United States Department of the Interior

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IN REPLY REFER TO:

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Memorandum

To: Associate Directors
Regional Directors
Superintendents

Through: Jackie Lowey, Deputy Director
Maureen Finnerty, Associate Director for Operations and Education

From: Associate Director Natural Resource Stewardship and Science

Subject: Social Science Research Reviews

The National Park Service Social Science Program is initiating a series of *Social Science Research Reviews*. Each paper in the series will focus on a specific issue critical to the management of the National Park System. The purpose of the series is to provide a basis for scientific understanding of these important issues from a social science perspective. Each paper presents a conceptual framework for understanding the issue, reviews methodologies used in relevant studies, and presents key findings from the published scientific literature, technical reports, and other documents. Each paper has been extensively peer-reviewed and reviewed by National Park Service managers.

The papers in this series are not intended to provide specific policy guidelines or management recommendations. Rather, they provide managers with an assessment of the scientific "state-of-the-art," and should assist in decision making by NPS managers.

Attached is the first paper of the series. It was prepared by Dr. James Gramann at Texas A & M University, and is entitled: "The Effect of Mechanical Noise and Natural Sound on Visitor Experiences in Units of the National Park System." The NPS commissioned this paper from Dr. Gramann to contribute to the planning and development of strategies for preserving the natural and cultural soundscapes in the parks. As part of our efforts to deal with this issue, we need to understand how visitors value the resource and experience of sound, and evaluate the utility of techniques for measuring visitor responses in the parks. This is especially timely as the NPS begins to address a range of noise issues related to commercial air tour overflights and airports, a variety of mechanical recreational equipment, transportation systems, and construction and maintenance projects. Director's Order 47, currently under development, will provide guidance on noise management.

The next paper in the *Social Science Research Review* series will be distributed Spring 1999 and will focus on minority use of national parks.

I hope that you will read the attached paper, and that you find this series useful. Please share the paper with your staff and others as appropriate. If you would like additional copies, please contact Gary Machlis, Visiting Chief Social Scientist, at (208) 885-7129 or gmachlis@uidaho.edu.

Attachment

Social Science Research Review

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The Effect of Mechanical Noise and Natural Sound on Visitor Experiences in Units of the National Park System

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Abstract

This paper reviews research on the effects of mechanical noise and natural sound on visitor experiences in national parks. Three approaches to studying noise impacts are described. Most noise research to date has addressed the impact of air-tour overflights on visitor experiences. These impacts are localized, with significant percentages of visitors in some parks reporting interference with natural sounds from aircraft noise. Research also shows that unthreatening natural environments can have significant stress-reducing effects for many people. However, it is unclear if these effects are due to hearing the sounds of nature or to a combination of hearing and seeing nature.

Introduction and Scope

Although the National Park Service (NPS) describes it as intangible (NPS 1988), "natural quiet" is an important resource in many units of the National Park System. It is considered in the same category of aesthetic, yet manageable, values as solitude, space, clear night skies, and a sense of history. Both federal legislation and NPS policy identify natural sound as a park resource and value worthy of protection. Important references to natural quiet are found in the NPS *Management Policies* (NPS 1988, chapters 1 and 4), the Grand Canyon National Park Enlargement Act (P.L. 93-620), and the National Parks Overflights Act (P.L. 100-91).

This paper is an overview for non-scientists. It critically reviews social science research on the effects of natural sound and mechanical noise on visitor experiences in national parks. Strengths and weaknesses of different ways to study noise, natural sound, and their impacts on visitor experiences are discussed. In addition, research findings are examined, and major gaps in social science knowledge relevant to policy formulation are identified.

It is important to keep in mind that the focus of this review is on *visitor experiences*. Conceivably, natural sound in parks could be protected without any consideration of the effect of noise on visitors. However, if the justification for preserving natural sound is to minimize the impacts of noise on visitor enjoyment, then information is needed on how different types of visitors react to unnatural, as well as natural, sounds in parks. The principle in this case is that at least some public input from park visitors should be considered in developing policies to manage natural sounds in parks.

Because most noise-impact studies in parks have dealt with visitors' reactions to commercial air-tour overflights, this is a major focus of the review. The effect of other types of aircraft noise on visitor experiences, including military operations, commercial aviation, and administrative overflights, has received little research attention. In addition, only a small amount of research addresses noise in parks other than that caused by aircraft. This includes the noise of highway traffic, off-road vehicles, and audio equipment. To the extent it is available, this research is also described.

The first section of this paper defines key terms used in the review. (Other terms that may be unfamiliar to the reader are highlighted in **bold face** and defined in a glossary at the end of the paper.) This is followed by a description of three approaches to studying the effects of mechanical noise on park visitors. The next section reviews research that has applied these approaches to investigate noise impacts on visitor experiences in national parks. Following this, theory and research describing how people are affected by natural sounds is described. Significant knowledge gaps are then identified, followed by conclusions to be drawn from research to date.

Definitions

Understanding the difference between **sound**, **noise**, and **natural quiet** is important. In psychology, sound is usually defined as a physical concept referring to the fluctuation in atmospheric pressure that is capable of producing an audible sensation in the ear. In this paper, sound also alludes to the natural **sonic** environment of parks. This is called **natural ambient sound** and includes the intermittent sounds of wind, water, and animals. In contrast, noise is a psychological evaluation of sound. Another definition of noise is "unwanted sound." As employed in this review, noise refers specifically to sounds of mechanical origin, including those produced by aircraft engines or other man-made devices.

The most complete definition of natural quiet is given in the NPS report to Congress on aircraft overflights (NPS 1995). Natural quiet is defined for Grand Canyon as natural ambient sound, plus the **self-noise** generated by visitors in non-mechanized activities. The term natural quiet probably should not be applied System-wide, since it is not used in either the social science or acoustical literature. In this paper, natural ambient sound is used instead. The definition of natural ambient sound does not include self-noise.

NPS policy considers natural sound to be an integral part of the visitor experience in backcountry and wilderness areas of the National Park System. (Approximately 80% of the area in the National Park System is either designated as wilderness or is managed as wilderness.) It may also be an important part of visitor experiences in many caves, as well as at cultural sites having strong memorial values.

Distinguishing between noise and natural sound is not hair-splitting. The difference is relevant to policy intended to preserve natural **soundscapes** in the National Park System. If policy protects natural ambient sound as a physical concept, this implies that soundscapes can be managed in physical terms, for example, by restricting the intrusion of mechanical noises above a certain loudness or duration into protected areas. In contrast, because noise is a psychological concept, presumably it would be defined in terms of visitors' evaluations of sounds. With a focus on noise, the protection of natural quiet would be directed at reducing visitors' reports of displeasure with different noise sources.

Theoretical Approaches for Understanding Effects of Mechanical Noise

Research on the effects of mechanical noise on people has been guided by three theoretical approaches. These are summarized in Table 1. More detailed descriptions of the approaches follow.

Psychological Approach

The psychological approach to studying noise impacts investigates people's evaluations of sound. Its basic assumption is that people differ in how they perceive their environment, and that this difference affects the way people judge the desirability of sound. The psychological approach treats actual sound as only one factor affecting noise evaluations. Another key factor is the expectations that people have for noise in various settings (Anderson et al. 1983; Kariel 1990; Wilshire and Powell 1981). For example, in one of the first discussions of noise impacts in recreation areas, Clark and Stankey (1979) reasoned that people's expectations for mechanical noise would depend on the area's development level. In undeveloped areas, mechanical noises would be evaluated negatively, presumably because visitors would not expect to hear this type of noise in primitive settings. But in developed areas, visitors might expect a mix of mechanical noises and non-mechanical sounds similar to the sonic environment of residential neighborhoods. Because of this, it was thought that they would be more tolerant of mechanical noises in developed areas.

Table 1. Summary of theoretical approaches employed in noise-effect studies

Theoretical approach	Key assumptions	Data collection methods	Strengths	Weaknesses
Psychological research	Noise exposure affects people' s well-being Evaluations of noise depend on noise type and on people' s psychological and social characteristics	Surveys, diaries	Allows input from affected publics, such as park visitors	Lacks measures of noise exposure, or uses subjective self-reports of exposure
Acoustical research	Properties of noise (loudness, frequency, duration, etc.) affect people' s well-being	Sound-measuring instruments, trained observers	Collects objective measures of noise exposures at specific locations	Relies on standards to evaluate noise exposure; no direct measures of human response Acoustical standards lacking for NPS areas, but being developed
Psychoacoustical research	There is a systematic relationship between objective noise exposure and people' s evaluations of noise	Sound-measuring instruments, trained observers, surveys	Combines strengths of acoustical and psychological approaches	Dose-response functions are highly place-specific Expensive to conduct in many NPS areas

Besides visitors' expectations for noise, the psychological approach is concerned with other factors that may affect people's reactions to sound. These include involvement in **foreground tasks** that divert attention away from sounds, thus reducing their **noticeability** (Fidell and Teffeteller 1981) and whether a sound is thought to be necessary or preventable (Kariel 1990). For example, the noticeability of aircraft noise at the threshold of hearing may be low if visitors are engrossed in taking photographs (a foreground task) or if the noise does not exceed non-aircraft sounds by more than ten **decibels** (Miller 1995). Also, wilderness hikers may tolerate the noise of a helicopter flying a fire suppression operation more than they would aircraft noise that was thought to be less necessary. Finally, if a sound is regarded as threatening or beyond the control of listeners, this may also influence people's reactions to it (Staples 1997). An example of a threatening noise to a swimmer or angler might be the engine roar of an approaching motorboat or personal water craft.

Psychological research on noise impacts in national parks and other recreation areas was uncommon until passage of Public Law 100-91, the National Parks Overflights Act of 1987. Since then, studies of noise impacts, especially from air tours, have been done in many NPS units and in wilderness areas managed by the U.S. Forest Service (HBRS/HMMH 1993; NPS 1995; USDA Forest Service 1992).

One benefit of the psychological approach is that visitor surveys provide systematic public input on the acceptability of different kinds of sounds and noises. This is critical in many public participation contexts important to the NPS, including the preparation of general management plans, environmental assessments, and environmental impact statements. One drawback of the psychological approach is the way in which the impacts of noise on visitors is determined. The problem is that some measures used to explain visitors' psychological reactions to noise are themselves defined in psychological terms. For example, a typical survey might ask visitors how much they were annoyed by aircraft noise, as well as how often they heard a noise, or how loud they thought the noise was. But in the minds of many persons, an annoying noise may be defined as one that is too frequent or too loud. Therefore, asking visitors how annoyed they were by aircraft noise could be the same as asking them if an annoying noise made them feel annoyed. Contrast this with an approach in which visitors report their annoyance levels, but the noise they were exposed to is measured *independently*, either by trained observers or by sound-recording instruments. In principle, this approach would give a more accurate picture of how visitors are affected by noise. Furthermore, it could be more useful to managers because the approach provides information on something that can be regulated directly, i.e., objective noise levels. Although the psychological approach has many uses, including providing public input into noise management planning, it provides no direct information on visitors' actual exposure to noise. Instead, it relies on self-reports of the amount of noise visitors think they were exposed to explain how they reacted to that noise.

Acoustical Approach

The second approach used in noise-impact research is based on sound or loudness metrics that are independent of human perception. A basic assumption of this acoustical approach is that prolonged exposure to loud noise has important consequences for personal well-being. These include psychological annoyance, interference with speech, sleep interruption, disruption of cognitive processes, temporary or permanent hearing disorders, and negative impacts upon the cardiovascular and endocrine systems (Staples 1996, 1997). More than the psychological framework, the acoustical approach considers the effects of physical properties of noise. Among these are loudness, duration, tone, frequency, pitch, and rhythmic qualities.

In contrast to the psychological approach, the acoustical method does not use surveys to measure people's reaction to sound. Instead, sound recording instruments or trained observers measure such physical qualities as a sound's **audibility** in terms of decibel (dB) level. One or more of these measures is then compared with a standard of acceptability to determine if the sound falls within a tolerable range. The standard of what is acceptable can come from any number of sources (Fidell 1979), including previous research on people's evaluations of noise, existing standards at other areas, from public comment on environmental assessments, environmental impact statements, and new regulations, or from existing laws, policies, regulations, and management plans.

The acoustical approach is not widely used in the National Park System. One reason for this is that noise-exposure standards for areas such as national parks do not exist (Miller 1995). Recently, however, a citizens advisory group, the National Parks Overflights Working Group, composed of representatives from the environmental and aviation communities, recommended to the Federal Aviation Administration and the NPS that a Federal Aviation Regulation to manage commercial air tourism over national parks be developed on a park-by-park basis. The park-by-park approach recognizes that the importance of natural ambient sound varies between NPS units. For example, an urban historic site may not be managed for natural sound conditions, but a park with extensive wilderness probably would. These standards would enable the NPS to preserve natural soundscapes as a physical resource because this protection could be based solely on **acoustics** (for example, protecting specific sound levels), without directly incorporating people's evaluations of noise, except as these are used in public involvement to develop the acoustic standards in the first place.

Psychoacoustical Approach

The third theoretical framework for understanding noise effects on visitors is the psychoacoustical approach. This approach combines elements of both the psychological and acoustical methods. It is based on the theory of psychophysics, which investigates the correlation between physical energies, such as light energy or sound energy, and psychological evaluations of these energies. In acoustical research, this correlation is called a dose-response function, the dose (or physical energy) usually being the loudness of a sound and the response being the reaction of people to it, typically measured as annoyance. The psychoacoustical approach has been used mostly in studies of aircraft noise impacts on communities near airports (Fidell et al. 1988; Wu et al. 1995).

Psychoacoustical studies record both human reactions to noise (usually through surveys), as well as respondents' exposure to independently measured noise levels. With these data, it is frequently possible to construct a statistical dose-response function that describes the likelihood that a certain percentage of a population (for example, visitors at a scenic overlook) will be annoyed at any noise level included within the observed or simulated range of the noise dose. Dose-response functions based on exposure to aircraft noise have been developed for sites in Haleakala, Hawaii Volcanoes, and Grand Canyon national parks to predict the proportion of visitors who would be moderately to extremely annoyed by progressively louder aircraft noise (Anderson et al. 1993; NPS 1995). Similar dose-response functions have been developed at three U.S. Forest Service wilderness areas (Fidell et al. 1996).

A major advantage of the psychoacoustical approach over the psychological method is that it collects measures of noise exposure that are independent of visitors' self-reports of exposure. Moreover, this exposure can be managed by regulating the source of the noise. Conceivably, this is information that could prove useful if NPS policy were aimed solely at preventing negative impacts on visitor experiences from noise.

Despite this, the application of the psychoacoustical approach in national parks has been limited by cost and logistical difficulties. As mentioned, the dose-response method was developed for studies of noise impacts in neighborhoods near airports. A major assumption of the method is that the noise exposure at dwellings in these areas is meaningful for policy, even though residents do not spend all of their time at home. And because dwellings are immobile, it is relatively easy to predict how much noise they will be exposed to, given fixed flight patterns. This is not the case for people in national parks. Visitors move, so their noise exposure is hard to measure with stationary instruments. Therefore, obtaining accurate noise doses for visitors over an extended stay is virtually impossible, given current technology. Furthermore, dose-response functions developed for one park cannot be applied uncritically to other units (Anderson et al. 1993). This is because the relationship between noise doses and visitor reactions depends heavily on contextual factors that differ from place to place. These include terrain and ambient sound differences that affect audibility, differences in noise sources (helicopters, fixed-winged aircraft, military jets, high-altitude flights), differences in the distance from aircraft to observers, variations in flight characteristics (level flights vs. take-offs and landings), and differences among visitors in their sensitivity to aircraft noise. Even within a park, a dose-response function that describes the effect of noise at one site may not be validly extended to other locations in the same park. One reason for this is that contextual features and visitors' expectations shift significantly from area to area. An example is the changes in expectations that a visitor arriving at a frontcountry site has upon entering a backcountry area.

Finally, in calculating dose-response functions there should be enough variation in noise to obtain an accurate and representative picture of the relationship between noise exposure and visitors' reactions. If the distribution of data points is restricted to one region of a dose-response curve (the low-exposure end), then responses in the remaining regions of interest (the mid- or high-dose regions) are mostly simulated, rather than based on actual field observations. These simulated responses may not reasonably reflect actual responses by visitors. For all of these reasons, the use of the psychoacoustical approach in national parks is challenging. It has been applied most successfully at scenic overlooks and short frontcountry trails. However, these may not be the types of places where protecting the experience of natural sound is a major concern.

Research on Effects of Mechanical Noise

Psychological Research

Conceivably, loud mechanical noise can affect visitors in severe ways, for example, by startling horses and causing them to throw their riders. However, these kinds of impacts are rare in parks (HMMH/HBRS 1994). A 1992 survey of visitors to 39 NPS units (selected to represent all non-Alaskan parks) found that the most common effects of aircraft encounters were psychological (NPS 1995). System-wide, about one-fifth of park visitors reported hearing or seeing aircraft during their visit (see Appendix). Two to three percent reported impacts from overflights. These included annoyance (reported by 1.6% of visitors), interference with enjoyment (cited by 1.9%), and interference with natural quiet and the sounds of nature (reported by 2.8%).

These System-wide figures mask the presence of NPS units where noise effects were more prevalent. Among the 39 parks studied, those in which more than 10% of visitors reported interference with natural quiet due to aircraft included Cumberland Island NS, Everglades NP, Yosemite NP, Mount Rushmore NMEM, Hawaii Volcanoes NP, Olympic NP, Haleakala NP, Fredericksburg and Spotsylvania County Battlefields Memorial, and Grand Canyon NP.

Within parks there are locations where noise impacts from aircraft are much greater than the park-wide average. Studies at Grand Canyon, Hawaii Volcanoes, and Haleakala national parks pinpointed places where annoyance levels due to aircraft overflights were much higher than for each park as a whole (NPS 1995). In some cases, within-park variation may be caused by differences in aircraft noise levels, in other instances by variation in natural ambient sound levels, and in still other cases by the co-occurrence of relatively loud aircraft noise with very quiet ambient sound conditions. For example, of 27 locations measured in Grand Canyon, Hawaii Volcanoes, and Haleakala national parks where aircraft were audible, 17 recorded occasional non-aircraft background sound at an **A-weighted decibel** level of 10 to 20 dBA (NPS 1995). This compares with an average day-night decibel level of 35-40 in many residential areas (Miller 1995).

Psychological research also shows that visitors' characteristics influence their likelihood of reporting annoyance and interference with natural quiet. Much of this is caused by differences in expectations, as well by differences in group size (people in large groups are less likely to report interference than people in small groups). It is also influenced by the recreation activities of visitors, since some activities (motorized rafting) produce more noise than others (standing at an overlook). In some cases, season of the year also affects the noticeability of noise and the perception of impacts by affecting background sound levels. For example, the masking sound of flowing water varies considerably by season as the volume of flow changes.

Psychological studies have identified still other visitor characteristics that affect responses to air-tour overflights. Exit interviews at 23 NPS units found that a higher percentage of backcountry than frontcountry users recalled hearing aircraft and were more likely to experience interference with enjoyment and natural quiet (NPS 1995). This may be because backcountry and frontcountry visitors generally seek different experiences in national parks. In addition, backcountry users usually spend more time in a park than frontcountry visitors, so their overall exposure to aircraft noise could be greater.

Another survey at Grand Canyon NP found that backcountry and river corridor users were more sensitive to aircraft noise than people in developed areas (HBRS/HMMH 1993). In addition, more fall visitors reported interference with natural quiet from aircraft than summer visitors. Whether this was due to differences in noise levels between seasons, to seasonally related changes in the expectations of visitors, or a combination of these factors is not clear. In addition, visitors on motorized trips on the Colorado River were less likely to be affected by aircraft noise than those in non-motorized craft, probably because the noise made by motorized craft totally or partially masked the noise from overflights.

The Grand Canyon survey also found that the number of reported aircraft encounters by river corridor and backcountry users was below expected levels based on overflight data collected by trained observers. One explanation is that visitors' concentration on foreground tasks, such as sightseeing and photography, plus the greater self-noise made by people in motion compared to stationary monitors, either drowned out aircraft noise or diverted attention from overflights. In other words, the loudness required for visitors to notice aircraft under these circumstances may have been higher than the level that was audible to an attentive listener.

In another study at Grand Canyon NP, overnight hikers filled out diaries evaluating their experiences at the end of each day. The hikers' self-reported exposure to aircraft did not correlate significantly with evaluations of crowding, satisfaction, or solitude (Stewart 1997). The reasons for this are unclear, but it could be due to differences in method (post-trip vs. during-trip surveys) or to differences in metrics (the diary had no measures of experience quality with known relationships to noise exposure).

Although most psychological research in NPS areas has focused on air-tour overflights, U.S. Forest Service surveys of hikers in the Superstition, Golden Trout, and Cohutta wilderness areas found that large percentages of visitors also noticed high-altitude overflights and low-flying military jets (Fidell et al. 1992). The Superstition is a desert wilderness near Phoenix, the Golden Trout is in California, and the Cohutta is in Georgia. These areas were chosen for study because of their exposure to military and civil aviation. For example, the Golden Trout is overflown by helicopters and low-flying jets from Edwards Air Force Base and the China Lake Naval Air Station, while the Cohutta is overflown by high-altitude commercial traffic en route to and from

Hartsfield International Airport in Atlanta. In general, annoyance due to aircraft was higher among these wilderness hikers than in the NPS studies. Among those who actually noticed aircraft, 13.1% reported at least moderate annoyance levels. However, only 0.2% of hikers in all three wildernesses said that aircraft noise was the least liked aspect of their visit. Crowding, inadequate trail maintenance, weather, insects, and other non-aircraft factors were more important sources of dissatisfaction than aircraft noise.

In contrast to air-tour studies, there has been little research in NPS areas investigating other noise sources. A survey of 90 NPS managers (HMMH/HBRS 1994) reported that 41% felt noise from road traffic was at least a moderate problem in their park, while 16% cited power generators, and lesser numbers listed audio equipment and domestic animals, including horses, mules, and pets, as causing moderate to serious noise problems.

Mountain climbers and auto-access campers surveyed at three national parks in the Canadian Rockies considered mechanical noises to be more annoying than natural sounds, while noises made by people, such as talking, received neutral evaluations (Kariel 1980). The most annoying noises were those from motorbikes, snowmobiles, motorboats, and cars. Dosages were not measured in this study.

Experiments conducted by Anderson et al. (1983) examined how different sounds enhanced or detracted from urban vs. wooded environments. Natural sounds, including those from songbirds, crickets, and wind, were rated by college students as strongly enhancing wooded sites, while mechanical noises, including downtown traffic, jet aircraft, and power lawnmowers, were rated as strongly detracting from these areas. Conversely, in downtown locations all sounds received relatively neutral ratings, although traffic sounds were rated as most enhancing. An experiment in Boston (Southworth 1969) also found that traffic noise enhanced many people's appreciation of a downtown area, but only if the noise level was not too loud. This suggests that the *type* of sound is not the only factor people consider when evaluating a soundscape. Whether or not sounds are *consistent* with the visual settings in which they are heard appears to be important as well.

Visitors to Padre Island National Seashore reported several noise sources as potential causes of interference with their recreation experiences (Ruddell and Gramann 1994). These included rowdiness, drunkenness, and loud radios. Visitors who were seeking peace and quiet were most likely to rate loud radios as a potential source of interference. The majority of visitors indicated that radios which were loud enough to be heard more than 25 feet away would interfere very much with their recreation experience. However, when asked about actual, as opposed to potential, interference from radios, only 13% of winter visitors and 18% of summer visitors reported problems (Gramann and Ruddell 1989). This may be due to low levels of actual noise exposure (dosages were not measured), to involvement in foreground tasks, or to other natural and human sounds that masked radio noise.

Focus groups discussing the Valley Implementation Plan at Yosemite NP were asked about impacts on experience quality in Yosemite Valley (Manning 1998). Although focus groups are not representative of all visitors, they can indicate the diversity of opinions on an issue. At Yosemite, focus groups listed several noise-related items that they believed reduced the quality of visitor experiences in the Valley. These included noise from tour buses, automobiles, RV generators, jet overflights, machinery, construction, and radios. In addition, opportunities for quiet moments and hearing natural sounds were mentioned by many focus group members as important indicators of experience quality in Yosemite Valley.

Psychoacoustical Research

Dose-response studies at Haleakala, Hawaii Volcanoes, and Grand Canyon national parks showed that relatively high percentages of visitors were moderately to seriously annoyed by aircraft noise at specific locations within those parks. Furthermore, the percentage of visitors reporting negative evaluations increased as the loudness and frequency of aircraft noise increased (Anderson et al. 1993; NPS 1995). Dose-response studies in the three U.S. Forest Service wilderness areas reported similar results (Fidell et al. 1996), even though the research methods were somewhat different.

Besides the finding that the percentage of annoyed visitors increased with aircraft loudness and frequency, NPS dose-response studies also reinforced the conclusion from psychological research that perceptions of interference depend on visitor characteristics. In general, first-time visitors were less sensitive to aircraft noise than repeat visitors, possibly because new visitors were more apt to believe that what they encountered during a visit was normal and appropriate (Knopf 1983). Also, groups of one or two people were more sensitive than larger groups, probably because large groups generate more self-noise. Finally, visitors who rated enjoying natural sounds as important reasons for their trip were more affected by aircraft noise than were other visitors (NPS 1995), showing once again that expectations have important influences on reactions to noise.

Another finding of the dose-response studies was that the proportion of visitors annoyed by aircraft at a given dosage differed considerably between parks. At 40 dBA, less than 10% of visitors at Lipan Point, a frontcountry overlook in Grand Canyon NP, reported moderate to extreme annoyance. In contrast, almost 40% of hikers on the Sliding Sands Trail (a short-hike frontcountry trail) at Haleakala NP were moderately to extremely annoyed at the same dosage (NPS 1995). The factors responsible for this may include variation in visitor characteristics, in overflight characteristics, and in non-aircraft noise levels between the two areas.

Theoretical Approaches for Understanding Effects of Natural Sound

There is a flip side to research on noise in national parks. Instead of concentrating on the impacts of mechanical noise, the effects of hearing natural sounds can be investigated. Even so, research in this area has been limited. Nevertheless, scientists are beginning to investigate the sonic component of natural settings. Some laboratories are archiving high-quality recordings of natural sounds, such as bird calls (see Additional Resources). Other scientists are conducting experiments to improve the understanding of how exposure to natural soundscapes affects humans. Eventually, these efforts may expand the definition of "environment" to include the acoustical characteristics of a place, in addition to its biological, physical, and social characteristics.

At least one theoretical approach may shed light on how natural sounds affect visitors in national parks. This **psychophysiological** framework focuses on the **restorative** benefits of unthreatening nature in reducing stress in human beings. Although this research has yet to isolate sound as a distinct environmental component, the extension of its theory is straightforward. One consistent finding stands out: when asked to rate their preference for natural vs. built environments, people almost invariably choose natural settings (Ulrich 1993).

Within the psychophysiological framework, several theoretical approaches have been taken to explain the preference that people show for natural settings. Arousal theories propose that recovery from psychological and physical stress occurs more rapidly in natural than built environments because natural areas contain fewer arousal-producing properties, such as complexity, intensity, and movement (Ulrich 1993). Similarly, stimulus overload theories (Milgram 1970) argue that the built environment contains higher levels of complexity and other stimulation that overtaxes human's information processing ability, thus slowing recovery from stress.

A different accounting is found in evolutionary theories (Orians and Heerwagen 1992). This perspective holds that, because humans evolved in natural habitats, people are to some extent adapted to natural, as opposed to urban, settings. Although this adaptation can be suppressed by cultural factors (people can learn to prefer built environments), it appears that there are several benefits—or biophilic responses—that people can gain from interactions with nature (Kaplan and Kaplan 1989; Wilson 1984). These range from simple liking/approach reactions, to stress recovery, to improved performance on creative tasks (Ulrich 1993).

Among the arousal-producing properties of a setting that influence stress, complexity is of special interest. Visually, complexity refers to the number of independently recognized elements in a setting, as well as to their diversity, novelty, incongruity, and irregularity (Berlyne 1973). In general, people prefer moderately complex settings (for example, a forest with several species of trees) to simple settings (such as a bare, open field) and very complex urban settings (Brunson 1996; Kaplan 1987).

It is interesting to speculate on how complexity contributes to preference for natural soundscapes. On one hand, the novelty of the sonic experience in a national park compared to most urban settings could enhance complexity, causing visitors to prefer such soundscapes. Even so, people who are strongly conditioned to the noise of urban areas may find natural ambient sound *too* novel and feel uncomfortable in these settings.

Research on Effects of Natural Sound

Many surveys show that quiet, solitude, and natural sounds play important roles in recreation experiences. Although these studies have not measured physiological restoration directly, recreation area users consistently state that escaping noise and enjoying the sounds of nature are among the most important reasons they visit natural areas (Driver et al. 1991). In the survey at three Canadian national parks described earlier (Kariel 1980), natural sounds were rated as significantly more pleasing than mechanical noises. Among the most preferred sounds were wind, water, and sounds made by birds, insects, and other animals. Similarly, Anderson et al. (1983) found that natural sounds, including those of songbirds, crickets, and wind, were rated most positively by college students, while engine noises were rated as most negative. Noises made by people (children yelling and laughing) and domestic animals (dogs, horses, cows, and chickens) received neutral evaluations.

Although these studies provide indirect evidence of the restorative effects of nature, they fail to separate this influence from other sources of stress reduction during recreational outings, such as physical exercise. Moreover, samples of visitors to parks are self-selected in that they consist mostly of people who choose to be in such areas. These samples may reveal little about persons who do not visit parks. Perhaps non-visitors receive no benefits at all from being in natural settings. If true, this would challenge the validity of theories about the restorative benefits of nature.

One of the few experiments to directly investigate the restorative properties of unthreatening nature, and to control for self-selection, was reported by Hartig et al. (1991). College students carried out 40 minutes of tasks designed to induce cognitive fatigue. The students were then randomly assigned to one of three experimental conditions: a 40-minute walk in a regional park with a stream and riparian habitat, a 40-minute walk in a well-kept urban area, or a 40-minute session in a comfortable well-lit room where they read magazines and listened to music. Psychological and physiological stress levels were measured before and after the experimental treatments. Persons who walked in the park reported significantly more positive emotional states after the walk than those in the other two conditions. They also performed better on a proofreading task. Although the groups did not differ in their physiological stress levels, this may be because the lack of mobile monitoring equipment resulted in physiological measures not being taken until almost an hour after the walks were over. Other research (Ulrich et al. 1991) reports that people exposed to nature often recover from stressful conditions in as little as four minutes. Nevertheless, the study is one of the few to incorporate (although not isolate) the effects of natural sound in its experimental procedures, and to show that psychologically restorative effects can occur in non-self-selected individuals who visit natural areas.

The remaining research on the restorative effects of nature has been conducted mostly in laboratory and institutional settings (Tarrant et al. 1994). Although these studies rely on exposure to simulated nature, they are able to monitor physiological stress and restoration much more comprehensively than is feasible in many outdoor settings.

In an experiment that exemplifies the laboratory approach, 120 persons were shown a 10-minute stress-producing video about industrial accidents (Ulrich et al. 1991). Compared to baseline levels before seeing the video, physiological measures during the presentation were much higher for such stress indicators as muscle tension and pulse rate. Self-reports immediately after the video also indicated that viewers had more negative emotional states compared to baseline measures. Subjects were then assigned randomly to treatments in which they viewed one of six videotapes. Two of the tapes portrayed natural scenes. In the first, the setting was dominated by trees and other vegetation. Birds and wind sounds in the range of 42-64 dB could be heard. The second video showed a setting dominated by trees and a fast-moving stream. The sound of rushing water was at a constant range of 63-64 dB. The remaining tapes depicted urban scenes dominated by vehicular and pedestrian traffic with noise levels in the range of 64-93 dB. Physiological stress was monitored during the video viewing, and self-reported measures of psychological stress were taken immediately afterward. For persons seeing the nature videos, physiological indicators returned to states at or near normal levels within four to seven minutes after the start of the tapes. In contrast, people viewing the urban scenes had less sharp declines, or even elevated levels of physical stress, compared to those measured during the industrial accident video. Similar patterns were found for reports of emotional states, including fear, anger, aggression, and happiness. Emotions were more positive after viewing the nature videos than after viewing the urban videos.

In summary, although field and laboratory studies in psychophysiology have not isolated the influence of natural sound, they do show that the combined effect of unthreatening natural landscapes and soundscapes on non-self-selected groups can reduce both physiological and psychological stress.

Knowledge Gaps

Significant gaps exist in the knowledge of noise impacts on visitor experiences in national parks. Noise interference from sources other than air tours has hardly been studied. These include noise from other types of overflights, as well as from other noise sources. Nor is it clear that annoyance or interference with the sounds of nature are the most useful indices of experience quality. For example, it's very possible that a visitor could report interference with natural sound without evaluating this interference negatively, especially if the noise was only moderately noticeable, infrequent in occurrence, or of short duration. Finally, we know very little about how the perceived need for mechanical noise may affect visitors' evaluations. This is an important issue in the case of administrative overflights. There are reasons for believing that perceived need would influence noise evaluations, but little research has been done on this topic.

Some NPS units are affected by their nearness to Military Training Routes or bases where low-flying military jets operate. Other units are located near airports with heavy civil and general aviation traffic that is either taking off or landing. The acoustical characteristics of steeply ascending or descending flights are quite different from those of level flights. Very little is known about how these kinds of noises affect park visitors.

No experiments have examined the restorative effects of natural sound independently of the visual qualities of a setting. Many studies demonstrate that the visual experience of unthreatening nature *without* sound (determined by people evaluating color slides or photographs) has stress-reducing powers (Kaplan and Kaplan 1989). This raises the possibility that, in experiments that combine exposure to visual and acoustical stimuli, the restorative effects observed are due to the visual experience alone and not to the sonic experience. True, landscapes and soundscapes are rarely experienced separately; however, it has not been shown that, in combination with a natural landscape, natural sound contributes any more to psychological or physical restoration than natural landscapes dominated by mechanical noise.

In psychophysiological experiments, people are isolated from others, or they are placed in small groups. Yet, this is not how most visitors experience national parks. There is a lack of field research in natural settings, using portable monitoring technology, that examines the restorative effects of nature when it is experienced in the presence of hundreds of other visitors. If natural sounds lower stress, are these effects reduced when the sounds are partially masked by noise from other people? No research to answer this question exists.

Summary and Discussion

Natural sound in NPS units is highly valued by many visitors. Part of this value may come from its novelty or the sheer aesthetic quality of extreme quiet that stands in marked contrast to most people's everyday experience. But it is also possible that natural soundscapes have restorative effects. Although studies have not addressed the issue directly, it may be that those persons most annoyed by mechanical noises in parks are among those who value natural sound for its stress-reducing properties. Certainly, in psychological surveys, many visitors mention stress reduction as a major benefit of visits to natural areas.

Air-tour overflights are the most studied source of interference with visitor experiences, but other sources could be causing impacts as well. Even so, in most NPS units studied, less than 5% of visitors reported moderate to serious interference with their enjoyment of the sounds of nature because of aircraft. Percentages of annoyed visitors were greater in selected U.S. Forest

Service wilderness areas where exposure to overflights was relatively high.

Despite this, in some national parks, greater numbers of visitors have reported effects on their experiences. This is especially true in such locations as the Grand Canyon backcountry, where noise exposure is relatively high and ambient sound conditions are often very quiet.

If large numbers of people visit natural areas to hear the sounds of nature, why is it that only a small percentage of park visitors in many areas reported that aircraft noise was annoying, or that it interfered with their appreciation of natural sounds? Several answers are possible. It may be that many visitors did not notice aircraft noise, either because of natural ambient sound conditions, their own self-noise, or because they were concentrating on foreground tasks. Among those who did notice noise, but reported little or no interference, exposure may have been too short to trigger a reaction, or experience expectations may not have ruled out aircraft noise as an acceptable part of a park visit. However, social science theory suggests an additional reason: in psychological terms, parks may be secondary rather than primary environments (Stokols 1976). Primary environments are those in which people spend much of their time, relate to others on a personal basis, and engage in a wide range of personally important activities. Examples include residential, classroom, and work areas. In contrast, secondary environments are those in which encounters with others are relatively short, anonymous, and unimportant. Examples of these are many transportation, recreation, and commercial settings.

Psychological theory predicts that people will react more strongly to interference with desired conditions, such as quiet, in primary environments than in secondary environments. This is because the consequences of that interference are more personally meaningful or more threatening to people's well-being (Schmidt and Keating 1979; Stokols 1976). This does not mean that extreme interference in secondary settings will not be disliked. But interference with desired experiences in parks, especially in those where the typical stay is short, may not have the significant repercussions that it has in residential or work settings.

On the other hand, people visiting wilderness or backcountry areas to experience natural soundscapes might well regard those environments as primary, precisely because natural sound is important to them, and they are going to great effort to obtain it. In this case, interference could have significant personal consequences. Finally, even for visitors who are not motivated by the desire to experience natural soundscapes, it's conceivable that interpretive information about its rarity in urban society, as well as its possible restorative benefits, could lead to support for its protection. Other research has shown that, especially in rural parks, communicating information to visitors about the reasons for policies can change people's attitudes and behaviors while in parks and increase public support for those policies (Bright et al. 1993; Gramann and Vander Stoep 1987; Martin 1992; Oliver et al. 1985; Reiling et al. 1988; Vander Stoep and Gramann 1987).

Conclusion

Returning to the point made at the beginning of this review, whether natural quiet is managed by protecting the physical condition of the natural ambient soundscape or the psychological experience of visitors is a consequential decision. Management actions will go in very different directions, depending upon this decision. Table 1 presented some of the strengths and weaknesses of the three approaches to conducting research on noise impacts. Although the psychological approach has been used most commonly in national parks, no single technique should be regarded as the best method for the entire National Park System. Each approach has characteristics that make it worthwhile for limited, well-targeted applications. The visitor surveys employed in the psychological approach are useful in situations where little is known about how visitors evaluate noise sources, or how various types of visitors differ in their evaluations. Surveys could also play a useful role in public involvement processes that establish acoustical standards on a park-by-park basis. This is because they provide representative input from an important constituent group that often is not heard from or is under-represented in other forums. Finally, the dose-response studies employed in the psychoacoustical approach have potential value in specific locations where it is desirable and practical to manage noise below a threshold of tolerance defined by the percentage of visitors who are likely to be impacted by noise exposure.

In all of this, sight should not be lost of the potential benefits to park visitors of hearing natural soundscapes. Although knowledge of the effects of natural sound is sparse, available research suggests that its restorative properties may be significant. This does not mean that preserving natural sound in the National Park System should hinge on demonstrating these benefits. But among the many values and resources of national parks that are considered in policy formulation, restorative effects may turn out to be an important contribution to the quality of visitor experiences.

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Appendix

Reported Exposure and Impact from Hearing Aircraft at Visitor Survey Parks (NPS 1995).

	National park unit surveyed	Number of visitors interviewed	Percent of visitors reporting			
			Hearing aircraft	Annoyance	Interference with	
					Enjoyment	Natural quiet
1	Assateague Island NS	516	29	1	< 1	3
2	Bandelier NM	424	34	3	1	1
3	Buffalo NR	171	40	4	4	5
4	Canaveral NS	252	32	< 1	2	4
5	Cape Cod NS	290	44	2	4	4
6	Cape Hatteras NS	280	37	< 1	1	2
7	Casa Grande Ruins NM	490	5	1	1	1
8	Cumberland Island NS	703	82	19	15	26
9	Delaware Water Gap NRA	277	22	1	1	2
10	Dinosaur NM	598	8	1	1	2
11	Everglades NP	268	49	17	17	21
12	Fort Sumter NM	474	17	1	< 1	2
13	Fredericksburg & Spotsylvania	230	36	11	6	12
14	Gettysburg NMP	356	16	1	1	2
15	Glacier NP	404	29	2	3	5
16	Glen Canyon NRA	285	52	4	4	8
17	Grand Canyon NP	536	34	5	5	10
18	Great Smoky Mountains NP	266	12	1	1	3
19	Gulf Islands NS	356	64	3	5	8
20	Haleakala NP	533	47	6	6	12
21	Hawaii Volcanoes NP	550	48	7	7	12
22	Hot Springs NP	623	13	1	1	1
23	Kings Canyon & Sequoia NP	304	13	3	3	5
24	Lake Mead NRA	199	32	1	2	3
25	Lake Meredith NRA	188	10	< 1	1	1
26	Lassen Volcanic NP	384	19	4	2	5
27	Mount Rainier NP	390	23	5	4	6
28	Mount Rushmore NMEM	530	61	9	10	17
29	North Cascades NP	437	17	2	3	5
30	Olympic NP	203	33	8	5	12
31	Perry's Victory	500	29	1	3	4
32	Rocky Mountain NP	501	11	1	1	2
33	Saguaro NM	270	21	3	5	7
34	Shenandoah NP	458	13	4	4	5
35	Sleeping Bear Dunes NL	372	16	1	2	3
36	Walnut Canyon NM	542	11	1	2	4
37	Wilson's Creek NB	453	19	1	2	3
38	Yellowstone NP	394	18	1	1	1
39	Yosemite NP	337	55	15	14	19

Glossary

A-weighted decibel: A unit of loudness that adds together the sound energy at all frequencies in a way that corresponds to how the human ear hears sounds, de-emphasizing low-frequency and high-frequency sound energy, while emphasizing sound in the frequency range important for understanding human speech. Abbreviated dBA.

acoustics: The science of sound, including the investigation of the causes of sound and the properties that affect its audibility and fidelity.

audibility: A sound's capability of being detected by a person with normal hearing, even in the presence of other background sounds. Laboratory research (Fidell and Teffeteller 1981) has shown that the minimal sound level audible to an attentive listener may not be noticed by an inattentive observer. See *noticeability*.

decibel: In acoustics, a measure of the relative loudness of a sound (i.e., the intensity of a sound wave). Abbreviated dB.

foreground task: Any mentally involving activity other than listening for intrusive sounds. Research indicates that one factor affecting the noticeability of intrusive sounds is a person's degree of involvement in a foreground task (Fidell and Teffeteller 1981).

natural ambient sound: The sound created by ongoing and more or less continuous processes in the natural environment that is being measured; distinguished from sounds that are produced by specifiable sources of interest, such as aircraft. In a park setting, ambient sound may include the sound created by wind, flowing water, crashing waves, mammals, birds, and insects.

natural quiet: In general, the natural ambient sound conditions of an area. The definition of natural quiet at Grand Canyon NP includes the self-noise generated by visitors participating in non-mechanized activities. This term is not widely used in either the social science or the acoustics literature. See *natural ambient sound* and *self-noise*.

noise: A psychological concept: unwanted sound, sound that is bothersome or even physiologically harmful. In this paper, noise refers to mechanical sound that may be negatively evaluated by listeners. Contrasted with *sound*, which is a physical concept.

noticeability: A level of sound above the average ambient level at which even an inattentive listener with normal hearing will hear a specified signal, such as engine noise. A sound can be audible, yet not noticeable to an observer (Miller 1995). See *audibility*.

psychophysiological: Referring to the psychological and physiological reactions of humans to any external stimulus, such as sound. Describing the branch of psychology that studies these reactions.

restorative: Of or referring to any stimulus or environment, such as a sound or a view, that reduces psychological or physiological stress levels in human beings.

self-noise: Any non-mechanical sound produced by park visitors. Examples are the sounds generated by hiking, running, talking, laughing, and swimming that may completely or partially mask other sounds.

sonic: Pertaining to sound, as in "sonic environment" or "sonic experience."

sound: A physical fluctuation in atmospheric pressure that is capable of producing an audible sensation in the ear. Contrasted with *noise*, which is a negative psychological evaluation of sound.

soundscape: The surrounding sonic environment that is experienced by hearing, rather than by seeing. Soundscapes may include both mechanical and natural sounds, and may vary in their character from day to night and from season to season.

Additional Resources

Acoustical Society of America
500 Sunnyside Boulevard, Woodbury,
New York 11797-2999
Phone: (516) 576-2360, FAX: (516) 576-2377
e-mail: asa@aip.org

This organization publishes the *Journal of the Acoustical Society of America*. It also maintains an online roster of engineers and scientists, categorized by interest areas.

Cornell Laboratory of Ornithology
159 Sapsucker Woods Road, Ithaca, New York 14850
Phone: (607) 266-7425, FAX: (607) 266-7423
e-mail: wbuny@ix.netcom.com

This lab operates the Bioacoustics Research Program, a leading facility for the study of animal communication and for censusing and tracking wildlife with arrays of microphones placed in natural environments. The Bioacoustics Research Program also maintains the world's largest library of wildlife recordings, the Library of Natural Sounds.

California Library of Natural Sounds
Oakland Museum of California, 1000 Oak Street,
Oakland, CA 94607
Phone: (510) 238-7482, FAX: (510) 238-3393.
e-mail: (not listed)

The California Library of Natural Sounds is part of the Natural Science Department of the Oakland Museum of California. It archives an extensive recording of wildlife and other natural sounds.

Environmental Psychophysiology Laboratory
College of Architecture, Texas A&M University,
College Station, TX 77843-3137
Phone: (409) 847-9351, FAX: (409) 845-4491
e-mail: 1-tassinary@tamu.edu

Measuring human physiological responses to computer-simulated stimuli, researchers in the Environmental Psychophysiology Laboratory are determining the effects of the natural and built environments on perception, cognition, emotion, and behavior, and the linkage to health and well-being.

About the Author

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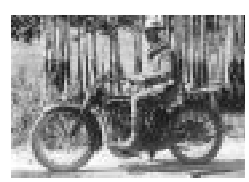

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