Carrying Capacity as “Informed Judgment”: The Values of Science and the Science of Values

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Abstract—Contemporary carrying capacity frameworks, such as Limits of Acceptable Change and Visitor Experience and Resource Protection, rely on formulation of standards of quality, which are defined as minimum acceptable resource and social conditions in parks and wilderness. Formulation of standards of quality involves elements of both science and values, and both of these elements must be integrated into “informed judgments” on the part of park and wilderness managers. That is, managers must ultimately make value-based judgments about the maximum acceptable level of visitor-caused impacts to the resource base and the quality of the visitor experience. However, such judgments should be as informed as possible by scientific data on the relationships between visitor use and resulting impacts, and the degree to which park and wilderness visitors and other interest groups judge such impacts to be acceptable. Such information represents the “values of science” to managing carrying capacity in parks and wilderness. A growing body of literature has begun to address the corresponding “science of values,” and how this type of information might be integrated in park and wilderness management. Visitor-based research has employed normative theory and techniques to explore the acceptability of a range of social and biophysical impacts related to visitor use, and findings from these studies are being integrated into a body of knowledge and applied in management decisionmaking. Conceptual and methodological extensions of the normative approach are currently being explored in a variety of park and wilderness contexts, and new theoretical and empirical approaches are being adapted to address tradeoffs inherent in carrying capacity. In these ways, the science of values is progressing to meet the opportunities and challenges of the values of science to park and wilderness management.

Crowding and Carrying Capacity

Crowding constitutes a long-standing issue in the field of park and wilderness management, and this issue often is addressed within the context of carrying capacity. In its most generic form, carrying capacity refers to the amount and type of visitor use that can be accommodated within a park or wilderness. Recent experience with carrying capacity suggests that it can be applied most effectively through formulation of indicators and standards of quality for biophysical conditions (resource carrying capacity) and for the visitor experience (social carrying capacity) (Graefe and others 1990; National Park Service 1997; Stankey and others 1985; Stankey and Manning 1986). Social carrying capacity focuses principal emphasis on defining the type of visitor experience to be provided and maintained. Indicators of quality are specific, measurable variables that define the quality of the visitor experience. Standards of quality define the minimum acceptable condition of indicator variables.

By formulating indicators and standards of quality, carrying capacity can be defined and managed. Indicator variables are monitored over time, and if standards of quality have been violated, management action is required. This approach to crowding and carrying capacity is central to contemporary park and wilderness management frameworks, including Limits of Acceptable Change (Stankey and others 1985), Visitor Impact Management (Graefe and others 1990) and Visitor Experience and Resource Protection (National Park Service 1997).

“Informed Judgment”

The contemporary carrying capacity frameworks noted above rely (either explicitly or implicitly) on a foundation of “informed judgment.” That is, park and wilderness managers must ultimately render judgments about the level of impacts and related visitor use levels that are acceptable. A growing body of research illustrates that, while such relationships may be complex, increasing use levels of parks and wilderness may lead to increasing impacts to biophysical resources and the quality of the visitor experience (Hammitt and Cole 1998; Manning 1999). To what degree are such impacts and associated visitor use levels acceptable?

This issue can be illustrated graphically as shown in figure 1. In this figure, hypothetical relationships between visitor use and impacts to the biophysical and social environments are shown. These relationships suggests that increasing recreation use can and often does cause increasing impacts in the form of damage to fragile soils and vegetation and crowding and conflicting uses. However, it is not clear from these relationships at what point carrying capacity has been reached. For relationship A, X1 and X2 represent alternative levels of visitor use that result in corresponding levels of impact as defined by points Y1 and Y2, respectively. But which of these points—Y1 or Y2, or some other point along the vertical axis—represents the maximum amount of impact that is acceptable?

To emphasize and further clarify this issue, some studies have suggested distinguishing between descriptive and

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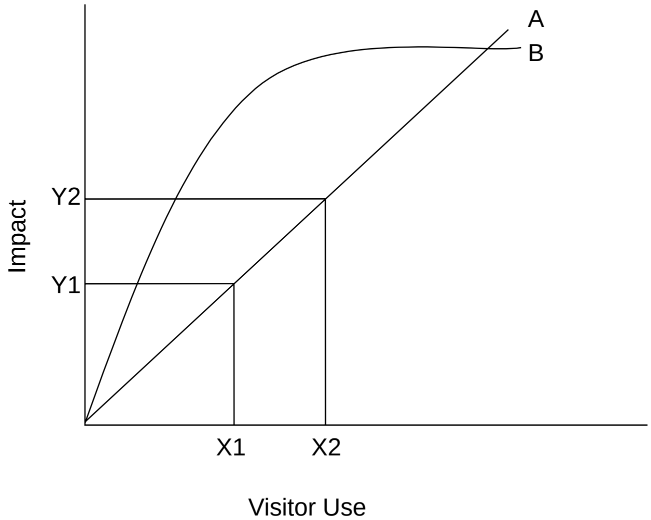

Figure 1—Hypothetical relationships between use and impact to the recreation environment.

prescriptive components of carrying capacity (Shelby and Heberlein 1984, 1986). The descriptive component of carrying capacity focuses on factual, objective data such as the relationships in figure 1. For example, what is the relationship between the amount of visitor use and perceived crowding? The prescriptive component of carrying capacity determination concerns the seemingly more subjective issue of how much impact or change in the recreation environment is acceptable. For example, what level of perceived crowding should be allowed?

From this discussion, it is apparent that carrying capacity management requires a strong element of “informed judgment.” Park and wilderness managers must ultimately render judgments about acceptable levels of biophysical and social impacts, and associated use levels, but such judgments should be as “informed” as possible. Findings from scientific studies represent an important approach to informing such judgments.

Values of Science

Science can inform management judgments about carrying capacity in at least two ways. First, research findings should serve as the basis of the descriptive component of carrying capacity. As noted above, the descriptive component of carrying capacity concerns the relationships between visitor use and the biophysical and social impacts of such use. A substantial body of scientific literature has been developed on both the resource and social components of carrying capacity, and recent meta-analyses have begun to integrate and synthesize this growing body of knowledge (Hammitt and Cole 1998; Manning 1999).

Second, research findings can also help inform the prescriptive component of carrying capacity. The prescriptive component of carrying capacity concerns the maximum acceptable level of biophysical and social impacts. Again, a substantial body of scientific literature has been developed on the degree to which park and wilderness visitors are perceptive of such impacts and their subjective evaluations of these impacts. This research explores the park and wilderness-related values of visitors, and can be integrated with other types of information (for example, legal and administrative mandates, agency policy, historic precedent, interest group politics) to help inform management judgments about carrying capacity.

Science of Values

Within the context of carrying capacity, scientific approaches to park and wilderness-related values have been applied primarily to formulation of standards of quality. Earlier in this paper, standards of quality were defined as the minimum acceptable levels of indicator variables. Research on visitor-based standards of quality has increasingly focused on normative theory and techniques.

Normative Approach

Developed in the disciplines of sociology and social psychology, the concept of norms has attracted considerable attention as a theoretical and empirical framework in park and wilderness research and management. In particular, normative theory has special application in helping to formulate standards of quality for park and wilderness experiences. As applied in outdoor recreation, norms are generally defined as standards that individuals and groups use for evaluating behavior and social and environmental conditions (Donnelly and others 1992; Shelby and Vaske 1991; Vaske and others 1986). If visitors have normative standards concerning relevant aspects of recreation experiences, then such norms can be measured and used as a basis for formulating standards of quality. In this way, carrying capacity can be determined and managed in a more informed manner.

Application of the normative approach to formulating visitor-based standards of quality in park and wilderness management is most fully described in Shelby and Heberlein (1986), Vaske and others (1986), and Shelby and others (1996). These applications have relied heavily on the work of Jackson (1965), who developed a methodology—return-potential curves—to measure norms. Using these methods, the personal norms of individuals can be aggregated to test for the existence of social norms or the degree to which norms are shared across groups. Normative research in outdoor recreation has focused largely on the issue of crowding (for example, Heberlein and others 1986; Patterson and Hammitt 1990; Shelby 1981a; Vaske and others 1996; Whittaker and Shelby 1988; Williams and others 1991), but also has been expanded to include other potential indicators of quality, including ecological impacts at wilderness campsites (Shelby and others 1988), wildlife-management practices (Vaske and Donnelly 1988), and minimum stream flows (Shelby and Whittaker 1995). Research findings from published studies of recreation-related norms have recently been compiled in Manning (1999).

A hypothetical social norm curve is shown in figure 2 to illustrate the methodology described above. The norm curve traces the average acceptability ratings of a sample of recreationists for encountering a range of groups of other

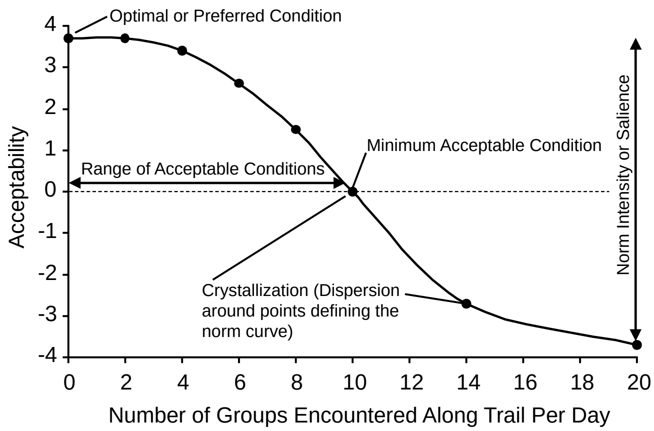

Figure 2—Hypothetical social norm curve.

visitors along a trail per day. The highest point on the norm curve represents the optimal or preferred condition. The range of acceptable conditions includes all points on the norm curve above the zero point of the acceptability scale. The minimum acceptable condition is defined by the point at which the norm curve crosses the zero point of the acceptability scale. The degree of consensus among the sample is indicated by the dispersion or variance of individual responses around the means that define the norm curve. This issue often is referred to as "crystallization." Finally, the distance of the norm curve above and below the zero point of the acceptability scale defines norm "intensity" or " salience," and is a measure of the degree to which the impact under study is important to respondents.

Extending the Normative Approach

As research on normative standards has proceeded, several approaches to measuring norms have evolved. Traditionally, outdoor recreation-related norms have been measured using a "numerical" or "narrative" approach. For example, respondents might be asked to evaluate a range of encounters (0, 5, 10, 15, and so forth) with other groups per day along trails. The personal normative data derived are aggregated and graphed (as illustrated in figure 2) to construct a "norm curve" from which social norms might be identified. This numerical or narrative approach often is shortened to reduce respondent burden by simply asking respondents in an open-ended format to report the maximum acceptable number of encounters with other groups per day. These two approaches might be called the "long" and "short" versions of this measurement technique.

More recently, visual approaches to measuring crowding and other outdoor recreation-related norms have been developed. Two of these studies used photographs of wilderness campsites that illustrated a range of ecological impacts (Shelby and Harris 1985; Shelby and Shindler 1990). Two other studies have used artistic renderings of alternative use levels and related impacts (Heywood 1993a; Martin and others 1989). More recently, computer software has been used to edit and produce photographs depicting a range of use levels and environmental impacts (Hof and others 1994; Manning and others 1996a,b, 1995). As with the numerical/narrative approach described previously, long and short versions of this measurement technique can be used. The long version asks respondents to evaluate each image in a series of photographs. The short version asks respondents to select the photograph that illustrates the highest impact or use level acceptable.

An issue implicit in all of these measurement approaches concerns the evaluative dimension used in these questions. When respondents have been asked to evaluate a range of use levels and related impacts, the response scale has included terminology specifying a variety of evaluative dimensions, including "acceptability," "preference," "pleasantness," "desirability," "satisfaction," and "tolerance." These alternative evaluative dimensions may have substantially different meanings to respondents, and may result in significantly different personal and social norms.

A related issue concerns the normative nature of evaluative dimensions. Application of normative theory and techniques to outdoor recreation has noted several important elements of norms as they traditionally are defined (Heywood 1993a,b, 1996a,b; McDonald 1996; Noe 1992; Roggenbuck and others 1991; Shelby and Vaske 1991; Shelby and others 1996; Williams and others 1991). One of these elements suggests that norms have a strong obligatory nature. That is, norms define what "should" be. This suggests that norms might be measured by asking respondents about what recreation conditions or level of impacts they feel managers "should" maintain.

Recent studies of crowding-related norms for several national parks have allowed comparisons of findings among the norm measurement approaches described above (Manning and others 1998, 1999a,b,c, 1997a,b,c, 2000). These comparisons suggest that alternative measurement approaches can affect resulting norms in a statistically significant and substantive way (Manning and others 1999d). The most powerful effects concern the evaluative dimension used and more explicit introduction of the normative notion of the recreation conditions that managers *should* maintain.

Examples of these findings are shown in table 1 and figure 3. Table 1 summarizes findings from several comparable studies, and figure 3 presents findings from one study in a graphic format. These findings suggest three important points. First, a range of personal and social norms can be estimated using a spectrum of evaluative dimensions that range from "preference" to "absolute tolerance." Second, the "management action" evaluative dimension may be of special interest to park and wilderness managers because it more explicitly addresses tradeoffs inherent in crowding-related issues (in other words, a desire to avoid crowding while also maintaining public access), and therefore may more closely approximate the traditional prescriptive nature of norms. For example, the "management action" question for the carriage roads of Acadia National Park, Maine, asked respondents "Which photograph shows the highest pattern of visitor use that the *National Park Service should allow* on this section of the carriage roads? In other words, at what point should visitors be restricted from using the carriage roads?" (Respondents were given options to report that visitor use should not be restricted at any point shown in the photographs, or that visitor use should not be restricted at all.) It is important to note that "management

Table 1—Alternative evaluative dimensions of crowding norms.

	Evaluative dimensions				
	Preference	Acceptability (short form)	Acceptability (long fom)	Management action	Absolute tolerance
Cariage roads, Acadia National Park (persons/viewscape)					
1995 (visitors)		10.7	12.7	17.8	25.2
1996 (visitors	5.4	9.7		17.5	20.9
1996 (residents)	7.0	10.1		15.6	19.1
Hiking trails, Grand Canyon National Park (1997) (persons/viewscape)					
Corridor Trails	3.4	6.9	9.0	9.1	12.8
Rim Trails	3.0	6.0	10.0	9.0	18.0
Threshold Trails	1.1	3.6	5.0	5.1	7.9
Attractions, Yosemite National Park					
Trail to Yosemite Falls (1998) (persons/viewscape)	18	32	40	46	60
Base of Yosemite Falls (1998) (people at one time)	43	75	92	100	126
Trail to Vernal Fall (1998) (persons/viewscape)	11.2	20.6	26	29.7	38.6
Trail to Bridalveil Fall (1999) (persons/viewscape)	7	13	18	20	26
Base of Bridalveil Fall (1999) (people at one time)	8	15	20	19	25
Glacier Point (1999) (people at one time)	19	34	42	49	61
Trail to Mirror Lake (1999) (persons/viewscape)	10.4	18.5	24	26.0	33.9
Statue of Liberty National Monument (1998) (waiting time in minutes to get into the Statue of Liberty)			45	64	61
Alcatraz Island, Golden Gate National Recreation Area (1998) (people at one time in cell house)	25.1	36.0	44	43.9	
Arches National Park					
Delicate Arch (1997) (people at one time)	12	33	37	49	67
North Window (1997) (people at one time)	8	23	23	30	47
Devils Garden (1997) (persons/viewscape)	6	13	13	8	23

action"-related norms are consistently and substantially higher than "preference"- and "acceptability"-based norms. Finally, the range of crowding-related norms developed in the literature based in alternative evaluative dimensions may be useful to researchers and managers as it facilitates a more comprehensive understanding of the prescriptive component of carrying capacity.

Beyond the Normative Approach

Data derived from the normative approach can be useful in helping managers formulate crowding-related standards of quality. However, such studies have also illustrated the complex nature of this research, as well as the strengths and weaknesses of normative theory and empirical techniques. In particular, conventional studies designed to estimate crowding-related norms may substantially underestimate such norms because these studies fail to explicitly (or even implicitly) introduce tradeoffs between the desire to avoid crowding and the desire to maintain reasonable public access to parks and wilderness.

Research on park and wilderness-related values might be strengthened through adaptation of alternative theoretical and empirical approaches, especially those that more explicitly address inherent tradeoffs in outdoor recreation. For example, indifference curve analysis developed in the discipline of economics, provides a model representing the tradeoff decisions an individual makes in allocating a fixed level of income between two consumer goods (Nicholson 1995). There are two primary components to the indifference curve model,

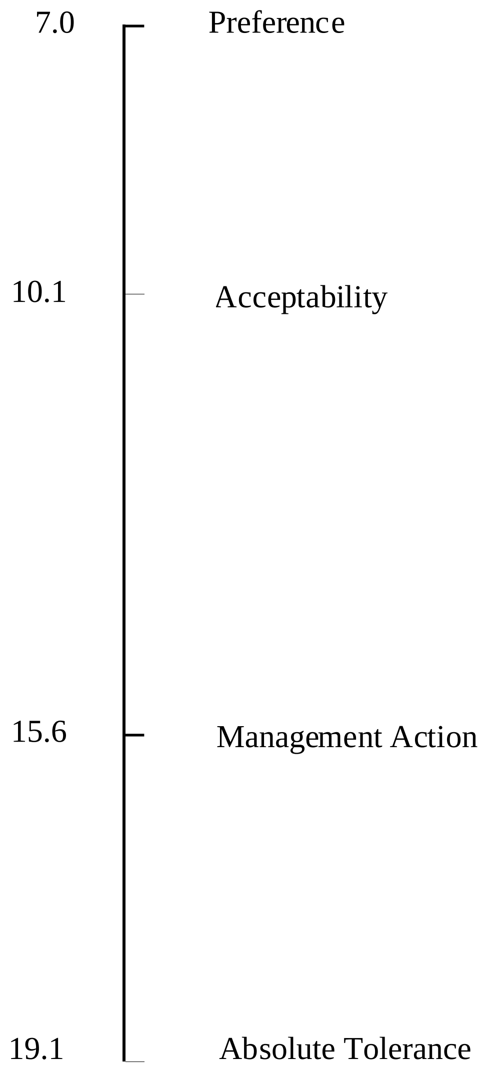

Figure 3—Relationships among alternative evaluative dimensions (taken from 1996 Acadia National Park community survey).

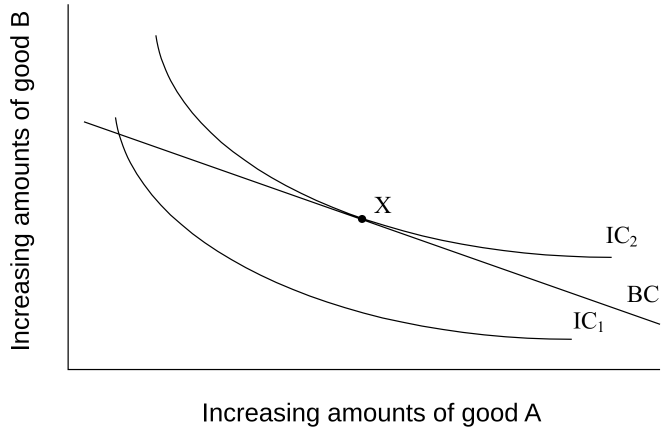

Figure 4—Indifference curve theory.

the individual's indifference curves and their budget constraint. A single indifference curve represents all possible combinations of two goods (for example, A and B) that provide the individual with the same level of utility (Pindyck and Rubinfield 1995). The curves labeled IC_1 and IC_2 in figure 4 are examples of indifference curves. The budget constraint represents the possible combinations of goods A and B the individual can purchase, assuming the individual spends all of his/her income (Pindyck and Rubinfield 1995). For example, the budget constraint labeled BC in figure 4 represents all possible combinations of the two consumer goods A and B, for a fixed income level.

According to indifference curve theory, the optimal combination of goods A and B for a given income is located where the budget constraint is tangent to one of the individual's indifference curves (Nicholson 1995). This represents the highest level of utility the individual can achieve from the consumption of goods A and B, given a fixed level of income. In figure 4, the optimal condition is represented by point X. A more complete discussion of indifference curve theory is represented in Lawson and Manning (2001a,b, in press a,b,c).

An initial application of indifference curve analysis to park and wilderness management was conducted within the context of social carrying capacity at Arches National Park, Utah, by substituting lack of crowding at Delicate Arch and accessibility to Delicate Arch for consumer goods (in other words, goods A and B in figure 4). Specifically, the number of people at Delicate Arch was substituted for good B along the y-axis, and the percent chance of receiving a hypothetical permit to hike to Delicate Arch was substituted for good A along the x-axis.

Indifference curves were estimated following a procedure adapted from MacCrimmon and Toda (1969). In this procedure, respondents are presented with a series of pairs of crowding and accessibility conditions. The first component of each pair of conditions is a fixed reference condition, against which respondents evaluate an alternative condition. Respondents are asked to indicate their preference within each pair of conditions they evaluate. In the Arches National Park example, respondents were asked to express their preference between a first set of conditions—having a 100 percent chance of receiving a permit to hike to Delicate Arch and seeing 108 people at Delicate Arch—and a second set of conditions—having a 50 percent chance of receiving a permit to hike to Delicate Arch and seeing 36 people at the Arch. Study methods are described more fully in Lawson and Manning (in press a,b,c).

Regression analysis was used to estimate an indifference curve for each respondent based on the data points derived from the respondents' evaluation of a series of access and crowding conditions at Delicate Arch. For each respondent, a hyperbolic, semilog, or quadratic curve was fit to the data points. The functional form for each individual indifference curve was selected based on the goodness of fit (R-square) of the regression equation, and the explanatory significance of the access variable (chance of receiving a permit) on the number of people at Delicate Arch.

A simulation model of visitor use at Arches National Park was used to estimate points defining the budget constraint, representing the possible combinations of visitor use levels and accessibility at Delicate Arch. Computer simulation models have been successfully applied to a variety of park and outdoor recreation areas (for example, Potter and Manning 1984; Wang and Manning 1999; Schechter and Lucas 1978). Additional information about the inputs used to develop the simulation model can be found in Lawson and Manning (in press a,b,c).

The simulation model was run at three levels of daily visitor use. The first level of use represented the Park's average daily use in the peak summer season, which was used as a proxy for a 100 percent chance of receiving a permit to hike to Delicate Arch. The second level of use was 50 percent of the Park's average peak daily use, which was used as a proxy for a 50 percent chance of receiving a permit to hike to Delicate Arch. The third level of use was 25 percent of the Park's average peak daily use, which was used as a proxy for a 25 percent chance of receiving a permit to hike to Delicate Arch.

For each use level, the model was run multiple times to account for variability in model parameters. The outputs from the simulation model runs were used to estimate the highest number of people any visitor would see at one time at Delicate Arch, for each of the three accessibility conditions. A linear budget constraint was estimated from the three resulting data points.

Lastly, each individual's indifference curve was mathematically adjusted to find the point where the indifference curve is tangent to the budget constraint. The point of tangency between the adjusted indifference curve and the budget constraint reveals the respondent's preferred combination of visitor use and accessibility, given the possible conditions at Delicate Arch.

Study data were gathered from a survey of 124 visitors to Delicate Arch in September of 1999. The study used computer-generated photographs representing a range of the number of visitors at one time at Delicate Arch (Manning and others 1996b). The survey was administrated on a lap top computer.

Study findings are shown in figure 5, which presents the percent of respondents with each of the preferred combinations of access and visitor use at Delicate Arch. The budget constraint for Delicate Arch is represented by the line labeled BC. Each point noted along the budget constraint represents a preferred combination of access and crowding at Delicate Arch for at least one respondent (the point of tangency between a respondent's indifference curve and the budget constraint). The number beside each point indicates the percent of respondents with the corresponding preferred combination of access and crowding. Data analysis and study findings are described in more detail in Lawson and Manning (in press a,b,c).

Study findings suggest that indifference curve analysis may provide a useful tool for park and wilderness managers to evaluate tradeoffs inherent in crowding and carrying capacity decisions. This research approach gathers data concerning crowding-related norms of visitors, but places such norms within a more realistic and applied management context regarding the tradeoffs inherent in such normative judgments.

Conjoint analysis represents another research approach to quantifying tradeoffs inherent in park and wilderness management. Conjoint analysis is a statistical procedure that has been developed in marketing research to measure

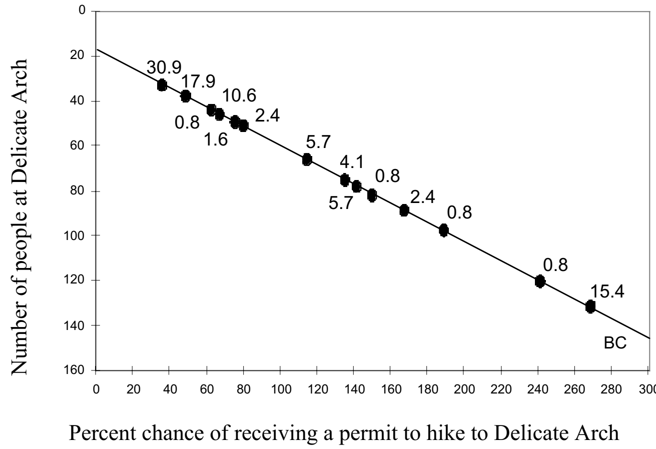

Figure 5—Findings from indifference curve analysis for Delicate Arch.

consumer preferences and tradeoffs among such preferences (Louviere 1988; Green and others 1988), and has recently been extended to applications in nonmarket and environmental policy contexts (Opaluch and others 1993; Dennis 1998). A standard research design involves assigning a range of performance levels to selected product or service attributes, then developing alternative scenarios that represent permutations of such attribute levels. Respondents then rate their preferences among scenarios and resulting data indicate which attributes are most important. In the context of park and wilderness recreation, indicators and standards of quality can be substituted for performance levels of product or service attributes (Lawson and Manning, in press a,b).

Conclusion

Crowding and carrying capacity are important issues in park and wilderness management, and they are likely to increase in urgency as the popularity of parks and wilderness continues to grow. Research on these issues, along with management experience, has developed a number of planning and management frameworks and research approaches for addressing these issues. It is clear from the literature that management of crowding and carrying capacity involves matters of both science and values, and that both of these elements must be integrated into "informed judgments" on the part of park and wilderness managers. That is, managers must ultimately make value-based judgments about the maximum acceptable levels of visitor-caused impacts to the resource base and the quality of the visitor experience. However, such judgments should be informed to the extent possible by scientific data on the relationships between visitor use and resulting impacts, and the degree to which park and wilderness visitors and other interest groups judge such impacts to be acceptable. Such information represents the "values of science" to managing crowding and carrying capacity in parks and wilderness.

A growing body of literature has begun to address the corresponding "science of values," and how this type of information might be integrated into park and wilderness management. Visitor-based research has employed normative theory and techniques to explore the acceptability of a range of social and biophysical impacts related to visitor use, and findings from these studies are being integrated into a body of knowledge and applied in management decisionmaking. Conceptual and methodological extensions of the normative approach are currently being explored in a variety of park and wilderness contexts, and new theoretical and empirical approaches are being adapted to address tradeoffs inherent in crowding and carrying capacity management. The science of values is progressing to meet the opportunities and challenges of the values of science to park and wilderness management.

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