Journal of Outdoor Recreation and Tourism 37 (2022) 100474

Contents lists available at ScienceDirect

Journal of Outdoor Recreation and Tourism

journal homepage: www.elsevier.com/locate/jort

Balancing quietness and freedom: Support for reducing road noise among park visitors

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ARTICLE INFO

Keywords:
Road noise
Soundscapes
Protected area management
National parks
Quiet pavement
Natural quiet

ABSTRACT

The importance of natural soundscapes and natural quiet to the recreational experience in protected areas is well established. While a growing body of research examines how recreationists are impacted by anthropogenic noise that inhibits their experience of natural soundscapes, a very limited amount of research examines recreationists' preferences for soundscape management. In fact, sparse research examines park visitors' preferences concerning the management of road noise—perhaps the greatest source of noise pollution in protected areas. It is therefore the purpose of this study to bridge a significant gap in the protected area soundscape literature by examining how varying road noise management actions—including quiet pavement—impact recreationist utility. In this research, the results of a field-based choice experiment in Death Valley National Park (USA) are used to analyze how visitors navigate the tradeoff between natural quiet and freedom and how varying management actions impact recreationist utility. Results show that recreationists require substantial gains in quietness to relinquish freedom; and quiet pavement and reduced speed limits have the least negative impact on recreationist utility. Implications of these results include improved management of road noise in protected areas and considerations for future research of park soundscapes.

Management implications: This research highlights the important roles natural quiet and freedom play in hikers' experiences in parks and protected areas. In this case of road noise mitigation, quiet pavement and reduced speed limits represent management actions that can achieve reduced road noise while remaining relatively unobtrusive to the recreationist experience and not leading to substantial losses in freedom. However, park managers must also consider the demographics and noise sensitivity of their visitors when assessing their soundscape management options, as the impacts of management actions and noise dispersion vary across nationality and noise sensitivities.

1. Introduction

Natural and culturally-important soundscapes are identified by the National Park Service (NPS) and the United States Congress as resources that must be protected (Manning et al., 2018). Visitor-caused noise, therefore, is considered a threat to the natural soundscapes of America's antiquities. In recent decades, social science examined both visitor impacts on park soundscapes and visitor perceptions of noise and natural sounds. Park management continues to implement strategies stemming from the results of these efforts with the intent to find "efficient, cost-effective tradeoffs in the matrix of noise, natural sounds, recreation, and preservation of ecological systems.

In recent years, a variety of studies examined the impacts of anthropogenic noise on visitor experiences in national parks. A large portion of this research focused on pedestrian-caused noise (e.g., Marin et al., 2011; Pilcher et al., 2009) and aircraft noise (e.g., Iglesias-Merchan et al., 2015; Miller et al., 2018; Taff et al., 2014; Taff et al., 2015; Weinzimmer et al., 2014). Some others have examined specific types of

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https://doi.org/10.1016/j.jort.2021.100474
Received 31 March 2020; Received in revised form 10 November 2021; Accepted 6 December 2021
Available online 18 December 2021
2213-0780/

vehicle noise emitted from snowmobiles and motorcycles (e.g., Benfield et al., 2018), limited research to date examines how common automobile road noise impacts the national park visitor experience.

This lack of research is striking, given the large role roads perform in the park visitor experience and the contested management of national park roads over the past century. As noted by Davis (2016), "More than any other aspect of national park policy, roads have served as focal points in the continuing debate over the appropriate level of management" (pp. 2–3). Moreover, it is known that park visitors are exposed to substantial amounts of vehicular noise (Francis et al., 2017; Weinzimmer et al., 2014). In Rocky Mountain National Park, for instance, researchers have modeled hikers' exposure to road noise and found they are exposed over approximately one third of their excursion (Park et al., 2010). Another study found that visitors in Grand Canyon National Park were exposed to road noise for approximately 61% of their visit (Miller, 2008). Considering that the NPS maintains 9,600 miles of roads within its park boundaries, for an average of 23 miles per park, these findings are likely not outside of the norm of all parks (Davis, 2016).

For these reasons, the NPS is assessing noise abatement among its road networks. Some parks use mass transit to manage visitor carrying capacity and road noise; others limit the number of vehicles allowed on the road or lower posted speed limits (Manning & Anderson, 2012). As of 2016, sixty-six mass transit systems were operating in NPS units (Davis, 2016). However, direct management actions like mandatory shuttle systems and vehicle quotas limit visitor freedom (White, 2007). In this study we rely on the conceptualization of freedom defined by Wilson et al. (2018) in their exploration of the concept through the lens of transportation in a U.S. national park. Though freedom is a highly dynamic, multi-dimensional concept in outdoor recreation (Dorman, 2019), Wilson et al. (2018) found (among other indicators) the ability to stop wherever the visitor wants, drive wherever is preferred, be on one's own schedule, and choose modes of transportation salient to freedom in the context of the implementation of a shuttle system. As noted by Orsi (2015), private vehicles are generally perceived to provide "maximum freedom regarding where and when to go, and how much time to spend at a given location: something that can be hardly equaled by common public transportation" (p. 20). Wilson et al. (2018) found that the limitation of freedom was a primary inhibitor to shuttle bus ridership in Sequoia and Kings Canyon National Parks (USA), and Louter (2006) concluded that the limitation of freedom was central to the failed proposal of a shuttle bus system in North Cascades National Park (USA). As a result, more unobtrusive strategies are preferred for noise abatement in park settings.

In 2018, the NPS trialed a new strategy in Death Valley National Park (DEVA) by piloting noise-reducing, quiet pavement on sections of park roads. In short, quiet pavement reduces friction or vibrations produced from roads through a smoother, more porous, or more rubberized surface (Praticò & Anfosso-Lédée, 2012). The impact of this management action on recreationists is of great interest to the NPS, as it evaluates noise abatement strategies. The purpose of this study is to address a significant gap in the national park soundscape literature through an examination of how visitors assess road noise impacts, and to examine how visitors navigate the tradeoffs necessary to reduce road noise. Additionally— given the quiet pavement management action currently being piloted at DEVA—we seek to understand park visitors' relative support for this management action as opposed to alternatives. Therefore, the following two research questions have been formulated:

R1: How much freedom are recreationists in DEVA willing to trade-off to attain quieter conditions through reduced road noise?
R2: What is the relative visitor support for reducing road noise through quiet pavement as opposed to other noise reduction mechanisms (e.g., vehicle quotas and shuttle systems)?

2. Literature review

The impacts of road traffic noise on human and ecological health are well-documented, requiring consideration by park managers when making decisions about transportation strategies such as quiet pavement.

2.1. Noise in national parks

Numerous federal policies mandate the protection of national park soundscapes with both recreational and ecological aims (Manning et al., 2018). The importance of the natural soundscape as an aspect of the recreational experience in public lands is well documented (see Francis et al., 2017; Li et al., 2018; Manning et al., 2018). Noise in national park settings is shown to impact evaluations of landscape quality (Weinzimmer et al., 2014), impair memory (Benfield et al., 2010), and negatively impact perceptions of naturalness, freedom, solitude, and tranquility (Mace et al., 1999). Due to noise's impacts on the visitor experience, a variety of management strategies have been derived to limit noise or noise exposure. Research subsequently examined the effectiveness of these management strategies. Manning et al. (2009) examined the efficacy of signage-based programs to reduce anthropogenic noise, finding it effective. Marin et al. (2011) suggested the creation of recreation zones based on noise levels—a method later examined for efficacy and proven useful by Herrera-Montes (2018). Other research has focused on economic valuation and trade-offs related to noise in park settings. Iglesias-Merchan et al. (2014) found that visitors were willing to pay an increased entrance fee as a means of funding a noise mitigation program in Peñalara National Park, ESP. Similarly, Calleja et al. (2017) found that visitors to an urban park in Madrid, ESP, were willing to pay 6.36 euros on average through a one-time payment to fund noise reduction efforts in the park space. Using similar methods, Wu et al. (2021) calculated the total economic value of the tidal soundscape created where the Qiantang River meets Hangzhou Bay, CHN, to be between 48.7 and 51.6 million U.S. dollars—focusing only on auditory aspects of the tourist experience. Through a choice experiment, Sever and Verbič (2018) found that traffic-related noise was the third most important factor related to visitor trail preferences in a nature park in Zagreb, HRV (after encounters with mountain bikers and traffic-related air quality).

A number of other studies have examined the feasibility and effectiveness of alternative transportation systems in protected areas, including Colonial National Historical Park, USA (Shiftan et al., 2006), Great Smoky Mountains National Park, USA (Sims et al., 2005), Teide National Park, ESP (González et al., 2019), and Zion National Park, USA (Mace et al., 2013). These studies have, in part, examined the feasibility of shuttle systems as tools for reducing road noise. While a typical shuttle bus has a sound power of approximately 12 dBA (decibels measured on a scale adjusted to conform with the capabilities of the human ear) higher than the typical car when traveling at 70 km per hour, the louder "40 passenger bus can replace roughly 20 cars (assuming a vehicle-occupancy of two per car) [when full]" (Newman et al., 2010). Additionally, a typical shuttle bus can be heard across a broader area than a typical car, thus increasing "noise intensity during finite events" (Monz et al., 2016). However, a mandatory shuttle bus system that replaces *all* car traffic in a park has the potential to reduce total noise emissions overall. Although the concentration of noise into short, more intense moments of disturbance must be weighed by managers when making decisions (Monz et al., 2016).

2.2. Impacts of road noise

Road traffic noise is a harmful environmental pollutant that adversely effects the psychosocial and physiological health of humans (Kim et al., 2012). Empirical studies have shown that road noise causes annoyance and sleep disturbance (Kim et al., 2012). Short-term exposures to road noise can lead to increased heart rate variability (Huang et al., 2013), hindered recall (Enmarker, 2004), and reduced attentiveness (Hygge et al., 2003). The impacts to wildlife are also well-documented (i.e., Halfwerk et al., 2011; Lengagne, 2008; Shannon et al., 2014). In the context of US national parks, the impacts of road noise on both recreationists and wildlife are of serious concern due to the National Park Service's mandate to purvey quality recreational experiences and preserve the natural environment (Manning et al., 2018). However, traffic as a source of noise pollution remains understudied from the recreationist standpoint—despite recognition of its importance (i.e., Francis et al., 2017; Weinzimmer et al., 2014).

2.3. Quiet pavement

Quiet pavement—a noise reducing asphalt mixture—represents technological strategy for soundscape management in protected areas (Buxton et al., 2019). These pavements change sound pressure levels and frequencies to improve environmental conditions (Li, 2018). Quiet pavement differs from "regular" pavement in at least one of three ways: increased porosity to improve sound absorption and reduce frequency of noise, optimized texture to even the road surface and reduce tire vibration, and/or increased pavement flexibility to reduce vibrations (Vaitkus et al., 2016). Overall, quiet pavement generally costs 30–50% more than conventional asphalt (Praticò & Anfosso-Lédée, 2012), however—according to NPS staff—the cost of quiet pavement in this study site was significantly lower than these estimates, in relation to conventional asphalt. In recent years, coatings and micro-coatings have also been used to retroactively make existing pavements quieter (Cabral et al., 2015). These coatings have been shown to reduce road noise by as much as 10 dB (Cabral et al., 2015). Rochat and Lau (2013) report the ambient natural sound within DEVA is at or below 20 dBA. The authors additionally found that road noise in DEVA reached a maximum sound pressure level of just over 80 dBA (Rochat & Lau, 2013). The authors additionally found that road noise in DEVA reached a maximum sound pressure level of just over 80 dBA (Rochat & Lau, 2013). Road noise at its maximum was measured 60 dBA louder than the natural ambient conditions, making it 16 times louder than natural ambient. A 10 dBA reduction in road noise through quiet pavement represents a condition 8 times louder than the natural ambient or—put another way—a halving of perceived loudness.

In the context of national parks, quiet pavement presents an indirect, unobtrusive management strategy to reduce road noise (Manning & Lime, 2000). Contrasted with other proposed strategies such as reduced speed limits or mandatory shuttle systems (Buxton et al., 2019), quiet pavement places the least burden on the park visitor and does not limit freedom (Taff et al., 2013). Therefore, quiet pavement presents a possible panacea of sorts—whereas the values inherent to both quiet and freedom might be retained. Understanding if this is the case, however, requires measuring the utility derived from quiet and freedom under varying noise management scenarios.

DEVA presents a location where these utilities can be measured. In 2018, managers at DEVA resurfaced segments of road with quieter pavements with hopes to "minimize noise heard by visitors at popular hikes" (Death Valley National Park, 2018). However, no research to date evaluates the efficacy of quiet pavement as a park management strategy. The goal of this research is to analyze the efficacy of this strategy of noise reduction by examining both how visitors navigate the tradeoff between quiet and freedom and to what degree visitors support this management action.

3. Methods

3.1. Study site

Death Valley National Park (DEVA) is the largest national park in the contiguous United States, preserving 3.4 million acres of the Mojave Desert in California and Nevada (Brean, 2019; Carver et al., 2013). In large part, DEVA is defined by its extremes (Rothman & Miller, 2013). It is home to both the hottest and driest places in the United States (Carver et al., 2013). However, it also contains numerous mountain ranges—reaching a maximum elevation of 11,049 feet above sea level at Telescope Peak a mere 15 miles from the lowest point in United States (282 feet below sea level) (Carver et al., 2013; Rothman & Miller, 2013). The park provides a variety of recreational opportunities ranging from wilderness trekking to jeep touring (Death Valley National Park, 2018). A number of day-use recreation areas have been developed in the park, including hiking trails and scenic drives and viewpoints (Death Valley National Park, 2018). Diverse hiking opportunities include slot canyons, mountain peaks, valley bottoms, and sand dunes (Death Valley National Park, 2018). In total, 91% of the park is congressionally designated as Wilderness. The preservation of natural soundscapes and quietness is one of the primary goals of DEVA's Wilderness management (Death Valley National Park, 2012). However, Buxton et al. (2019) found that some highly trafficked areas of DEVA experience noise exceedance levels of greater than 10 dB. Therefore, in 2018, managers installed quiet pavement on eight sections of Highway 178 (Badwater Road) from Furnace Creek in Death Valley to Salsberry Pass in the Black Mountains to preserve the natural soundscape of DEVA and improve the backcountry experience of hikers (Death Valley National Park, 2018).

3.2. On-site surveying

To examine how visitors weigh tradeoffs associated with road noise, we conducted a quantitative surveying effort in DEVA over 21 days during the autumn of 2018. The visitor survey was administered at two road-proximate recreation areas: Golden Canyon Trailhead and Mesquite Flat Sand Dunes Trailhead (Fig. 1). These two locations were selected through a discussion with park staff based on their high autumn use level and proximity to paved park roads. Quiet pavement was installed near the Golden Canyon Trailhead in 2018.

Qualtrics-based surveys were administered by trained technicians via iPad. A combination of stratified random sampling and convenience sampling was used to maximize the sample size (Singh & Mangat, 1996). The random component consisted of randomly selecting sampling days, locations, and times using a random number generator to meet predefined quotas for times and locations. The convenience sampling component existed in the field. As visitors exited a trail at either survey location, they were intercepted by a research technician and asked to participate in a 10-min survey informing the management of DEVA. If they declined, only observational data were collected (gender and sampling location) for non-response bias purposes. If a group was intercepted, the member with the next upcoming birthday was asked to participate. Immediately following each survey, the technician would intercept the next individual or group exiting the trail. A minimum of two research technicians were surveying concurrently at all times.

3.3. Survey instrument

3.3.1. Selecting a method

Choice experiments are a method of non-market valuation. In this way, they are used to derive relative values—or utility—for goods or services that are not easily derived through either market prices or revealed preferences of consumers (Tietenberg & Lewis, 2016). They have been used broadly throughout the recreational social science field of study to inform management actions in protected areas (e.g., Arnberger et al., 2017; Koemle & Morawetz, 2016; Newman et al., 2005; Pröbstl-Haider et al., 2016). This method of valuation is robustly applied in transportation research (see Holmes et al., 2017), a trend which is mirrored in its application to transportation in park settings (Newton et al., 2018; Pettebone et al., 2011).

To gain an understanding of how a park visitor values a certain aspect of their experience, that aspect must be examined in relation to

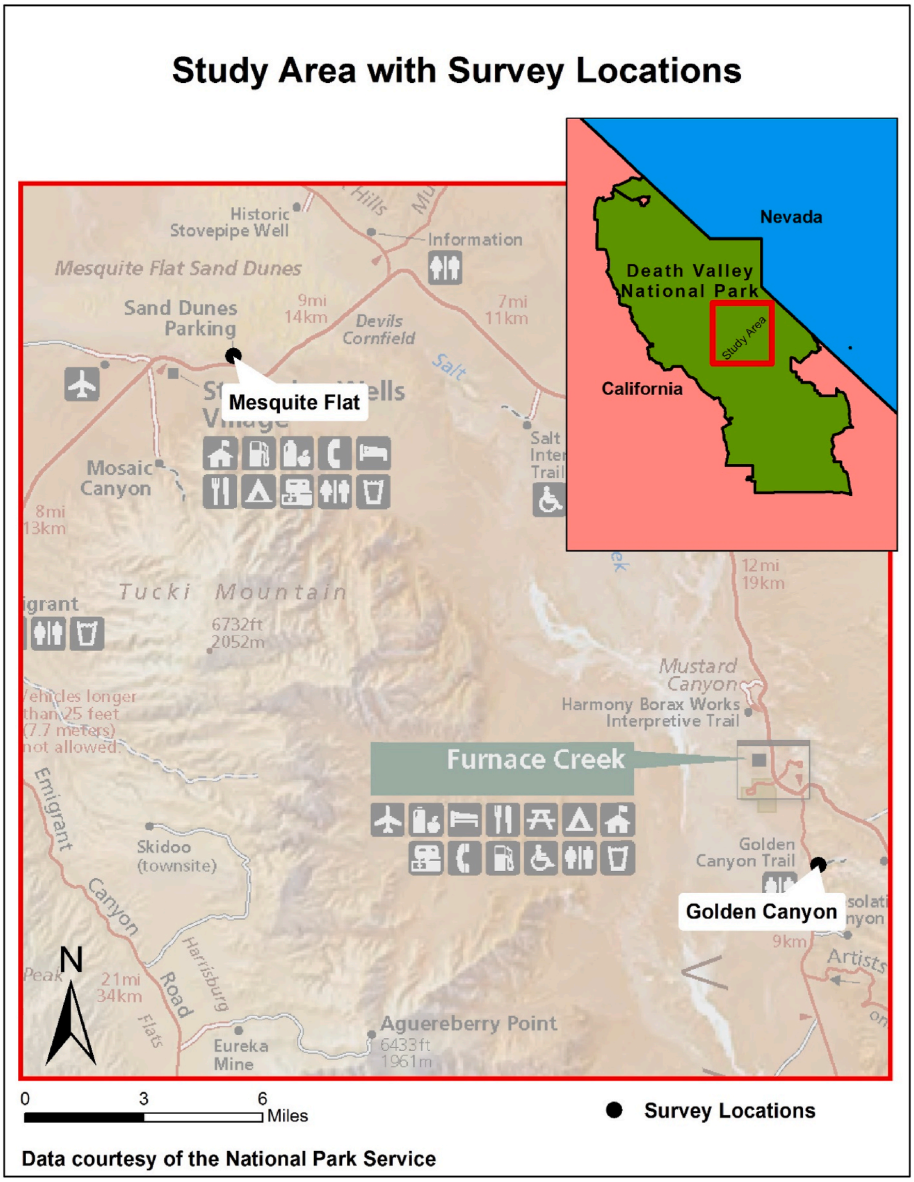


Fig. 1. Study area within Death Valley National Park with survey locations.

another part of the experience. In this way, the opportunity cost of selecting one action over another can be synthesized—whereas a tradeoff exists between one aspect of the experience and another. Finding a relevant tradeoff for the aspect of interest, therefore, is key to the design of a choice experiment (Adamowicz et al., 1998).

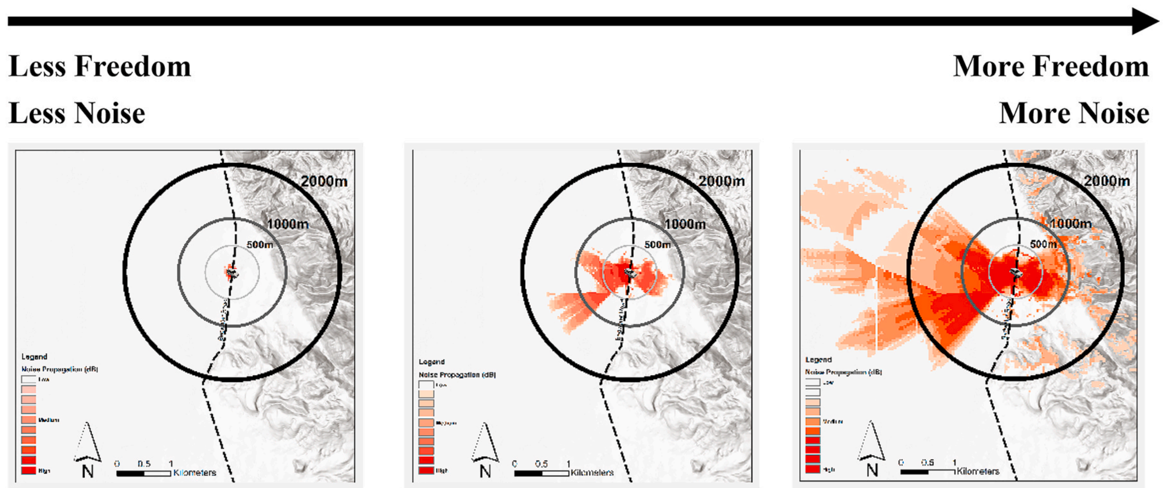
3.3.2. Choice experiment design

An evident tradeoff for quiet in the visitor experience is visitor freedom. This follows the assumption that less regulated and directly managed visitors are more likely to create more anthropogenic noise, thus masking the natural soundscape. Our tradeoff is then: the protection of natural quiet versus freedom.

Four attributes were selected for inclusion in our choice experiment—two attributes representing quietness and two attributes representing freedom. Road noise dispersion and percent reduction in road noise were chosen to represent the preservation of natural quiet, while speed limits and varying management actions were used to represent freedom. Three levels were given to each attribute (see Table 1). Levels were chosen to reflect feasible management alternatives or goals. The levels of management actions, for instance, were selected on a continuum from a very indirect, unobtrusive strategy (quiet pavement installation) to a very direct, obtrusive strategy (a shuttle system) (Manning & Lime, 2000). Visitors were assumed to prefer more indirect management strategies that allow more freedom. Similarly, visitors were assumed to prefer—and find more freedom through—higher speed limits. Increased speed limits have been previously used to examine willingness to trade-off freedom for natural sounds in a park setting (Levenhagen et al., 2021). This follows the research of Ahie et al. (2015), which found that people driving for fun preferred faster speeds than their everyday speeds. It was further assumed that visitors prefer more quietness and less road noise propagation.

Noise propagation maps were utilized to illustrate road noise dispersion, as it can be a rather abstract concept. Noise propagation maps were generated using the open-source ArcMap tool SPreAD-GIS and based on spectral sound data collected by the NPS Natural Sounds and Night Skies Division and the U.S. Department of Transportation's Volpe National Transportation Systems Center in DEVA. The highest level of noise propagation is represented using unaltered noise propagation data with a maximum volume of 70 dBA. The other two levels were altered to display propagation levels with maximum volumes of 53

Table 1
Choice Experiment Attributes and their associated Levels.

Attribute	Level 1	Level 2	Level 3
Road Noise Dispersion			
Overall Reduction in Road Noise	20%	10%	0%[a]
Speed Limit on Park Roads	30 MPH	45 MPH	60 MPH[a]
Management Action	A mandatory shuttle system transports visitor along major park roads with parking on either end to reduce road noise	A quota on the number of vehicles allowed on major park roads at one time is implemented to reduce road noise	A noise-reducing pavement is installed on major park roads to reduce road noise[a]

MPH = miles per hour.
[a] Denotes reference level.

dBA and 35 dBA, respectively. Each of the attributes contained one status quo level (reference level) so that utility could be modeled for the other levels as changes from the baseline condition (Holmes et al., 2017). Each respondent received seven choice sets, to maximize the degrees of freedom in the model, while considering respondent survey fatigue (Bradley & Daly, 1994; Holmes et al., 2017). Given our number of attributes, seven choice sets are well within the bounds of acceptability given research in this area (Hess et al., 2012). Similarly, the number of attributes and their respective levels were selected based on a review of previous literature and an estimation of total park visitor burden hours.

This 4 × 3 design yielded 81 possible profiles ($3^4 = 81$). Additionally, when two profiles were paired together, this design had a possible 3,240 [$3^4 \times (3^4 - 1)/2$] choice sets. The design allowed for the pairing of certain attribute choice levels against themselves, thus making it a full factorial design (Johnson et al., 2013). Orme's (1998) rule of thumb for stated choice experiments was used to calculate a minimum sample size—as reported by Rose and Bliemer (2013)—yielding a target sample size of at least 107 respondents to estimate parameters at a statistically significant level.

Randomizing the choice scenarios presented to each individual was the final task in designing our experiment, conducted using the Conjoint Survey Design Tool (Strezhnev et al., 2014) designed in conjunction with Hainmueller et al. (2014). This software generates random choice set profiles by randomizing attribute levels in accordance with any preset restrictions, and has become a popular means of generating choice sets for choice experiments (e.g., Crowder-Meyer et al., 2020; Findor et al., 2021; Motta, 2021; Teele et al., 2018). It was used as an alternative to d-optimal choice experiment design software's such as NGENE, which may offer a preferred design approach. We utilized the Conjoint Survey Design Tool to develop a full factorial design of choice sets (see Boehm et al., 2019). To ensure realistic scenarios were produced, a number of restrictions were implemented using the software (Johnson et al., 2013; Zhirkov, 2021). Our experimental design contained three restrictions whereas one given attribute level could not be paired with another in the same choice scenario: a mandatory shuttle system and the largest noise dispersion level, a 0% reduction in road noise and the smallest noise dispersion level, and a 20% reduction in road noise and the largest noise dispersion level. In total, the software created 35 choice sets. From this bank of choice sets, seven sets were randomly presented to each respondent using Qualtrics surveying software. A sample scenario is shown in Fig. 2.

3.4. Analysis

The mixlogit package STATA was used for data analysis. A mixed logit model was selected because, as opposed to a simple multinomial logit model, it accounts for heterogeneity across respondents by allowing parameters to vary across individuals (Tu et al., 2016). Before running the choice model, reference (or base) levels were assigned to each attribute using dummy coding (Eggers et al., 2018). Reference levels represent baseline conditions. For this reason, the utilities of the reference levels are set to zero (Eggers et al., 2018). The reference levels selected can be seen in Table 1. After the reference levels were assigned, the utility function (U_{itq}) was specified for individual respondent i in scenario t in the set q:

$$\begin{aligned} U_{itq} = {} & \beta_i^1 + \beta_i^s Speed_{itq} + \beta_i^m Management_{itq} + \beta_i^d Noisedispersion_{itq} \\ & + \beta_i^r Reducenoise_{itq} + \beta^{dlh} Noisedispersion_{low} {}^* Hikefar_{itq} \\ & + \beta^{dlh} Noisedispersion_{medium} {}^* Hikefar_{itq} \\ & + \beta^{msf} Management_{shuttle} {}^* Foreign_{itq} + \varepsilon_{itq.} \end{aligned}$$

Herein, individuals are allowed to have varying tastes for *Speed*, *Management*, *Noisedispersion*, and *Reducenoise*, represented by the individual specific coefficients, β_i^X including the intercept β_i^1. *Hikefar* and *Foreign* represent random attribute vectors derived through the survey, used exclusively in interaction terms with *Noisedispersion* and $Management_{shuttle}$ respectively. The definitions of the attributes included

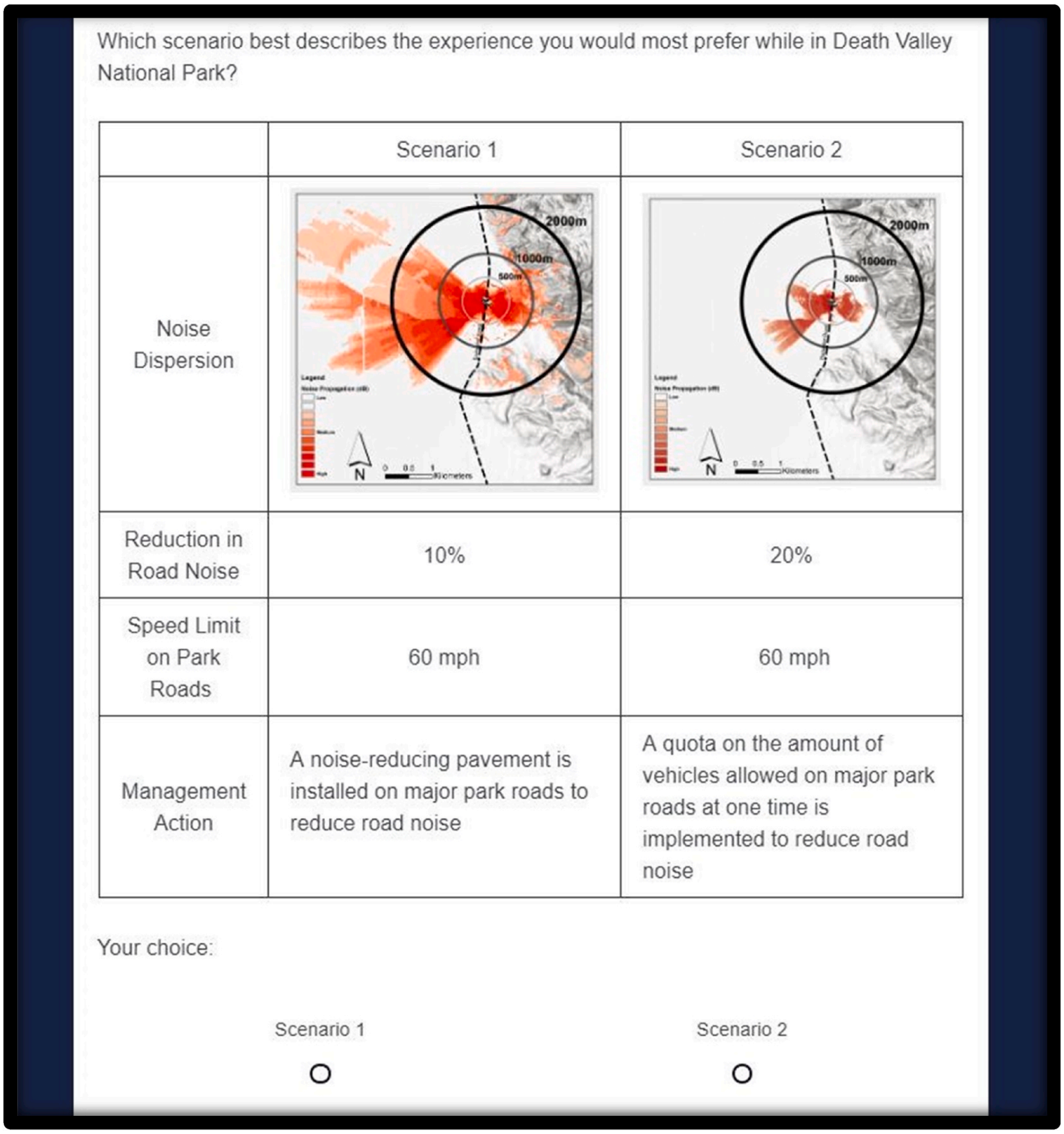


Fig. 2. A sample choice set presented to respondents.

in the model can be found in Table 2.

This model was hypothesis-driven. *Speed*, *Management*, *Noisedispersion*, and *Reducenoise* were included as they were the non-random, choice variables. Interactions between willingness to hike further to reduce the amount of road noise heard by one half (*Hikefar*) and the low and medium road noise dispersion maps (*Noisedispersion*) were included per the hypothesis that those willing to hike further to reduce their exposure to road noise would be more sensitive to the dispersion of road noise to backcountry settings. In this way, it was hypothesized that these visitors would have significant and higher positive values for the low noise dispersion map.

Table 2
Choice model attributes and definitions.

Attribute	Definition
Speed	Speed limit in choice scenarios: 30, 45, or 60 MPH
Management	Management action in choice scenarios: noise-reducing pavement, quota on the number of vehicles allowed on major park roads mandatory shuttle system
Noisedispersion	Noise dispersion map in choice scenarios: low (max. 35 dBA), medium (max. 53 dBA), or high (max. 70 dBA)
Reducenoise	Percentage reduction of overall road noise in DEVA in choice scenarios: 0%, 10%, or 20%
Hikefar	Dichotomous variable for respondent's willingness to hike to reduce exposure to road noise by one half: 1 = Yes or 0 = No
Foreign	Dichotomous variable for respondent's residence: 1 = Non-US resident or 0 = U.S. resident

MPH = miles per hour, dBA = A-weighted decibels.

The interaction between the management action of implementing a shuttle system ($Management_{shuttle}$) and a respondent being a resident of a country other than the United States (*Foreign*) was included to see if foreign visitors would be more willing to take shuttle systems than American visitors. It was hypothesized that foreign visitors would be more willing to take shuttle systems to reduce road noise. This was guided by the research of Pucher (1995) and Buehler and Pucher (2012), finding that Americans have weaker preferences and less exposure to public transit than residents of other developed countries.

3.4.1. Model testing

To generate information about how visitors value the various attributes in our choice experiment, we first needed to define a specific model to test. As previously mentioned, we selected a mixed logit model. A mixed logit model allows explicit incorporation of individual's heterogenous tastes, which are assumed to follow a normal distribution. Following the approach outlined by Chapman and Feit (2015), an uncorrelated mixed logit model was run first. This model assumes that the coefficients are not correlated with one another. Next, the coefficients were correlated with one another— creating a correlated mixed logit model. This model was then tested using the Wald test to see if correlation was, in fact, held among the coefficients.

4. Results

In total, 1,135 park visitors were asked to participate in the study. Of those, 168 were unable to take the survey because of a language barrier. Of the remaining 967 visitors, 667 agreed to take the survey—for an overall response rate of 68.9%. According to Vaske's (2008) guidelines for conducting representative park visitor surveys, this provides a reasonable, conservative sampling error between ±3 and ± 5% at a 95% confidence interval based on 2018 visitation to DEVA (1,678,660 recreational visits). Between the two sampling locations, 296 surveys were collected at Mesquite Flat Sand Dunes and 371 surveys were collected at Golden Canyon. Given the parameters of the DEVA research permit, we were unable to ask a non-response bias question and were therefore forced to rely on observational data for our assessment of non-response bias: sampling location and gender. Pearson's chi-square tests revealed no meaningful non-response bias (Vaske, 2008). Of the $n = 667$ respondents surveyed, 52.4% were male. The average age of respondents was 43 years old. Foreign visitors made up the majority of the sample, with 57.1% of visitors being residents of countries other than the United States. In total, 97.9% ($n = 649$) of respondents entered the park via a personal or rental vehicle.

4.1. Choice experiment

The uncorrelated mixed-logit choice model yielded the results seen in Table 3. To ensure an uncorrelated model should be used over a correlated model, the Wald test was used to test the strength of the correlations between coefficients (Chapman & Feit, 2015). It was confirmed that the coefficients are uncorrelated at a 99.9% confidence interval. The utility coefficients should be interpreted as net impacts to visitors' utility in relation to the reference—or base—level (i.e., the degree to which a given level is more or less favorable than the reference level) (Eggers et al., 2018). Significant utilities indicate that a level of a certain attribute significantly influenced choice behavior. Results indicate that seven of the eleven utilities were significantly different from zero at a 99% confidence interval. Percent net road noise reductions throughout DEVA show rather linear results, with utility gradually increasing from the reference level of no reduction to the third level of a 20% reduction. The large, significant result of the 20% reduction in road noise underscores its preference among visitors, as expected.

Table 3
Choice model output with means and standard deviations of variables.

Attributes	Mean Utility Coefficient	Std. Error	Standard Deviation Coefficient	Std. Error
Noise Dispersion-Low	0.02	0.32	1.42***	0.26
Noise Dispersion-Medium	0.76	0.25	−0.11	0.28
Noise Dispersion-High	0	*reference level, not included in model*		
Noise Reduction-0%	0	*reference level, not included in model*		
Noise Reduction-10%	0.54***	0.14	−0.11	0.25
Noise Reduction-20%	0.97***	0.17	0.48	0.32
Speed- 30 MPH	0.13	0.15	1.41***	0.22
Speed- 45 MPH	0.46***	0.14	−0.01	0.39
Speed- 60 MPH	0	*reference level, not included in model*		
Management Action: Pavement	0	*reference level, not included in model*		
Management Action: Quota	−1.12***	0.19	2.30***	0.27
Management Action: Shuttle	−2.85***	0.46	3.98***	0.40
Shuttle *x* Foreign	1.72***	0.50	0.01	0.68
Low Dispersion *x* Hikefar	0.88**	0.32	0.11	0.43
Medium Dispersion *x* Hikefar	0.11	0.25	−0.03	0.15

Significance: * ≥95% confidence, ** ≥99% confidence, *** ≥99.9% confidence.
Log-Likelihood Ratio = −1520.28.

Concerning management actions, the utility estimates suggest—holding all else constant—that quiet pavement has a substantially less negative impact on visitors' utility as opposed to other noise mitigation strategies. Conversely, on the whole, a vehicle quota or mandatory shuttle system significantly reduces visitors' utility. Utility measures of foreign visitors, however, suggest that they are less averse to shuttles than U.S. residents ($-2.85 + 1.72 = -1.13$).

Finally, the standard deviation coefficients for four of the attributes are significantly different from zero. This pattern is indicative of heterogeneity among respondent preferences—meaning that preferences varied considerably by respondent (see Newton et al., 2018). Additionally, some attributes have estimates of standard deviations with a larger magnitude than their respective means. For these attributes, this suggests that there was not an overwhelming preference at a given level. Moreover, this signifies that some, or many, respondents hold preferences that are counter to the majority.

5. Discussion

5.1. R1: Tradeoff between quiet and freedom

Our first research question asked how much freedom recreationists are willing to relinquish to attain quieter conditions through reduced road noise. In answering this question, we must examine noise reduction and noise dispersion separately. Utility from noise reduction increased linearly from 0% to 20%, with a 20% reduction yielding a relatively high utility value of 0.97 that boasts statistically significant influence on decision-making between choices. However, this difference in utility from 0% to 20% noise reduction (0.97) is still substantially less than the difference in utility between quiet pavement and a mandatory shuttle system (−2.85). Still, the utility derived from a 20% reduction in road noise is approaching the magnitude of the negative utility derived from a vehicle quota (−1.12)—suggesting that if a quota could lead to a 20% reduction in road noise, it would not have a substantial net impact on the visitor experience ($0.97 + -1.12 = -0.15$). The same would be true for the impact of a mandatory shuttle system on the experience of foreign visitors ($0.97 + -1.13 = -0.16$).

In contrast to more direct management actions, speed limits represent a more favorable means of reducing noise. Lower speed limits—permitting less noise—were more favorable than the highest speed limit of 60 MPH. Thus, low speed limits represent an action that can improve the provisioning of natural quiet while also increasing visitor utility—and freedom. Overall, we posit that visitors are willing to give up freedom by way of lower speed limits to increase the provisioning of natural quiet and may be willing to accept more direct management actions like a quota or mandatory shuttle system if gains in noise reduction are substantial.

Noise dispersion utility coefficients were not statistically significant. With this in mind, the most striking result is the significant impact willingness to hike has on preferences for low noise dispersion. For those willing to hike further to reduce their exposure to road noise by one half, the net utility is positive and significant ($0.02 + 0.88 = 0.90$). This result makes sense given that those willing to incur a cost to reduce their exposure are likely more sensitive to noise propagation.

5.2. R2: support for management actions

Our second research question examined the relative support for reducing road noise through quiet pavement as opposed to other noise reduction mechanisms. Quiet pavement has a less negative impact on net visitor utility compared to other management actions. A proposed quota on vehicles in DEVA yielded a negative utility coefficient (−1.12) and significantly influenced choice behavior. This result was expected, as quotas are relatively obtrusive to the visitor experience (Manning & Lime, 2000) and therefore were expected to yield a more negative utility. This result is valuable, however, as quotas on vehicles are becoming increasingly popular in U.S. national parks (Timmons, 2019).

In relation to a quota, the prospect of a mandatory shuttle system resulted in a relatively larger negative utility value (−2.85) that significantly impacted choice behavior. This indicates that the vast majority would not support this management action, all else being equal. Interestingly, however, utility from this management action was substantially less negative for foreign visitors. This result—though expected based on previous research (e.g. Buehler & Pucher, 2012; Pucher; 1995)—is especially important given the large proportion of DEVA visitors hailing from foreign countries, as confirmed by this study (57.1%). Overall, it is possible that visitors did not perceive shuttle systems to be a feasible solution to noise reduction, given the scale of DEVA and the presumption that a sizable portion of DEVA visitors are exiting the park in a different direction from which they entered. Previous feasibility studies of shuttle services in U.S. national parks have highlighted the need to consider scale and geography (Cotton et al., 2012; Filosa et al., 2013).

Decreased speed limit levels—relative to the reference level of 60 MPH—yielded positive utility coefficients. This is a curious result, as vehicular speed limit and travel time are often used as cost measures in transportation choice models (e.g., Hensher et al., 2015; Li & Hensher, 2012; Newton et al., 2018). However, as discussed by Small (2012), valuations of travel time are highly dependent on trip purpose and road conditions. In DEVA, travelers are driving primarily for leisure purposes in non-congested traffic conditions—therefore making travel time less costly to them. Additionally, national park travelers have historically valued the scenic driving experience in parks (Davis, 2016). Thus, this result indicates that speed limit could be an effective means of reducing road noise, especially when coupled with quiet pavement. Previous research shows that such reductions can have considerable impacts on road noise (de Freitas et al., 2012; Waters, 1970).

5.3. Future research and limitations

Three primary implications for future research arise from this study. First, given the positive impact of lower speed limits, it is recommended that speed limits be used with caution in future tradeoff models in national park settings. Though speed limits below 30 MPH or above 60 MPH may lead to diminished utility—and therefore present a cost to visitors—these speed limits are outside of most parks' acceptable bounds. As discussed by Davis (2016), the driving experience in national parks is unique in that it is not only a means to recreation, but recreation unto itself. Therefore, speed limit does not present the same burden in national parks as it does in other settings. Second, related to the previous recommendation, future research should examine the motivations and outcomes associated with the iconic recreational experience of scenic driving in parks and protected areas. As noted by Merry et al. (2020), this popular activity merits further inquiry. Finally, future economic analyses should examine how the implementation costs of quiet pavement compare to other noise reduction management actions and their associated impacts on the soundscape itself. The visitor preferences revealed through this study can inform the design of future econometric inquiry in soundscape management.

The primary limitation of this study was the lack of a "true" cost measure. We were unable to capture how much visitors were willing to pay to reduce road noise, and are thus reliant on the tradeoff of freedom. This is a reality of administering surveys in U.S. national parks, as gaining approval to ask questions associated with monetary valuation can take multiple years. However, we feel that—given our research questions developed in concert with park managers—the choice experiment we administered provides sufficient, reliable, and actionable data to DEVA and the broader NPS system as they move forward with their soundscape management. Second, the sampling strategy used in this study presents an additional limitation. Though the sampling days, locations, and times were randomly selected, respondent intercepts were based on convenience. Third, we acknowledge that the percentage reduction of noise used in the choice experiment is a rather intangible means of quantifying noise reduction. Since decibels are a logarithmic scale, percentage change represents an abstract means of quantification.

The narrow conceptualization of freedom provides a third potential limitation to this research. In parks and protected areas, freedom is an intrinsic, multidimensional concept—boasting a variety of meanings in varying contexts (Dorman, 2019). This research focused on the context of transportation, and therefore did not account for other dimensions of the freedom concept that might be indirectly related to this work. However, we acknowledge that—even in the context of park transportation—freedom has multiple meanings and can be conceptualized differently based on visitors' motivations, abilities, and needs (Orsi, 2015; White, 2007). An additional, related limitation is likely found in the theorized negative relationship between freedom and both mandatory shuttle systems and lower speed limits. Previous research on park shuttle buses and freedom suggests that "visitors differed somewhat in their opinions about whether traditional or alternative transportation enhanced their feelings of freedom" (White, 2007, p. 59). Following the implementation of a mandatory shuttle bus in Zion National Park, USA, "visitors found their freedom impinged upon" (Mace et al., 2013, pp. 1280–1281). However, as the mandatory shuttle system became more established and accepted, visitors felt less constrained (Mace et al., 2013). Concerning speed limits, Hallo and Manning (2009) find that "speed limits on experiential roads may be more important to their users [compared to urban roads] because they permit visitors to slow down or safely stop to see the scenic beauty of a park" (p. 497). However, importantly, this previous research specifically examined the existence of a speed limit, not the level of the limit.

6. Summary and conclusions

A choice experiment was used in this study to assess how much freedom recreationists are willing to relinquish to reduce road noise and the relative support for reducing road noise through quiet pavement as opposed to other noise reduction mechanisms. From our results, we can conclude:

i. Recreationists in DEVA value natural quiet and are willing to relinquish some freedom to attain quieter conditions.
ii. Quiet pavement and reduced speed limits represent management actions that can achieve reduced road noise while remaining relatively unobtrusive to the recreationist experience and not leading to substantial losses in freedom.
iii. Road noise in DEVA must be reduced substantially for recreationists to find the implementation of a vehicle quota acceptable.
iv. Park managers must consider the demographics and noise sensitivity of their visitors when assessing their soundscape management options, as the utility impacts of management actions and noise dispersion vary across nationality and noise sensitivities.

This research represents the first empirical study of national park recreationists' support for quiet pavement. At the same time, this research adds to a growing cannon of literature concerning soundscape management in national parks and, in doing so, explores the trade-offs recreationists are willing to make to experience quieter conditions. Further, this study adds insight into a century-long debate concerning the presence of roads in U.S. national parks (Davis, 2016). In 1967, advisors to the U.S. Secretary of the Interior wrote in a letter to the U.S. Senate, "Perhaps the most dangerous tool [available to national park managers] is the roadgrader" (United States Department of Interior, 1967; p.97). Our findings counter this proclamation. As far as soundscape management is concerned, perhaps the most effective tool is a roadgrader installing quieter pavement.

CRediT authorship contribution statement

William L. Rice: Conceptualization, Methodology, Software, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration, Funding acquisition. **Peter Newman:** Conceptualization, Methodology, Investigation, Writing – review & editing, Project administration, Funding acquisition. **Katherine Y. Zipp:** Conceptualization, Methodology, Software, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Supervision. **B. Derrick Taff:** Conceptualization, Investigation, Writing – review & editing, Project administration, Funding acquisition, Supervision. **Ashley R. Pipkin:** Data curation, Writing – original draft, Writing – review & editing, Project administration. **Zachary D. Miller:** Conceptualization, Investigation, Writing – review & editing, Project administration, Funding acquisition. **Bing Pan:** Investigation, Writing – review & editing.

Acknowledgements

This research was funded by the National Park Service, Natural Sounds and Night Skies Division (NSNSD) through the Cooperative Ecosystem Studies Unit network, which helps train the next gen- eration of federal scientists [grant number P17AC00827]. The authors are very grateful for the work, support, and leadership of Dr. Frank Turina, Dr. Adam Becco, Dr. Kurt Fristrup, and Karen Trevino of the NSNSD. We are also grateful for the aid of Caleb Meyer and Anthony Myers for help during data collection.

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