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Human Response to Aviation Noise: Development of Dose-Response Relationships for Backcountry Visitors

Volume I: Study Methods

Prepared by:



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The Federal Aviation Administration and National Park Service conducted joint research to better understand the effects of noise due to commercial air tour operations over units of the National Park System. To evaluate the relationship between aircraft noise exposure and the quality of National Park visitor experience, research was conducted at backcountry sites providing day- and overnight-hiking and camping opportunities. This research expands upon work performed during the 1990's at frontcountry sites. Over 4600 visitor surveys and fifty days of acoustical measurements were collected and analyzed to develop dose-response relationships for backcountry visitors. This report, the first of two volumes, describes the study methods, visitor surveys, research locations and data collected. Volume two describes the model-fitting approach used to identify the noise exposure metrics and mediator variables that best predict visitor responses to aircraft noise. The models developed can be used as a tool to evaluate potential effects of air tours on visitors to National Parks.

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EXECUTIVE SUMMARY

The Federal Aviation Administration (FAA) Western Pacific Region, Office of Special Programs, the FAA Office of Environment and Energy, and the National Park Service (NPS) Natural Sounds and Night Skies Division sponsored a research program to further the understanding of human response to aviation noise in protected natural areas. The research, conducted by the John A. Volpe National Transportation Systems Center (Volpe Center), entails the collection and analysis of aviation noise-exposure dose and corresponding visitor response to aviation noise through mathematical relationships between the noise exposure 'dose' and people's stated judgments about the effect of the exposure on the quality of their experiences, measured through survey instruments (i.e., a dose-response relationship).

The data described in this report were collected with the goal of understanding *backcountry* visitors' (those on both day-hikes and overnight hikes) response to aircraft noise and developing dose-response relationships for these visitors. Together with similar relationships developed for data collected at frontcountry sites (overlooks and short hikes), the relationships will inform evaluations of air tour noise effects on visitors to National Parks. Due to interest in understanding how visit motivation might influence perceived impacts, preliminary measurements were also taken at one site where cultural/historic attractions were a main focus of visits.

Data were collected at seven backcountry day- and overnight-hike sites and one cultural/historic site in four National Parks; Grand Canyon (GRCA), Bryce Canyon (BRCA), Zion, and Glacier (GLAC) during the period April through August 2011. This research resulted in a database consisting of over 4,600 completed visitor experience surveys and associated noise-exposure dose measurements.

Three surveys were included in this research: Human response to aviation noise survey 1 (HR1); Human response to aviation noise survey 2 (HR2); and the human response to aviation noise survey, audio recording version (audio clip). Each survey was designed to assess visitor evaluations of aircraft noise by different methods, utilizing evaluative dimensions including annoyance, interference with particular visit aspects, and acceptability. All surveys shared a subset of standardized questions on visit aspects, motivations, and demographics. The HR1 survey replicates research methods used in the 1990's frontcountry studies; it asks respondents explicitly to evaluate aircraft. The HR2 survey is designed to minimize the potential for

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response cueing bias that may result from direct queries on aircraft noise. It asks respondents to identify sounds they heard in the study area from a list that includes both anthropogenic noise and natural sources. The Audio Clip survey is designed address the sound level range limitations of studying human response to aviation noise using *in situ* overflights. It allows researchers to collect visitor ratings of a range of aircraft noise exposure doses by presented overflights in a series of short audio simulations. Subsequent questions allow visitors to evaluate aircraft noises heard during their site visit.

Survey responses were used for general comparisons of visitor populations among sites and site types. Most visitors (80-85%) at backcountry hiking sites reported that experiencing natural quiet and the sounds of nature was a very or extremely important reason for their visit to the site, second only to those who reported viewing the scenery as important reasons for their visit (85-90%). At the cultural/historic site, 60% of respondents reported natural quiet as being very or extremely important, while 80% reported that appreciation the history and cultural significance of the site was very or extremely important.

Of the over 4,600 total surveys, approximately 80% of single day-visit surveys (day-hike, shorthike, and cultural-historic visits) were associated with acoustic dose data of acceptable quality. For overnight hikers, about 50% could be associated with enough required information to compute their corresponding acoustic dose. These surveys and associated dose data were used to determine dose-response relationships for visitors on backcountry day-hikes (the majority of the collected dataset). The analysis of day-hike dose-response data involved model fitting and dose-descriptor and mediator testing. The best models were defined as those which minimize information loss based on the Akaike Information Criteria (AIC). Dose-response models were identified which best fit the 'Annovance' and 'Interference with natural guiet' responses for three dichotomizations of visitor responses (noted as 'Slightly or More', 'Moderately or More', and 'Very or More'). These models include dose variables of sound exposure level, percent time audible, and energy percentages due to helicopters and fixed-wing propeller aircraft. Mediator variables identified include visitor ratings of the 'importance of calmness, peace and tranquility', attributes of adults-only in group, first visit to the site, having taken an air tour, and participation in activities of watching birds or listening to an interpretive talk.

The regression model to predict the probability that a visitor will respond as annoyed by a given level of aircraft noise is given according to the following equation:

Х

 $z = C_0 + C_1(L_{AE}) + C_2(\%TAud) + C_3(P_{EnHelos}) + C_4(P_{EnProps}) + C_5(S_{HR1}) + C_6(S_{HR2})$ $+ C_7(M_{ImpCP}) + C_8(M_{SiteVisitBefore}) + C_9(M_{AdultsOnly}) + C_{10}(M_{AirTour})$ $+ C_{11}(M_{WatchBirds})$

$$R = \frac{1}{1 + e^{-z}}$$

Where S = 1 if the given survey instrument was received and S=0 if a different survey instrument was received.

Mediator (M) variables are defined as:

 M_{ImpCP} : Respondent rated the 'calmness, peace and tranquility' as a very or extremely important aspect of the visit.

M_{SiteVisitBefore}: Respondent had visited the site before.

M_{AdultsOnly}: Respondent's personal group consisted of only adults (no children under the age of 16).

M_{AirTour}: Respondent had taken an air tour.

M_{WatchBirds}: Respondent had participated in bird watching during the visit.

Where M = 1 for Yes responses and M=0 for No responses.

Dose variables L_{AE} , %TAud, $P_{EnHelos}$, and $P_{EnProps}$ are calculated according to:

$$\begin{split} L_{AE} &= 10 * \text{log10} (\Sigma 10^{(\text{LAeq,1s/10})}) \\ \text{\%TAud} &= 100 * (\text{Duration of aircraft noise} (T_{AC}) / \text{Duration of visit} (T_{resp})) \\ P_{\text{EnHelos}} &= 100 * (10^{L_{AE}Helos/10} / 10^{L_{AE}/10}) \\ P_{\text{en,Props}} &= 100 * (10^{L_{AE}Props/10} / 10^{L_{AE}/10}) \end{split}$$

The equation for the probability that a visitor will experience Interference with natural quiet is similar, but includes a 'Talk' mediator (respondent had participated in an interpretive talk) and does not include the 'Survey' (S) variables, or the 'SiteVisitBefore' and 'WatchBirds' mediators.

The magnitude and statistical significance of the 'Survey' (S) coefficient estimates indicate that visitor response to aircraft noise varied significantly between the survey instruments for the annoyance response. HR2 survey respondents were less likely to report hearing aircraft and

were less annoyed by aircraft noise at a given aircraft dose, when compared to HR1 or audio clip survey respondents. The difference in the annoyance responses between the surveys may be attributed to both the point scales utilized in the surveys (five point neutral to negative for AC and HR1 versus nine point positive to negative for HR2) and the avoidance of direct queries on aircraft noise in the HR2 survey instrument. The slightly or more and moderately or more relationships are most affected by these differences, while the very or more relationship is unaffected. Although unaffected, this relationship may have limited utility for assessments as there are few reports of very or extreme annoyance at low noise exposures.

A representation of the dose-response day-hike model is presented below for both the annoyance and interference with natural quiet responses (Figure 1). In these plots, the L_{AE} dose variable is explicitly visualized, while the effects of the %TAud, P_{EnHelos}, and P_{EnProps} doses on visitor response are represented using a function relating each to L_{AE}. Thus, the shape of the dose-response curves includes the effects of additional dose variables on visitor response through their relationships with the primary dose variable. The three individual curves (solid lines) in the plots represent the three dichotomizations of visitor response (Slightly or More, Moderately or More, and Very or More); dashed lines represent the 95% confidence intervals. Values of the survey-based mediator variables were held constant at the average values for the 2011 day-hike survey data. The data points (dots) are jittered to aid in visualization and represent the Slightly or More dichotomization.





Figure 1. A-weighted sound exposure level (L_{AE}) dose-response relationships (solid lines) and 95% confidence intervals (dotted lines) for the *Annoy* and *Interfere* responses for dichotomies of Slightly or more, Moderately or more and Very or more.

The relationships depicted in the previous graphic represent one dimension of a multi-factor, multi-dimensional model. As stated above, the values of the factors not depicted are set to the average or most likely value for the 2011 dataset. Changes in these values can influence the shape and relative position of these curves and care must be taken when utilizing these models. A change in the values of the dose descriptors %TAud, $P_{EnHelos}$, and $P_{EnProps}$ can greatly influence the predicted visitor response, and these variables can vary widely between sites. In contrast, the average values of the non-acoustic, visitor-based mediators do not vary as widely between sites, and do not strongly affect the shape or relative position of the dose-response curve. Spreadsheets or computer programs are preferred to properly exercise these models.

Many of the mediator variables shown to be important predictors of backcountry visitor responses to aviation noise were not included in the frontcountry survey instrument. This result confirms that many of the enhancements to the 2011 survey instrument provided important information that can be utilized to assess the responses of park visitors to aircraft. These predictors include ratings of the 'Importance of calmness, peace and tranquility', having taken an air tour, participation in an interpretive talk and watching birds. In particular, the significance of the 'Importance of calmness, peace and tranquility' variable corroborates earlier research suggesting that this is an important value in National Park settings. The significance of the 'Talk' and 'Watch birds' activity variables confirms that participation in specific activities can increase the severity of response to aircraft noise.

Detectability-based dose metrics were calculated and tested for predictive power within the model-fitting exercise. These metrics account for the signal-to-noise ratio of aircraft noise and ambient sounds in one-third octave bands, and are most often used to predict when a person will detect a given sound within a background of noise. Although less powerful than the primary dose metrics, the detectability exposure level has useful predictive power at the 'slightly or more' level for the annoyance response. This result may corroborate earlier evidence that there is a relationship between annoyance and the detectability of low level sounds.

The best-fit backcountry model differs from that identified for the frontcountry, most notably in the noise dose metrics. However, there is some similarity in these exposure metrics, as the equivalent sound level dose (frontcountry model) is derived from components of L_{AE} and visit duration; missing is the duration of aircraft noise included within %TAud in the backcountry model. This indicates that the total noise exposure is important in both models, while the relative duration of the aircraft exposure exhibits more significance in the backcountry model, possibly due to longer visit durations.

For comparative purposes, a regression was fit to the frontcountry data using the dose combination of L_{AE} , %TAud, $P_{EnHelos}$ and $P_{EnProps}$ as identified for the backcountry data. Intuitively, one might expect that a greater percentage of backcountry respondents would report annoyance due to lower ambient sound, levels, longer duration of exposure, and further immersion in the natural soundscape. The models yield similar predictions in the region between 70 and 80 dBA, and a greater percentage of *frontcountry* short-hike respondents are predicted to report annoyance at sound exposures below 70 dBA. The confidence intervals surrounding the day-hike and short-hike relationships overlap through the majority of the data range, and neither relationship is based on significant amounts of data at sound exposures below 50 and above 85 dBA. Therefore, it is likely that these behaviors are an artifact of data limitations and predictions outside the available data range should be used with caution. Analysis of a combined frontcountry and backcountry dataset could produce a single model and yield further insights.

During the current research effort, dose-response data were also collected for overnight backcountry users. Due to the lower number of overnight users and increased variability in their visit patterns (i.e., hike routes and camp locations), fewer usable data points were acquired for overnight visitors (approximately 287 respondents, compared to 2054 day-hike respondents). Survey responses from these visitors show that overnight hikers were more likely to be repeat visitors to the location and less likely to have children with them, two important mediators of

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response to aircraft noise, suggesting these visitors would have greater sensitivity to aircraft noise. A multi-level regression model was fitted to day-hike and overnight hikers for comparison. The initial analysis results suggest that overnight hikers were more sensitive to aircraft noise than day-hikers.

This research included an additional component based on visitor responses to audio clips of aircraft overflights. This method may be advantageous, as audio clips can provide a wide range of controlled sound level exposure. However, responses to overflights conveyed via audio clip did not replicate key information needed for use within a dose-response application framework. The data showed that visitors responded similarly regardless of the site-type or activity of the respondent (day-hike versus overnight hike), whether there were "children in group", if this was a "first time visit". This is in direct contrast to *in situ* dose response data, where it has been shown that these factors all play a key role in visitor evaluations. Site-to-site responses do, however, show some variability; there is a slight tendency for respondents at sites with higher *in situ* exposures (Hermit and Grandview at Grand Canyon and Hidden Lake at Glacier) to rate the clips more annoying or unacceptable. Although hearing or not hearing aircraft *in situ* did not influence audio clip evaluations, this suggests that the *in situ* sound exposure due to aircraft may have some influence on the evaluations.

Dose-response relationships developed for the *in situ* day-hikers were compared to similar dose-response relationships developed from the audio clip playback survey responses. Comparison of relationships developed using the equivalent sound level descriptor showed that audio clip noise exposure is rated stronger than similar noise exposures experienced *in situ*. If audio clips are to be used within the dose-response framework, additional research would be necessary to determine if there are methods to better replicate the aircraft overflight and context within the visit experience.

The dataset presented in this report is robust for day-hike visitors and provides a strong basis for the dose-response relationships developed for this category of visitors. The dataset also complements the prior dataset from the 1990's encompassing overlook and short-hike visitors. Together, the relationships developed will inform evaluations of the effects of aviation noise on visitor experience. There are opportunities to strengthen and expand upon these results through further analysis of overnight hiker data as well as expansion to other visit types such as those focusing on cultural and historic sites.

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1. INTRODUCTION

Spurred by the National Parks Overflights Act of 1987¹ and the National Parks Air Tour Management Act of 2000 (NPATMA),² the FAA Western Pacific Region, Office of Special Programs, the FAA Office of Environment and Energy, and the NPS Natural Sounds and Night Skies Division have embarked on a research program to further the understanding of human response to aviation noise in protected natural areas. The foundation of the research program is the collection and analysis of aviation noise dose and corresponding visitor response data in National Parks. This approach is used to understand and quantify human response to aviation noise through mathematical relationships between the noise exposure 'dose' and people's stated judgments about the effect of the exposure on the quality of their experiences, measured through survey instruments (i.e., a dose-response relationship). This research approach has been widely accepted and used for many years within federal transportation noise regulations to determine noise impacts in residential environments.^{3,4,5,6,7} In particular, transportation noise dose-response relationships form the basis for FAA guidelines. However, it is recognized that park visitor impacts from transportation sources cannot be based on the dose-response relationships cited by FAA guidelines, as impacts on park visitors are likely very different from those in residential areas.

This document, the first of two volumes, summarizes the results of a dose-response study conducted on seven backcountry trail sites in four National Parks (Grand Canyon, Bryce Canyon, Zion, and Glacier) during the period April through August 2011. Volume 2 contains greater detail on the analyses and development of dose-response relationships.

1.1. Objectives

This research focused on quantifying the effect of noise from aircraft operations^{*} upon visitor experiences in National Park units. The data described in this report were collected with the goal of developing dose-response relationships for visitors to backcountry sites. Together with similar relationships developed for frontcountry sites from data collected in the 1990's,⁸ these relationships will inform evaluations of aviation noise effects on visitor experience.

^{*} Noise from aircraft operations includes contributions from both tour aircraft and high-altitude commercial jets, as they are concurrent and their effects on park visitors cannot effectively be separated.

1.2. Background

Prior to the data collection presented herein, the FAA and NPS funded several dose-response studies at NPS units. In 1992, the NPS and Harris Miller Miller & Hanson Inc. (HMMH) conducted a study of aircraft over-flights at short hike and scenic overlook sites in Grand Canyon, Haleakala, and Hawaii Volcanoes National Parks.⁹ Following the HMMH study, three other dose-response studies were conducted in NPS Units. In 1997, the FAA and Volpe Center collected data at short-hike sites in Bryce Canyon National Park,¹⁰ followed in 1998 by a data collection effort at scenic overlook sites in Bryce Canyon and Grand Canyon National Parks.¹¹ The most recent study was conducted in 1998 by the NPS, the US Air Force, and HMMH at White Sands National Monument at one short-hike site.¹² All four studies shared the same data collection protocol, basic questionnaire format, and core response questions. These studies resulted in an extensive database of noise exposure dose and related visitor response measurements. The data from these studies ('the 1990s dataset') were combined and analyzed to develop a comprehensive set of dose-response relationships for frontcountry sites. This analysis, documented in Anderson et al.,⁸ was used to inform the research documented herein.

Additional studies employing a variety of methodologies have also provided useful insight into the general effect of different types of sounds, including aircraft noise, on NPS visitors' experiences.^{13,14,15} Many of these studies focused on defining soundscape-based indicators and standards of quality for use within current NPS management frameworks.¹⁶ These studies consistently demonstrate that opportunities to experience natural quiet and natural sounds are among the most important reasons for visitation to National Parks, and that human-caused noises generally detract from the quality of visitors' experiences. In related research,¹⁷ park visitors listened to a series of audio recordings containing natural ambient sounds and increasing levels of air tour helicopter noise, and rated the acceptability of the soundscape heard in each recording. These results provided the NPS with an empirical basis to include soundscape-related indicators of quality in planning documents and monitoring programs, including the percent of time human noises are audible and measures of sound level.

In planning the current research, the team applied knowledge and information gleaned from all of these prior studies, along with extensive analyses of the aforementioned dose-response database. A panel of researchers including social-scientists with expertise in outdoor recreation studies and acoustical scientists with expertise in measuring and analyzing aviation noise, collaborated in developing the research design and survey instruments.¹⁸ The Volpe Center hosted three workshops – October 2008,¹⁹ May 2009,²⁰ and September 2010¹⁷ – which

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generated essential guidance on a wide range of issues, including sampling protocol, acoustical monitoring, and development of audio clips.

The research described in this report expanded on, and differed from, previous dose-response work in four ways:

- It extended survey collection to site types^{*} not previously represented in the doseresponse data (frontcountry historical/cultural sites, day- and multi-day hikes). Visitors to these site types – in particular, backcountry areas – may have different sensitivity to aircraft noise than the frontcountry visitors represented in the 1990s dose-response data.
- It simultaneously tested multiple survey instruments in the same settings to compare methodologies. These comparisons led to a number of conclusions that could improve future research, including simplified or more flexible data collection methods, reduced respondent burden, and the ability to compare fully the results from prior research studies.
- 3. It used (and demonstrated the viability of) tablet PCs to administer the survey instruments electronically in remote, outdoor settings. Tablet PCs provide options not possible with paper instruments for requiring complete responses, randomizing the order of some sub-question options, and automating question skip patterns. Also, electronic survey administration enables automatic data capture, which eliminates laborious human data-entry and associated potential for error. Finally, for the audio-clip survey, electronic administration enabled the audio clip files to be integrated into the survey instrument (rather than on a separate digital audio player, for example), with clip order randomized for each respondent. The researchers gained valuable insights that will improve future use of electronic survey administration in field research.
- 4. It employed GPS tracking of respondents to enable more accurate estimates of dose and to permit precise comparisons of dose across multiple monitoring stations to determine the minimum number of such stations needed to collect valid data.

1.3. Report Organization

Section 1 of this report presents an introduction and the objectives of this document. Section 2 describes the survey instruments and survey administration protocols. Section 3 discusses

^{*} Site type is used in this research to refer to the context in which the noise exposure is presented. It encompasses both physical location and likely activities at that location.

instrumentation. Section 4 describes the site selection process and provides an overview of the sites at which data were collected. Section 5 discusses data reduction and noise exposure computations, concluding with a summary of the material presented in Volume 2. Volume 2 presents the research results in more detail; including the results of the study, comparisons among survey instruments, dose response relationships, and comparisons with other data sets. Volume 2 also provides suggestions and guidance for using the results of the dose-response research in National Parks to assess potential impacts.

Appendix A contains paper versions of the dose-response survey instruments. Appendix B contains detailed information on the collection of the audio clip recordings. Appendix C contains the survey pre-intercept and intercepts scripts. A glossary and all related references are presented at the end of this document.

2. VISITOR SURVEYS

This section describes the survey administration component of the data collection, involving visitor intercept at the start of their visit to the study area, tracking of the duration and timing of their visit, and post-visit intercept to take part in the survey. The data collection protocol was designed so that an accurate noise exposure dose can be calculated for each visitor interviewed based on:

- 1. The time the visitor entered the study area
- 2. The location (or a location estimate) of each visitor at any given time
- 3. The sound level at or near that location
- 4. The sources contributing to the sound level
- 5. The time the visitor exited the study area (i.e., the time they were interviewed).

Survey administration protocols were followed to track aspect numbers 1, 2 and 5. Time synchronization was crucial to this study in order to accurately correlate noise dose with response data. All sound level measurements, sound source logs, and visitor intercept logs were time stamped in synchrony with a master timepiece.

2.1. Instruments

The visitor surveys for this research program were developed collaboratively by members of the research team, many with expertise in outdoor recreation studies. The surveys were developed with three goals: to expand the previously collected dataset to include more parks and types of activities, to improve upon past methodology, and to incorporate additional research methods.

Much of the dose-response research performed previously at NPS units used a single, uniform survey instrument,^{9,10} in part based on methods developed to assess impacts from commercial aviation in residential settings. However, limitations have been identified in this research and the associated survey instrument, including:

- The questions used to measure response to aviation noise exposure may cue respondents to the issue of aircraft noise, resulting in potentially biased survey response data.
- The research method yields estimates of the proportion of visitors affected by the existing noise/sound conditions; a different basis than that used in the adaptive management framework, which relies on preferred or desired noise/sound conditions.

- The research method relies on *in situ* aircraft overflights, which limits the range of noise exposure dose that can be experienced at a single location, resulting in a dataset that must be extrapolated to project responses at lower and higher aircraft doses.
- *In situ* aircraft noise doses can be challenging to accurately compute because aircraft noise is difficult to separate from noise from other anthropogenic sources in the study area. Furthermore, visitors may have difficulty distinguishing among anthropogenic noises and responding to the "correct" dose.

The current study addresses these issues using a revision of the original survey instrument and expanding the program to include two additional instruments which apply other, complementary, research strategies. Administering these survey instruments simultaneously provides a consistent basis for comparing the research strategies.

The three park visitor survey instruments are modified versions of the previous dose-response instrument used by the FAA and NPS, and previous soundscape-based instruments used by NPS. Their historical roots and basic research strategies are as follows:

HR1: <u>The human response to aviation noise - visitor survey, version 1</u>. This is an adaptation of the NPS / FAA / USAF Aircraft Overflight Studies visitor survey (OMB Nos. 1024-0088, 2120-0610, and 0701-0143). It replicates research methods used in the 1990's frontcountry studies and provides a basis for comparison across study locations and contexts. This instrument asks respondents explicitly to evaluate aircraft noise in dimensions including annoyance, interference with the appreciation of the natural sounds, acceptability, and interference with tranquility or solitude.^{*}

HR2: <u>The human response to aviation noise - visitor survey, version 2</u>. This is an adaptation of the NPS Soundscape Attended Listening survey (OMB No. 1024-0224, NPS No. 07-014). This survey is designed to minimize the potential for response cueing bias that may result from direct queries on aircraft noise by asking respondents to identify sounds they heard in the study area from a list that includes both anthropogenic and natural sources. The survey includes evaluative dimensions of pleasing-annoying and acceptable-unacceptable; ratings are collected on a nine-point positive to negative scale. This type of scale is typically used to support decisions about numerical thresholds for desired conditions.</u>

^{*} Evaluations of annoyance and interference with appreciation of the natural sounds were included in the 1990's surveys, while evaluations of acceptability and interference with tranquility of solitude were not.

Audio Clip: <u>The human response to aviation noise – visitor survey, audio recording</u> <u>evaluation version</u>. This is an adaptation of the NPS Soundscape Audio Recording Evaluation survey. (OMB No. 1024-0224, NPS No. 07-014). The Audio Clip survey is designed address the sound level range limitations of studying human response to aviation noise using *in situ* overflights. It allows researchers to collect visitor ratings of a range of aircraft noise exposure doses by presented overflights in a series of short audio simulations. (the Recorded Audio Clips section provides further discussion of the audio simulations). Subsequent questions allow visitors to evaluate aircraft noises heard during their site visit.

The questionnaires each include a variety of dimensions (including annoyance, acceptability, interference with the appreciation of the natural sounds of the park, and degradation of tranquility or solitude) to collect park visitor ratings of the effect of sounds from different sources on numerous types of park experiences. Both HR2 and the audio clip survey include aspects of a normative research approach. The normative approach is designed to elicit evaluations from visitors of "indicators of quality' associated with aircraft overflights. Indicators of quality might include variables such as frequency of hearing aircraft or loudness of aircraft-related noise. Resulting data can be used to identify the threshold of acceptability (or other evaluative dimensions such as preference) for these indicator variables. Respondents are asked to make judgments about the acceptability of the conditions presented, usually on a nine-point response scale ranging from very unacceptable to very acceptable with a neutral or zero point.^{15,21}

Paper versions of these survey instruments are included in Appendix A. The Office of Management and Budget (OMB) approved the information collection request (ICR) (Control #2120-0744) and the three survey instruments for this study.²²

A summary of the survey formats is presented in Table 1. All instruments contain three identical sections: Introduction, trip information and respondent demographics. The introduction includes questions concerning the type of visit (either day or multi-day, overnight) and the date and time at which the visit began. The trip information section includes questions concerning the number of previous visits to the site, the activities the visitor engaged in, and the importance of various motivations for their visit to that particular location. The demographics section includes questions concerning the visitors' group size and composition, gender, age, state or country of residence, level of formal education, race, and ethnicity.

The surveys diverge in the 'sounds' section. In all surveys, this section contains the first mention of aircraft or aircraft noise. Each survey is designed to assess visitor evaluations of

aircraft noise by different methods, while still utilizing three main evaluative dimensions: annoyance, interference with particular visit aspects, and acceptability. The questions are as follows:

Annoyance:

During your time at <site>, how much did noise from airplanes, jets, helicopters, or other aircraft bother, disturb, or annoy you?

Evaluations of annoyance due to aircraft noise are the most widely used measure of aircraft noise impact in most environmental noise studies. The question format is based on recommendations from the International Standards Organization.²³ It is directly comparable to questions in studies performed in the 1990s. This question is included in all surveys, but within-survey placement and rating scales differ between surveys. HR1 and the audio clip survey use a five-point scale ranging from 'not at all annoyed' to 'extremely annoyed', while HR2 uses a nine-point scale ranging from 'extremely annoying' to 'extremely placeming'.

Interference with...:

How much did the sounds from aircraft interfere with each of the following aspects of your visit at <site>?

- Enjoyment of the site
- Appreciation of the natural quiet and sounds of nature at the site
- Appreciation of the historical and cultural significance of the site
- Experiencing a feeling of calmness, peace, or tranquility
- Experiencing a sense of adventure or challenge
- Hearing something said during a ranger talk, campfire program, or other ranger-led activity
- Hearing any other performance, talk, or group presentation
- Appreciating natural sounds at night
- Sleeping at night

This series of questions measures visitors' subjective impression of extent to which the sound affected their experiences. The questions use unipolar, negative scales because this is consistent with the general finding that noise interferes with these types of experiences. The questions rely on the visitor's ability to make a causal judgment about the extent to which the noise interferes with an experience. The first three aspects are directly comparable to queries used in the studies performed in the 1990s, while the others are new to this study and intended to address additional visit aspects which are directly related to the backcountry overnight and cultural/historic site-types within this study. This question is included in only the HR1 and HR2 surveys.

Acceptability:

How acceptable or unacceptable was the sound from aircraft that you heard during your time at <site>?

Evaluations of the acceptability of aircraft sound are widely used in the normative evaluation framework. Respondents are asked to make judgments using a nine-point response scale ranging from 'very unacceptable' to 'very acceptable'. The positive-negative aspects can help identify a point where conditions turn from acceptable to unacceptable. This question is included in all surveys, but within-survey placement differs.

HR1	HR2	Audio Clip		
Introduction	Introduction	Introduction		
Trip Information	Trip Information	Trip Information		
		Audio Clip Evaluation		
 Sounds Did you HEAR airplanes, jets, helicopters, or any other aircraft during your time at [site]? During your time at [site], how much did noise from airplanes, jets, helicopters, or other aircraft bother, disturb, or annoy you? How much did the sounds from aircraft interfere with each of the following aspects of your visit at [site]? How acceptable or unacceptable was the sound from aircraft that you heard during your visit at [site]? 	 Sounds Which of the following sounds did you hear during your time at [site]? Insect sounds Bird or animal sounds Airplanes, jets, helicopters, or other aircraft, etc. (10 sounds total) How acceptable or unacceptable were these sounds during your time at [site]? How much did these sounds please or annoy you during your time at [site]? How much did these sounds positively add or negatively detract from your experience during your time at [site]? 	 Sounds Besides the recording you just listened to, did you HEAR airplanes, jets, helicopters, or any other aircraft during your time at [site]? During your time at [site], how much did noise from airplanes, jets, helicopters, or other aircraft bother, disturb, or annoy you? 		
Demographics	Demographics	Demographics		

Table 1. Comparison of survey formats

2.2. Recorded Audio Clips

Audio simulations for the audio clip survey were recorded specifically for the purposes of this research program. These recordings were designed to be as realistic as possible, conveying

spatial information as well as sound level and frequency characteristics by utilizing binaural equipment. Recordings of air tour and high-altitude aircraft overflights were collected at Grand Canyon National Park during November 2010. Recordings were made at five locations, each a specific distance from active air-tour flight corridors, to ensure the recordings reflected a wide range of sound levels. A more detailed summary of the equipment and measurement procedures used to collect the audio simulations can be found in Appendix B. Over 100 aircraft overflights of the following aircraft models were recorded:

- Helicopters: Eurocopter EC-130, and Bell 206L;
- Propeller-Driven Aircraft: DeHavilland Vistaliner, Cessna 207, Cessna 208, and Cessna 182; and
- Commercial Jets.

Each recording was typically about two minutes in length, and captured the aircraft's as it approached the recording station from a distance (beginning inaudible, gradually increasing sound level), passed the recording station (period of maximum sound level), and flew away from the recording station (decreasing sound level down to inaudible).

For onsite intercept studies using audio simulations, it is necessary to use relatively short duration audio recordings, in the interest of minimizing respondent burden associated with completing the survey task. Additionally, researchers have observed that many listeners tend to make judgments in the first 10-15 seconds of the clip. As previous studies of this type had successfully used 30-second recordings,^{13,14} it was decided that this study should also target recordings of similar length.

Ultimately, recordings were standardized to 36 seconds in length, depicting the loudest portion of each aircraft overflight. The aircraft overflight noise was overlaid on a single clip of representative natural ambient sounds (low-level wind and non-descript birdcalls) recorded in a National Park setting. The natural sounds provided a context in which the respondent can evaluate the aircraft noise. The sound level of the natural sounds in the clips is quite low (approximately 20 dBA) in keeping with the low ambient levels found in many natural areas.

Each clip contains five seconds of ambient before and after a 26-second aircraft overflight. To more closely mimic the amplitude characteristics of an actual overflight, the 26-second overflight portion of the clip was modified with a 12-second "fade-in" to simulate the aircraft approaching the listener and a 5-second "fade-out" to simulate the aircraft receding.

The final pool of audio clips contained 49 overflights, shown in Table 2, in ascending order by sound level.^{*} The pool was structured to have a uniform distribution across both sound level and aircraft type. In other words, there are an equal number of helicopters and fixed-wing propeller aircraft, at sound exposure levels evenly distributed between approximately 37 and 79 dBA. Commercial jets are not equally represented in the pool (1:2), as the sound levels of jet overflights spanned a much smaller range: 30-45 dBA.

^{*} Out of the original pool of 100 clips, 49 were determined to be usable. The remainder were either contaminated by ambient sounds (generally wind or birds) or were duplicates (i.e., there was often more than one overflight of each aircraft type at similar sound levels).

Helicopter Aircraft	L _{ASmx} (dBA)	SEL (dBA)	Fixed-wing propeller Aircraft	L _{ASmx} (dBA)	SEL (dBA)	High altitude jet aircraft	L _{ASmx} (dBA)	SEL (dBA)
Bell 206L	25.3	43.4	Cessna 182	18.1	37.2	Unidentified Jet	18.5	37.8
Eurocopter EC-130	25.9	45.3	Unidentified FW	25.8	39.3	Unidentified Jet	19.6	39.8
Eurocopter EC-130	29.8	47.5	De Havilland Vistaliner DHC-6	23.1	41.3	Unidentified Jet	22.5	41.8
Eurocopter EC-130	30.6	49.6	Cessna 207	26.3	43.4	Unidentified Jet	30.8	43.8
Eurocopter EC-130	33.1	51.4	De Havilland Vistaliner DHC-6	27.6	45.4	Unidentified Jet	28.0	45.8
Bell 206L	36.4	53.4	Cessna 207	33.6	47.4	Unidentified Jet	26.8	47.8
Eurocopter EC-130	36.7	55.6	De Havilland Vistaliner DHC-6	30.9	49.2	Unidentified Jet	32.0	49.8
Bell 206L	40.8	57.2	De Havilland Vistaliner DHC-6	33.2	51.5	Unidentified Jet	32.6	51.8
Eurocopter EC-130	41.0	59.5	Unidentified FW	28.2	53.6	Unidentified Jet	34.4	53.4
Bell 206L	44.3	61.4	Unidentified FW Prop	37.0	55.8	Unidentified Jet	39.8	55.5
Eurocopter EC-130	45.0	63.2	Unidentified FW	40.5	57.8			
Eurocopter EC-130	45.5	65.1	Unidentified FW	39.7	59.6			
Eurocopter EC-130	50.8	67.2	Cessna 182	41.3	61.4			
Bell 206L	51.8	69.4	Cessna 207	43.8	63.2			
Eurocopter EC-130	54.4	71.5	Cessna 207	47.4	65.2			
Eurocopter EC-130	55.7	73.6	Cessna 207	47.1	67.2			
Bell 206L	56.7	75.4	Cessna 207	51.5	69.1			
Eurocopter EC-130	59.6	77.6	Cessna 202	53.8	71.4			
Eurocopter EC-130	61.6	79.1	Cessna 182	54.4	73.2			
			Cessna 182	56.4	75.2			

 Table 2. Audio clip pool content

During the survey, each respondent was asked to evaluate five of the 49 clips. Clips were presented using a partially randomized design to minimize any bias due to aircraft, aircraft type, selection of clips, or presentation order. The clips for each respondent were drawn from the pool which was divided into three sound level bins: Low ($L_{AE} \le 50$), Medium ($50 < L_{AE} \le 65$), and High ($L_{AE} > 65$). Sampling logic in the survey instrument software ensured that each respondent heard a low, a medium, and a high audio clip, in random order, for the first three clips, with each clip randomly selected from the pool in each bin. For clips four and five, two of the three pools of sound clips (i.e., Low, Medium, or High) were first randomly selected, and one clip was randomly drawn from each of the two randomly selected pools.

To provide the highest fidelity, most realistic audio clips possible, a special hardware package was assembled for playback via tablet PCs (shown in Figure 2). It included a small, battery-powered, external digital-to-analog converter (DAC) / headphone amplifier (a FiiO Model E7) and professional-grade, studio monitor circumaural headphones (AKG model 271 MKII). The DAC used the tablet PC's USB output to process digital sound files and produce amplified analog output to the headphones. This resulted in audio clips with much lower noise floors than would have been possible using the PC's internal sound cards. The headphones fully enclose the respondent's ears, provide a good deal of acoustic isolation, and have a linear frequency response from 16 Hz to 28 kHz.*

Noise-cancelling headphones were evaluated and rejected, because they lack a flat response curve, and therefore changed the character of the audio clips.



Figure 2. Photo of audio-clip playback system

Prior to the start of the clips, on-screen instructions directed the respondent to put on the headphones. The respondent then heard recorded instructions as follows:

Shortly, we will ask you to listen to five brief recordings of natural and aircraft sounds.

As you listen to each recording, imagine how you would have felt if you had heard the aircraft sounds in the recording during your time on the [NAME OF TRAIL]/during your time at [NAME OF SITE]. Please listen to each recording in its entirety; after each recording is finished playing, the computer will automatically advance to a page with questions about the recording.

When you are ready to listen to the first recording, please click "Next Page".

Respondents were asked to rate each of the five audio clips on two dimensions, using ninepoint response scales:

How acceptable or unacceptable would the aircraft sounds in Recording #<recording number> have been if you had heard them during your visit to <site>?

How pleased or annoyed would you have been by the aircraft sounds in Recording #<recording number> if you had heard them during this visit to <site>?

Respondents clicked "next page" to start each of the five audio clips. In this way, each respondent could take the survey at his or her own pace.

2.3. Electronic Implementation

Survey instruments were administered via tablet PCs in a web-based interface. Several models of tablet and touch-screen PCs were evaluated on the basis of price; operating system; hardware characteristics; battery life; availability of field-swappable batteries; and the ability to withstand the inevitable jostling and bumps that are part of field research in remote areas. Ultimately, small, "NOBI" computers made by Equus Computer Systems were selected. The NOBI PCs run the Windows operating system, and have both a touch screen and keyboard in a "clamshell" design: the screen can be swiveled and folded over the keyboard, effectively turning the device into a tablet PC. Designed for heavy use in grade-school classrooms, the NOBIs are rugged and spill resistant.

The NOBIs lack a screen explicitly designed for viewing in direct sunlight (such screens add significantly to the cost of tablet PCs, in some cases nearly doubling the per-unit cost. With the addition of small, inexpensive, fabric laptop sunshades, the NOBIs functioned acceptably even in bright sunlight.

The electronic survey implementation had many advantages and advanced capabilities:

- Survey question skip patterns were automatically coded (i.e., if a respondent indicated they did not hear aircraft, questions of ratings of aircraft noise did not appear).
- Respondents did not have the ability to skip ahead and look at future questions.
- Audio clips were "embedded" in the survey instrument, rather than requiring a separate audio player.
- The specific audio clips presented to each respondent were drawn at random with respect to both aircraft type and sound level – eliminating potential order bias – and were automatically tracked.
- The list of sounds presented in survey instrument HR2 was presented in random order for each respondent, eliminating potential question order bias.
- In survey instrument HR2, each respondent received rating scales (i.e., "annoyance," "interference," "acceptability") only for the specific sounds he/she reported hearing. Respondents did not have to contend with a large matrix of all potentially-heard sounds, and could instead focus their attention on just the specific sounds they heard.

- The phrasing of each question was automatically tailored to include the specific site names (e.g., "Hermit Trail") and site types (e.g., "at this site" vs. "on this hike"). This helped each respondent focus on the specific park experience in question.
- Survey results were automatically collected, time and date stamped, and entered into a master database, thereby eliminating manual data entry. This saved time, reduced costs, and eliminated data-entry error.

In some cases individual respondents were unable to use the tablet PCs, and the survey team administered paper-and-pencil survey instruments instead. For example, some respondents had trouble seeing the NOBI screens; others had difficulty using the keyboards or touch screens.

2.4. Survey Administration Procedures

Survey teams generally consisted of four members who rotated amongst duties of preintercepting visitors at the starts of their visits or hikes, and intercepting visitors at the conclusions of their visits/hikes to administer the survey. Survey administration occurred during typical visitation hours, generally beginning between 8 and 9 am and concluding at 4 pm. Visitor volumes never exceeded the capacity of the survey team (busier sites had larger survey teams), and consequently a random group sampling methodology was not needed. Instead, all visitors were pre-intercepted, and those who were at least 18 years old and with whom the interviewers could reasonably communicate in English were invited to participate.

The survey pre-intercept served two purposes. First, survey personnel were able to recruit survey participants in advance, and accurately note their entry times into the study area and intended destinations. Second, each visitor (or group hiking together) was given a small GPS tracking device, enabling an accurate record of his/her location at any given moment. The pre-intercept is new to this type of study and was necessitated by the scope of the study, which includes surveying park visitors who undertook lengthy day and multi-day hikes. Previous studies of this type utilized indirect observations of visitor characteristics (group composition and unique qualities (i.e., clothing and accessories)) to correlate and track entry and exit times and hiking routes. This method was not suitable, due to the possibilities of group changes, clothing/accessory changes, and unknown, undefined, and/or multiple route possibilities.

Surveys were administered on tablet PCs via a browser interface.^{*} Survey personnel rotated through the survey instruments so that each instrument was administered to an equal number of respondents. Where practical, visitors within the same group received different surveys.

The following survey administration procedures were followed during the data collection. Detailed intercept scripts, documented in Appendix C, were prepared and followed to minimize potential surveyor bias.

- 1. As each visitor or group entered the study area to begin a visit, a survey team member asked if they would be hiking/visiting for more than one hour. If the response was positive, they were asked if they would agree to participate in a visitor experience study. Upon agreeing to participate, each visitor in the group was given a uniquely-numbered ticket, and one member of the group was given a GPS tracking device. Participants were asked to return to the study station at the end of their visit. In accordance with OMB guidance, visitors were informed about the use of GPS data, including that data from the tracking device would remain anonymous,[†] and that they would be asked to complete a short questionnaire at the completion of their visit/hike. The survey team member noted the time, group size, and trip destination.
- 2. The visitor(s) continued and completed the visit to the study area with no other contact with study personnel.
- 3. As the visitor(s) exited the study area, the interviewer intercepted the group, retrieved the tracking unit and numbered tags, recorded the time, screened out any visitors who could not readily communicate in English, and asked all eligible visitors to come over to the study station area to complete a short questionnaire. Folding chairs were available at most locations for respondents to use when taking the survey. Refusals and refusal reasons were noted.
- 4. At the conclusion of the questionnaire, the interviewer thanked respondents for their participation and completed any observation data that were needed, including an assessment of whether the respondent had sufficient English comprehension to understand the survey.

^{*} This also was a departure from methods used in prior studies, where surveys were interviewer-led: respondents were provided with an answer sheet to record responses, and survey questions were posed verbally by the interviewer.

⁺ The GPS trackers did not permit real-time tracking (i.e., no data are transmitted during the hiker's visit). They simply recorded their locations at set intervals, for later downloading and analysis.

2.5. Visit Time and Visitor Location Tracking

The study employed small, lightweight GPS tracking devices (Qstarz Q1000XT) to collect visitor location data. These tracking devices were carried by each visitor or affiliated group of visitors (one tracking device per group). Generally, a survey team member would attach the tracking device to a carabineer and clip it to the backpack of one member of the group. The survey team member also instructed the hiker carrying the tracking device that, in the event no survey administrators were present when the hikers returned from the trail (e.g., if they returned in the evening or early morning), to return the tracker to a drop box (generally a rural-type mailbox). These boxes were placed unobtrusively at trailheads (usually on the ground near trail signage) and marked with the NPS research permit number.

The numbered tickets given to all participating hikers at start of their hikes served as a second layer of time tracking, to ensure that each respondent's start and end times in the study area were accurately recorded. As each participating hiker was given his or her numbered ticket, the ticket number was also entered into the survey intercept log sheet, along with the time, and the GPS tracker number. At the completion of the hike, as the survey team retrieved the GPS tracker and numbered tickets from each group, each hiker's ticket number was entered into the survey administration log sheet, along with the time. In this way, the log sheets recorded the start and end times of each hiker's visit to the study area (i.e. the period of potential aircraft noise exposure). In addition, each respondent's ticket number was entered into the NOBI at the beginning of the survey administration, tying the survey data to the respondent's start time, end time, and GPS data file.

The GPS devices recorded location (latitude, longitude and altitude) at one-second intervals. The resulting data served two purposes. First, the data enabled the research team to create a detailed route map for each tracked visit, showing the exact path followed through the study area. Second, because both the GPS data and sound level monitor data were time-stamped, they could be cross referenced. Thus, each visitor's unique aircraft noise "dose" could be calculated using data from the monitors he or she was closest to during each aircraft overflight. For those 30% of visitors who did not receive or refused to carry a tracking device, a location record was estimated by using the visitor's entry time into the study area, intended destination (when noted on log sheets), the starting time of the interview, and average hiking speeds of similar visitors who did carry GPS tracksticks.

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2.6. Pretesting

Survey instruments and data collection methods were pretested at Minuteman National Park (MA) and Great Smoky Mountains National Park (NC, TN) during May and June of 2010. The extension of data collection into backcountry areas, along with overall refinements made to the social survey instruments, necessitated testing and evaluation of a number of aspects of the data collection protocol including:

- The phrasing, layout and duration of the three visitor opinion surveys.*
- Procedures for a pre-visit intercept to distribute GPS tracking device and evaluation of whether this intercept affects a visitor's behavior or opinions.
- Procedures for post-visit intercept and survey administration.
- All equipment that was 'new' to this study: (audio clip playback devices, electronic survey administration devices and GPS devices).

In both instances, the survey team conducted post-survey interviews with respondents to ascertain their reactions to question wording, survey length, the electronic survey format and other survey instrument design elements. Based on the results of these pretests, numerous survey and procedural refinements were adopted prior to the 2011 data collection efforts.

OMB guidelines allowed fewer than 10 respondents for pretests of each unique survey.

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3. ACOUSTICAL MONITORING

Accurate representation of the sound environment experienced by each individual survey respondent is essential to the success of a dose-response study. This was accomplished using specialized acoustical and meteorological collection systems assembled for the purpose of this study. This section describes the following:

- Acoustical Monitoring System (Section 3.1), which collected:
 - Continuous, one-second, A-weighted sound levels and their associated one-third octave-band un-weighted spectrum from 20 to 20,000 Hz;
 - o Continuous digital audio recordings
 - o Meteorological: Continuous, one-second wind speed and direction data
- Sound Source Identification (Section 3.2)
- General considerations for siting the acoustical measurement system (Section 3.3)

3.1. Acoustical Monitoring Equipment

The acoustical monitoring systems used are robust, portable, and designed to run outdoors, unattended, continuously for 30+ days without system maintenance. Each system is powered by a 100 amp-hour LiFePo4 battery pack. The systems can collect continuous one-third-octave band noise measurements and synchronous, full-spectrum digital audio recordings in low-sound-level, outdoor environments. A system diagram is shown in Figure 3.

3.1.1 Microphone System

The G.R.A.S. Model 40AQ pre-polarized microphones used in this study are electret condenser microphones. Being pre-polarized, the microphone functions as a closed system with regard to humidity, thus eliminating the potential for condensation in high humidity situations. Additionally, Larson Davis[™] (LD) Model PRM831 preamplifiers were employed at each site. The cable to preamplifier connection is protected by plastic housing, which can contain desiccant cartridges to minimize humidity.

The microphone is protected from precipitation and birds with a LD Model EPS2108 environmental shroud, which consists of a special acoustic foam windscreen outfitted with bird-spikes and a shroud, which houses desiccant cartridges to provide temperature/ humidity stability. The use of a windscreen also reduces the effects of wind-generated noise at the microphone diaphragm. Such reduction can improve the signal-to-noise ratio of sound measurements.

3.1.2 Sound Level Meter

The microphone system was connected to a LD Model 831 sound level meter / real-time analyzer. The Model 831 SLM was set up to continuously measure the overall A-weighted equivalent sound level with slow exponential time-weighting for each 1-second sample, as well as the Z-weighted (flat or un-weighted) equivalent sound level in each 1/3-octave-band from 12.5 Hz to 20 kHz.

3.1.3 MP3 Audio Recorder

Continuous digital audio recordings were collected using a Roland R-05 audio recorder. The AC output of the LD 831 SLM was connected directly to the input of the recorder. MP3 audio files were saved on an SDHC card.

3.1.4 Ultrasonic Weather Sensor

A Vaisala Weather Transmitter Model WXT520 outfitted with bird-spikes was used to measure barometric pressure, humidity, precipitation, temperature, and wind speed and direction. The sensor was set up to sample wind speed and direction at a rate of 4 samples per second and 1-second averaged output. The output of this unit is sent to the LD831.

3.1.5 Other Instrumentation

Three additional pieces of acoustic-support instrumentation were used to support the data collection effort:

- Sound level calibrator A B&K Model 4231 sound level calibrator was used in the field for establishing and checking the sensitivity of the entire acoustical instrumentation system (i.e., microphone, preamplifier, cables, and SLM). The Model 4231 was used to produce a 94-dB sound pressure level at a frequency of 1 kHz.
- Microphone simulator A microphone simulator was used to establish the electronic noise floor of the entire electrical system absent of the microphone.
- GPS unit A GPS unit was used to perform time synchronization of all pertinent instrumentation and documentation of the exact site location.

dose response relationships for backcountry visitors



Figure 3. Acoustical monitoring system diagram

3.2. Sound Source Identification

The purpose of sound source identification and logging is to maintain a continuous, timed record of sound source audibility during survey administration to correlate with the measured sound level data. Observers logging in the field can closely match the experience of park visitors. Field observers can take full advantage of human binaural hearing capabilities and identify sound source origin, simultaneous sound sources, and directionality. During survey administration time periods, teams of observers continuously documented all audible sound sources in the vicinity of the acoustical monitoring systems, whether a single source (e.g., windin-trees), or multiple, simultaneous sources (e.g., two aircraft). In this manner, a timed record of audible sounds is created.

At the majority of measurement locations, there were more sound-level monitoring systems than available personnel for sound source logging. Consequently, field logging was performed at nearby monitors on a rotating basis. For example, on Hermit Trail one team of observers was responsible for monitors GRCA101, GRCA102, and GRCA106 (see Section 4 for trail maps showing monitor locations). These observers generally followed a schedule whereby they were stationed by site GRCA101 on day 1, site GRCA102 on day 2, site GRCA106 on day 3, and back to site GRCA101 on day 4, etc.

Members of these observer teams who were not actively logging sounds were responsible for photographic documentation of aircraft overflights (where visual sighting was possible). These photos were primarily intended to serve as records of aircraft slant distance (estimated through photo scaling) which can be used as input for computer modeling of the noise exposure.

Each field observer used a NOBi computer running custom-developed software (programmed by the Volpe Center) that provided a touch-screen interface to enable simple, rapid input for sound sources and durations. The touch-screen interface allows users to tap the appropriate button when a particular sound becomes audible, and then tap again when the sound becomes inaudible. In this manner, the software places a time stamp at the beginning and end of each sound event. The software tracks as many sound sources as necessary, meaning that any number of sound sources can be specified as audible at any moment in time.

Sounds are typically color-coded in the on-screen interface to designate the three primary acoustical states: aircraft, human, and natural. Aircraft intrusions include air tour, commercial jet, general aviation, military and other aircraft noise. Human noises can include surface

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vehicles and voices. Natural sounds can include wind-induced sounds, insects, and birds. Each individual button within the interface can be customized to allow identification of subcategories of sounds. For instance, sub-categories of aircraft can include, helicopter, fixed-wing propeller aircraft, or commercial jet. The software is customizable such that these specific sources can be tailored to an individual site. An example of the touch-screen interface is shown in Figure 4.

Natural		Aircraft		Human		13:48:1 17 sec
Light Wind	Heavy Wind	Jet, Comm.	Aircraft, Unknown	Vehicle	Automobile	
nd-induced Natural	Rain/Fog	Jet, Comm. #2	Propeller	Truck	Motorcycle	
Water	Thunder	Jet, Comm. #3	Prop. G/A	Bus	V. Alarm, Horn	
in dust	THE REAL	Jet. Comm. #4	Prop. Mil	Vehicle Door	People	
Flow. Water	Insect	Jet, Military	Prop. Air Tour	Voices	Footsteps	
Bird	Chipmunk	let Miltan #2	Prop. Air Tour #2	Boardwalk	Train	
Mammal	Squirrel	Vet, minuty H2	Trop, we Toke He	Train Hom	Motor	
Amphibian	Reptile	Jet	Prop. Air Tour #3	Grounds	Domestic Animal	
		Heli, Air Tour	Prop. Comm	Building	Heavy Equip.	
Nat. Unknown	Animal (Nat.)	Heli, Air Tour #2	Helicopter	Watercraft	Construction	
Natural Other	Silence	Heli, Air Tour #3	Heli, Mil	Non-Nat. Unk.	Non-nat. Other	End Ses
SoundSource Beg	n End Duration	Edit Delete	Tab	~	ATMP Default	Save
			Sound Category	Sound		Save
Button Cr			Button Color	V Add		

Figure 4. Image of example of touch-screen interface used for sound source identification logging

3.3 Acoustical Monitoring Locations

Measurement of sound levels throughout the study areas utilized a system of stationary acoustical monitoring systems. The specific number and placement of the monitors at each location were tailored to each site, based on topography, the spatial character of visitor use, and the nominal aircraft overflight altitudes and routes (where available). Prior to field measurements, examination of topographical maps with air tour route information, scoping visits, and discussions with park staff all were used to guide monitor location selection.

In general, the team located monitoring systems such that the difference in sound exposure level (L_{AE}) between adjacent monitors for individual aircraft overflights was less than 6 dBA. This ensured that any error in sound level estimation for a visitor located halfway between

adjacent monitors was less than 3 dBA. Tolerances such as this can be achieved if monitors are laterally spaced at distances less than twice the expected distance from the overflight route (i.e., the distance between the visitor and any one monitor is never more than the distance between the visitor and the aircraft). For instance, at the Hermit Trail site, the aircraft route runs parallel to the majority of the trail, and is located approximately ½ mile to the west. Therefore, monitors could be spaced at one-mile intervals. This lateral spacing also ensured that adjacent monitors were separated by no more than 1000 feet in altitude. As Hermit Trail was the worst-case scenario, where heavily-used air tour routes are in close proximity to hiking trails, the aforementioned spacing (1-mile lateral or 1000 feet vertical) was used at all sites throughout the study. Section 4 includes trail maps of all the study sites, showing the locations of the monitoring systems.

Trained personnel deployed the monitoring systems during a one or two day period prior to the start of survey administration. Generally, monitors were deployed in locations that were representative of the environment experienced by hikers in the area, but 1) out of direct view of visitors hiking along the trail, and 2) in areas free of localized noise sources and/or reflective surfaces. Data collection commenced immediately after the deployment of the monitors, and continued without interruption for the entire duration of the study. Personnel rotated throughout the study area periodically to check the monitoring systems and ensure they were working properly.

4. SITE SELECTION AND STUDY AREAS

Previous dose-response work in the National Parks has shown that visitor response varies depending on the type of site they visit and/or the activity in which they engage. For example, visitors who stop at scenic overlooks (with associated parking lots, human activity and noise) have different responses to aircraft noise than do visitors who spend 15-45 minutes hiking down a trail away from a trailhead.⁸ The goal of the data collection presented herein was to expand on the previously collected data by measuring dose-response relationships at sites where visitor behavior (i.e., activity) differs from previous collections, in order to better understand how the context of a visitor's park experience mediates his or her response to aircraft noise. As with any data collection program, the selection of the specific study site(s) was critical to the success of the program. The following section describes the sampling plan, the site selection process and the specific parks and sites chosen for data collection.

4.1. Sampling Plan

To make the best possible use of the available resources, data from similar collections performed in the 1990s were analyzed to determine the sample sizes necessary in this study to evaluate dose-response relationships with sufficient accuracy (95% certainty with 80% power). These data provided an anticipated response rate (70%) and anticipated incomplete data level for a respondent (60%). The data were collected with only one of the three proposed survey instruments (HR1). However, that survey instrument employs more alternative responses and more predictors in the mathematics than do the other two instruments. Its analysis was anticipated to require more data points than the other two. The target sample size of 175 survey responses per site was therefore anticipated to provide more-than-adequate samples for the other two survey instruments. Since all three surveys were administered evenly at every site as described above, the target of 525 survey respondents at every site. Data were collected from several sites in each selected park, depending upon the park type and the availability of desired site types. In all, data were collected at a total of four parks and eight sites.

^{*} Most incomplete data were, in previous studies, caused by the physical inability to adequately measure and calculate various noise metrics under adverse weather or ambient-noise conditions.

4.2 Site Selection

For this dose-response research, each study site met at least three basic criteria: 1) aircraft, both commercial air tours and high altitude jets, were regularly audible, 2) visitation was sufficient for survey data collection as discussed in Section 4.1, and 3) topography allowed for acoustical monitor placement and survey intercept. Beyond this, the study team chose sites that provide a variety of natural settings and terrain, to capture at least some of the diversity of the national park system.

There are additional physical site characteristics that can influence any or all aspects of the data collection methods. These physical characteristics include the spatial character of visitor use (i.e., out-and-back versus circular trails), the number of points of entry to the study area, and geographic features such as buildings, cliffs, or other large objects that can shield the visitor from the noise source.

Together, these visit and site characteristics define a finite set of general site-types that can be used to represent the possible range of actual sites. In other words, a site where visitors are hiking in a remote (un-crowded) location with an overnight stay would be one type of site: overnight hiking/camping backcountry. These site-types are:

- Overlook: Locations where average visits are less than 30 minutes. Activities may include viewing scenery or other natural features of interest and participating in interpretive events.
- Short hike: Locations where average visits are less than one hour. Activities may include hiking for distances of 1 mile or less, viewing the natural scenery and participating in interpretive events.
- Day hike: Locations where average visits are between one and eight hours. Activities may include hiking for distances greater than 1 mile and viewing the natural scenery.
- Backcountry overnight: Locations where average visits are greater than eight hours with an overnight stay. Activities may include hiking, viewing the natural scenery, and camping.
- Frontcountry cultural/historic: Locations where average visits are less than two hours. Activities may include viewing cultural and/or historic points of interest, walking, and participating in interpretive events.

• Backcountry cultural/historic: Locations where average visits are greater than two hours. Activities may include viewing cultural and/or historic points of interest, hiking, and participating in interpretive events.

Previous dose-response data collections of this type focused on short hikes and scenic overlook site types. The research team, in collaboration with experienced social-scientists with expertise in outdoor recreation studies, and other acoustical scientists with expertise in measuring aviation noise, identified backcountry day-hike visitor experiences as high priorities for the current research focus, as visitors engaging in longer, more remote visits may have higher sensitivity to aviation noise and/or be in sensitive sound environments (such as the very low-level ambient noise levels in remote areas). Additional site-types, such as overnight visits and those where the preservation of cultural resources or historic character is of concern, were also identified as a priority as they had not been previously studied, but only exploratory initial data collection was undertaken for these two site types.

Candidate sites within the two backcountry site-types (day hike and multi-day hike) were selected based on the criteria discussed above. Using this candidate list, small teams of researchers (consisting of both acoustical scientists and social scientists/survey specialists) conducted scoping visits to six national parks (Great Smoky, Mount Rainier, Glacier, Bryce Canyon, Zion, and Grand Canyon) to further investigate possible sites. The research teams documented and assessed aircraft audibility, aircraft visibility, locations for acoustical monitor placement, visitor behavior and visitation, and locations for survey intercepts. These visits allowed the researchers to evaluate numerous potential sites and site-types, and also to meet with park staff to discuss the research plans and get advice on specific trails and other potential data collection locations.

Based on these scoping visits, as well as subsequent discussions with the FAA and NPS, the research team developed a final list of specific data collection sites. Table 3 summarizes these sites and Figure 5 shows their general locations, while Sections 3.1-3.4 provide detailed descriptions. In addition to the site types already described, some additional short-hike data were also collected at one of the day-hike trails with an option for a shorter visit. These data were collected on opportunistic basis as personnel were available, with the goal of expanding and enhancing the existing dose-response datasets.

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Figure 5. Location of study sites

Park	Site	Site-Type(s)	Aircraft overflight activity	Visitation
Grand Canyon (GRCA)	Hermit Trail	Day- and multi-day hikes	High	Low- Moderate
Grand Canyon (GRCA)	Grandview Trail	Day- and multi-day hikes	Moderate	Low- Moderate
Grand Canyon (GRCA)	Tusayan Ruins	Cultural/Historic viewpoint	High	High
Bryce Canyon (BRCA)	Fairyland Trail	Day-hike	Low-Moderate	Low- Moderate
Zion (ZION)	West Rim Trail	Day- and multi-day hikes	Low-Moderate	Low
Zion (ZION)	Taylor Creek Trail	Day-hike	Low-Moderate	Moderate
Glacier (GLAC)	Sperry Trail Snyder Lake Trail* Fish Lake Trail*	Day- and multi-day hikes	Moderate-High	Moderate
Glacier (GLAC)	Hidden Lake Trail and Overlook	Short- and day- hikes	Moderate-High	High

*Snyder Lake and Fish Lake trails are branches originating from Sperry Trail

4.3 Grand Canyon National Park (GRCA), Arizona

Grand Canyon National Park, although not covered by NPATMA, is perhaps the optimal location in the United States for an aircraft dose-response study. There is a high volume of air-tour activity, and regulated air tour routes provide predictable noise exposure doses in known locations. Within the park, there are numerous site-types, from scenic and cultural vistas to backpacking opportunities in rugged wilderness areas. It is also one of the most heavily visited parks in the NPS system, which allows researchers to obtain sufficient survey samples in a relatively short amount of time.

Survey and acoustic data were collected at three sites within Grand Canyon National Park during the period April 10-26, 2011. These sites, along with air tour route information, are shown in Figure 6.



Figure 6. GRCA study sites and air tour corridors

Hermit Trail: Hermit Trail provides opportunities for both day-hikes and multiple-day backpacking. It runs 9.2 miles from the trail head to the Colorado River, descending 4340 feet, and intersects with other significant backcountry trails along the way, including the Dripping Spring Trail. Popular day-hike destinations along this trail include Waldron Basin (1.5 mi), Santa Maria Spring (2.5 mi), and Dripping Spring (3.5 mi.). Hermit Creek Camp, near the terminus of the trail, contains 4 campsites. Park statistics indicated that, on average, approximately 50 visitors hike on Hermit Trail daily.

Hermit Trail experiences many nearby air tour aircraft overflights. The 'Dragon' air tour route runs essentially parallel to, and approximately ½ mile east of, the Hermit Trail. This route carries both helicopter and fixed-wing operations (generally more helicopters than fixed-wing).

A total of six acoustical monitoring systems were deployed on the Hermit Trail - one along the steep initial section, approximately ¼ linear mile from the trailhead (GRCA101), one at Waldron Basin (GRCA102), one on the Dripping Springs Trail approximately 1 mile from the intersection

of Hermit and Dripping Springs trail (GRCA106), two systems along the remaining length of the trail, at approximately one-linear-mile intervals (GRCA103 and GRCA104), and one nearby the designated Hermit Creek camping area (GRCA105). Two teams of two sound source observers / loggers were deployed during each measurement day: one team nearby monitors at the top of Hermit Trail, and one team nearby monitors at the bottom of Hermit Trail. Figure 7 presents the final acoustical monitor locations.



Figure 7. Acoustical monitor and survey locations along Hermit Trail

A team of three to six survey administrators were deployed along the trail. Visitors were preintercepted about 5 minutes beyond the trailhead, and surveys were administered just before the trailhead as visitors returned (i.e., about 1/8 down the trail). **Grandview Trail:** Grandview Trail also provides opportunities for both day-hikes and multipleday backpacking. The trail runs 3.5 miles from the trailhead to the trail terminus at Horseshoe Mesa with a change in elevation of 2,500 feet. It is a feasible and rewarding day hike for many visitors, and also attracts hikers wishing to camp overnight on the Mesa. This trail averages 25 to 40 hikers daily. Air tour activity over the Grandview trail is low, as it is five miles or more from designated air tour routes. High-altitude jets are regularly audible from Grandview trail.

Three acoustical monitoring systems were deployed along the Grandview Trail – the first between the trailhead and the Coconino Saddle (GRCA201), the second between the Saddle and Horseshoe Mesa (GRCA202) and the third on the Mesa (GRCA203). Figure 8 presents the final acoustical monitor locations. A team of two sound source observers / loggers was deployed daily to log sound in the vicinity of the monitors nearest Horseshoe Mesa.



Figure 8. Acoustical monitor and survey locations along Grandview Trail

The survey team pre-intercepted hikers about 5 minutes beyond the trailhead. Surveys were administered further down the trail from the pre-intercept location, approximately 0.25 linear miles from the trailhead. This location was a natural stopping point for returning hikers before they began their final ascent to the rim.

Tusayan Ruins: Tusayan Ruins is an 800-year-old Pueblo Indian site located within Grand Canyon National Park. The NPS considers Tusayan Ruins to be one of the most significant archeological sites in Arizona. The site contains the well-reserved remains of a pueblo featuring a living area, storage rooms, and a kiva. In addition, the Park runs a small museum adjacent to the ruins site. The Park offers regularly scheduled interpretive talks at the site (generally, two per day) and the site has abundant signage for self-guided tours. This site typically receives 500 or more visitors per day in April.

Air tour activity over Tusayan Ruins is high, as it is less than one mile from the point at which the "Dragon" air tour track first crosses the canyon rim. Park staff at the Ruins site reported frequent air-tour activity, and occasional low-flying aircraft that are loud enough to disrupt the interpretive talks.

A single acoustical monitoring system was deployed at the Ruins. The system was located approximately 200 feet due north of the large kiva at the center of the ruins, hidden from view by trees. A team of two sound source loggers was deployed nearby.

A team of four survey administrators was deployed. Due to high visitor volume, survey activity took place for only three days, April 13-15, 2011. Visitor surveys took place at the margin of the Ruins site, in a location that provided shade and bench seating for visitors. Again, due to the high visitor volume, visitors were not pre-intercepted. The survey team recruited visitors as they exited the Ruins site.

4.4 Zion National Park (ZION), Utah

Zion National Park was selected as a study site for three reasons. First, it provided wide variety of natural environments, including canyon, scrub forest, and broad, open plateau. Second, Zion offered several important types of study sites: day-hikes, short hikes, and multi-day backcountry hikes. Third, although there are no official air tour routes over the park, anecdotal information from park staff, as well as observations made by the Volpe team during a site scoping visit to the park, indicated that there was moderate to high general aviation activity in the area. Zion is heavily visited during the summer months, allowing researchers to obtain sufficient survey samples in a relatively short amount of time. Survey and acoustic data were collected at Zion during the period June 12-25, 2011.

West Rim Trail: The West Rim Trail is well-maintained and provides a true backcountry experience for hikers. The trail begins at Lava Point (accessible via the Kolob Terrace Road)

and extends 14.4 miles through the canyon, while dropping 3,140 feet in elevation to end at the Grotto, in the heart of Zion (Figure 1). Hiked north to south, the trail is moderately strenuous. Backcountry camping is available at nine designated sites, which are available by reservation or (for some of the campsites) on a walk-up basis. The West Rim trail provides stunning views of Zion Canyon, and is therefore a popular trail for backcountry hikers. Park statistics²⁴ on visitor use indicate that 10 to 20 visitors per night obtain backcountry camping permits for the area, including West Rim Trail during the summer months.

During the scoping visit to Zion, Volpe team members spent two hours near mid-day at Lava Point (from which the majority of the West Rim Trail is visible) observing aircraft. In that time span, the team observed three general aviation aircraft (fixed-wing prop) and multiple highaltitude jets flying over the study area.

A total of six acoustical monitoring systems were deployed along West Rim Trail between Lava Point and Scout Lookout, spaced at approximately 1 to 1.5 mile intervals. Figure 9 shows the locations for these monitors, denoted ZION101 through ZION106. A two-person team of soundsource observers/loggers was deployed daily on the West Rim Trail. On 12 of the 14 data collection days, the team was stationed near monitor ZION106 at the southern end of the trail. On two of the days (6/18/2011 and 6/22/2011), the observer team was stationed at the northern end of the trail, in the vicinity of Lava Point nearby monitor ZION101.



Figure 9. Acoustical monitor and survey locations along West Rim Trail

Two survey teams collected data from hikers on the West Rim trail. One survey team member staffed the Lava Point trailhead each day to pre-intercept hikers and ask them about their hiking plans. Only those visitors who intended to hike the entire length of the trail (i.e., all the way to the Grotto) were asked to participate in the study. The pre-intercept survey team member also asked visitors whether they intended to camp during their hike, or to hike the entire trail in one day. This survey team member was also available to administer surveys to the small number of hikers who hiked the trail south to north and therefore ended their hikes at Lava Point.

A second survey team, this one with two members, staffed the survey administration site located at "the Patio," which is about ½-mile north of Scouts Lookout along the West Rim Trail.

This location provided the natural setting, quiet, and distance from the crowds at the Grotto and Angels' Landing necessary for the survey administration, and it allowed hikers to remain in the environment to which the surveys refer. The survey administration team administered surveys to visitors who had hiked the length of the West Rim trail from Lava point, and also hikers who had come up from the southern trailhead near the Grotto, and who had gone past the survey station and into the park wilderness (for this latter group, the survey team also did pre-intercepts and issued GPS trackers). Hikers who went only as far as Angels' Landing were not surveyed, because they had not been in quiet areas.

Taylor Creek Trail: Taylor Creek trail is in the Kolob Canyons section of Zion, about an hour's drive north of the park headquarters. The trail, which follows an active creek for 2.5 miles, offers the opportunity for even inexperienced hikers to explore a narrow canyon containing a beautiful riparian habitat. Because it is short and level and has parking at the trailhead, Taylor Creek trail is popular and attracts casual hikers, including families, who often hike it in sneakers or sandals.

Cedar City Municipal Airport is about 15 miles from Taylor Creek trail. Regional and general aviation aircraft use this airport for flights north to Salt Lake City, south to St. George and Las Vegas, and to other areas in the region. Many of the aircraft follow the I-15 corridor (approximately 2 miles west of the trailhead) and, consequently, pass over the study site. St. George Municipal Airport is approximately 30 miles from the study site. During the scoping visit, the Volpe team logged seven low-altitude, general aviation prop aircraft in a span of about four hours. Although all were clearly audible, not all were visible from the trail.

Two acoustical monitors were deployed along the Taylor Creek Trail, one approximately 0.7 miles from the trailhead (ZION201), and another 1 mile further and 0.35 miles from the end of the trail (ZION202). Figure 10 includes the locations of these monitors. A team of two soundsource observers was deployed along the trail daily nearby monitor ZION201.



Figure 10. Acoustical monitor and survey locations along Taylor Creek Trail

Taylor Creek trail has a single trail head, making it an easy location at which to conduct surveys. A single survey team positioned a short distance from the trailhead (to get away from parking lot noise), conducted pre-intercept and survey administration. Weekdays, this team comprised two members. On weekends one additional survey team member was added.

4.5 Bryce Canyon National Park (BRCA), Utah

Bryce Canyon was selected as a study area because it offered a unique natural environment – huge, horseshoe-shaped amphitheaters containing myriad limestone rock spires known as "hoodoos" – and high visitation as well as directly comparable data collected in the 1990s for overlook at short hikes at Bryce Canyon. In addition, the relative proximity of Bryce and Zion meant that the Volpe team could manage data collection efforts at both parks during a single, multi-week deployment rather than needing two separate trips.

At the time of the data collection, there were 16 registered air tour operators in the vicinity of Bryce Canyon. However, most of the air tour activity at the canyon comes from one local operator, flying either a fixed-wing aircraft out of Bryce Canyon Airport adjacent to the park, or a helicopter from a landing pad at "Ruby's Inn" about a 1 mile drive north of the park boundary. According to the operator, on a "good" day, he might run 10 flights. During the study period, the operator had grounded his helicopter due to operating costs, but was still flying fixed-wing air tours.

Fairyland Trail: Fairyland Trail begins at Fairyland Point, in the northern portion of the park, and continues through spectacular hoodoos and scenery along the rim and into the canyon, including a spur trail to Tower Bridge, a dramatic rock formation that is a popular hiking destination. The trail incorporates a 2.5-mile portion of the Rim Trail from Sunset Point to Fairyland Point. The entire Fairyland loop is 8 miles, and typically takes about four to five hours to hike. This hike is considered strenuous due to its length and meandering layout with multiple elevation changes.

Two acoustical monitoring systems were deployed in the study area – defined as the 5.5 mile main portion of the trail (i.e., not including the 2.5 mile portion of the Rim Trail). The first monitor (BRCA101) was located about 1.5 miles from the northern trailhead of the Fairyland trail; the second monitor (BRCA102) was located in the Sunrise Point area. Both monitors were set back from the trail and were hidden from view to the extent possible, given the lack of vegetation. Figure 11 shows the locations for these monitors. A two-person team of sound source observers/loggers was deployed daily during the 17-day data collection. The team logged near each system on alternate days.



Figure 11. Acoustical monitor and survey locations along Fairyland Trail

A two-person survey team was deployed at each end of the Fairyland trail – about 15 minutes walking distance from the respective trailheads. Because hikers traveled in both directions (i.e., from Fairyland Point to Sunset Point, and vice-versa), both survey teams conducted preintercepts and surveys. Only those visitors who intended to hike for at least one hour were asked to participate in the survey.

4.6 Glacier National Park (GLAC), Montana

The inclusion of Glacier National Park in the research provided additional natural settings, different from the other study areas. Glacier includes both dense forest and expansive alpine meadow and lake environments. Also, the park has fairly heavy air tour activity of both fixed-wing aircraft and helicopters, providing good opportunities for noise "dose" exposure of study participants.

Sperry Trail. This popular trail traverses the heart of Glacier National Park, and intersects Going to the Sun Road at Lake McDonald, Jackson Glacier Overlook, and Sunrift Gorge, providing three convenient trailheads for multi-day backpacking trips. From its northern

trailhead at 5,284 feet, the trail ascends to 6,946 at Gunsight Pass (where it crosses the Continental Divide), increases to 7,050 feet at Lincoln Pass, and then descends to Lake McDonald at 3,213 feet. Consequently, the majority of multi-day hikers follow the trail from north to south. From end to end, the trail is over 20 miles. In addition to the main trail, a two-mile spur from the Gunsight Trail provides a popular route to campsites at Snyder Lakes, and another one-mile spur is a popular day-hike over Sprague Creek to Fish Lake.

Sperry Trail is popular, and heavily used. On a site scoping visit to the trail in August 2010, the scoping team encountered 40 visitors at Gunsight Lake over the course of a single (8-hour) day. Some 29 of these visitors were identified as multi-day backpackers. At Sperry Chalet, 104 visitors were counted in one day, 20 of whom were backpackers. Another indicator of potential visitation is campsite capacity. There are five backcountry camping areas proximate to the Sperry Trail and Snyder Lakes spur. The aggregate capacity of these campsites is 80 people. In addition, Sperry Chalet has 17 guest rooms, ranging in occupancy from one to five people. At maximum occupancy, the Chalet can accommodate 50 visitors.

During the scoping visit, 13 helicopters and two high-altitude jets were noted during a 7½ hour period at Gunsight Lake (1.7 helicopters per hour, average). At Sperry Chalet, a 6½ hour observation recorded 6 helicopters and 2 high-altitude jets (0.92 helicopters per hour, average). The air tours typically fly over the regions of the park that contain the largest glaciers and other scenic attractions. Because the Sperry Trail is in the vicinity of several glaciers, it is beneath numerous potential air tour routes.

During the study period, the northern half of Sperry Trail was closed due to snow, so the acoustical monitoring and visitor surveys concentrated on the southern end of the trail between Lake McDonald and Sperry Chalet, including the Snyder Lake and Fish Lake spur trails. The study area included Sperry Chalet, a popular overnight destination for hikers. Eight acoustical monitoring systems were deployed: five along Sperry Trail, two along Snyder Lake Trail, and one near Fish Lake. All monitors were set back from the trail, and were hidden from view. Figure 12 shows the locations for these monitors, denoted GLAC101 through GLAC108. Two-person teams of sound source observers/loggers were deployed daily during the 19-day data collection. Teams conducted source logging near each system on alternating days; on most days, two teams were in the field.

A two-person survey team was deployed daily near the Lake McDonald parking area. All hikers – whether traveling to the Sperry Chalet for an overnight stay, or day hiking to Snyder Lake or

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Fish Lake – began their hikes from this trailhead. All hikers were pre-intercepted; those who intended to hike for at least one hour were invited to participate in the study, and issued GPS trackers. Horseback riding is permitted on Sperry Trail, and is a popular activity there. A concessionaire-run stable is situated at the trailhead. The survey team did not interview horseback riders.





Hidden Lake Trail. Hidden Lake Trail is an extremely popular and heavily visited front country day-hike trail. The trail begins at the Logan Pass Visitor Center, and extends three miles to Hidden Lake. The trail is paved (although frequently snow covered) for the first 1.5 miles – from the Visitor Center to a popular overlook that affords a spectacular view of the lake. From the overlook, the trail descends steeply 780 feet to the lake's shore. Fishing is permitted at Hidden Lake and is a popular activity there. During the study period the trail was covered in snow. This did not diminish the number of visitors hiking to the overlook (the trail was slippery but accessible), but it did reduce the number of visitors who hiked down the steep descent from the overlook to the lake.

During the scoping visit in August 2010, the team encountered 10 to 30 visitors per hour on the second half of the trail (overlook to lake); visitor volumes were consistent over the course of the day. Most visitors hiking to the lake spent at least ½ hour there before returning. On the first leg of the trail (Visitor Center to overlook), visitor volumes were much higher, and varied with time of day: before noon, 50 to 100 visitors per hour; after noon, 100 to 300 visitors per hour.

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Like the Sperry Trail study site, the Hidden Lake study site lies beneath multiple air tour flight corridors. During a 5½-hour observation period, the scoping team noted seven air-tour helicopters (1.27 per hour, average) and two general-aviation propeller aircraft. Helicopter tours often hover above the lake (in clear view of and easily audible from the overlook site).

Two acoustical monitoring systems were deployed along Hidden Lake Trail. All monitors were set back from the trail, and, to the extent possible, were hidden from view. Figure 13 shows the locations for these monitors, denoted GLAC201 and GLAC202. A two-person team of sound source observers/loggers was deployed daily nearest GLAC201 during the 7-day data collection.

A team of four survey personnel was deployed daily at the Hidden Lake study site. Initially, the team surveyed only visitors who were planning to hike all the way to Hidden Lake; these hikers were provided with GPS trackers and surveyed after returning from the lake. Because of the small number of visitors hiking to the lake, the sample was expanded to include visitors who had hiked to the overlook site (overlook visitors were considered to be participating in a short hike while visitors who went to the lake were considered day-hikers).



Figure 13. Acoustical monitor and survey locations along Hidden Lake Trail

4.7 Data Collection Summary

During the spring/summer of 2011, 114 days of survey and acoustic data were collected at seven locations in four National Parks. The complete database from these measurements consists of over 4,600 completed visitor experience surveys and associated acoustic dose measurements. Table 4 summarizes the data collection locations, number of days, number of completed surveys, and number of hours of live field sound source logs collected at each location. This information is further detailed in Section 6.

Park	Site	Number of Days	Number of Surveys Collected	Observer Log hours
Grand Canyon (GRCA)	Hermit Trail	18	584	237
Grand Canyon (GRCA)	Grandview Trail	18	417	128
Grand Canyon (GRCA)	Tusayan Ruins	3	374	23
Bryce Canyon (BRCA)	Fairyland Trail	18	1102	133
Zion (ZION)	West Rim Trail	15	309	105
Zion (ZION)	Taylor Creek Trail	15	453	104
Glacier (GLAC)	Sperry Trail Snyder Lake Trail* Fish Lake Trail*	20	885	227
Glacier (GLAC)	Hidden Lake Trail and Overlook	7	516	51

Table 4. Summary of data collected

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5. DATA REDUCTION

Three sets of data were collected during each measurement trip: survey, acoustic, and visitor track (GPS trackstick) data. Each of these datasets required cleaning and reducing prior to computation of the noise exposure dose for each respondent and assembly of the final dose-response database. Figure 14 presents a flow diagram of the data reduction process.

The survey data consist of:

- The survey response data files collected via the tablet PCs, and the hard copies of paper questionnaires.
- The pre-intercept and survey-intercept log sheets. The pre-intercept log sheets contain the visit start time, ticket and GPS trackstick numbers, number of adults and children in the visitor group, refusals, and hand-written notes on length of stay and destination or refusal reason. The survey log sheets contain visit end time, ticket and GPS trackstick numbers, refusals, and hand written notes on length of stay and destination or refusal reason.

The acoustic data consist of:

- Continuous, one-second, A-weighted sound levels and their associated one-third octaveband, un-weighted spectra from 20 to 20,000 Hz.
- Continuous digital audio recordings.
- Meteorological data in the form of continuous, one-second wind speed and direction data.
- Observer Logs from field observers. These files contain a second-by-second record of audible sound sources.

The visitor track data consist of:

• Continuous, one second latitude, longitude and altitude data for each participating visitor or group.



Figure 14. Diagram of data reduction process

5.1. Survey Data

Park visitor survey data collected via the tablet PCs were consolidated into a single file. All records were checked for completeness and survey notes were inspected to determine if any respondents were noted as invalid (i.e., worked for NPS, wearing personal audio device during hike, etc.), or of any other inconsistencies were observed [i.e., talking to others during surveys, bad weather, wind (which could affect audibility of audio clips), thunder, or other loud sounds]. Park visitor survey data collected via paper surveys were coded and merged into the master survey database.

For each visitor, the pre-intercept date and time, destination, group size, survey date and time and other hand-noted information from the survey intercept logs were entered into the survey database. This information was assigned to the correct visitor by cross-correlating the GPS trackstick numbers and paper ticket numbers noted both in the survey logs and in the tablet PC survey records.

5.2 Track Data

Each trackstick file contained one-second records of latitude, longitude and altitude for each participating visitor group. These data encompass not only the duration of the visit, but also time before and after each visit, as the tracksticks were commonly activated well before the visitor arrived and deactivated after the visitor departed the survey location. As a result, these files were very large, commonly exceeding 10,000 records.

Special software was developed to read these trackstick files, reduce them to only the duration of the visit, compare the one-second position records with the position of the acoustical monitors at each study area, and determine, for each position record, which monitor was in closest proximity. The software then output a condensed version of each visit record, referred to herein as a tracklog, containing a time/monitor-segmented account of the visit. Each segment corresponds to the period of time during which the visitor was proximate to a specific acoustical monitor as the visitor moved through the study area. An example of this tracklog file from an overnight hike on West Rim Trail is shown in **Error! Reference source not found.**. This file shows the date, segment start time, segment end time, and the designation of the proximate acoustical monitor. The software also flags time periods within the tracklog corresponding to positions outside the study area (defined as greater than one mile from an acoustical monitor). Visitors who remained outside the study area for more than one hour were eliminated from the

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dose-response pool: noise exposure doses were not computed for these visitors, but survey responses are retained in the master database.

",614,10:03:00,10:52:39,ZION101" ",614,10:52:40,12:01:57,ZION102" ",614,12:01:58,14:50:40,ZION103" ",614,14:50:41,16:32:38,ZION104" ",614,16:32:39,23:59:59,ZION105" ",615,00:00:00,09:29:24,ZION105" ",615,09:29:25,10:10:00,ZION106"

Figure 15. Example GPS tracklog

This process was carried out for the respondents who carried GPS tracksticks (approximately 70% of the total respondents). For visitors who did not carry a GPS trackstick, estimated tracklogs were created using information noted in the survey logs, including destination and approximate start time, along with average hike times of similar visits (with tracklogs). In cases where start time or destination was unknown, tracklogs could not be created and dose information for these visitors could not be computed.

5.3 Acoustic Data

Raw sound level monitor data from the LD831 contain both acoustical and meteorological data. These files were translated into ASCII text files, such that each line of the text file represents a 1-second data sample containing the date, time, equipment ID, battery voltage, internal temperature, average wind speed and wind direction, Z-weighted (flat or no frequency weighting) L_{ASeq} , A-weighted L_{ASeq} , and Z-weighted spectral data (12.5 – 20,000 Hz).

The text files containing the sound level monitor data were examined for errors and cleaned. Prior to detailed data reduction and analysis, several quality assurance filters, checks, and adjustments were applied to the acoustic data to ensure that any questionable data were identified and that only 'good' data were reduced and analyzed. The list of filters used to identify 'bad' or questionable data include the following:

- Data collected during potential system malfunction (battery problems, temperature limits, anemometer error, etc.);
- Data with associated 1-second average wind speeds greater than 5 m/s, indicating

measurement system noise resulting from high-wind conditions;*

- Data with associated 1-second Z-weighted sound levels exceeding the LD Model 831 SLM's instrumentation noise "ceiling level" for the gain setting of the instrument ;
- Data with associated ½-octave frequency band data that do not deviate by at least one standard deviation (dB) across all 33 bands, typically represented by no variations in sound levels within the bands, which indicates a problem with the LD831 sample;
- Data that were measured during time periods that may be potentially contaminated by field personnel handling instrumentation during the calibration process, observer logging, and/or entering/leaving the site area.

The adjustments applied to the 1/3 octave-band acoustic data include:

- Calibration. These adjustments accounted for calibration drift as determined by measuring a calibration signal at the start and end of each data collection period.
- Microphone frequency response. These adjustments accounted for frequency response biases of the microphone and were provided by a microphone calibration facility.
- Windscreen frequency response. These adjustments accounted for frequency response effects of the windscreen.
- Noise floor. These adjustments accounted for contamination effects of the system noise floor. Application of the adjustments provide for more accurate estimation of the true ambient sound levels without being limited by the equipment's electrical noise floor.

The one-second 1/3 octave-band sound level time history data resulting from this process for each monitor are used as input to the noise exposure dose computation software described in Section 5.5.

5.4 Sound Source Data

In order to accurately compute a noise dose for each hiker, continuous sound source logs must be available for the entire measurement period at each acoustical monitor. The sound-source logs created by live observers during the data collection period cover only a portion of the sound source records required to compute an accurate dose for each visitor. Although *in situ* observations represent the most accurate method for obtaining records of audible sound sources (takes full advantage of human binaural hearing capabilities, allows identification of

^{*} Available data (HighWindCutoff) suggests that there is a high probability of microphone-induced distortion above this wind speed threshold.

sound source origin, simultaneous sound sources, and directionality, and closely matches the experience of park visitors), the cost of stationing live observers nearby all monitors at all times is prohibitive. Thus, live observers were not stationed nearby every acoustical monitor deployed, nor during all hours (especially overnight) when participating visitors were within the study area.

In lieu of continuous live observer monitoring, several methods are used to produce accurate records of audible sound sources: 1) post-measurement listening, where trained listeners use the audio recordings along with the tablet PCs and software used in the field to simulate the *in situ* logging process, and 2) visual review of spectrograms, plots that convey information on time, sound level and frequency of the sound environment. To develop contiguous, 24-hour sound-source logs for the entire measurement period at each monitor, these three methods were often combined.

The visual review of spectrograms was primarily used to streamline the process for night-time hours and within very quiet environments, as this method is most viable when aircraft overflights are infrequent and are the only noises that penetrate an otherwise quiet environment. An example spectrogram used with this method is shown in Figure 16. This Figure represents information for the 9 am hour at a site on Sperry Trail in GLAC. The x-axis represents time, the y-axis represents frequency (from low to high) and the brightness indicates amplitude. The low-frequency, high amplitude signatures of three helicopters are visible in this plot.





Following the preparation of a contiguous set of sound-source logs for at each monitor, the logs were converted to a hierarchal structure, to compute noise exposure doses comparable to those

from prior studies. In this study, sound-source observers continuously documented *all* audible sound sources, whether a single source (e.g., wind-in-trees), or multiple, simultaneous sources (e.g., wind-in-trees, people talking, and an aircraft overflight). As a result, at any given time, numerous sound sources could have been recorded – all of which contributed to the overall sound level at that time. In prior studies sound-sources were logged within a hierarchal structure: first were helicopter overflights, followed by propeller-driven aircraft, commercial jets, other human-caused noises (i.e., autos or voices), then natural sounds. At any given time, only the highest-priority sound was logged, no information on the presence or absence of lower-priority sounds was recorded. These hierarchal sound source logs for each monitor are used as input to the noise exposure dose computation software described in Section 5.5.

5.5 Noise Exposure Dose Computation

Specially-developed computer software was used to read the 1-second one-third octave band sound level records, and 1-second sound-source designation, combined with time and location information in the visitor tracklogs, to compute the corresponding aircraft noise exposure doses.

The initial step in this process was to synchronize the sound level time history data with the sound source logs to form a second-by-second database of 1/3 octave-band sound levels and associated sound source. At this point, a final adjustment was applied to acoustic data which were identified as corresponding to an aircraft source. These sound levels may also include contributions from natural and human sounds (i.e., ambient sounds) which were present during the aircraft overflight. To present more accurate aircraft sound levels, the ambient influence is removed in data processing. Ambient sound levels are represented by a 30-second energy-average (L_{Aeq,Tamb}) of adjacent data samples (either contiguous or non-contiguous) which are identified as non-aircraft.

For each visit period, the software computes several basic pieces of duration and aircraft noise exposure information, from which numerous acoustical descriptors can be computed to describe the noise exposure dose. This basic information includes:

- 1) T_{resp} : The duration of the respondent's visit in the study area;
- *T_{AudAC}*: The duration during which aircraft were audible (i.e., the total number of 1-second records which were identified with an aircraft source);
- T_{AC}: The number of 1-second records of 'good' aircraft data (i.e., data not removed due to the various filters including high winds);

- 4) $L_{AE,:}$ The sound exposure level due to aircraft, computed using only 'good' data, where $L_{AE,:} = 10 * \log 10 (\Sigma 10^{(LAeq, 1s/10)})$; and
- 5) *L_{Amx}*: The maximum A-weighted sound level (1-second record) from aircraft during the visit.

This information was computed in aggregate for all aircraft (regardless of type), and also in aircraft-type components of helicopters, fixed-wing propeller aircraft, and high-altitude jet aircraft. These aircraft-type components are both informative and necessary for computation of metrics in the primary dose-response regression model.

Similarly, basic sound level metrics for non-aircraft sounds were computed for each visit period:

- 1) $L_{AE,Hum}$: The sound exposure level due to non-aircraft human sounds;
- 2) T_{Hum} : The total duration of human sounds^{*};
- 3) *L_{AE,Nat}*: The total sound energy of natural sounds;
- 4) T_{Nat} : The total duration of natural sounds[†];
- 5) Natural Ambient L_{50} : The 50-percentile exceeded sound level of natural ambient sounds (sounds tagged as natural in the sound source logs). A statistical descriptor describing the sound level exceed 50 percent of a specific time period; and
- Natural Ambient L₉₀: The 90-percentile exceeded sound level of natural ambient sounds. A statistical descriptor describing the sound level exceeded 90 percent of a specific time period.

Additional diagnostic information was also summarized and reported for each visit period: number of aircraft sound level records that were uncorrectable (aircraft sound level < ambient sound level), number of records which were filtered (removed) due to high winds, and number of records where corresponding sound source information was not available. Respondents where more than 50% of the available data were removed due to any combination of these issues were not included in the final dose-response pool. The majority of these removals occurred for visits during periods of high-wind, where data was removed either through the 5 m/s wind cutoff filter or due to high ambient sounds. This 50% threshold is lower than that which is generally recommended (75%)²⁵. However, using a threshold of 75% would eliminate an additional 1012 respondents from the dose-response data pool – nearly 40% of the available respondents. For

^{*} This corresponds to time periods when non-aircraft human sounds are audible. Due to the sound source hierarchy, natural sounds are likely present during these periods.

[†] This corresponds to time periods when only natural sounds are audible, excluding all human and mechanical noise.
cumulative measures of noise exposure, removal of a portion data has the potential to bias the measurement such that visitors' exposure is underestimated, resulting in a conservative, overestimate of the visitor response at a given sound level. Conversely, incorporating the high-wind data has the potential to bias the measurement such that the exposure is overestimated, resulting in an underestimate of the visitor response. As it is desirable to use as much of the respondent data as possible, a conservative estimate of visitor response is seen as the more desirable outcome.

These basic dose components were used within analysis software to compute additional noise exposure dose metrics of interest:

• *L_{Aeq,Tresp}*: The equivalent sound level due to aircraft, normalized to the respondent's visit duration

$$L_{Aeq,Tresp} = L_{AE} - 10*log_{10}(T_{resp})$$

- $L_{Aeq,TAC}$: The equivalent sound level due to aircraft, normalized to the duration during which aircraft noises were audible
- %TAud: Percent time aircraft are audible

$$%TAud_{AC} = 100 * (T_{AC} / T_{resp})$$

- %Energy_{Heli} (P_{EnHelos}): The portion of the sound energy forming the basis for L_{Aeq,Tresp} which is contributed by helicopters
- %Energy_{Prop} (P_{en,Props}): The portion of the sound energy forming the basis for L_{Aeq,Tresp} which is contributed by propeller aircraft.

In addition, aircraft detectability level metrics were calculated from the one-second one-third octave-band records. Detectability level (D[']L) is computed from the root-mean-square sum of the signal-to-noise ratios across one-third-octave-bands of interest (for this dataset, 50 to 2000 Hz), adjusted for bandwidth and frequency-specific human hearing characteristics.^{26,27} From the one-second D[']L values, summary detectability metrics analogous to A-weighted metrics were computed for each respondent. These include:

- Detectability exposure level (D[']L_E , analogous to L_{AE});
- Equivalent detectability level (D'L_{eq}, analogous to L_{Aeq});
- Maximum detectability level (D'L_{max}); and
- Percent time 'noticeable' (%TN): The percentage of time during the visit where D'L ≥ 17.²⁸

5.6 Master Database

The result of the data cleaning and reduction process is a master database of noise exposure and survey response information, with one record for each respondent. The complete database consists of over 4,600 completed visitor surveys and associated acoustic dose measurements. This database is the foundation for the results and analyses presented in a Volume 2 companion report to this document. Table 5 summarizes the data collection locations, their sitetype classification, and the number of completed surveys with dose data at each location.

Park	Site	Day- Hike	Overnight Hike	Short Hike	Cultural/ Historic	Total
Grand Canyon	Hermit Trail	449	135			584
Grand Canyon	Grandview Trail	291	126			417
Grand Canyon	Tusayan Ruins				374	374
Zion	Taylor Creek	453				453
Zion	West Rim Trail	182	127			309
Bryce Canyon	Fairyland Trail	1102				1102
Glacier	Hidden Lake Trail	181		335		516
Glacier	Sperry Trail	540	345			885
	Total	3198	733	335	374	4640

Table 5. Summary of 2011 survey data collected

Volume 2 of this report addresses details of the analyses based on these data, including statistical summaries of responses and noise exposure dose information, comparisons of the three surveys instruments, analyses supporting dose response relationships for backcountry day-hikes exploratory summaries analyses of dose-response relationships for backcountry overnights, analyses of data collected with audio clips, and application considerations and an example utilization of the dose-response relationships.

APPENDIX A. SURVEY INSTRUMENTS

This appendix contains the three surveys that were administered at Zion National Park. Surveys administered at Grand Canyon, Bryce Canyon and Glacier were identical with the exception of park and trail names. Details regarding each of the surveys are described in detail in Section 2:

- Appendix A.1: The human response to aviation noise visitor survey, version 1 (HR1);
- Appendix A.2: The human response to aviation noise visitor survey, version 2 (HR2); and
- Appendix A.3: The human response to aviation noise visitor survey, audio recording evaluation version (audio clip).

These instruments were administered evenly among visitors, and within a group every attempt was made to get responses to all three surveys.

A.1 Human Dose-Response Survey 1 (HR1)

National Park Service

Zion National Park Visitor Survey

Thank you for agreeing to participate in this survey. Your participation in the survey is voluntary, and the answers you provide will remain anonymous.

This questionnaire asks about your experiences during your time on this trail in Zion National Park.

- 1. Was your hike a day hike or a multi-day, overnight hike on this visit?
 - Day hike **→** At what time did you start your hike at the trailhead? _____ AM / PM
 - Multi-day, overnight hike (Answer a and b below)
 - a. On which date did you start your overnight hike on this trail? ____/ 2011
 - b. At what time did you start your hike at the trailhead on the first day of this overnight hike? _____ AM / PM
- 2. Is this your first visit to this trail or had you visited here before?

First visit_____ → Skip to question 3.

Visited before Answer a

a. Approximately how many times have you visited this trail before?

(Please enter a number or select a checkbox.)

Times before _____ (approximate)

or check one of the following:

Visited this trail 100 or more times	
Don't know /not sure]

3.	Did you take part or not take part in each of the following activities during your time
	on this trail?

		Take part ▼	Not take part ▼
a. Viewing the scenery			
 b. Viewing a sunrise or sunset 			
c. Picnicking or having a meal			
d. Watching birds			
 e. Viewing wildlife (other than birds))		
 f. Hiking or walking 			
g. Camping			
 h. Entering a visitor center, lo building 	dge, store or other		
 Attending a ranger-led talk program 	, walk, or campfire		
 Attending some other dem or performance [Please describe.] 	onstration, talk or other organized activity		
L,			
k. Other activity [What activity?]		_	

4. How important was it that your time on this trail provide you with the opportunity to... (Mark "Not relevant" if an experience was not relevant for this visit.)

				Importance				
		Not relevant ▼	Not at all important ▼	Slightly important ▼	Moderately important ▼	Very important ▼	Extremely important	
a.	View the natural scenery							
b.	Enjoy the natural quiet and sounds of nature							
C.	Appreciate the history and cultural significance of the site							
d.	Experience a feeling of calmness, peace or tranquility							
e.	Experience a sense of adventure or challenge							

5. During your time on this trail, how much did you... (Mark "Not relevant" if an experience was not relevant for this visit.)

			? How much did you?				
		Not relevant ▼	Not at all important ▼	Slightly important ▼	Moderately important ▼	Very important ▼	Extremely important
a.	Appreciate the natural scenery						
b.	Enjoy the natural quiet and sounds of nature						
C.	Appreciate the history and cultural significance of the site						
d.	Experience a feeling of calmness, peace or tranquility						
e.	Experience a sense of adventure or challenge						

6. Did you HEAR airplanes, jets, helicopters, or any other aircraft during your time on this trail?

	• Yes - heard	
ļ	No - did not hear	→ Skip to question 11.

7. During your time on this trail, how much did noise from airplanes, jets, helicopters or other aircraft bother, disturb or annoy you?

Not at all	
Slightly	
Moderately	
Very	
Extremely	

8. How much did the sounds from aircraft interfere with each of the following aspects of your visit on this trail? (Mark "Not relevant" if an aspect was not relevant for this visit.)

į.

		Not		Aircraft sound interfered				
		relevant ▼	Not at all ▼	Slightly ▼	Moderately ▼	Very ▼	Extremely	
a.	Enjoyment of the site							
b.	Appreciation of the natural quiet and sounds of nature at the site							
C.	Appreciation of the historical and cultural significance of the site							

9. How much did the sounds from aircraft interfere with each of the following aspects of your visit on this trail? (Mark "Not relevant" if an aspect was not relevant for this visit.)

	Not	Aircraft sound interfered				
	relevant	Not at all ▼	Slightly ▼	Moderately ▼	Very ▼	Extremely
History and Culture						
a. Experiencing a sense of connection to the history, events or people commemorated here						
Nature						
b. Experiencing a sense of connection with nature						
c. Appreciating scenic beauty						
Other feelings						
d. Experiencing a feeling of calmness, peace or tranquility						
e. Experiencing a sense of adventure or challenges						
Listening to a presentation						
 Hearing something said during a ranger talk, campfire program, or other ranger-led activity 						
g. Hearing any other performance, talk or group presentation						
Nighttime experiences (Mark "Not						
relevant" if you did not stay at or visit this site at night.)						
 h. Appreciating natural sounds at night 						
i. Sleeping at night						

	Ticket	number:	_
--	--------	---------	---

10. How acceptable or unacceptable were the sounds from aircraft that you heard during your time on this trail?

Unacceptable				Acceptable				
Extremely	Very ▼	Moderately ▼	Slightly ▼	Neutral ▼	Slightly ▼	Moderately ▼	Very ▼	Extremely

Earlier: Q.5 asked: Did you hear aircraft?

Next: Q.10 asks: Did you SEE aircraft?

11. Did you SEE airplanes, jets, helicopters, or any other aircraft during your time on this trail?

No - Did not see → Skip to question 12.

Yes - Did see..... → Answer a -----

a. During your time on this trail, did seeing aircraft bother, disturb or annoy you?

Not at all.....

12. Have you ever taken a scenic air tour over Zion National Park or any other park? (*Please check all that apply.*)

Yes, I have taken a scenic air tour over Zion National Park
Yes, I have taken a scenic air tour over another national park
No, I have never taken a scenic air tour over a park

13. Would you take a sightseeing air tour over Zion National Park, even if visitors on this trail could hear the aircraft during their visit?

Yes	
No	
Don't know/not sure	

Background Information

14. How many adults and children were in your personal group (spouse, family, friends) on this visit to this trail?

Adults (age 16 or older) _____Number

Children (age 15 or younger)

____Number

15. Were you or your personal group part of some larger commercial, educational, or other organized group of visitors?

Yes	
No	

16. What is your gender?

Female	

17. In what year were you born?



18. Where do you live?

United States	What is your Zip code? 🔶	
Another country	What country do you live in?➔	

19. What is the highest level of formal education you have completed? (Check <u>one</u>.)

Some high school	
High school graduate or GED]
Some college, business or trade school]
College, business or trade school graduate]
Some graduate school]
Master's, doctoral or professional degree]

20. Are you Hispanic or Latino? (Check one.)

Yes	
No	

21. What is your race? (Check all that apply.)

American Indian or Alaska Native
Asian
Black or African American
Native Hawaiian
Pacific Islander other than Native Hawaiian
White

Please give your questionnaire to the survey administrator.

Thank you for taking the time to complete this survey!

PRIVACY ACT and PAPERWORK REDUCTION ACT statement: 16 U.S.C. 1a-7 authorizes collection of this information. This information will be used by park managers to better serve the public. Response to this request is voluntary. No action may be taken against you for refusing to supply the information requested. The permanent data will be anonymous. An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number. BURDEN ESTIMATE statement: Public reporting burden for this form is estimated to average 15 minutes per response. Direct comments regarding the burden estimate or any other aspect of this form to: Cynthia Lee, USDOT/RITA/Volpe Center, 55 Broadway, Cambridge, MA 02142, Cynthia.Lee@dot.gov.

OMB control number: 2120-0744

Ticket number: _____

A.2 Human Response Survey 2 (HR2)

Thank you for agreeing to participate in this survey. Your participation in the survey is voluntary, and the answers you provide will remain anonymous.

This questionnaire asks about your experiences during your time on this trail in Zion National Park.

National Park Service

Zion National Park Visitor Survey

1. Was your hike a day hike or a multi-day, overnight hike on this visit?

Day hike **→** At what time did you start your hike at the trailhead? _____ AM / PM

Multi-day, overnight hike (Answer a and b below)

a. On which date did you start your overnight hike on this trail?

b. At what time did you start your hike at the trailhead on the first day of this overnight hike? _____ AM / PM

2. Is this your first visit to this trail or had you visited here before?

First visit_____ → Skip to question 3.

Visited before Answer a

a. Approximately how many times have you visited this trail before?

(Please enter a number or select a checkbox.)

Times before _____ (approximate)

or check one of the following:

Visited this trail 100 or more times

Don't know /not sure

3. Did you take part or not take part in each of the following activities during your time on this trail?

	Take part ▼	part ▼
a. Viewing the scenery		
b. Viewing a sunrise or sunset		
c. Picnicking or having a meal		
d. Watching birds		
 e. Viewing wildlife (other than birds 		
f. Hiking or walking		
g. Camping		
h. Entering a visitor center, lodge, store or other building		
i. Attending a ranger-led talk, walk, or campfire program		
j. Attending some other demonstration, talk or other organized activity or performance [Please describe.]		
k. Other activity [What activity?]		

4. How important was it that your time on this trail provide you with the opportunity to... (Mark "Not relevant" if an experience was not relevant for this visit.)

					Importance		
		Not relevant ▼	Not at all important ▼	Slightly important ▼	Moderately important ▼	Very important ▼	Extremely important
a.	View the natural scenery						
b.	Enjoy the natural quiet and sounds of nature						
c.	Appreciate the history and cultural significance of the site						
d.	Experience a feeling of calmness, peace or tranquility						
e.	Experience a sense of adventure or challenge						

5. During your time on this trail, how much did you... (Mark "Not relevant" if an experience was not relevant for this visit.)

		Not		How	much did you	u?	
		relevant	Not at all ▼	Slightly ▼	Moderately ▼	Very ▼	Extremely T
a.	Appreciate the natural scenery						
b.	Enjoy the natural quiet and sounds of nature						
C.	Appreciate the history and cultural significance of the site						
d.	Experience a feeling of calmness, peace or tranquility						
e.	Experience a sense of adventure or challenge						

6. Answer Question A, B, and C about each of the sounds you heard during your time on this trail. (Mark "Did not hear" if sound not present.)

		A. How acceptable or unacceptable were these sounds during your time on this trail?								B. How much did these sounds please or annoy you during your time on this trail?									C. How much did these sounds positively add to or negatively detract from your experience during your time on this trail?									
		UnacceptableAcceptable							AnnoyPlease								-	Nega	ative	ly de	Positively add -							
SOUNDS	Did Not hear	 Extremely 	 Very 	 Moderately 	 Slightly 	 Neutral 	 Slightly 	 Moderately 	 Very 	 Extremely 	 Extremely 	 Very 	 Moderately 	 Slightly 	 Neutral 	 Slightly 	 Moderately 	 Very 	 Extremely 	 Extremely 	 Very 	 Moderately 	 Slightly 	 Neutral 	 Slightly 	 Moderately 	 Very 	 Extremely
a. Insect Sounds																												
b. Bird or animal sounds																												
c. Waterfalls, running water, or waves																												
d. Wind, rain, or thunder																												
e. Group of people talking																												
f. Someone's radio, TV, IPod, or other audio device																												
g. Cars or trucks in a parking lot																												

		A. How acceptable or unacceptable were these sounds during your time on this trail?				on	B. How much did these sounds please or annoy you during your time on this trail?				r	C. How much did these sounds positively add to or negatively detract from your experience during your time on this trail?					ely \il?											
		Un	acce	ptab	le		Acceptable		e	Annoy			Please		Negatively detract			Po	Positively add		- bb							
SOUNDS	Did Not hear	 Extremely 	 Very 	 Moderately 	 Slightly 	 Neutral 	 Slightly 	 Moderately 	 Very 	 Extremely 	 Extremely 	 Very 	 Moderately 	 Slightly 	 Neutral 	 Slightly 	 Moderately 	 Very 	 Extremely 	 Extremely 	 Very 	 Moderately 	 Slightly 	 Neutral 	 Slightly 	 Moderately 	 Very 	 Extremely
h. Cars or trucks on a road or highway																												
 Airplanes, jets, helicopters, or other aircraft 																												
 Motorboats or motorized watercraft 																												

7. Did you HEAR airplanes, jets, helicopters, or any other aircraft during your time on this trail?



8. How much did the sounds from aircraft interfere with each of the following aspects of your visit on this trail?

		Not	Aircraft sound interfered									
		relevant	Not at all ▼	Slightly ▼	Moderately ▼	Very ▼	Extremely					
a.	Enjoyment of the site											
b.	Appreciation of the natural quiet and sounds of nature at the site											
c.	Appreciation of the historical and cultural significance of the site											

		Strongly Support	Support	Neither Support nor Oppose	Oppose	Strongly Oppose	Don't Know/ Not Sure ▼
a.	Reduce the number of sightseeing tour aircraft allowed to fly over the park				• □		•
b.	Maintain the number of sightseeing tour aircraft allowed to fly over the park at the current level						
C.	Increase the number of sightseeing tour aircraft allowed to fly over the park						
d.	Allow sightseeing tour aircraft to be flown over the park only during specially designated dates and						
e.	Allow sightseeing tour aircraft to use designated flight paths over limited areas of the						
f.	park Prohibit sightseeing tour aircraft from flying over the						
	park						

9. To what extent would you support or oppose each of the following potential actions at Zion National Park?

10. Have you ever taken a scenic air tour over Zion National Park or any other park? (*Please check all that apply.*)

Yes, I have taken a scenic air tour over Zion National Park
Yes, I have taken a scenic air tour over another national park
No, I have never taken a scenic air tour over a park

11. Would you take a sightseeing air tour over Zion National Park, even if visitors on this trail could hear the aircraft during their visit?

Yes	
No	
Don't know/not sure	

Background Information

12. How many adults and children were in your personal group (spouse, family, friends) on this visit to this trail?

Adults (age 16 or older) _____Number

Children (age 15 or younger) _____Number

13. Were you or your personal group part of some larger commercial, educational, or other organized group of visitors?

Yes	
No	

14. What is your gender?

Male	
Female	

15. In what year were you born?



16. Where do you live?

United States	What is your Zip code?	→		

Another country.... → What country do you live in?→

17. What is the highest level of formal education you have completed?

Some high school
High school graduate or GED
Some college, business or trade school
College, business or trade school graduate
Some graduate school
Master's, doctoral or professional degree

18. Are you Hispanic or Latino?

Yes	
No	

19. What is your race? (Check all that apply.)

American Indian or Alaska Native
Asian
Black or African American
Native Hawaiian
Pacific Islander other than Native Hawaiian
White

Please give your questionnaire to the interviewer.

Thank you for completing the survey!

PRIVACY ACT and PAPERWORK REDUCTION ACT statement: 16 U.S.C. 1a-7 authorizes collection of this information. This information will be used by park managers to better serve the public. Response to this request is voluntary. No action may be taken against you for refusing to supply the information requested. The permanent data will be anonymous. An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number. BURDEN ESTIMATE statement: Public reporting burden for this form is estimated to average 15 minutes per response. Direct comments regarding the burden estimate or any other aspect of this form to: Cynthia Lee, USDOT/RITA/Volpe Center, 55 Broadway, Cambridge, MA 02142, Cynthia.Lee@dot.gov.

OMB control number: 2120-0744

A.3 Audio Clip Survey

Note: As the audio clips survey was solely administered via tablet PC, this is a representation of the survey as it appeared on the tablet PC screen.

National Park Service

Zion National Park Visitor Survey

Thank you for agreeing to participate in this survey. Your participation in the survey is voluntary, and the answers you provide will remain anonymous.

This questionnaire asks about your experiences during this visit to *<site>* in *<park>*.

Please click "Next Page" to begin.

1. Was your hike a day hike or a multi-day, overnight hike on this visit?

- a. Day hike
- b. Multi-day, overnight hike

[If answered "Multi-day, overnight hike" in previous question] Please click in the box below to indicate what date your visit to *<site>* started.

Date:_____

Using the slider below, please indicate what time you started your hike at the trailhead <"today" (day hike)/"on this date" (multi-day, overnight hike)>.

I began my hike at:

2. Is this your first visit to <site>?

- a. Yes
- b. No

[If answered "No" in previous question] Approximately how many times have you visited <site>?

Please enter a number or select the checkbox.

Times before:_____

- a. Visited *<site>* 100 or more times
- b. Don't know/not sure
- 3. Which of the following activities did you take part in during your time <"on the" (day/multi-day hike trail) / "at" (Overlook/Cultural Resource Study Site)> <site>?

Please check all that apply.

- a. Viewing the scenery
- b. Viewing a sunrise or sunset
- c. Picnicking or having a meal
- d. Watching birds
- e. Viewing wildlife (other than birds)
- f. Hiking or walking
- g. Camping
- h. Entering a visitor center, lodge, store, or other building
- i. Attending a ranger-led talk, walk, or campfire program
- j. Attending some other demonstration, talk, or organized activity or performance, please specify:_____
- k. Other, please specify:
- l. None of the above

4. **How important was it that your time** <"on the" (day/multi-day hike trail) / "at" (Overlook/Cultural Resource Study Site) > < site > provide you with the opportunity to...?

Mark "Not relevant" if an aspect was not relevant for this visit.

[Grid question with 6 columns: Not relevant, Not at all, Slightly, Moderately, Very, Extremely]

- a. View the natural scenery
- b. Enjoy the natural quiet and sounds of nature
- c. Appreciate the history and cultural significance of the site
- d. Experience a feeling of calmness, peace, or tranquility
- e. Experience a sense of adventure or challenge
- 5. **During your time** <"on the" (day/multi-day hike trail) / "at" (Overlook/Cultural Resource Study Site)> <site>, how much did you...?

Mark "Not relevant" if an aspect was not relevant for this visit.

[Grid question with 6 columns: Not relevant, Not at all, Slightly, Moderately, Very, Extremely]

- a. Appreciate the natural scenery
- b. Enjoy the natural quiet and sounds of nature
- c. Appreciate the history and cultural significance of the site
- d. Experience a feeling of calmness, peace, or tranquility
- e. Experience a sense of adventure or challenge

For the next set of questions, we would like you to listen to five short recordings of natural and aircraft sounds <"on the" (day/multi-day hike trail) / "at" (Overlook/Cultural Resource Study Site)> <site>.

Please place the headphones on your head and click "Next Page" to continue.

Shortly, we will ask you to listen to five brief recordings of natural and aircraft sounds.

As you listen to each recording, imagine how you have felt if you had heard the aircraft sounds in the recording during your time <"on the" (day/multi-day hike trail) / "at" (Overlook/Cultural Resource Study Site) > <site>.

Please listen to each recording in its entirety; after each recording is finished playing, the computer will automatically advance to a page with questions about the recording.

When you are ready to listen to the first recording, click "Next Page".

6. Please listen to Recording #1 <u>in its entirety</u> and then answer the questions that appear after the recording is done playing.

How acceptable or unacceptable would the aircraft sounds in Recording #1 have been if you had heard them during your visit to <*site*>?

[Grid question with 9 columns; "Acceptable" over first 4 columns and "Unacceptable" over last 4 columns: Extremely, Very, Moderately, Slightly, Neutral, Slightly, Moderately, Very, Extremely]

7. How pleased or annoyed would you have been by the aircraft sounds in Recording #1 if you had heard them during this visit to <*site*>?

[Grid question with 9 columns; "Pleased" over first 4 columns and "Annoyed" over last 4 columns: Extremely, Very, Moderately, Slightly, Neutral, Slightly, Moderately, Very, Extremely]

Please click "Next Recording" to listen to recording #2 of 5.

8. Please listen to Recording #2 <u>in its entirety</u> and then answer the questions that appear after the recording is done playing.

How acceptable or unacceptable would the aircraft sounds in Recording #2 have been if you had heard them during your visit to <*site*>?

[Grid question with 9 columns; "Acceptable" over first 4 columns and "Unacceptable" over last 4 columns: Extremely, Very, Moderately, Slightly, Neutral, Slightly, Moderately, Very, Extremely]

9. How pleased or annoyed would you have been by the aircraft sounds in Recording #2 if you had heard them during this visit to <*site*>?

[Grid question with 9 columns; "Pleased" over first 4 columns and "Annoyed" over last 4 columns: Extremely, Very, Moderately, Slightly, Neutral, Slightly, Moderately, Very, Extremely]

Please click "Next Recording" to listen to recording #3 of 5.

10. Please listen to Recording #3 in its entirety and then answer the questions that appear after the recording is done playing.

How acceptable or unacceptable would the aircraft sounds in Recording #3 have been if you had heard them during your visit to <*site*>?

[Grid question with 9 columns; "Acceptable" over first 4 columns and "Unacceptable" over last 4 columns: Extremely, Very, Moderately, Slightly, Neutral, Slightly, Moderately, Very, Extremely]

11. How pleased or annoyed would you have been by the aircraft sounds in Recording #3 if you had heard them during this visit to <*site*>?

[Grid question with 9 columns; "Pleased" over first 4 columns and "Annoyed" over last 4 columns: Extremely, Very, Moderately, Slightly, Neutral, Slightly, Moderately, Very, Extremely]

Please click "Next Recording" to listen to recording #4 of 5.

12. Please listen to Recording #4 in its entirety and then answer the questions that appear after the recording is done playing.

How acceptable or unacceptable would the aircraft sounds in Recording #4 have been if you had heard them during your visit to <*site*>?

[Grid question with 9 columns; "Acceptable" over first 4 columns and "Unacceptable" over last 4 columns: Extremely, Very, Moderately, Slightly, Neutral, Slightly, Moderately, Very, Extremely]

13. How pleased or annoyed would you have been by the aircraft sounds in Recording #4 if you had heard them during this visit to <*site*>?

[Grid question with 9 columns; "Pleased" over first 4 columns and "Annoyed" over last 4 columns: Extremely, Very, Moderately, Slightly, Neutral, Slightly, Moderately, Very, Extremely]

Please click "Next Recording" to listen to recording #5 of 5.

14. Please listen to Recording #5 <u>in its entirety</u> and then answer the questions that appear after the recording is done playing.

How acceptable or unacceptable would the aircraft sounds in Recording #5 have been if you had heard them during your visit to <*site*>?

[Grid question with 9 columns; "Acceptable" over first 4 columns and "Unacceptable" over last 4 columns: Extremely, Very, Moderately, Slightly, Neutral, Slightly, Moderately, Very, Extremely]

15. How pleased or annoyed would you have been by the aircraft sounds in Recording #5 if you had heard them during this visit to <*site*>?

[Grid question with 9 columns; "Pleased" over first 4 columns and "Annoyed" over last 4 columns: Extremely, Very, Moderately, Slightly, Neutral, Slightly, Moderately, Very, Extremely]

Please click "Next Page" to continue.

We would like to know how often you think it's acceptable to hear aircraft sounds during your <"on the" (day/multi-day hike trail) / "at" (Overlook/Cultural Resource Study Site)> <site>.

Please listen to a short recording of natural and aircraft sounds, and then answer a few questions about the aircraft sounds in the recording.

When you are ready to listen to the recording, click "Next Page" to continue.

16. Please listen to Recording #6 in its entirety and then answer the questions that appear after the recording is done playing.

How acceptable or unacceptable would the aircraft sounds in this recording be if it occurred the following number of times in an hour during your visit to *<site>*?

[Grid question with 9 columns; "Acceptable" above first 4 columns, "Unacceptable" above last 4 columns: Extremely, Very, Moderately, Slightly, Neutral, Slightly, Moderately, Very, Extremely]

- a. 12 aircrafts an hour (every 5 minutes)
- b. 6 aircrafts an hour (every 10 minutes)
- c. 2 aircrafts an hour (every 30 minutes)
- d. 1 aircraft an hour (every 60 minutes)
- 17. How frequently would you prefer to hear sightseeing tour aircraft as your heard in Recording # 6 while <"on the" (day/multi-day hike trail) / "at" (Overlook/Cultural Resource Study Site)> <site>? Please enter a number or select the checkbox.

No more than _____ scenic air tours in an hour OR I would prefer to never hear scenic air tours

How frequently could you hear sightseeing tour aircraft as you heard in Recording # 6 <u>before</u> <u>you would no longer visit</u> *<site>*? Please enter a number or select the checkbox.

No more than _____ scenic air tours in an hour

OR I would visit *<site>* regardless of how frequently scenic air tours are heard

OR I would no longer visit *<site>* if I heard <u>any</u> scenic air tours

You have completed the listening portion of your survey; you may now remove your headphones from your head.

Please click "Next Question" to continue.

- 18. Besides the recordings you just listened to, did you HEAR airplanes, jets, helicopters, or any other aircraft during <"on the" (day/multi-day hike trail) / "at" (Overlook/Cultural Resource Study Site) > <site>?
 - a. Yes
 - b. No [Skip to Q21]
- 19. During <"on the" (day/multi-day hike trail) / "at" (Overlook/Cultural Resource Study Site)> <site>, how much did noise from airplanes, jets, helicopters, or other aircraft bother, disturb, or annoy you?
 - a. Not at all
 - b. Slightly
 - c. Moderately
 - d. Very
 - e. Extremely

20. To what extent would you support or oppose each of the following potential actions at cpark?

[Grid question with 6 columns: Strongly support, Support, Neither support nor oppose, Oppose, Strongly oppose, Don't know/Not sure]

- a. Reduce the number of sightseeing tour aircraft allowed to fly over the park
- b. Maintain the number of sightseeing tour aircraft allowed to fly over the park at the current level
- c. Increase the number of sightseeing tour aircraft allowed to fly over the park
- d. Allow sightseeing tour aircraft to be flown over the park only during specially designated dates and times
- e. Allow sightseeing tour aircraft to use designated flight paths over limited areas of the park
- f. Prohibit sightseeing tour aircraft from flying over the park

21. Have you ever taken a scenic air tour over *<park>* or any other park?

Please check all that apply.

- a. Yes, I have taken a scenic air tour over *<park>*
- b. Yes, I have taken a scenic air tour over another park

- c. No, I have never taken a scenic air tour over a park
- 22. Would you take a sightseeing air tour over <park>, even if visitors <"on the" (day/multi-day hike trail) / "at" (Overlook/Cultural Resource Study Site)> <site> could hear the aircraft during their visit?
 - a. Yes
 - b. No
 - c. Don't know/Not sure
- 23. How many adults and children were in your personal group (spouse, family, friends) on this visit to <site>?

Adults (age 16 or older):

Children (age 15 or younger):

24. Were you or your personal group part of some larger commercial, educational, or other organized group of visitors?

- a. Yes
- b. No

25. What is your gender?

- a. Female
- b. Male

26. In what year were you born?

[Dropdown starting with "Before 1930" and then going from 1930 to "after 2000"]

27. Where do you live?

- a. United States, please enter your ZIP code:____
- b. Another country, please enter the country in which you live:_____

28. What is the highest level of formal education you have completed?

- a. Some high school
- b. High school graduate or GED
- c. Some college, business, or trade school
- d. College, business, or trade school graduate
- e. Some graduate school
- f. Master's, doctoral, or professional degree

29. Are you Hispanic or Latino?

- a. Yes
- b. No

30. What is your race?

Please check all that apply.

- a. American Indian or Alaska Native
- b. Asian
- c. Black or African American
- d. Native Hawaiian
- e. Pacific Islander other than Native Hawaiian
- f. White/Caucasian

Thank you for taking the time to complete this survey. You may now return this device to the survey administrator.

PRIVACY ACT and PAPERWORK REDUCTION ACT statement: 16 U.S.C. 1a-7 authorizes collection of this information. This information will be used by park managers to better serve the public. Response to this request is voluntary. No action may be taken against you for refusing to supply the information requested. The permanent data will be anonymous. An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number. BURDEN ESTIMATE statement: Public reporting burden for this form is estimated to average 15 minutes per response. Direct comments regarding the burden estimate or any other aspect of this form to: Cynthia Lee, USDOT/RITA/Volpe Center, 55 Broadway, Cambridge, MA 02142, Cynthia.Lee@dot.gov.

OMB control number: 2120-0744

APPENDIX B. AUDIO CLIP FIELD RECORDING SUMMARY

High-quality audio clips were recorded specifically for the purpose of this study using dualchannel, binaural equipment. Binaural clips can convey spatial information on the location of the aircraft during flyover, thus giving more realism to the clip.

B.1 Locations

The recordings were collected in an opportunistic fashion at Grand Canyon National Park. That is, the aircraft or route were not directed or controlled. Grand Canyon was chosen because the aircraft are known to fly year-round and the routes are regulated. The aircraft used by the operators at GRCA are representative of the models, speeds, and powers typically used in many other air tour situations. The operational flight parameters were uncontrolled and largely undocumented.

The individual aircraft models in use at GRCA include:

- Helicopters: Eurocopter EC-130, Eurocopter AStar (AS350), and Bell 206L
- Propeller-Aircraft: Dehavilland Vistaliner, Cessna 206, Cessna 207, and Beechcraft
- Commercial Jets: No model distinction can/will be made.

Variations in sound level were collected by recording at varying distances from the selected aircraft flight route – the northbound Zuni corridor. This corridor runs south-north across the canyon. Helicopters are regulated to fly at 7500 ft., fixed wing (propeller) aircraft at 8000 ft. Eight recording locations were selected at increasing distances east of this corridor, along the south rim of the canyon.

These locations were chosen so as to provide a 4-5 dBA drop-off in sound level between similar overflights at adjacent locations, so that the 8 locations will provide a range of 30-40 dBA.

Location	Lateral distance to air tour corridor (ft)	Slant distance to air tour corridor (ft)	Latitude	Longitude	Elevation (ft)
L0	-750	791	36.01988	111.88332	7258
L1	0	250	36.01958	111.88075	7312
L2	433	500	36.01942	111.87923	7291
L3	968	1000	36.01919	111.87751	7260
L4A	1984	2000	36.02073	111.87362	7232
L5A	3992	4000	36.02118	111.86711	7236
L6A	6295	6300	36.01226	111.85981	7174
L7A	9997	10000	36.01775	111.84745	7268

Table 6. Binaural recording locations



Figure 17. Binaural recording locations
B.2 Procedure

Recordings were made in sequentially at each location using a single binaural system as the primary recording system, supplemented by a monaural recorder / sound level meter at an adjacent location. In other words, the primary system was first placed at location 0, with the supplemental system placed at location 1. The simultaneous collection of acoustic data at two locations provided the necessary variations in sound level. The following data were collected:

- Sound-level data: Continuous, one-second, A-weighted sound levels and their associated one-third octave-band un-weighted spectrum from 12.5 to 20,000 Hz;
- Meteorological data: Continuous, one-second wind speed data (and wind direction, outside air temperature data, and humidity when possible); and
- Digital audio recordings:
 - At the primary location: Continuous binaural audio recordings stored as two (left ear and right ear) 16 Bit .wav files; and
 - At the secondary location: Continuous monaural audio recordings to provide an archival record as well as the ability for repeated playback of the recordings.

Measurements continued until a sufficient number of clean overflights were recorded at each location. An overflight was deemed "clean" (i.e., free of contamination) if other noise sources, such as other aircraft, road traffic, or loud bird/animal sounds, were not audible within +/- 30 seconds (60 seconds total) of the time of maximum sound level. A sufficient number of overflights were regarded as at least 3 of each type of aircraft.

Personnel were located proximate to the primary system to monitor the system, but at a sufficient distance to minimize noise contamination. The start time, maximum sound level (using a handheld sound level meter), and end time of each overflight, along with information such as aircraft type was documented. Additional personnel were placed in a location giving good visibility to the aircraft flight track (likely nearby location 1 or 2), to photograph and document each overflight, recording information such as aircraft type, model, operator, and overflight time.

Page left blank intentionally.

APPENDIX C. INTERCEPT SCRIPTS

C.1 Dose Response Survey Setup and Initial Intercept Protocol & Script

Initial Survey Station Set Up:

- Be sure to arrive at the trail head early in the morning 7:00 AM is the target arrival time.
- If the DROP BOX has not already been setup make sure to set the DROP BOX up in a secure, highly visible location and make sure the DROP BOX is clearly signed (preferably the trailhead or destination that every hiker will pass and see).
- Turn on the GPS TrackSticks and the Garmin GPS unit. They need several minutes to find the GPS satellites. Refer to detailed TrackStick Instructions.
- Complete the information at the top of the Initial Intercept Log. This includes GPS coordinate information from the Garmin GPS unit.
- TURN CELL PHONES TO VIBRATE , SILENT, or OFF
- Set up tables, folding chairs, and refreshments for respondents (if applicable)

NOTE: If possible, the survey administration area should be set up so that it is not visible to hikers when they first arrive at the trailhead and are pre-intercepted. At a minimum, the survey administration area should be spatially separated from the pre-intercept area.

- Set out the following on the table(s) (or flat surface):
 - o Numbered tickets
 - o GPS TrackSticks
 - Initial Intercept Log Sheets on clipboards.

Interception:

- At the start of sampling, intercept the first arriving visitor group.
- Use the following intercept script:

"Good morning. We are doing research with the National Park Service. The research involves taking a brief survey about your experiences in the park. You would take the survey after you've completed your hike. It is anonymous, and takes about 10-15 minutes. Do you think you might be interested in participating? I can tell you more about it. • **IF NO:** No problem. Enjoy your hike.

Circle *Decline* in the *Non-Response Status* column of the *Initial Intercept Log*, and enter time, group size, number of children, overnight or not, and any notes.

- IF YES: "Great. We'd really appreciate your help. First, will you be hiking for an hour or more and be returning to this spot [or other trailhead we are administering surveys when appropriate] later today, before 6:00 PM [or applicable time]?"
 - IF NO: Find out if the visitor will be returning to the trailhead within the remaining portion of the multi-day survey collection (e.g., they are an overnight visitor that will be returning to this trailhead). If yes, proceed with introduction. If no, thank visitor and terminate intercept.
 - IF YES: "OK, here's what's involved. We'd give each of you a ticket, so we can identify you as participants when you finish your hike. Also, as part of the study, we want to get a better idea of how visitors move through the park. To do this, we're asking each group of participants to carry this little GPS unit (show them the TrackStick). The information it collects is anonymous; it simply records its location every few minutes. It does not record sound, or take pictures or anything like that. We will NOT be able to track where you are in real time. We'll collect the ticket and TrackStick, when you take the survey. So, how does this all sound? Are you willing to participate in the study?"
 - IF NO: "OK, no problem. Thanks for your time, and enjoy your hike."

Circle *Decline* in the *Non-Response Status* column of the *Initial Intercept Log*, and enter time, group size, number of children, and any notes.

• IF YES: "That's great, thank you. Where will you be headed today?"

Mark down the expected destination and duration/return time on the log. If MULTIDAY – mark down their expected return date.

"Let me give you your ticket(s) first."

Tear off the appropriate number of tickets, write the ticket number(s) in the *Initial Intercept Log* (last 4 digits of each number), and distribute the tickets to the members of the group.

MAKE SURE EVERY GROUP MEMBER GETS THEIR OWN INDIVIDUAL TICKET (do not allow one group member to take all of the tickets!).

Enter the GPS TrackStick number into the log sheet. Select a member of the group (over age 16) to carry the TrackStick, confirm that the GPS stick is working (blinking orange light) and that the return instructions are attached. Find a secure, external location for the GPS stick, such as an outside backpack pocket or mesh panel and attach the TrackStick for them.

"OK. You are all set. When you take the survey, we will collect your ticket and the GPS unit. If by chance the survey team is not here when you finish your hike, there are return instructions attached to the TrackStick and [here] is the location of the DROP BOX. Have a great hike and thanks again!"

Make sure to tell them about the return instructions and the location of the DROP BOX.

Enter start time, group size, number of children, and any notes in the *Initial Intercept Log.* If the participant previously indicated that they would be returning within the survey period, rather than the same day, note "Yes" in the "Overnight" column on the log, and mark the date they are expected to return in the "Return to Site" column.

Non-intercepts:

For any hikers that are not intercepted (e.g., the survey team members are all busy with other hikers), on the *Initial Intercept Log* fill in the time, group size, number of children, overnight or not, and circle NI in the *Non-Response Status* column. This may be difficult to do in high-use areas. Do the best you can.

NOTE – Stop the initial intercept at least 3 hours prior (may be changed, dependent on site) to the end of your sampling day for DAY HIKERS (to allow time for respondents to have a hike).

Hand out TrackSticks all day to MULTIDAY HIKERS.

IF AT ANY POINT YOU RUN OUT OF TRACKSTICKS PRIOR TO THE END TIME – continue to intercept visitors and handout tickets, to introduce visitors to the study and provide an official

start time for their hike/visit. Make sure to note this on the log (e.g., "ran out of GPS units at 1:30 PM).

Filling out Initial Intercept Log:

- Make sure to fill out all of the information on the top of the log sheet.
- Make sure to write down group number (consecutive throughout the day), all ticket numbers (last 4 digits), and the TrackStick number for each group member.
- Note Start Time, Group Size, # of Children, Overnight and Return to Site (Date and Time).
- In the NOTES column note their approximate destination (if known) or estimated hike length; and any other notes of relevance (e.g., reason for declining).

When TrackSticks are returned:

- Mark an R (for returned) in the Status column of the Initial Intercept Log.
 - o If a TrackStick is not returned place a "N" for Not, or an "O" for Overnight
- Place all of the used, returned TrackSticks in the same place so we know which TrackSticks have data that need to be downloaded and which TrackSticks have not been used.
- If a TrackStick has been handed out more than once make sure to note this and keep this TrackStick by itself (away from the TrackSticks that only have one track on them).

C.2 Dose Response Survey Intercept

- Turn on all of the NOBi's and fill out the NOBi Survey Count Log. Prepare all of the NOBi's based on the To Launch A Survey protocol.
- Fill in the information on the top of the Survey Intercept Log sheet. This includes GPS coordinate information from the Garmin GPS unit.
- As each park visitor or group nears the intercept location, note the time, and approach them. Smile, and use the following script:

"Hello. Have we already talked to you about taking a survey? "

IF NOT PREVIOUSLY INTERCEPTED: "That's OK. If you are interested, I can tell you about the survey, and we'd love to have you participate."

ADMINISTER a survey to anyone that has hiked for more than 1-hour (even if they don't have a TrackStick), including Multi-Day Hikers.

IF VISITOR IS INTERESTED IN LEARNING MORE: "This is a survey about your experience on this trail today. The answers are anonymous, and the survey will take about 10-15 minutes total. Would you like to participate?"

- IF YES: "Great. Have you hiked more than 1-hour down the trail today?"
 - o IF YES: "Great. Please step over here, have a seat and we'll get you started."
 - If multiple respondents in group, ask them not to discuss surveys. You can tell them they have different surveys.
 - Manually assign a unique ID for each group member and record this on the Log (under Ticket #) and in the NOBi under "Tag ID." ID's should be Site Initial and a # and consecutive for that site throughout the study period (e.g., Hermit = *H12*)
 - Provide respondent(s) with Tablet PCs (see To Launch a Survey instructions).
 - Record previously-noted intercept time on appropriate row of Survey Intercept Log.
 - Record instrument administered
 - Record intercept time, group size, overnight or not, number of children (in Notes column) in Survey Intercept Log
 - Record for **Day**: where they hiked to and how long they were out, or **Multi-Day**:
 where they started their hike and what time they started in NOTES column on Log.
 - Note any "Events affecting survey quality" in Notes Column.
 - o IF NO: "OK. Enjoy the rest of your visit."
- IF NO: "OK. Thanks for your time."

IF PREVIOUSLY INTERCEPTED: "Great. Are you ready to take the survey?"

- IF YES: "OK. Please step over here, have a seat and we'll get you started."
 - Collect ticket(s) and GPS from respondent. Turn GPS TrackStick off. This is to "mark" the resulting data file to indicate that respondent has completed hike.
 - Record previously-noted intercept time, ticket number(s), GPS number, and instrument administered on appropriate row of *Survey Intercept Log*.

- Administer tablet PC survey (see To Launch a Survey instructions). If all tablets are being used by other respondents, give a paper survey instead.
 - If using a paper survey (as backup, if NOBi fails), be sure to write the respondent's ticket number on the survey form. Also, complete the survey ID number at the top left of the survey form, by filling in the date and site number (park number and instrument number will be pre-written).
- If multiple respondents in group, ask them not to discuss surveys. You can tell them they have different versions of the survey.
- If multiple respondents and you know one group member will be taking Audio
 Clips administer this instrument first (as it takes longest).
- Note any "Events affecting survey quality" in Notes Column.
- When respondent has completed the survey, click "Administrator," then "Accept w/out comment" or "Comment" on the data. If "Comment" provide comments.
 - **IF NO:** "No Problem. Just let me collect your ticket(s) and GPS unit. Is there any particular reason why you decided not to participate?"

Record ticket and GPS number in *Survey Intercept Log*, and circle *Declined* in Status column. If respondent provides reason, record that also.

 Make sure to fill in all information on the appropriate log sheets (Survey Intercept Log and the Survey Completes Tally Log).

TERMINOLOGY

This section presents pertinent terminology used throughout the document. Note: Definitions are generally consistent with those of the American National Standards Institute (ANSI).

A-WEIGHTING – A frequency-based methodology used to account for changes in human hearing sensitivity as a function of frequency. The A-weighting network de-emphasizes the high (6.3 kHz and above) and low (below 1 kHz) frequencies, and emphasizes the frequencies between 1 kHz and 6.3 kHz, in an effort to simulate the relative response of human hearing.

ACOUSTIC ENERGY – Commonly referred to as the mean-square sound-pressure ratio, sound energy, or just plain energy, acoustic energy is the squared sound pressure (often frequency weighted), divided by the squared reference sound pressure of 20 μ Pa, the threshold of human hearing.

ACOUSTICAL ENVIRONMENT – The actual physical sound resources, regardless of audibility, at a particular location.

AKAIKE INFORMATION CRITERION (AIC) – A statistical measure of the log of the likelihood of a regression model which incorporates a penalty for the number of parameters used to fit the model. The likelihood is a measure of the probability of the observed data, given the estimated parameter values. The AIC value is calculated as -2*log-likelihood+2*npar, where npar is the number of parameters included in the model.

AMBIENT – The composite, all-inclusive sound associated with a given environment, excluding the analysis system's electrical noise and the sound source of interest. Several definitions of ambient noise have been adopted by different organizations depending on their application.

- Existing Ambient: The composite, all-inclusive sound associated with a given environment, excluding only the analysis system's electrical noise (i.e., aircraft-related sounds are included);
- Existing Ambient Without Air Tours: The composite, all-inclusive sound associated with a given environment, excluding the analysis system's electrical noise and the sound source of interest, i.e., commercial air tour aircraft for ATMPs;
- Existing Ambient Without All Aircraft (for use in assessing cumulative impacts): The composite, all-inclusive sound associated with a given environment, excluding the analysis system's electrical noise and the sounds produced by the sound source of interest, in this

case, all types of aircraft (i.e. commercial air tours, commercial jets, general aviation aircraft, military aircraft, and agricultural operations); and

• Natural Ambient: The natural sound conditions found in a study area, including all sounds of nature (i.e., wind, streams, wildlife, etc.), and excluding all human and mechanical sounds.

ANNOYANCE – Any bothersome or irritating occurrence.

AUDIBILITY – The ability of animals with normal hearing, including humans, to hear a given sound. Audibility is affected by the hearing ability of the animal, the masking effects of other sound sources, and by the frequency content and amplitude of the sound.

AVIATION NOISE – Aviation noise in the context of this study includes contributions from both tour aircraft and high-altitude commercial jets, as they are concurrent and their effects on park visitors cannot effectively be separated.

BACKCOUNTRY – Any location in a study area subject to minimal human activity, such as designated wilderness areas or restricted, hiking and camping areas (destinations generally located 1 hour or more from frontcountry locations).

CULTURAL/HISTORIC SITE – A location with cultural or historic significance (or importance in American history) and historic integrity (or physical authenticity). Such locations are eligible for listing or are listed on the National Register of Historic Places, and the NPS has a Federal government leadership role in preserving them.

DAY HIKE – Backcountry study area or destination generally requiring a hike of more than one hour and subject to low to moderate human activity.

DAY-NIGHT AVERAGE SOUND LEVEL (DNL, denoted by the symbol Ldn) - 24-hour average sound exposure level (see definition below), adjusted for average-day sound source operations. In the case of aircraft noise, a single operation is equivalent to a single aircraft operation. The adjustment includes an addition of 10 decibels for operations occurring between 2200 and 0700 hours, local time.

DECIBEL – A unit of level when the base of the logarithm is the tenth root of ten, and the quantities are concerned are proportional to power. Measure for defining a noise level or a noise exposure level. Unit symbol, dB. The number of decibels is calculated as 10*(Log₁₀(sound level/reference sound level)).

DICHOTOMIZATION – The separation into two parts, classifications, or groupings.

EQUIVALENT SOUND LEVEL (TEQ, denoted by the symbol LAeqT) - Ten times the base-10 logarithm of the time-mean-square, instantaneous A-weighted sound pressure, during a stated time interval, T (where T=t2-t1, in seconds), divided by the squared reference sound pressure of 20 μPa, the threshold of human hearing. LAeqT is related to LAE by the following equation:

 $L_{AeqT} = L_{AE} - 10Log(t2-t1) (dB)$

Where L_{AE} = Sound exposure level (see definition below).

The L_{Aeq} for a specific time interval, T1 (expressed in seconds), can be normalized to a longer time interval, T2, via the following equation:

 $L_{AeqT2} = L_{AeqT1} - 10Log(T2/T1) (dB)$

FRONTCOUNTRY - Any location in a study area subject to substantial human activity, such as scenic overlooks, visitor centers, recreation areas, or destinations reached by short hikes (1 hour or less).

FREQUENCY – For a function periodic in time, the reciprocal of the period (the smallest increment of an independent variable for which a function repeats itself). Unit, hertz (Hz)

HERTZ - (abbreviation Hz) Unit of frequency, the number of times a phenomenon repeats itself in a unit of time.

HR1 - The human response to aviation noise - visitor survey, version 1. This survey is an adaptation of research methods used in the 1990's frontcountry studies and provides a basis for comparison across study locations and contexts. This instrument asks respondents explicitly to evaluate aircraft noise in dimensions including annoyance, interference with the appreciation of the natural sounds, acceptability, and interference with tranquility or solitude.

HR2: The human response to aviation noise - visitor survey, version 2. This survey is an adaptation of the NPS Soundscape Attended Listening survey. It is designed to minimize cueing response bias that may be inherent in the HR1 survey by asking respondents to identify sounds they heard in the study area from among a number of options, and evaluate each on a series of response scales. It allows for measurement of the same core variables contained in the HR1 design. This instrument includes scales that are designed specifically to support decisions about numerical thresholds for desired soundscape conditions.

 L_{50} - A statistical descriptor describing the sound level exceeded 50 percent of a specific time period. For example, from a fifty-sample measurement period with the samples sorted from highest sound level to lowest sound level, the twenty-fifth sound level is the 50-percentile exceeded sound level.

 L_{90} - A statistical descriptor describing the sound level exceeded 90 percent of a specific time period. For example, from a fifty-sample measurement period with the samples sorted from highest sound level to lowest sound level, the forty-fifth sound level is the 90-percentile exceeded sound level.

LAE (see Sound Exposure Level)

LAeq (see Equivalent Sound Level)

L_{Aeg,Tac} - Equivalent sound level using a time basis of a an aircraft overflight duration.

L_{Aeq,Tresp} - Equivalent sound level using a time basis of a respondent's visit duration.

L_{ASmx} (see Maximum Sound Level)

L_{dn} (see Day-Night Average Sound Level)

LOW-LEVEL NOISE ENVIRONMENT - An outdoor sound environment typical of a remote suburban setting, or a rural or public lands setting. Characteristic day-night average sound levels (DNL, represented by the symbol, Ldn) would generally be less than 45 dB, and the everyday sounds of nature, e.g., wind blowing in trees and birds chirping would be a prominent contributor to the DNL.

MAXIMUM SOUND LEVEL - Greatest fast A-weighted sound level, within a stated time interval associated with a given event (see figure with definition of sound exposure level).

NATURAL AMBIENT (see Ambient)

NATURAL QUIET - The natural sound conditions found in a study area. Natural quiet is a subset of ambient noise. Traditionally, it is characterized by the total absence of human or mechanical sounds, but includes all sounds of nature, such as wind, streams, and wildlife.

NATURAL SOUNDSCAPE - In accordance with National Park Service's Director's Order #47, the natural soundscape is the Natural Ambient sound level of a park. It is comprised of the natural sound conditions in a park, which exist in the absence of any human-produced noises.

NOISE – Undersired sound. By extension, noise is any unwarranted disturbance within a useful frequency band, such as undesired electric waves in a transmission channel or device.

NOISE DOSE - A measure of the noise exposure to which a person is subjected.

OVERLOOK - Any frontcountry location in a study area subject to substantial human activity, or destinations reached by automobile or bus, and generally traversable within thirty minutes.

OVERNIGHT HIKE – Backcountry study area or destination generally requiring a hike of more than one hour with an overnight stay (either in a camp or cabin setting) and subject to low to moderate human activity.

 $P_{EnHelos}$ – The percentage of the sound energy forming the basis for $L_{Aeq,Tresp}$ (aircraft equivalent sound level using a time basis of a respondent's visit duration) contributed by helicopters.

 $P_{EnProps}$ - The percentage of the sound energy forming the basis for $L_{Aeq,Tresp}$ (aircraft equivalent sound level using a time basis of a respondent's visit duration) contributed by propeller aircraft.

SHORT HIKE - Any frontcountry location in a study area subject to moderate to substantial human activity, or destinations generally reached within one hour of hiking.

SITE TYPE - Site type is used in this research to refer to the context in which the noise exposure is presented. It encompasses both physical location and likely activities at that location.

SOUND – Auditory sensation evoked by the oscillation in pressure, stress, particle displacement, particle velocity, etc., in a medium with internal forces (e.g., elastic or viscous), or the superposition of such propagated oscillations.

SOUND EXPOSURE LEVEL (SEL, denoted by the symbol LAE) – Ten times the logarithm to the base ten of a given time intergral of squared instantaneous A-weighted sound pressure over a stated time interval or event, T (where T=t2-t1, in seconds), to the product of the squared reference sound pressure of 20 μ Pa, the threshold of human hearing, and reference duration of 1 second.

 L_{AE} is related to L_{AeqT} by the following equation:

$$L_{AE} = L_{AeqT} + 10Lg(t_2 - t_1)$$
 (dB)

Where L_{AeqT} = Equivalent sound level in dB (see definition above).

SOUND PRESSURE LEVEL (SPL) - Ten times the logarithm to the base ten of the ratio of the time-mean square sound pressure of a sound, in a stated frequency band (often frequency-weighted), t reference sound pressure of 20 μ Pa, the threshold of human hearing.

$$SPL = 10Lg[p^2/p_{ref}^2]$$

Where p^2 = time-mean-square sound pressure; and p_{ref}^2 = squared reference sound pressure of 20 µPa.

SOUNDSCAPE - In accordance with National Park Service's Director's Order #47 (http://www.nps.gov/policy/DOrders/DOrder47.html), soundscape is defined as "the total ambient acoustical environment associated with a given environment in an area such as a national park. In a national park setting, this soundscape is usually composed of both Natural Ambient sounds and a variety of human-made sounds."

SPECTRUM – used to signify a continuous range of sound pressure levels in component frequency bands, usually one-third octave-bands.

TIME AUDIBLE – The percentage of time that a time-varying sound level can be heard by a a typical human with healthy hearing in a given area during a given time period.

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