Research to Estimate and Manage Carrying Capacity of a Tourist Attraction: A Study of Alcatraz Island

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Carrying capacity has been a long-standing issue in management of parks, outdoor recreation and tourism. Contemporary carrying capacity frameworks rely on formulation of indicators and standards of quality to define and manage carrying capacity. This paper describes a programme of research to support estimation and management of carrying capacity of Alcatraz Island, an historic site within Golden Gate National Recreation Area, California, USA, and a heavily visited tourist attraction. Research included: (1) a survey of visitors to Alcatraz Island to identify indicators and standards of quality for the visitor experience; and (2) development of a computer simulation model of visitor use to estimate maximum daily use levels without violating standards of quality. Study findings are used to estimate a range of carrying capacities for the prison cellhouse and for the island as a whole.

Carrying Capacity

The question of how much public use can be accommodated in a park or related tourist attraction is often framed in terms of carrying capacity. Indeed, much has been written, in both the scientific literature and popular press, about the carrying capacity of parks and related tourist attractions (e.g. Manning, 2001; Mitchell, 1994; Stankey & Manning, 1986; Wilkinson, 1995). The underlying concept of carrying capacity has a rich history in the natural resource professions. In particular, it has been applied in wildlife and range management where it refers to the number of animals that can be maintained in a given habitat (Dasmann, 1964). Carrying capacity has obvious parallels and intuitive appeal in the field of park and tourism management. However, the first rigorous applications of carrying capacity to management of parks and related areas did not occur until the 1960s.

These initial scientific applications suggested that the concept was more complex in this new management context. At first, as might be expected, the focus was placed on the relationship between visitor use and environmental conditions. The working hypothesis was that increasing numbers of visitors cause greater environmental impact as measured by soil compaction, destruction of vegetation and related variables. It soon became apparent, however, that there was another critical dimension of carrying capacity dealing with social aspects of the visitor experience. Wagar (1964), for example, in his early and
important monograph on the application of carrying capacity to outdoor recreation, reported that his study was initiated with the view that carrying capacity of recreation lands could be determined primarily in terms of ecology and the deterioration of areas. However, it soon became obvious that the resource-oriented point of view must be augmented by consideration of human values.

Wagar's point was that as more people visit a park or related area, not only can the environmental resources of the area be affected, but the quality of the visitor experience as well. Again, the working hypothesis was that increasing numbers of visitors cause greater social impacts as measured by crowding and related variables. Thus, as applied to parks and related tourist attractions, carrying capacity has two components: environmental and social.

The early work on carrying capacity has since blossomed into an extended literature on the impacts of visitor use and their application to carrying capacity (e.g. Graefe et al., 1984; Hammitt & Cole, 1998; Kuss et al., 1990; Lime & Stankey, 1971; Manning, 1985, 1999; Shelby & Heberlein, 1986; Stankey & Lime, 1973). But despite this growing scientific literature, efforts to determine and apply carrying capacity have sometimes failed. The principal difficulty lies in determining how much impact, such as crowding, is too much. Theoretical development, backed up by empirical research, generally confirms that increasing use levels and encounters among visitors leads to increased environmental and social impacts. But how much impact should be allowed? This basic question is often referred to as the 'limits of acceptable change' (Frissell & Stankey, 1972; Lime, 1970). Given substantial demand for public use of parks and related areas, some decline or change in the quality of natural/cultural resources and the visitor experience appears inevitable. But how much decline or change is acceptable or appropriate before management intervention is warranted?

![Figure 1 Hypothetical relationships between visitor use and crowding](image-url)
This issue is illustrated graphically in Figure 1. This figure addresses the social impact of crowding, and two hypothetical relationships between visitor use and crowding are shown. It is clear from both that visitor use and crowding are related: increasing numbers of visits cause visitors to feel increasingly crowded. However, it is not clear at what point carrying capacity has been reached. The hypothetical relationships in Figure 1 suggest that some crowding is inevitable, given even relatively low levels of visitor use. Thus, some level of crowding must be tolerated if parks and related tourist attractions are to remain open for public use. For the relationship defined by line A, X₁ and X₂ represent levels of visitor use that result in differing levels of crowding as defined by points Y₁ and Y₂, respectively. But which of these points – Y₁ or Y₂, or some other point along this axis – represents the maximum amount of crowding that is acceptable? Ultimately, this is a value judgement. Again, the principal difficulty in carrying capacity determination lies in deciding how much crowding (or of some other impact) is acceptable. Empirical relationships such as those in Figure 1 can be helpful in making informed decisions about carrying capacity, but they must be supplemented with other information and, ultimately, management judgements.

To emphasise and further clarify this issue, some writers have suggested distinguishing between descriptive and evaluative (or prescriptive) components of carrying capacity (Shelby & Heberlein, 1984, 1986). The descriptive component of carrying capacity focuses on factual, objective data such as the types of relationships in Figure 1. For example, what is the relationship between the number of visitors entering a park and the number of encounters that occur among groups of visitors? Or what is the relationship between the level of visitor use and visitor perceptions of crowding? The evaluative or prescriptive component of carrying capacity determination concerns the seemingly more subjective issue of how much impact or change in resource conditions and the quality of the visitor experience is acceptable. For example, how many contacts between visitor groups are appropriate? What level of perceived crowding should be allowed before management intervention is needed?

Recent experience with carrying capacity suggests that answers to the above questions can be found through formulation of management objectives and development of associated indicators and standards of quality (Graefe et al., 1990; Manning, 1997, 1998; Manning et al., 1998; National Park Service, 1997; Stankey et al., 1985). This approach to carrying capacity focuses principal emphasis on defining the degree of resource protection and the type of visitor experience to be provided and maintained, monitoring conditions over time, and adopting management practices to ensure that acceptable conditions have been maintained.

Management objectives are broad, narrative statements that define the degree of resource protection and the type of visitor experience to be provided. They are based largely on review of the purpose and significance of the area under consideration. Formulation of management objectives may involve review of legal, policy and planning documents; consideration by an interdisciplinary planning and management team; historic precedent; local, regional, national or international context of the park or related tourist attraction; and public involvement.

Indicators of quality are measurable, manageable variables that reflect the essence or meaning of management objects; they are quantifiable proxies or
measures of management objectives. Indicators of quality may include elements of both the biophysical and social environments. Standards of quality define the minimum acceptable condition of indicator variables.

An example of management objectives, indicators and standards may be helpful. Review of the US Wilderness Act of 1964 suggests that areas of the National Wilderness Preservation System are to be managed to provide opportunities for visitor solitude. Thus, providing opportunities for solitude is an appropriate management objective for most wilderness areas. Moreover, research on wilderness use suggests that the number of visitors encountered along trails and at campsites is important to wilderness visitors in defining solitude. Thus, trail and camp encounters may be good indicators of quality and help to make the general management objective of solitude more operational. Further research suggests that wilderness visitors may have normative standards about how many trail and camp encounters are acceptable before the quality of the visitor experience declines to an unacceptable degree (Heberlein et al., 1986; Lewis et al., 1996; Manning et al., 1996a, 1996b, 1999a; Roggenbuck et al., 1991; Shelby & Vaske, 1991; Vaske et al., 1986; Whittaker & Shelby, 1988). Such data may help define standards of quality.

By defining indicators and standards of quality, carrying capacity can be determined and managed through an associated programme of monitoring and management. Indicators of quality can be monitored and management actions taken to ensure that standards of quality are maintained. If monitoring suggests that standards of quality have been violated (or may soon be violated), then carrying capacity has been exceeded and management action is required. This basic approach to carrying capacity is central to contemporary park, recreation, and tourism management frameworks, including Limits of Acceptable Change (LAC) (Stankey et al., 1985), Visitor Impact Management (VIM) (Graefe et al., 1990), and Visitor Experience and Resource Protection (VERP) (National Park Service, 1997).

When and where feasible, the above approach to carrying capacity might be supplemented by computer simulation modelling. Computer simulation models of visitor use have been developed to estimate the relationship between visitor use levels and selected indicators of quality, such as the number of encounters among hiking groups (Manning & Potter, 1984; Potter & Manning, 1984; Schechter & Lucas, 1978; Smith & Krutilla, 1976; Wang & Manning, 1999). Such models could be used to estimate the maximum use level that could be accommodated in a park or related area without violating specified crowding-related standards of quality. In this way, carrying capacity could be estimated.

Research to Estimate Carrying Capacity of Alcatraz Island

This paper describes a programme of research to help estimate and manage carrying capacity of Alcatraz Island. The island is an historic site within Golden Gate National Recreation Area, a unit of the US National Park System, and is a heavily visited tourist attraction. It is located in San Francisco Bay and is widely known for its history as a federal prison for incorrigible criminals. This history has been romanticised and popularised in several books and movies. Consequently, demand to visit Alcatraz is high, visitation exceeds several hundred
thousand annually, and continues to grow rapidly. There is concern that visitation may exceed carrying capacity, and a programme of research was undertaken to help estimate and manage carrying capacity of the island. This programme of research was conducted to help apply the VERP framework noted above.

**Indicators and standards of quality**

Two components of research were conducted. The first focused on gathering data that would help formulate indicators and standards of quality for the visitor experience at Alcatraz Island. A survey of a representative sample of visitors was conducted in the summer of 1998. Visitors were selected as they completed their visit and waited to board a ferry to leave the island, and given a self-administered questionnaire to complete as they travelled back to San Francisco. The first five visitors in line for each returning ferry boat were selected and asked to participate in the survey. This yielded approximately 50 completed questionnaires for each of the sampling days. The survey was conducted on 17 randomly selected days during the peak use season (July, August and early September). The study questionnaire was printed in five languages – English, French, German, Italian, and Japanese – to help ensure that nearly all visitors could participate in the survey. The sampling plan resulted in 854 completed questionnaires.

The study questionnaire addressed both indicators and standards of quality. Indicators of quality were addressed through a series of open- and closed-ended questions. Open-ended questions probed respondents for what they enjoyed most and least about their visit to Alcatraz. Questions included ‘What did you enjoy most about your visit?’, ‘What did you enjoy least about your visit?’, and ‘If you could ask the National Park Service to improve some things about the way visitors experience Alcatraz Island, what would you ask managers to do?’. Close-ended questions asked respondents to rate the seriousness of several potential problem issues. These issues included ‘the number of visitors on the island’, ‘the number of visitors on the ferry’, ‘the number of visitors on the tour of the prison cellhouse’, ‘the number of visitors in the bookstores/gift shops’, ‘visitors making too much noise’, and ‘visitors not following rules and regulations’. A three-point response scale was used that ranged from 1 (‘not a problem’) to 3 (‘big problem’).

Standards of quality focused on crowding-related issues. Specifically, a series of questions measured crowding norms for the prison cellhouse, the principal visitor attraction. Since use levels are relatively high in the prison cellhouse, a visual approach was used to measure crowding norms (Manning et al., 1996a). A series of computer-edited photographs was prepared for the ‘Michigan Avenue’ corridor of the prison cellhouse (an intergal part of the cellhouse) showing a range of visitor use levels or ‘people-at-one-time’ (PAOT). Study photographs are shown in Figure 2. Respondents were asked to rate the acceptability of each photograph on a scale that ranged from −4 (‘very unacceptable’) to +4 (‘very acceptable’). In addition, respondents were asked to judge the photographs using two other dimensions of evaluation (Manning et al., 1999a). These included ‘preference’ (‘Which photograph shows the level of use that you would prefer to experience in the cellhouse?’) and ‘management action’ (‘Which photograph shows the highest level of use that the National Park Service should allow in the cellhouse? In other words, at what point should visitors be restricted from
touring the cellhouse?'). Finally, respondents were asked 'Which photograph looks most like the number of visitors you typically saw on your tour of the cellhouse today?'

**Computer simulation model**

The second component of research focused on developing a computer-based simulation model of visitor use at Alcatraz Island. The primary purpose of the model was to determine the relationship between the number of visitors and potential standards of quality for the maximum PAOT in Michigan Avenue of the cellhouse. In this way, carrying capacity could be estimated in relationship to crowding-related standards of quality for the cellhouse. The model was constructed using the commercial object-oriented dynamic simulation package, Extend, developed by Image That, Inc. Model input was based on detailed visitor counts and observations, including number of visitors per ferry, frequency of
ferries, length of time between debarkation of visitors on the island and their arrival into the cellhouse audiotour ticket line, time spent in the cellhouse audiotour ticket line, and time spent touring the cellhouse.

The structure of the model was built with hierarchical blocks that represented specific components of the Alcatraz Island visitor system. A block labelled ‘Dock’ generated simulated visitor groups as they disembarked from ferry boats. A block labelled ‘Up the Hill’ represents the time that visitors take to walk from the dock to the prison cellhouse. Blocks labelled ‘Audio Tour Line’ and ‘Cashier’ represent the time visitors spend in line waiting to enter the prison cellhouse and purchase their audio tour tape and player. Blocks labeled ‘Tour Beginning’, ‘Tour Middle’ and ‘Michigan Avenue’ represent the time that visitors take to proceed through sections of the tour of the prison cellhouse. The data used to build and operate these blocks were derived from the detailed counts and observations of visitor use described above. More detailed information on this approach to simulation modelling and its application to outdoor recreation and tourism can be found in Lawson and Manning (2002), Wang and Manning (1999), and Wang et al. (2001).

A short survey was also administered to 187 visitors as they completed the cellhouse audiotour to determine the relationship between PAOT in Michigan Avenue as reported by visitors using the computer-edited photographs and the actual PAOT in Michigan Avenue as estimated by the simulation model.

Study Findings: Estimates of Carrying Capacity

The sample of visitors to Alcatraz Island was characterised by the following socioeconomic and demographic descriptors:

- Most visitors come in small groups of family and friends.
- Most visitors (71%) are from the United States, with 46 states and Washington, DC represented among the sample. A plurality of visitors are from California.
- A sizable minority of visitors (29%) are from outside United States, with 30 countries represented among the sample. A plurality of international visitors are from the United Kingdom.
- The vast majority of visitors (82%) report that English is their ‘first’ or ‘native’ language. Among those who did not report English as their first or native language, the vast majority (86%) reported that they understood English either ‘very well’ or ‘pretty well’.
- Visitors stay on Alcatraz Island an average of about two hours.
- The vast majority of visitors (86%) are visiting Alcatraz Island for the first (and probably only) time.
- Nearly all visitors (93%) took the audiotour of the prison cellhouse.

Indicators and standards of quality

The first component of research yielded information on potential indicators and standards of quality for the visitor experience at Alcatraz Island. Responses to open-ended questions were coded verbatim, and then grouped into similar categories. Frequency distributions and mean values were calculated for responses to close-ended questions. Based on this analysis, the number of
Figure 3 Norm curve

Table 1 Alternative crowding-related norms (PAOT) for Michigan Avenue

<table>
<thead>
<tr>
<th>Preference</th>
<th>Acceptability</th>
<th>Management Action</th>
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<tr>
<td>25</td>
<td>44</td>
<td>44</td>
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visitors in the prison cellhouse emerged as especially important in defining the quality of the visitor experience at Alcatraz. The vast majority of respondents (75%) reported that the audiotour of the cellhouse was the element of their experience that they enjoyed the most. Moreover, the number of visitors on the tour of the cellhouse was rated by respondents as the most problematic of six potential issues on the island; 54% reported that this was either a 'big problem' or a 'small problem'. Thus, the number of visitors in the cellhouse is a good indicator of quality in that it is measurable, manageable, and important in defining the quality of the visitor experience.

Data on standards of quality for the number of people in the cellhouse are shown in Figure 3 and Table 1. Figure 3 graphs the average acceptability ratings for the six study photographs. As this ‘norm curve’ illustrates, 44 PAOT in Michigan Avenue represents a threshold of acceptability – the point at which aggregate sample ratings fall out of the acceptable range and into the unacceptable range. Table 1 reports summary findings for all three evaluative dimensions explored – ‘acceptability’, ‘preference’, and ‘management action’. Respondents would prefer to see an average of 25 PAOT in Michigan Avenue, think the
Figure 4 PAOT in Michigan Avenue over the minutes of a simulated day

National Park Service should allow a maximum of 44 PAOT, and (as noted above) would find a maximum of 44 PAOT to be acceptable. These data suggest a potential range of crowding-related standards of quality. Neither of the points defining this range (25 to 44), nor any of points along this range, are necessarily any more ‘valid’ than any other. Each point has potential strengths and weaknesses. For example, standards of quality based on preference-related norms may result in very high quality visitor experiences but would restrict access to a relatively low number of visitors. In contrast, standards of quality based on acceptability or management action allow access to a greater number of visitors but may result in visitor experiences of lesser quality. Findings that offer insights into multiple evaluative dimensions provide a potentially rich base of information and may lead to formulation of the most thoughtful and informed standards of quality. Such data allow more explicit understanding of the potential tradeoffs between use level and quality of the visitor experience.

Computer simulation model

The second element of research developed a computer-based simulation model of visitor use at Alcatraz Island. The model was used to estimate the maximum total daily use levels (i.e. daily carrying capacities) that could be accommodated without violating the normative crowding standards shown in Table 1. Model output could be generated in several graphic and numerical forms. For example, Figure 4 traces minute-by-minute PAOT levels in Michigan Avenue over the duration of a simulated day. This particular model run was generated using an average summer day total use level of 4464 visitors (derived from the counts of visitor use taken to construct the model). It can be seen from the graph that the number of visitors in Michigan Avenue fluctuates between about 50 and about 90 throughout most of the day. The model was ultimately run multiple times (to ‘average out’ the randomness associated with each individual model run) to estimate the maximum total daily use levels that could be
Table 2 Alternative daily carrying capacities of Alcatraz Island

<table>
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<tr>
<th>Standards of quality</th>
<th>Daily carrying capacity</th>
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</thead>
<tbody>
<tr>
<td>Preference (25 PAOT)</td>
<td>2560</td>
</tr>
<tr>
<td>Acceptability (44 PAOT)</td>
<td>4800</td>
</tr>
<tr>
<td>Management action (44 PAOT)</td>
<td>4800</td>
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</tbody>
</table>

accommodated on the island without violating each of the crowding-related norms shown in Table 1 more than 10% of the time, and findings are shown in Table 2. (This 10% allowance is discussed later in the paper.) It is clear from Table 2 that there is a range of daily carrying capacities (from approximately 2500 visitor per day to approximately 4800 visitors per day) for Alcatraz Island depending upon the crowding-related standard of quality that is selected. A daily carrying capacity could be implemented relatively easily through management of the ferry system serving the island.

As noted earlier, a short survey was also administered to 187 visitors as they completed their audiotour of the cellhouse. Visitors were asked to select one of the study photographs of Michigan Avenue (described above) that looked most like the PAOT they typically saw at this location. The PAOT in the photographs selected by respondents averaged 35. The simulation model estimates that on the days when the survey was conducted there was an average of 70 PAOT in Michigan Avenue. This suggests there is a 2 to 1 ratio of the actual PAOT in Michigan Avenue and the number of people that can be seen at any one time. This is due to the fact that people in the foreground and middle ground tend to obscure some people in the middle ground and background. Thus, the crowding-related norms derived by the photographs underestimate the actual PAOT that can be accommodated in Michigan Avenue by about half. That is, if visitors report that a maximum of 44 PAOT is acceptable in Michigan Avenue (the PAOT visitors find acceptable to see), then there can actually be approximately 88 PAOT in Michigan Avenue.

A final analytical approach used in this study employed the computer simulation model of visitor use to explore the effect of alternative ferry schedules on carrying capacity. Currently, ferries depart San Francisco for Alcatraz Island every half hour from 9:30 a.m. to 5:30 p.m. If ferry departures were reduced to every hour, daily carrying capacity would also be substantially reduced. Relatively large numbers of visitors arriving at the same time would result in many visitors seeing relatively large PAOT's in Michigan Avenue. For example (as reported in Table 2), using the acceptability and management action standards of quality of 44 PAOT, the computer simulation model estimates that approximately 4800 visitors per day could be accommodated on Alcatraz Island without violating that standard of quality more than 10% of the time. This analysis is based on the existing ferry schedule of departures every half hour. However, when ferries depart only every hour, the computer simulation model estimates that only 3200 visitors per day could be accommodated without violating the 44 PAOT standard of quality more than 10% of the time. Similarly,
for the preference based standard of quality, daily carrying capacity drops from approximately 2500 visitors per day under the existing ferry schedule to approximately 1840 visitors per day under the reduced ferry schedule. Comparable increases in carrying capacity are not possible in this case by increasing the frequency of ferry service beyond the existing schedule. For example, increasing the frequency of departures to every 15 minutes would increase acceptability and management action based carrying capacity from approximately 4800 visitors per day (under existing ferry service) to approximately 4896 visitors per day, and would increase preference based carrying capacity from approximately 2560 visitors per day to approximately 2656 visitors per day.

Discussion

The programme of research described in this paper raises a number of issues regarding estimation and management of carrying capacity of parks and related tourist attractions. As noted at the beginning of this paper, an emerging principle of carrying capacity is that decision-making must be guided by management objectives and associated indicators and standards of quality. A corollary of this principle is that there is no one inherent carrying capacity of a park or tourist attraction. Rather, each park or tourist attraction (or even site within such an area) has a range of capacities depending upon the degree of resource protection and type of visitor experience to be provided.

Data developed in this study illustrate this point. The number of people encountered (PAOT) in the prison cellhouse is a potentially good indicator of quality. Study findings show that nearly all visitors take the audiotour of the prison cellhouse, and feel this is the highlight of their visit. However, there are indications that visitors are concerned with growing use levels in the cellhouse. Visitors rated crowding in the cellhouse as the most problematic of several visitor-related issues. Moreover, visitor perceptions of current use levels in the cellhouse are approaching the maximum PAOT judged acceptable (as reported in Table 2). Finally, visitors rated the prison cellhouse as 'somewhat crowded' (an average of 4.2 on a 9-point crowding scale that ranged from 1 ('not at all crowded') to 9 ('extremely crowded')), and this represented the highest level of crowding for any location on the island. However, standards of quality for this indicator vary substantially, depending upon the evaluative dimension used in the study (i.e. the type of visitor experience). Crowding norms ranged from a low associated with 'preference' (a very high quality experience) to a high associated with 'acceptability' and 'management action' (a lower quality experience). The carrying capacity of the prison cellhouse, and ultimately Alcatraz Island as a whole, varies accordingly.

A related principle of carrying capacity is that some element of management judgement must be exercised. Again, the data developed in this study illustrate this principle. What point (or points) along the range of standards of quality and associated carrying capacities should be selected for management purposes? This is ultimately a judgement that should consider a variety of other factors inherent in carrying capacity, including the purpose and significance of the area (as may be defined in law or policy), the fragility of natural and/or cultural resources, financial and/or personnel resources available for management,
historic precedent, and interest group politics. Management judgements about standards of quality and associated carrying capacities are not necessarily ‘either/or’ decisions. In fact, it may be highly desirable to provide a spectrum of visitor opportunities within a park or tourist attraction, among such sites within a region, and/or over time.

Even though management judgements must ultimately be rendered in determining and managing carrying capacity, such judgements must be as ‘informed’ as possible. The data reported in this study offer an empirical foundation for such judgements. Study data suggest PAOT standards in Michigan Avenue in the range of 25 to 44, depending on the evaluative dimension used. Additional study data and other considerations may suggest a standard of quality in the high end of this range. First, the low end of this range is associated with visitor ‘preferences’ and does not include explicit consideration by respondents of the tradeoffs between crowding (or lack of crowding) and maintaining reasonable public access to Alcatraz. In contrast, the upper end of this range is associated with the use level visitors feel the National Park Service ‘should allow’, and is more explicitly informed by tradeoffs between crowding and public access. (The question asked visitors to select the photograph that represented the point at which visitors should ‘be restricted from touring the cellhouse’.) This issue is reinforced by two other sets of questions that addressed tradeoffs between crowding and access. Visitors were asked to rate the importance (on a five-point scale ranging from 1 (‘very important’) to 5 (‘very unimportant’)) of crowding (defined as the ‘ability to visit Alcatraz Island without it being crowded’) and availability of tickets to visit the island (defined as the ‘ability to get a ticket when wanted’). These attributes were judged to be nearly equally important (average importance ratings of 1.76 and 1.82 respectively). Visitors were also asked to allocate 10 ‘points of importance’ between crowding and access. Once again, both issues were judged to be important, with crowding receiving an average of 5.4 ‘points of importance’ and access receiving an average of 4.6.

Second, public demand to visit Alcatraz Island is very high, and it may be unrealistic and ultimately unacceptable to greatly restrict public access to achieve a very low level of crowding. Third, the crowding norms measured in this study are slightly underestimated. A small number of respondents (between 28 and 30, depending on the question) reported that all of the study photographs were acceptable or that the National Park Service should not limit use at any point represented in the study photographs. These responses could not be included mathematically in the values reported in Table 2. Fourth, current use levels are perceived by respondents to be about 41 PAOT in Michigan Avenue, and visitors reported feeling ‘somewhat crowded’. This suggests that use levels could be at least a little higher without causing very high levels of perceived crowding. Fifth, since current use levels average near the high end of the range of potential standards of quality, it may be politically unrealistic to set standards near the low end of the range. Sixth, most visitors to Alcatraz are first-time visitors, and many live outside California and even outside the US. This suggests that for many visitors, this may be their only realistic opportunity to visit Alcatraz, and management decisions about crowding should be made in light of strong public demand to visit the island. Finally, overall visitor enjoyment of Alcatraz Island is very high despite some degree of crowding in the prison
cellhouse. For example, using a response scale from 1 ('strongly agree') to 5 ('strongly disagree') visitors were asked the extent to which they agreed or disagreed with the statement 'I enjoyed my visit to Alcatraz Island'. The average score was 1.52. This suggests that management decisions about carrying capacity of Alcatraz Island should not be made exclusively on the basis of crowding in the prison cellhouse.

As noted above, it may be wise to consider a range of standards of quality and associated carrying capacities for Alcatraz Island. Since the island is relatively small and the prison cellhouse is the 'icon' visitor attraction, it may not be feasible to do this in a spatial or geographic way. However, alternative standards of quality and associated carrying capacities could be established on a temporal basis. For example, a relatively high carrying capacity could be established for the summer peak visitor use season and a lower carrying capacity during the off seasons. Moreover, the National Park Service has recently begun special evening tours of the island, and these could be managed to a different standard of quality, thereby providing a diversity of visitor experiences.

Finally, study findings illustrate that carrying capacity can be influenced by alternative management practices. For example, the frequency of ferry departures can substantially affect daily carrying capacities.

The programme of research described in this paper relies on several distinctive methodological approaches. First, visitor surveys provide the empirical foundation for the indicators and standards of quality developed, and the carrying capacities ultimately derived. This is important as it involves those who are most directly interested in this site and who have much to gain or lose as a result of management decisions. It may be wise, when and where feasible, to expand this research to other interest groups as well, including residents of local communities and even the general population (Manning et al., 1999a).

Second, a visual approach is used to measure crowding-related norms. A visual approach may be more realistic and 'valid' than conventional narrative and numeric approaches (i.e. asking respondents to evaluate encountering selected numbers of other people), especially in relatively high use contexts (Manning et al., 1999a). Research suggests that visitors may process some encounters with other people at a subconscious level, especially when such people are perceived to be 'like' the respondent in terms of recreation activity, behaviour, and other appearance. A visual approach to measuring crowding norms allows for subconscious processing, while narrative/numerical approaches call explicit attention to all persons encountered. When and where feasible, visual approaches might be extended to normative evaluation of other recreation-related impacts such as resource impacts to trails and campsites, litter, vandalism and graffiti.

Third, multiple evaluative dimensions (preference, acceptability, and management action) were employed in asking respondents to evaluate alternative use levels. Resulting data are complex, but provide empirical, detailed insights into how visitors feel about alternative use levels, including how use levels affect the quality of the visitor experience, and tradeoffs visitors might make between avoiding crowding and maintaining reasonable public access to parks and related tourist attractions (Lawson & Manning, 2001; Manning et al., 1999a).

Fourth, computer simulation modelling was used to estimate carrying capacities. Contemporary carrying capacity frameworks such as LAC and VERP
suggest that carrying capacity is determined through monitoring of indicators of quality. When monitoring suggests that standards of quality have been violated, carrying capacity has been reached. However, computer simulation modelling allows estimation of visitor use levels (i.e. carrying capacities) that will violate selected standards of quality. This facilitates a more proactive approach to defining and managing carrying capacity, and enables estimates of carrying capacity under alternative management scenarios such as more or less frequent ferry schedules.

Clearly, the programme of research described in this paper has important limitations. First, it addresses social carrying capacity only. The resource component of carrying capacity noted at the beginning of this paper also needs research and management attention. However, the methodological approaches outlined above may have some application to the resource component of carrying capacity, or at least the interaction between these components. For example, recreation impacts to soil and vegetation at campsites have a potentially important aesthetic component, and the visual approach to measuring normative standards for such impacts may be useful in formulating standards of quality for these resource-related indicators of quality.

Second, even within the social component of carrying capacity, this study addresses only crowding-related indicators and standards of quality. The visitor survey conducted at Alcatraz Island suggests the importance of crowding-related indicators, but also suggests other potential indicators of quality such as noise, availability of information/education about the island, and visitor compliance with rules and regulations. Expanded treatment of other potential indicator variables and associated standards is warranted.

Third, estimation of carrying capacities from the computer simulation model allowed for standards of quality to be violated up to 10% of the time. This allowance was factored into modelling because it may not be reasonable to prescribe that standards of quality will 'never' be violated. Visitor use of parks and related tourist attractions has an inherent random element that tends to result in occasional peaks or spikes of activity and associated encounters. The graph in Figure 4 tracing minute-by-minute PAOT levels in Michigan Avenue is representative. Occasionally, by happenstance, a number of visitor groups may arrive at an attraction site simultaneously, and this may result in isolated spikes in PAOT levels. Total use levels would have to be kept very low to ensure that these spikes never (or rarely) occur, and this may not serve public interests for reasonable access to parks and related tourist attractions. A 10% allowance was adopted in this study, but this figure was arbitrarily chosen. Additional research is warranted to derive a more empirically sound basis for specifying this allowance.

Finally, it should be noted that the concept of carrying capacity of parks and related tourist attractions has been controversial. Carrying capacity has been variously characterised as 'slippery' (Alldredge, 1973), 'elusive' (Graefe et al., 1984) and 'illusive' (Becker et al., 1984). In fact, a recent special issue of the Journal of Sustainable Tourism Vol. 9, No. 5 was devoted to assessing the complexity of carrying capacity and related topics. However, there is emerging consensus that management-by-objective approaches, such as the VERP framework, are most appropriate for analysing and managing carrying capacity (Manning, 2001; McCool & Lime, 2001). There remains disagreement on some
aspects of carrying capacity, including the ability to specify a numerical carrying capacity (McCool & Lime, 2001). However, in the case of this study of Alcatraz Island, numerical carrying capacities are thought to be justified because (1) the primary indicator of quality of the visitor experience is the number of other visitors in the prison cellhouse, and (2) a computer simulation model of visitor use was developed to estimate the maximum daily use level of Alcatraz without violating standards for this indicator variable.

Conclusions

The programme of research described in this paper was designed to support application of the concept of carrying capacity to Alcatraz Island, an historic site within the US National Park System, and an important tourist attraction. In particular, it was designed to provide an empirical foundation for application of the contemporary carrying capacity framework, VERP. Study findings suggest a potentially important crowding-related indicator of quality (PAOT within the prison cellhouse), a range of potential standards for this indicator variable, and associated carrying capacities for the prison cellhouse and the Island as a whole. Management judgements will still have to be rendered in choosing among alternative standards of quality and associated carrying capacities (or perhaps more than one standard and carrying capacity to facilitate a diversity of visitor opportunities at the island). However, study data help to provide an informed basis for such management judgements.

Within the field of parks and outdoor recreation, the concept of carrying capacity has traditionally been applied to resource-based parks and related areas. Nevertheless, the research described in this paper suggests that contemporary, indicator-based carrying capacity frameworks such as LAC and VERP, along with an associated programme of research, can be applied to heavily used historic sites and tourist attractions that include significant elements of the built environment. In such cases, indicators of quality may vary from those conventionally used in outdoor recreation, such as the number of encounters with other groups along trails per day and resource impacts to trails and campsites. Recent and current research, for example in highly developed, urban recreation areas, suggests that visitors are concerned with crowding and other recreation-related impacts, but that these impacts are manifested in other ways. For example, a potential indicator of quality for the visitor experience at Statue of Liberty National Monument is the time required to wait in line to enter the Statue (Manning et al., 1999b), and potential indicators of quality for the visitor experience at Boston Harbor Islands National Recreation Area include the amount of litter, vandalism and graffiti seen (Manning et al., 2001). Application of carrying capacity frameworks and associated programmes of research should be expanded to a full spectrum of parks and related tourist attractions to ensure protection of their resource base and the quality of the visitor experience.

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