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Understanding and Managing Experiential Aspects of Soundscapes at Muir Woods National Monument

Ericka J. Pilcher · Peter Newman · Robert E. Manning

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Abstract Research has found that human-caused noise can detract from the quality of the visitor experience in national parks and related areas. Moreover, impacts to the visitor experience can be managed by formulating indicators and standards of quality as suggested in park and outdoor recreation management frameworks, such as Visitor Experience and Resource Protection (VERP), as developed by the U.S. National Park Service. The research reported in this article supports the formulation of indicators and standards of quality for human-caused noise at Muir Woods National Monument, California. Phase I identified potential indicators of quality for the soundscape of Muir Woods. A visitor "listening exercise" was conducted, where respondents identified natural and human-caused sounds heard in the park and rated the degree to which each sound was "pleasing" or "annoying." Certain visitor-caused sounds such as groups talking were heard by most respondents and were rated as annoying, suggesting that these sounds may be a good indicator of quality. Loud groups were heard by few people but were rated as highly annoying, whereas wind and water were heard by most visitors and were rated as highly pleasing. Phase II measured standards of quality for visitor-caused noise. Visitors were presented with a series of 30-second audio clips representing increasing amounts of visitor-caused sound in the park. Respondents were asked to rate the acceptability of each audio clip on a survey. Findings suggest a threshold at which visitor-caused sound is judged to be unacceptable, and is therefore considered as noise. A parallel program of sound monitoring in the park found that current levels of visitor-caused sound sometimes violate this threshold. Study findings provide an empirical basis to help formulate noise-related indicators and standards of quality in parks and related areas.

Keywords Soundscapes · Noise · Visitor-caused noise · Indicators and standards · Muir Woods National Monument

E. J. Pilcher
National Park Service, Natural Sounds Program, 1201 Oakridge Drive, Suite 100, Fort Collins, CO 80525, USA
e mail: ericka pilcher@partner.nps.gov

P. Newman (✉)
Department of Human Dimensions of Natural Resources, Warner College of Natural Resources, Colorado State University, 233 Forestry Building, Fort Collins, CO 80523, USA
e mail: pnewman@cnr.colostate.edu
URL: http://www.warnercnr.colostate.edu/NRRT/people/peter.htm

R. E. Manning
Rubenstein School of Environment and Natural Resources, Recreation Management Program, University of Vermont, 356 George D. Aiken Center, Burlington, VT 05405, USA

Introduction

A growing body of research has documented the potential environmental impacts of outdoor recreation in national parks and related areas (Hammitt and Cole 1998; Leung and Marion 2001). These impacts apply to multiple components of the landscape including soil, vegetation, water, and wildlife. Impacts can degrade the quality of the environment and can also diminish the quality of the visitor experience through their aesthetic implications (Manning and others 2004). The research reported in this article extends this body of work to "soundscapes," and focuses on how the aural impacts of outdoor recreation and other sources of noise can affect the quality of the visitor experience in parks and related areas.

Because human-caused noise can interfere with ecological systems and visitor enjoyment in parks, the U.S. National Park Service (NPS) has been measuring natural ambient sounds and intruding noise levels at national parks for over twenty years. However, researchers face several challenges when measuring and evaluating appropriate soundscapes for park settings. Procedures to measure noise intrusions have been based on audibility considerations and acoustic energy measurements; however mangers must also consider how visitors perceive soundscapes and how sounds affect their experience (Downing and Hobbs 2005; Downing and Stunsick 2000; NPS 2000). Although it is important to capture acoustical measurements, few studies have been able to connect those measurements to visitor response data (Krog and Engdahl 2005). Therefore, more work is warranted in order to build tools that can measure acoustical data and assess resulting impacts on visitors. This article addresses this problem and links acoustic research and visitor evaluation by using a dose-response study at Muir Woods National Monument, California (Muir Woods).

Dose-response methodology refers to the process of estimating the amount of noise (the dose) an individual was exposed to, and then documenting the individual's response (either cognitive or behavioral) to that dose of noise (Fidell and others 1996). The organizational framework of indicators and standards of quality was used to help guide this research (this framework is described more fully in the next section). In addition, acoustical measurements were collected by the NPS Natural Sounds Program Office and were used for comparative analysis in this study. Phase I research identified potential indicators of quality by determining the sounds that visitors heard at Muir Woods and measured the degree to which those sounds were judged by visitors to be pleasing or annoying. Phase II research identified potential standards of quality by measuring the degree to which a range of human-caused sounds (one of the principal indicator variables identified in Phase I) were judged as acceptable by park visitors.

In this article, soundscapes have been defined as the composite of all sounds at a specific locale, as perceived by park visitors. This definition is currently being used by the NPS Natural Sounds Program Office. "Noise" is an essential concept for this article, but the term is inconsistently used and defined, even in the field of acoustics. Noise is often used as a synonym for sound. In this article, noise has been defined using the Dictionary of Acoustics, and is distinguished as sound that is extraneous or undesired (Morfey 2001). Extraneous sounds can be eliminated without compromising any activities or values; they are not pertinent or essential to the activity. However, the desirability of sounds is intrinsically personal and dependent on context; one visitor's intentionally produced sounds may be noise in terms of impacts to park resources or another visitor's experience. In particular, human-caused noise can mask the sounds of nature and detract from the quality of the visitor experience. "Natural quiet" the sounds of nature uninterrupted by human-caused noise has been identified by Congress and the National Park Service as an important resource in national parks that must be protected (NP Overflights Act of 1987; NP Air Tour Management Act of 2000; NPS Management Policies 2006).

Indicators and Standards

This study was designed to extend our understanding of soundscapes in national parks and related areas and to help manage experiential aspects of soundscapes with the development of indicators and standards of quality. (Stankey and others 1985; National Park Service 1997; Manning 2001). Indicators and standards have emerged in the scientific and professional literature as a guide to formulating management policies for parks and outdoor recreation (Shelby and Heberlein 1986; Vaske and others 1993; Manning 1999). For example, indicators and standards are fundamental elements of park and outdoor recreation carrying capacity and related planning/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; Manning 2001). Indicators of quality are measurable, manageable variables and are quantifiable proxies or measures of management objectives. Indicators of quality may include elements of both the natural and social environment that are important in determining the quality of the visitor experience. An example of a soundscape indicator would be the percent of time that human noises are audible. Standards of quality define the minimum acceptable condition of indicator variables. An example of a soundscape standard would be that human noise should be audible for only 50 percent of the day. Parks can be managed by formulating indicators and standards, monitoring indicator variables, and taking management actions designed to maintain standards (Manning 1999).

Research can help support the application of this management approach in several ways, including providing an empirically informed basis for identifying indicators and formulating standards. Qualitative and quantitative research designs, including interviews with visitors and other stakeholders, and visitor surveys that employ open and close-ended questions, have been used to help identify potential indicators (Manning 2007). Research on formulating standards has relied primarily on normative theory and related empirical methods (Vaske and Whittaker 2004;

Shelby and Vaske 1991; Shelby and others 1996; Vaske and others 1986; Manning 1999; Manning 2007). In this approach, visitors and/or other stakeholders are asked to evaluate the acceptability (or other evaluative dimensions) of a range of resource and experiential conditions (Manning and others 1997). The personal norms of visitors are then aggregated to test for the existence of social norms, or the degree to which norms are shared across social groups. A common analytical approach is to plot the average acceptability ratings for a range of resource and experiential conditions to derive a "social norm curve." Resulting data can be used to help guide formulation of standards (Vaske and others 1986; Manning 1999).

Dose-Response Studies

Dose-response studies have been used in a variety of soundscape studies and some have proven useful in developing soundscape standards (Sutton 2001). For example, a dose-response study conducted at Westland National Park, New Zealand investigated the social impacts of aircraft overflights in terms of annoyance. Results suggested that standards could be set when respondent levels of annoyance reached unacceptable levels (Sutton 2001). Most dose-response studies have focused on respondent reactions to aircraft noise (Aasvang and Engdahl 1999; Booth 1999; Fidell and Silvati 2004; Hunt 1999; Krog and Engdahl 1999; Krog and Engdahl 2004; Krog and Engdahl 2005; Miller 1999; Sutton 2001; Tarrant and others 1995). For example, Fidell and others (1996) used on-site and telephone surveys to assess annoyance due to aircraft noise in wilderness areas and reported the relationship between noise and annoyance. Noise-induced annoyance was found to be a robust measure capable of producing predictable reactions of visitors in wilderness and related areas. Dose-response studies have also been conducted at Grand Canyon, Hawaii Volcanoes, and Haleakala National Parks (Miller 1999). Dose-response measures were useful for mangers because they provided guidance that could be used for developing limits that would minimize interference to natural quiet.

Noise

Noise issues in parks and related areas are an outgrowth of societal concerns over noise more broadly (Berglund and Lindvall 1995; Marquis-Favre and others 2005b). A growing body of research has begun to document the effects of prolonged exposure to loud noise on humans (Staples 1996; Staples 1997; Hatfield and others 2002; Ulrich and others 1991; Ouis 2001). Noise pollution can affect the physical and mental wellbeing of people through psychological annoyance, interference with speech, interruption of sleep, disruption of cognitive processes, temporary or permanent hearing disorders, and negative impacts to the cardiovascular and endocrine systems (Gramann 1999). For example, laboratory studies have shown that duration, intensity, and type of noise can increase blood pressure in humans (Marquis-Favre and others 2005a). Noise is a danger to human health by causing both physical and psychological stress (Ouis 2001). Although people may try to ignore noise, the human ear is continuously processing and transmitting information to the nervous system, thus causing a reaction from the body. In one representative study, participants indicated problems sleeping, relaxing, reading, studying and watching TV due to noise sources inside buildings or caused by neighbors (Wallenius 2004).

Soundscapes in Parks and Outdoor Recreation

Although a variety of studies have documented human response to noise in general, the effects of noise on the visitor experience in parks and outdoor recreation has been the subject of a limited body of research. However, related studies have shown that quiet, solitude, and natural sounds are important in helping to define the quality of visitor experiences in parks (see Gramann 1999 for a review paper). For example, park visitors often report that escaping noise and enjoying the sounds of nature are among the most important motivations for visiting parks and related areas (Driver and others 1991). In fact, a national study found that 72% of Americans surveyed regarded opportunities to experience natural quiet and the sounds of nature as a very important reason for preserving national parks (Haas and Wakefield 1998). In another survey specific to park visitors, 91% of respondents considered enjoyment of natural quiet and the sounds of nature as compelling reasons for visiting national parks (McDonald and others 1995).

Research focusing on the impacts of noise in national parks and related areas was uncommon until passage of the National Parks Overflights Act of 1987 (Public Law 100-91, Gramann 1999). Most of the research spawned by this legislation has examined the issue of noise generated by aircraft, particularly the activity of commercial air tours or "flight seeing" (Wu and others 1995; Anderson and others 1993; HMMH/HBRS 1994; Miller 1995; HBRS/HMMH 1993; Stewart 1997). For example, a 1992 survey in 39 units of the national park system found that an average of about 20 percent of visitors reported hearing or seeing aircraft, but that only a small minority of visitors reported (1) being annoyed, (2) interference with enjoyment, or (3) interference with natural quiet and the sounds of nature

(NPS 1994). However, these findings varied by park location and type of visitor. A similar study in three U.S. Forest Service wilderness areas found that larger percentages of respondents had noticed aircraft overflights and reported higher levels of annoyance (Fidell and others 1992).

Other research has begun to address various sources of noise in parks and outdoor recreation environments (Hartig and others 2003; Stokes and others 1999; Vitterso and others 2004; Sutherland 1999; Harrison and others 1980; Cessford 1999; Mace and others 1999, 2003; Kariel 1990; Aasvang and Engdahl 2004; Freimund and others 2002). For example, the U.S. Forest Service issued a report that predicted the impacts of noise on recreationists (Harrison and others 1980). This report emphasized that noise is a negative interpretation of sound for a particular context or setting. Accordingly, there are times when visitor expectations can be inappropriate or unrealistic. Therefore, standards based on visitor perception of noise need to be established only in terms of specified situations (Harrison and others 1980). Finally, the authors suggest that the Recreation Opportunity Spectrum (ROS) (Clark and Stankey 1979; Brown and others 1978, 1979; Driver and Brown 1978) could be helpful for making judgments about acceptable noise impacts. A study at Padre Island National Seashore documented the impacts of loud radio noise on visitor attainment of recreational goals (Ruddell and Gramann 1994). In this context, sounds from loud radios are not extraneous, but they qualify as noise to some visitors because they are undesired. Visitors who reported "peace and quiet" as an important motivation for their visit were most likely to report loud radios a potential source of interference with obtaining "peace and quiet." The majority of visitors indicated that radios loud enough to be heard more than 25 feet away would substantially interfere with their recreation experience. Focus groups of visitors and other stakeholders at Yosemite National Park reported a number of noise-related items that participants believed detracted from the quality of the visitor experience (Manning 1998). These included noises from tour buses, automobiles, RV generators, aircraft overflights, machinery, construction, and radios. In addition, opportunities for peace and quiet and hearing the sounds of nature were noted by many participants as important indicators of the quality for the visitor experience.

The Study

Muir Woods lies just north of San Francisco and is a popular tourist area. The park hosts nearly three-quarters of a million visits annually, with the summer months being the busiest period. The park is noted for its 500 acre grove of ancient redwood trees and has six miles of paved and unpaved trails, but most visitors walk primarily along the main paved trail which extends approximately one mile from the visitor center. Therefore, most visitors experience a "front-country" setting that is heavily used. Facilities include a visitor center, cafe, gift shop, public restrooms, outdoor classroom, boardwalks, bridges, and interpretive displays.

Although this article focuses on experiential aspects of soundscape management, it should be noted that Muir Woods began managing the park's soundscape to protect the threatened Northern Spotted Owl (*Strix occidentalis caurina*) during its breeding season. Providing the owls with a natural acoustic environment to raise their young posed park managers with the challenge of controlling intrusive human noises, and educating the public about natural soundscapes (Monroe and others 2007). Interest in soundscape research at Muir Woods was also initiated by a visitor survey on crowding and carrying capacity that was conducted in 2003, (Manning and others 2005). Responses to an open-ended question about the quality of the visitor experience found that 16.9% of visitors reported that "peacefulness," "quiet," "the sounds of nature," and related qualities were aspects of the park that visitors enjoyed most. Some (11.4%) respondents also reported that "noisy visitors," "loud talking," and related issues were enjoyed least. A close-ended question included the item "visitors making too much noise" as a potential issue in the park, and 50.3% of respondents rated this item either "a small problem" or "a big problem" (Manning and others 2005). Because protecting the park's soundscapes is an important management objective of the NPS, these study findings led to a program of research designed to address soundscape issues in the park more directly. The study reported in this article was conducted in the summer of 2005 to help identify and formulate indicators and standards of quality for the soundscape of Muir Woods. Results from this study are intended to support development of the park's soundscape management plan and air tour management planning efforts. Soundscape research can also provide information to be included in the park's current General Management Plan process. The study was conducted in two phases as described in the following sections.

Phase I

Study Methods

The first phase of research was designed to identify soundscape-related indicators by addressing (1) the sounds visitors hear at Muir Woods, and (2) the extent to which those sounds are judged to be pleasing or annoying. Visitors ($n = 280$) to Muir Woods participated in a "listening

exercise" from July 16th 24th and July 26th 27th, 2005. Visitors were surveyed at three locations along the main park trail. These locations were selected as representative points of three management zones within Muir Woods as specified by a pilot program of the Bay Area Network of National Parks to document audibility of natural sounds (Lynch and Schirokauer 2005). There were no restrictions on who could participate in the survey because this listening exercise was also intended to act as an interpretive opportunity for visitors to Muir Woods. However, only responses from teenagers and adults were included in the analysis. Because this exercise was conducted at least partially for the purpose of educating park visitors about soundscapes, it should be acknowledged that there may be response bias and self selection limitations involved when evaluating the representative nature of this component of the study. Managers were aware of these limitations and believed that it was more important to reach out to all interested visitors while conducting this research project. Additionally, because the study was conducted in July, results can only be generalized to visitors that come to the park during the peak summer season.

As visitors walked past the three survey stations, they were asked if they would participate in a listening exercise. Only one individual or one group was asked to participate at a time to ensure the attendant would not distract listeners by talking to people passing by. When visitors were relaxed and ready to listen, the attendant instructed them to close their eyes and listen to the sounds around them, including both human-caused and natural sounds. They were instructed to open their eyes after three minutes or when they had heard all of the sounds they thought they were likely to hear, and then complete a sound checklist. Written instructions for the listening exercise were given to each respondent. The attendant also explained these instructions before passing out a checklist of sounds. When the individual or group finished the exercise, the attendant would ask the next individual or group that passed by if they would like to participate in the exercise. Similar to research conducted by Kariel (1990), the exercise consisted of listening to and identifying the sounds heard in the park and rating the extent to which each type of sound was "pleasing" or "annoying." Specifically, visitors were asked to report the types of sounds they heard on a 34-item checklist that was provided. The checklist used was developed by the NPS Natural Sounds Program Office and is used throughout the national park system (Lynch and Schirokauer 2005). Respondents were asked to evaluate each type of sound they checked on a scale that ranged from −4 ("very annoying) to +4 ("very pleasing").

Findings

The percentage of respondents in the listening exercise that heard each of the 34 types of sounds included in the study checklist was calculated and graphed on the X-axis of Fig. 1. The most frequently heard types of sounds were (1) water (81%), (2) wind (74%), (3) group talking (73%), (4) unknown people (73%), (5) bird songs (60%), (6) bird chatter (50%), (7) group activities (43%), and (8) loud

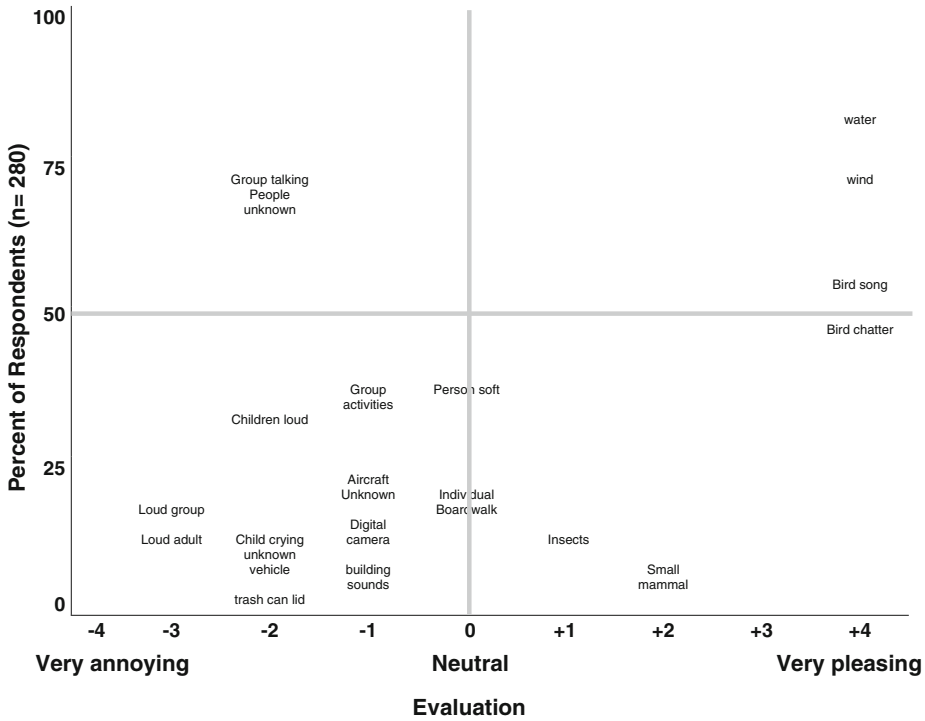

Fig. 1 Importance/Performance analysis of the types of sounds heard by visitors

children (34%). Mean respondent evaluations ("annoying" to "pleasing") of all 34 types of sounds were also calculated, and these are graphed on the Y axis of Fig. 1.

Figure 1 represents a type of "importance/performance" analysis and suggests where planning and management attention might best be focused (Hollenhorst and Gardner 1994). This analytical approach can also be used as a method to identify potential indicators of the quality of the visitor experience (Manning 2007). In this case, these findings suggest soundscape-related indicators. Checklist items in the upper right-hand quadrant of the figure are potential soundscape-related indicator variables that relatively large percentages of visitors heard in the park and which they found highly pleasing. Checklist items in the upper left-hand quadrant are potential soundscape-related indicator variables that relatively large percentages of visitors heard in the park and which they found highly annoying. Both sets of variables are good potential indicators because they are commonly experienced and they substantively contribute to or detract from the quality of the visitor experience.

Phase II

Study Methods

The second phase of research was designed to help formulate standards for visitor-caused sounds in the park. Findings from Phase I identified visitor-caused sound as a potentially important soundscape-related indicator (based on the variables found in the upper left-hand quadrant of Fig. 1). Based on these findings, five thirty-second audio clips were prepared that included a range of natural and visitor-caused sounds. All sounds included in the audio clips were recorded in Muir Woods and the resulting audio clips were created by a professional sound designer from the Nature Sound Society (http://www.dandugan.com/#nature). The sounds were recorded with shoulder mounted omnidirectional headphones with deep-pile fabric windscreen domes. A description of each of the audio clips is shown in Table 1. The sound clips were ordered by increasing decibel (dB) levels with visitor-caused sounds masking the park's natural sounds, and ranged in sound pressure level from 31 to 48 dB. Actual sound pressure levels recorded in the park during the visitor survey were similar to this range and were measured with A-weighted decibel (dBA) levels (adjusted for the fact that humans do not hear well at very low and high frequencies). Levels ranged from 31 dBA at L_{90} to 47 dBA at L_{10}. The L_{90} and L_{10} metrics essentially represent the quietest and loudest sound levels during the measurement period, respectively (Lynch and Schirokauer 2005).

These audio clips were included as part of a larger visitor survey administered to a sample of visitors in August, 2005. Visitors were randomly selected (every nth visitor) as they exited the park (at the park's primary entrance/exit location) and were asked to participate in the survey. A response rate of 40% was attained yielding 298 completed questionnaires. Debriefing of survey attendants suggests that many visitors to Muir Woods were also visiting other tourist attractions in the San Francisco Bay area and that this busy schedule caused some visitors to decline participation in the survey. Visitors were administered the soundscape-related portion of the questionnaire in a sound booth that had been prepared in a small room adjacent to the Visitor Center. Visitors listened to the audio clips using headphones that electronically cancelled exterior sounds. Approximately 40 dB of isolation was achieved, nearly eliminating the chance that sounds from outside would affect their responses. After listening to each sound clip, respondents were asked to rate the acceptability of the sound clip on a scale that ranged from −4 ("very unacceptable") to +4 ("very acceptable"). In addition, respondents were asked to report the type of sounds on each audio clip they found to be "pleasing" and "annoying," and to indicate which audio clip was most like the soundscape conditions they had experienced in the park.

Findings

Respondent acceptability ratings for each of the five audio clips were averaged with mean (M) ratings and standard deviation (SD) plotted in Fig. 2. This social norm curve indicates that respondents found rising levels of visitor-caused sound (and decreasing levels of natural sounds) to be increasingly unacceptable. The standard deviation bars

Table 1 Description of audio clips

Clip 1	Included natural sounds that were a composite of three layers recorded along the main paved trail and included running water, an insistent squirrel, and ravens
Clip 2	Included the baseline natural sounds from clip one with the addition of quiet visitors
Clip 3	Included the baseline natural sounds from clip one with the addition of a mid sized crowd
Clip 4	Included the baseline natural sounds from clip one with the addition of a large crowd
Clip 5	Included a composite of three layers including the baseline natural sounds from clip one, and an intentionally extreme crowd of visitors that was fabricated by overlaying two crowd layers

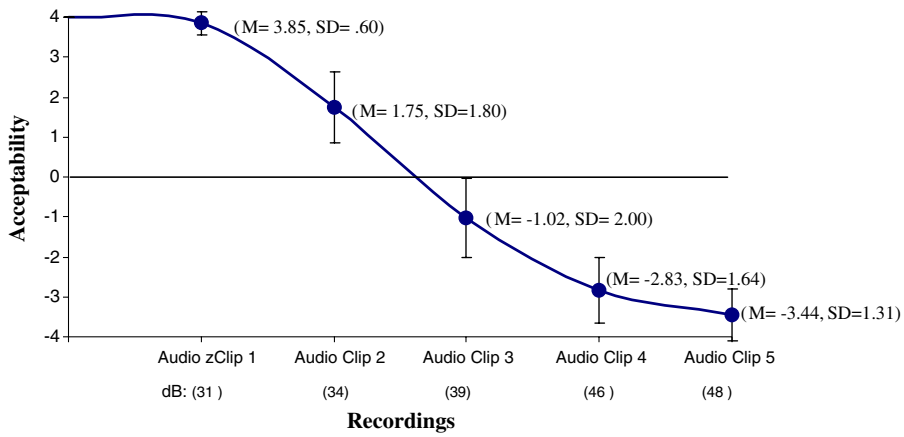

Fig. 2 Social norm curve for visitor caused noise

in Fig. 2 suggest that there is a relatively high level of agreement about the acceptability ratings. The point at which aggregate ratings fall out of the acceptable range and into the unacceptable range (i.e., the point at which the social norm curve crosses the neutral point on the acceptability scale) is between audio clips two and three. Decibel levels of visitor-caused noise for each of the audio clips were calculated, and these are also shown on the X-axis of Fig. 2. The social norm curve crosses the neutral point of the acceptability scale at 37 dB.

Respondents also reported the types of sounds they found "pleasing" and "annoying" from each of the audio clips. These data were pooled for all of the audio clips and are shown in Table 2. It is clear that most respondents found natural sounds (e.g., flowing water, bird songs, wind) to be pleasing and visitor-caused sounds (e.g., groups talking, loud groups) to be annoying. These findings generally corroborate results from Phase I research.

Table 2 Types of sounds reported as "pleasing" and "annoying"

	Frequency	Percent
Sounds reported as "pleasing"		
Bird song	562	41.8
Water	465	34.6
Wind	59	4.4
Group, talking	32	2.4
Bird chatter	29	2.2
Other[a]	83	6.1
Sounds reported as "annoying"		
Group, talking	458	39.2
Group, loud	248	21.2
Group activities	210	18.0
People, unknown	89	7.6
Other[b]	46	4

[a] Other pleasing sounds included: animal, group activities, soft per son, small mammal, unknown people, individual on boardwalk, ranger program, and insects

[b] Other annoying sounds included loud children, loud adults, bird chatter, soft person, trash can lid, and bird song

Finally, respondents reported the audio clip that best represented the soundscape conditions they experienced in the park on the day they participated in the visitor survey. Most visitors (67.5%) reported that audio clip 2 was most representative. Only 17.9% reported that audio clip 1 was representative, 12.5% thought that audio clip 3 was representative, and 2.1% reported that audio clip 4 was representative of the park soundscape.

Discussion

Study findings contribute to our knowledge about managing parks and related areas for outdoor recreation, and enhance our ability to address associated issues related to soundscapes. Research on the environmental impacts of outdoor recreation has conventionally focused on components of the landscape such as soil, vegetation, water, and wildlife, but this study suggests that outdoor recreation can also have a potentially important aural element and that outdoor recreation research and management attention should be extended to include more explicit consideration of soundscapes. Moreover, impacts to the soundscapes of parks and related areas can diminish the quality of the visitor experience and this also warrants more research and management attention. These findings are a natural extension of research on the impacts of human-caused noise on human health and quality of life more generally. Most respondents to our study reported hearing human-caused sounds at Muir Woods; most of these sounds were judged to be annoying. Most respondents reported hearing natural sounds in the park and that they judged these sounds to be pleasing. Respondents reported thresholds of human-caused noise in the park that they considered unacceptable. These findings suggest that soundscapes warrant greater research and management attention in parks and related areas.

The study also extends the application of indicators and standards in planning and managing parks and outdoor recreation. Indicators and standards are a vital component of contemporary "management-by-objectives" approaches to managing parks and related areas. Findings from this study offer an empirical basis for identifying indicator variables associated with soundscapes and formulating standards of quality for these indicators. This study suggests that visitors to Muir Woods find that visitor-caused noise detracts from the quality of the park experience and that when this type of noise reaches a level of approximately 37 dB it is judged as unacceptable. Managers can use this information to monitor sound levels and take management actions to ensure that soundscape-related standards of quality are maintained.

The importance of managing soundscapes at Muir Woods is pronounced by the fact that current levels of visitor-caused noise sometimes violate the social norms of acceptability as reported by visitors. Audio clips 3 and 4 (representing 39 and 46 dB, respectively) were reported by a total of 14.6% of respondents as most representative of the conditions that were experienced at Muir Woods on the day respondents participated in the Phase II visitor survey. These findings are generally corroborated by simultaneous sound monitoring in the park that registered sound pressure levels in the range of 31 dBA at L90 to 47 dBA at L10. This suggests that visitor-based standards for human-caused noise in the park are being violated at least some of the time and that the quality of the visitor experience is thereby being degraded to an unacceptable degree. Moreover, this problem is likely to get worse as visitor use levels continue to grow.

Research on experiential aspects of soundscapes in parks and related areas is in its early stages, and our study suggests a number of issues that warrant more study. For example, findings from the Phase I listening exercise demonstrate that not all human-caused sounds are judged as equally annoying. Loud visitors were reported as substantially more annoying than aircraft and building sounds. This type of research can help focus management attention on the types of noise that impact the quality of the visitor experience to the greatest degree. More research is also warranted on the characteristics of visitors that make them most susceptible to noise impacts. Visitors can be characterized by a number of variables, including experience level, motivations, and place attachment (Manning 1999). If sensitivity to noise is affected by such characteristics, then this may allow managers to establish educational programs and special use zones to help address this sensitivity. Coping and displacement of visitors is a closely related issue (Anderson and Brown 1984; Shelby and others 1988; Hammitt and Peterson 1991; Robertson and Regula 1994; Manning and Valliere 2001). If some visitors are being displaced from parks because of sensitivity to human-caused noise, then this may require special management attention and may suggest that normative standards for visitor-caused noise are underestimated in studies like ours (because noise-sensitive visitors are no longer present to render their judgments). The efficacy of management actions to control visitor-caused noise also needs research attention. The scientific and professional literature in parks and outdoor recreation suggests that there is a range of indirect (e.g., information/education programs) and direct (e.g., regulatory) management practices that can be applied to reduce visitor impacts (Manning 1999), but little is known about the effectiveness of these management practices as applied to soundscape-related issues. Finally, this study addressed only one measure of visitor-caused noise sound pressure or loudness (as represented by the conventional metric of dB). However, other measures warrant consideration, including duration of noise and percentage of time that visitor-caused noise is audible.

Beyond the need for more research as outlined above, our study has some potentially important limitations. Inclusion of visitors in the Phase I listening exercise was non-representative and this may limit the extent to which findings can be generalized. However, the potential indicators of quality identified in Phase I were generally corroborated by the findings from the more representative visitor survey conducted in Phase II (in which respondents reported the types of noises on study sound clips they found to be particularly pleasing and annoying). The 40% response rate to the Phase II visitor survey raises the issue of non-response bias. Unfortunately, the study did not allow for any follow-up contact with non-respondents. As noted earlier, a substantial number of visitors who declined to participate in the survey were on tight travel schedules which required them to board a bus on time, and this seemed to be the primary reason for refusals.

A more important policy-related limitation of this research is that it includes only the perceptions of current park visitors. Park visitors may have incomplete knowledge of the policy contexts of parks, particularly as they apply to soundscapes, and some visitors may have unrealistic expectations and preferences related to national parks (Harrison and others 1980; Miller 1999). Data from visitors should be incorporated into park management as appropriate, but should be supplemented with appropriate ecological and legal/policy considerations. Moreover, as noted earlier, consideration should be given to the possibility of displaced visitors, though this may be challenging. Finally, an appropriate range of soundscape conditions should be applied across parks and park systems as suggested by the ROS concept as noted earlier.

Conclusions

The issue of sound is becoming increasingly important in society in general and in parks and related areas more specifically. Manifestations of this importance are reflected in federal legislation and associated policy initiatives. For example, the 1972 federal Noise Control Act mandated formulation and enforcement of noise controls in work and other places, including national parks (Miller 1996; Sheikh and Uhl 2004). Subsequent legislation, including the 1987 National Parks Overflights Act, required assessment and management of noise impacts in national parks (NPS 1994; Sheikh and Uhl 2004; Schwer and others 2000). Under the direction of this legislation, an air tour management plan was enacted for Grand Canyon National Park to help restore natural quiet (NPS 1994; Schwer and others 2000).

Soundscape-related legislative initiatives have more recently been extended to other noise sources including snowmobiles and other forms of mechanized travel in national parks and related areas (Sheikh and Uhl 2004). In 2000, NPS Director's Order #47 was promulgated to address management of soundscapes in the national parks more broadly (NPS 2000). The agency's Natural Sounds Program Office was recently created to guide this management initiative with the objective "to articulate National Park Service operational policies that will require, to the fullest extent practicable, the protection, maintenance, or restoration of natural soundscape resource in a condition unimpaired by inappropriate or excessive noise sources."

Given the growing importance and urgency of soundscape policy and management, research is needed to better understand how and when human-caused sounds in parks and related areas are negatively interpreted as noise and when this noise reaches unacceptable levels. The framework of indicators and standards of quality can be adapted to help address these issues and guide management of park soundscapes. The type of research reported in this article can help support application of this management approach.

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