations. Indeed, the term "carrying capacity", still commonly used by many visitor management professionals (e.g., Manning 1999), is a good example of this influence. A clarification of terms is currently needed in the field and it is suggested that the term "carrying capacity" which implies a number determined by use-impact relationships, be replaced with "visitor capacity" which denotes a broader decision process integrated with current planning procedures (Haas 2001; Appendix II).

More comprehensive development of the visitor capacity concept began with the work of Wagar (1964) where recognition was given to the dual importance of the resource attributes of the biophysical environment and human values in the social environment. Further thinking added the managerial environment, recognizing that certain management actions (e.g., site hardening, visitor education, etc.) could also affect an area's capacity (Wagar 1968, Manning and Lime, 1996). More recent thinking also includes factors such as institutional foundation (Organic Act, history, traditions, etc.) and the public demand as important considerations in any capacity decision process (Haas 2000).

Considerable research has been directed towards the effects of visitor use and behavior on natural resource and social conditions and these findings have been reviewed and summarized (Leung and Marion 2000, Hammitt and Cole 1998, Manning 1999). This growing body of knowledge indicates that increases in visitor use often result in impacts to both the physical and social environments, with subsequent changes in the managerial environments often occurring in

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response (Manning 1999). In order to apply these fundamental theories to management, several decision frameworks have been developed such as the Limits of Acceptable Change (LAC) process (Stankey, et al., 1985) and Visitor Experience and Resource Protection Planning Framework (National Park Service 1997) and others (Nilsen and Taylor 1997). Although there are some differences in the specific steps, these approaches focus on 1) setting specific objectives or desired future conditions; 2) developing measurable indicators of social and biophysical change; 3) setting standards of the minimally acceptable conditions not to be exceeded and 4) monitoring to determine if objectives are being met. These processes are well developed, can be effective, and represent a considerable advancement in the application of the capacity concepts. In addition, they do not require the specification of a number or range of visitors for a capacity determination, but rather imply a capacity by focusing on measurable resource and social outcomes. Recently, approaches such as LAC have been improved and clarified after more than ten years of application in the field (McCool and Cole 1997).

The need for numerical capacity determinations

Questions have been raised recently as to the effectiveness and practicality of the aforementioned frameworks in a management context (Lundquist and Haas 1999). Capacity decisions continue to be vexing for many reasons, especially given the multi-dimensional nature of the issues. For example, the current framework approaches do not necessarily take into account such complexities as 1) the fundamental moral dilemma associated with the excluding

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the public from public lands; 2) what can be and should be done in the absence of rigorous social and biophysical data; 3) the lack of capacity planning on a regional or systems basis and 4) the increasing role of the judicial and political system in management policy formation. Moreover, as mentioned in Chapter III, the available planning frameworks are managerially complex and costly to initiate and maintain. As such, protected area managers often cite this reason for their limited application and are calling for the further development of tools for this process (Brown 2001).

Recent efforts to continue to address management concerns have demonstrated that in many cases, managers regard a numerical capacity as needed or desirable (Lundquist and Haas 1999). Recent efforts by the Federal Interagency Task Force on Visitor Capacity (Haas 2001) have also helped further clarify the need for numerical capacities (Appendix I) but this issue is likely to be debated for some time to come. Regardless, it has been recognized that there are situations where numeric capacities are useful (e.g., Stankey and McCool 1992) and current thinking points to a greater number of situations where visitor capacity approaches are likely to be applied (Haas 2001).

Perspectives on management issues

Chapter III presents eleven proposed principles of capacity decision making that are an initial effort to further this process, but is clear that more efforts in this regard are needed. The following represent two areas of particular concern.

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1. *Professionals in the field must strive to develop a clear and consistent visitor capacity decision-making approach across agencies.* Currently there are at least six formal framework approaches and several other planning process that either directly or indirectly address visitor capacities (Nilsen and Tayler, 1997; Manning 1999). This plethora of planning models developed in the last 20 years largely reflect the specific institutional needs and concerns from which they originate, not major conceptual differences. Despite the advantages of having a process tailored to a particular institution, this situation has lead to much confusion among mangers, stakeholders and the general public. Moreover, the different framework approaches are often combined and modified (e.g., Rocky Mountain National Park 2001), which reinforces the idea that perhaps a more robust and universally accepted approach is needed. The principles presented in Chapter III are an initial step in the development of a more universal process and currently significant inter-agency efforts are also underway in this regard (Haas 2001).

2. *The determination of visitor capacities will likely be an iterative process in most cases with a reliance on clear protected area goals and adaptive management strategies.* The management of protected areas is usually an iterative process involving an understanding of the interactions and basic conditions of the biophysical, social and managerial environments. It is unlikely that clear goals, or desired future conditions can be developed without some basic information as to the current conditions. Similarly, it is difficult to determine what elements to assess without some idea of management objectives (Manning 1999). Therefore, in order for these activities to be effective, they must occur in unison, with the understanding that several iterations will probably be needed in the process.

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It is likely that any reasonable visitor capacity process will also be iterative in nature, relying on feedback and adaptive strategies in order to be accurate, appropriate and successful. In some cases, determining capacities equitably and to a high degree of precision is possible initially, in other cases it is not. Regardless, the accuracy and precision of a visitor capacity can always be improved and modified through the inclusion of new information, and in "learning by doing" as in adaptive management.

Perspectives on research needs

Reliable and accurate information is essential in any visitor capacity decision process. Capacity decisions will only be effective and credible if they are based on long- term, objective information. The multidimensional nature of these decisions makes this a complex process, involving information from the biophysical, visitor experience and managerial realms. This is further complicated by the often site-specific nature of these realms as protected areas and the visitor experiences realized in these areas are diverse. Given these challenges, it is clear that research efforts in support of management will need to be significant and ongoing. Several important categories for future research are as follows:

1. *Long term studies across ecosystem types and visitor-experience settings.* Additional long-term studies are needed to examine the tolerance of biotic communities to recreation stress, the effectiveness of management actions and the fundamental nature of the visitor experience in protected areas. Heretofore, limited work has been done on time scales longer than a few years. The

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experimental work presented in Chapter II occurred over a period of four years is a small start at a longer time frame of observation, especially since most trampling studies to date have examined only two years of responses. Moreover, we need to examine the consequences of recreation across ecosystem types, with identical methods. Large-scale studies have a long history in ecosystem science and these approaches could be utilized in recreation science. This large-scale approach needs to also be applied to understanding the dynamics of the visitor experience and changing visito demographics over longer time frames.

2. *Limiting factors to visitor capacities.* Future research is needed to identify the overall site specific, limiting factors to visitor use. These factors are likely to vary widely depending on the biophysical, social and managerial environments of concern. The trampling study in Chapter II is reasonable and appropriate, given the biophysical, managerial and social environment in which it was conducted. It is likely that in this environment, certain biophysical components may prove to be among the suite of limiting factors considered in a visitor capacity and visitor management decision process. It is possible that the results of a trampling study may not be as important in a different setting and that other biophysical, social or managerial factors would be more limiting. Regardless, in nearly every case where a visitor capacity is being determined, it will be important to identify and consider the overall limiting factors.

3. *More effective collaborations across the management and research disciplines.* Although the research literature on many specific elements of the use-impact relationship (i.e., trampling crowding, etc.) is significant, it remains unclear as to how much of this information is utilized by managers. Research often focuses on testing theories or furthering empirical knowledge, but not necessarily on

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problems and issues of management concern. For example, recent additions and modifications to the LAC process (McCool and Cole 1997), while significant and important, have not necessarily furthered the application of this framework in a management context. In order for capacity decision processes to be effective, managers must be able to apply them correctly and consistently across a range of protected area settings. Recent activities by the Interagency Task Force on Visitor Capacities (Haas 2001) are a significant step at bringing mangers, researchers and stakeholders together toward this common goal.

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APPENDIX I

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THE NEED OF AND PURPOSE FOR VISITOR CAPACITIES

There are many reasons and advantages to make decisions on visitor capacity, and these will vary across situations, locations, and times. The following is a listing of the conclusions of the Federal Interagency Task Force on Visitor Capacity on Public Lands as to the need and utility of visitor capacity decisions (Haas 2001).

Public Health and Safety

- Capacities are an important and responsible risk management tool to help protect the health and safety of recreationists or other publics, particularly those participating in or around activities or locations of potential high risk.

Protection of Unique or Critical Resources

- Capacities are an important and responsible risk management tool to preserve important historic, cultural and natural resources (e.g., historic and cultural resources, floodplains and wetlands, farmlands, endangered species, water and air quality, ecological critical areas).

Resource Allocation Decisions

- Capacities give the private sector, commercial recreation operators, local communities, special interests, and others more clarity and sense of predictability.

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- Capacities are important for allocating opportunities (e.g., permits) among recreational users, and between recreation and non-recreational users.
- Capacities can help in deciding to expand or change a licensed or permitted use on public lands (e.g., river outfitter, church and educational groups, scientific study, prospecting, grazing).
- Capacities, when established for specific sites across a regional scale, will help local communities, tribal groups, regional governments, private sector, and others to understand their regional recreation market, problems and potentials, and opportunities for diversifying and expanding their supply of recreation opportunities.
- Capacities can help justify the allocation and distribution of facilities, programs, services, budget, and personnel, priorities (i.e., areas where demand is approaching capacity triggers can prompt increased resources).
- Capacities can help expand the scale of planning and management from site-level planning to regional planning.
- Capacities can help regional, multi-jurisdictional planning efforts to better understand its recreation demand-supply relationship, where to make future investments, determine priorities, how to respond most effectively and efficiently to opportunity.
- Capacities should prompt more consideration of allocation tradeoffs and mitigation strategies to accommodate those uses or users who may feel disenfranchised.

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Increased Monitoring and Science

- Capacities can serve as triggers to justify increased financial resources for monitoring and scientific study (i.e., as current recreation demand approaches capacity triggers, it will help to justify increased resources).
- Monitoring current visitor use levels or demand is a relatively easy, inexpensive, and historic activity. Thus, comparing current use to capacity can be relatively easy, inexpensive, and benefit from historic data for the purposes of triggering consideration of other management responses (e.g., increased monitoring, public education efforts, patrol, voluntary compliance, rules, permits, reservation, time quotas).
- Capacities can help to establish monitoring priorities and the level of scientific sophistication that is appropriate for a given situation (i.e., monitoring priorities may favor those areas where current recreation demand is approaching or within capacity range).

Public Understanding and Response

- Capacities will help the American public recognize that managers cannot provide all things for all people all the time; that recreational opportunities are finite, and that allocation decisions and limits on their personal freedoms may be necessary to assure a quality experience.
- Capacities help managers, users, stakeholders, and others understand, accept, and anticipate that some future management actions may be necessary.
- Capacities can be proactive, and when overuse does arise, their prior establishment will help to avoid surprising the public, allegations of arbitrary

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reactions, over reactions, or to prolonged delays in management responses brought by appeals and litigation.

Clear Communications

- Capacities help to provide clarity for more meaningful agency and stakeholder discussions and analysis—"clarity is in the details."
- Capacities help to explain the desired future conditions for an area by supplementing the narrative description and quality standards typically used to describe.
- Capacities can be a simple, discreet number that managers can use as an omnibus reflection of the array of multiple interacting standards defining the desired resource, social, and management conditions.
- The public may accept and understand numeric visitor capacities more than standards, because standards are more technical, scientific, and whose scientific relation may not be well understood by the layperson.

For the Administrative and Historic Record

- Capacities become part of the administrative record and thus provide a historic anchor from which to learn from natural change, human induced change, and management interventions.
- Capacities become part of the historic record and this reference point can help managers understand change, the success of different tools/strategies, trends, and likely futures.
- Capacities become part of the administrative record and thus transcend personnel and programmatic changes without principled and reasoned analysis.

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Better Planning and Decision Making

- Capacities will enhance planning and management based upon a better understanding of recreation demand and supply (i.e., a capacity is the measure of available supply).
- Capacities take full advantage of the reasoned and deliberate analysis which comes from an integrated and comprehensive planning process with meaningful public participation. Or stated otherwise, to proceed through a NEPA-compliant planning process and not make capacity decisions for important areas may be a lost opportunity and inefficient/incomplete use of public taxpayer dollars.
- Capacities prompt the consideration of the local and regional supply of the same opportunities, similar opportunities, or substitutable opportunities.
- Capacities can help in considering the consequences from adjacent or external land use proposals.
- Capacities can help in the creating a reasonable range of management alternatives and in the full assessment of consequences (allocations) among recreational groups and between recreational groups and other public land users.
- Capacities as a measure of available supply can be helpful in deciding the appropriateness of a categorical exclusion, environmental assessment, or environmental impact statement.

Legal and Professional Responsibility

- Capacities may be a legal requirement for some agencies.
- Understanding an area's capacity or available supply of opportunities is a fundamental professional imperative.

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- Capacities that are based on sound professional judgement and a NEPA-compliant planning process, will more likely have the deference of the courts.

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APPENDIX II

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A comparison of past approaches to carrying capacity and visitor capacity approaches.[1]

Past approaches	Visitor capacity approach
• Referred to as recreational carrying capacity	• Referred to as visitor capacity
• Capacities are an unnecessary step and a diversion from the more important need to establish resource and social standards.	• A capacity is a highly desired step built upon and a supplement to the establishment and monitoring of resource, social and managerial standards.
• Capacities are determined by science using a formula, model or computation.	• A capacity is decided by a responsible official using professional judgement and the best available science.
• A capacity is reactive to unacceptable change and prompts visitor limits.	• A capacity is a proactive decision. As use approaches or is within the capacity range, te full range of management responses is considered.
• There are different kinds of capacities (e.g., physical, biological, and design).	• There is one visitor capacity which considers physical, biological , social and design concerns.
• The purpose of a capacity of to set quotas.	• The purpose of a capacity is multi-faceted including allocation decisions, risk management, assessment of alternatives, regional planning, etc.
• The scale of capacity planning is the agency site or unit.	• The scale of planning may vary from an agency site to a milt- jurisdictional region.
• Field monitoring is vital and must be scientifically precise and accurate.	• Field monitoring is vital but comprehensive data are sometimes unavailable.
• Capacity focuses on recreation use.	• Capacity considers all visitors (recreation, non-recreation, commercial and public).
• A capacity is determined in response to findings from a monitoring program.	• Capacities are included in each management alternative for public consideration and are adaptive to the results of a monitoring program.
• Capacities are arbitrarily determined.	• Capacities are principled and reasoned.
• A capacity does not exist where a capacity has not been determined.	• A capacity exists whether it is explicitly stated, indirectly stated or not stated at all.
• A capacity is inherent	• A capacity is a function of the management objectives, quality standards, current uses, desired future conditions, management capability and other inputs to the planning process
• A capacity is fixed.	• A capacity is adaptive to new information, science and circumstances.
• A capacity is a fixed single number.	• A capacity is an adaptive numeric range or number.
• A capacity is a limit.	• A capacity is a trigger or signal.

[1] Source: Haas 2001.

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