The effects of aircraft overflights on visitors to U.S. National Parks

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Aircraft overflights of U.S. National Parks have become a source of sound intrusion into otherwise undisturbed natural environments. Public and park management concern about the potential noise impacts of overflights have motivated several studies of the benefits and impacts of aircraft flights over National Parks. The methods and results of two of the studies are summarized in this paper. Dose–Response studies conducted in Grand Canyon, Hawaii Volcanoes, and Haleakala National Parks are described. A Cognitive Survey conducted at a site in White Sands National Monument is the second study for which methods and results are presented. An approach is suggested for using Dose–Response studies to assess relative aircraft overflight impact on visitors.
[S0736-2501(99)00803-6]

Primary subject classification: 66.1; Secondary subject classification: 13.1

1. INTRODUCTION

Aircraft overflights of public lands, and specifically of U.S. National Parks, increasingly have become a source of sound intrusions into otherwise undisturbed natural environments. In response to both park management and public concern about the effects of these overflights, several studies have been conducted to examine the benefits and the impacts of aircraft flights over National Parks. This paper summarizes the methods and results of two such studies: (1) Dose–Response studies conducted at six sites in Grand Canyon, Hawaii Volcanoes, and Haleakala National Parks; and (2) a Cognitive Survey conducted at a site in White Sands National Monument. In addition, this paper offers an approach for using the results of the Dose–Response studies to judge the relative impacts of aircraft overflights on visitors.

It is important to emphasize that the subject addressed here is the effect of aircraft overflight noise on park visitor experience, as judged by the visitors themselves. But this self-defined experience is only one of several dimensions of concern to U.S. National Park management. It is not unusual for visitors to be unaware of the type of experience provided by the park or by a specific park setting. Park management objectives, such as resource protection, are also significant in determining the appropriateness of aircraft overflights. These management objectives can be fundamental to the National Park Service in general, or may reflect Congressional mandates for a specific park. Therefore, it is important to keep in mind that visitor reactions are not likely to be the sole or final determinant of whether or not aircraft overflights are acceptable for a given park setting.

The following section, Section 2, provides general descriptions of the two types of studies reported here. Next, Section 3 describes the methods and results of the Dose–Response studies, while Section 4 describes the details for the Cognitive Survey. Section 5 presents a method for using the results of the Dose–Response studies to characterize the relative impacts of overflights using only acoustic data. Finally, Section 6 summarizes the author's observations about the overall value of the information provided here.

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2. BACKGROUND

The two types of studies reported here have quite different objectives. The Dose–Response studies statistically relate visitor judgements of aircraft overflights (response) to a quantitative measure of the sounds the visitor may have heard (dose). The Cognitive Survey is neither statistical nor quantitative. Rather, it is a means for learning about the thought processes a visitor uses in answering specific survey questions about the effects of aircraft overflights.

The Dose–Response studies were conducted at specific park sites by simultaneously measuring sound levels, identifying sources of the sounds measured, and surveying visitors who were present at the site during the measurements. Thus, for each visitor surveyed, a complete quantitative, time-stamped record of sound levels and sound sources was created to associate with that visitor's time at the site. By statistically analyzing several hundred such records of visitor responses and sound exposures, mathematical relationships between the two are developed.

The Cognitive Survey also depends upon surveying visitors at a site, but focuses on obtaining visitors' interpretation of the questions asked. For the Cognitive Survey, the Dose–Response study questionnaire was used, but after specific questions of interest, ''probe'' questions were asked. For example, one of the primary questions asked was whether the visitor was bothered or annoyed by aircraft noise. (Possible answers: not at all, slightly, moderately, very, extremely.) After this question was answered, the visitor was asked probe questions about the meaning of the word ''annoyed'' and what conditions would be necessary to cause him/her to have increased annoyance. The Cognitive Survey provides several useful explanations of how park visitors judge the sound of aircraft.

3. DOSE–RESPONSE STUDIES

A. The studies

Four sites in the Grand Canyon and one each in Hawaii Volcanoes and Haleakala National Parks were selected as data collection sites.[1] The working hypothesis used in the design of the data collection and analysis was that visitor reaction, as measured with appropriate survey questions, could be correlated with the aircraft overflight sounds that the visitors may have heard while visiting the site. At the site, simultaneous sound level measurements, visitor surveys, and sound source identification provided three data bases that were then combined. The combined data base permitted association of each visitor's response with various metrics of the sound levels measured during the visitor's time on-site. Statistical analyses (logistic regression) yielded Dose–Response curves that showed the percent of visitors adversely affected at various levels of aircraft noise.

B. Site selection

Because of the effort and expense required to collect data, measurement sites were carefully selected to yield a large number of completed surveys for visitors who were present during aircraft overflights. The requirement for accurate acoustic data also placed conditions on the site selection. The following factors were considered when identifying the sites for data collection:

Visitation rate: In order to collect about 100 useful surveys in four days, locations were identified that were likely to experience between 5 and 10 groups of visitors per hour.

Number of overflights: Locations were identified that would have at least 2–4 overflights per hour to maximize the likelihood that most visitors would be present during an overflight.

Size of area: When possible, the size of the area used by visitors was kept small so that sound levels for the entire area could be characterized by use of a single sound monitor. (At the sites in Hawaii, however, more than one monitor was required and algorithms were developed to associate a specific sound monitor with each visitor as a function of time, depending upon estimates of the visitor's location while at the site, a complex process.)

Ease of interviewing: In order to easily observe and record the time of the visitors' entry into the site, and to easily intercept visitors before they left the site, park locations with a single entry/exit point were chosen.

Visit duration: Most visitors were at the sites long enough to have a high probability of experiencing at least one overflight. Sites where visitors usually stayed for at least 15 minutes were preferred.

Few additional noise sources: Because the effort was designed to measure and assess the effects of aircraft, sites selected were largely unaffected by nonaircraft sources of noise.

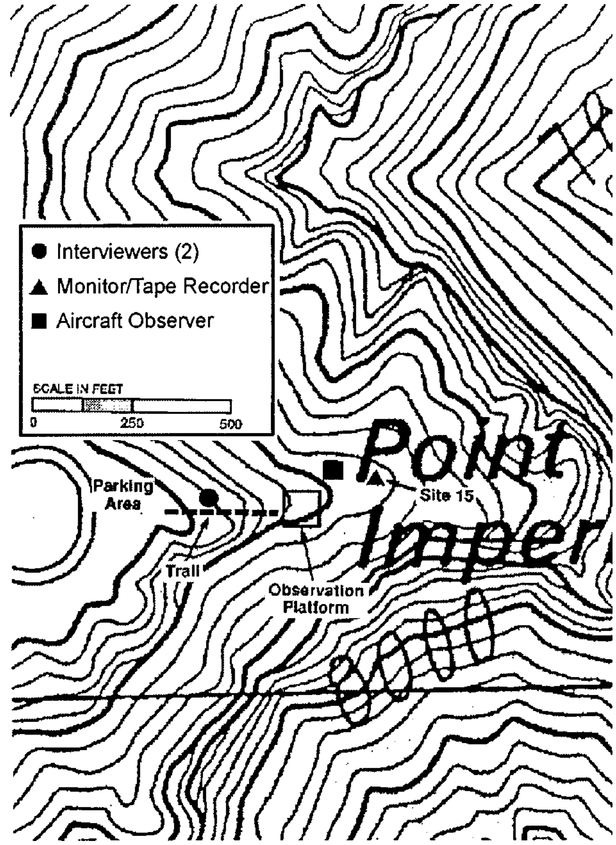

Fig. 1 – Site configuration for Dose–Response data collection.

All visitor activity outdoors: Finally, the sites could have no buildings or structures that visitors might enter, affecting the degree of aircraft sound exposure they experienced.

Table 1 summarizes the types and amount of data collected at each of the six sites. In the analysis, data from Havasu Creek were not used because background sound levels (produced by waterfalls) were loud enough to prevent visitors from hearing aircraft and to prevent accurate measurements of the aircraft.

C. Data collection

1. Interviews

Figure 1 shows a typical site configuration for the data collection effort. Interviewers were located at positions that

TABLE 1 – Dose–Response sites.

Park	Study area	Type area	Number of respondents	Range of typical background Leq. dB (A-wtd)	Aircraft per hour (approx.)
Grand Canyon	Lipan Point	Overlook	193	40–50	24
	Point Imperial	Overlook	124	25–40	22
	Havasu Creek	Short Hike	30	65–70	9
	Hermit Basin	Short Hike	32	20–25	31
Haleakala	Sliding Sands	Short Hike	213	20–30	8
Hawaii Volcanoes	Wahaula	Short Hike	180	35–45	9

allowed them to see visitors arriving at and departing from the site. The site in this case, Point Imperial, was an observation platform where visitors could stand and view the Canyon. As a visitor entered the site, the time of arrival was noted. When the visitor left the site, an interviewer would intercept the visitor and ask if a brief interview could be given. The interviewer would note the time of intercept so that the visitor's complete time at the site could be determined.

The interviewer used a survey instrument that was designed to explore visitor judgements of the effects of aircraft noise. The instrument was pretested to ensure that questions were unambiguous and that administering it took no longer than 5–7 min. Questions asked whether the visitor heard aircraft and whether aircraft noise caused annoyance or interfered with their enjoyment or their appreciation of natural quiet and the sounds of nature.

2. Sound monitoring

The sound monitor was located nearby, as unobtrusively as possible, in a position where it would receive virtually the same sound levels as those experienced by visitors at the site. This monitor measured and stored a complete time history of one-second, A-weighted sound levels. Tape recordings were also made periodically during data collection to document the frequency content of the sounds.

3. Sound source identification

An observer was located near the monitor. This observer created a detailed, second-by-second log of all sounds. He/she used a palm-top computer to record the start time of each change in acoustic environment, according to a prearranged hierarchy of sound sources. Thus, a second-by-second record of the audible sound sources was created for later association with the A-weighted time history. These sets of data—the second-by-second record of sound sources, the interview results, and the A-weighted time history—represented all the necessary data for computation of a multitude of sound exposure metrics to associate with each visitor's responses.

D. Data analysis

The three collected data sets (visitor survey, sound level data, and source identification) were combined, and sound metrics computed for each visitor's time at the site. Specific doses were computed for each visitor, and these doses and the visitor responses were analyzed using logistic regression to develop the Dose–Response relationships. First, two doses and two responses were chosen for analysis. Then, the responses were ''dichotomized'' (divided into two categories) and logistic regression used to develop the relationships.

1. Doses

The two sound metrics (or doses) that proved to be well correlated with visitor responses were the following:

(1) The percent of time aircraft were audible while the visitor was at the site. This dose was determined by using the observer logs to calculate the percentage of the total visitor's time on-site that aircraft could be heard. The calculation is simply a ratio of the number of seconds the observer logged aircraft as audible to the total number of seconds that the visitor was at the site.

(2) The difference between the aircraft produced equivalent sound level, L_{eq} (aircraft), and nonaircraft produced or background equivalent sound level, L_{eq} (background) [or L_{eq} (aircraft)$-L_{eq}$ (background)] during the visitor's time at the site. Equivalent sound levels must apply to a specific period of time. L_{eq} (aircraft) was computed for the time the visitor was at the site. It was the total sound energy produced by aircraft heard while the visitor was at the site, adjusted to the total time the visitor was at the site. Hence, for a given amount of aircraft sound energy (e.g., for a given number of aircraft overflights), the longer the visitor was at the site, the lower would be the L_{eq} (aircraft) for that visitor. L_{eq} (background) was computed using the sound levels that were measured when no aircraft were audible. The L_{eq} (background) measured during these times was treated as representative of the background for the entire time that the visitor was at the site.

2. Responses

Two visitor responses were analyzed with respect to the two doses. Specifically, responses to the two following questions were used:

(1) Were you bothered or annoyed by aircraft noise during your visit to (name of site)? Possible responses to this question were ''not at all,'' ''slightly,'' ''moderately,'' ''very,'' and ''extremely.''

(2) Did the sound from aircraft interfere with your appreciation of the natural quiet and sounds of nature at the site? Possible responses to this question were also ''not at all,'' ''slightly,'' ''moderately,'' ''very,'' and ''extremely.''

3. Logistic regression

Logistic regression is a statistical analysis process that yields the probability of an outcome for a given value of the independent variable. In this analysis, logistic regression was used to determine the likely visitor response for given sound doses. For example, each visitor's response and the dose received by each visitor were used to compute relationships that gave the percent of visitors who said they were annoyed for various degrees of sound exposure.

To conduct this logistic regression, visitor responses to the two questions were first dichotomized by categorizing answers of ''not at all'' or ''slightly'' as ''no'' responses, and answers of ''moderately,'' ''very,'' or ''extremely'' as ''yes'' responses. Logistic regression then computes the percent of visitors who answered ''yes'' (that is, for example, reported they were moderately, very, or extremely annoyed) for various values of the sound metrics.

E. Results

The resulting relationships are presented in Figs. 2–5. Figures 2 and 3 give the relationships for the metric of difference in L_{eq} (aircraft L_{eq} minus background L_{eq}) for the two responses, while Figs. 4 and 5 show the results for the metric of percent of time aircraft were audible. There

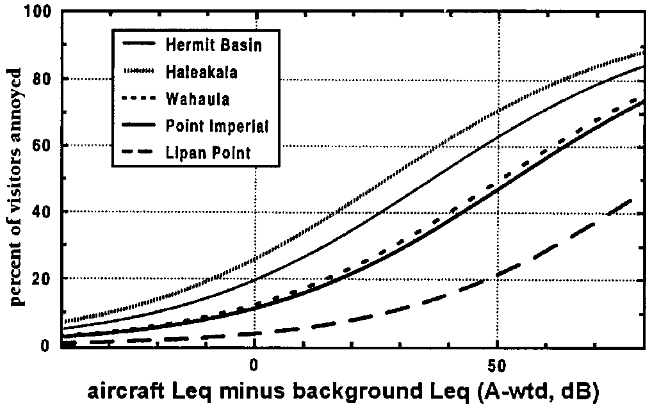

Fig. 2 – Dose–Response relationship, annoyance vs difference in Leq.

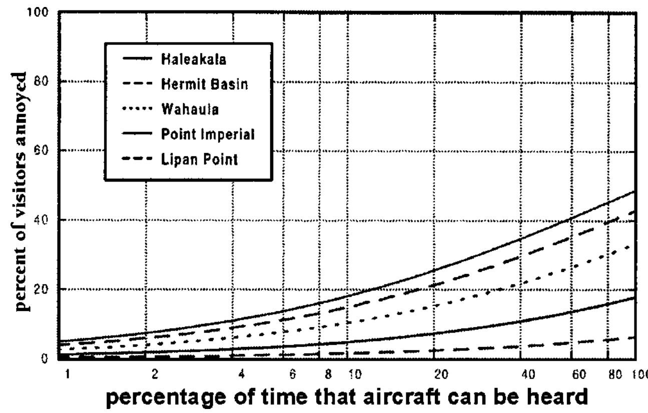

Fig. 4 – Dose–Response relationship, annoyance vs percent of time audible.

are three significant observations. First, the sites of Hermit Basin, Haleakala, and Wahaula are always more sensitive than Point Imperial and Lipan Point. That is, for a given level of sound exposure, visitors at these three sites reported more annoyance or interference with natural quiet than visitors at the other sites. The reasons for this higher sensitivity are speculative, but it is known that visitors at these sites walked some distance from their cars. These three sites may be considered ''short-hike'' sites where visitors committed some time to walking along a trail. Both Point Imperial and Lipan Point are Canyon overlook opportunities where visitors walked only a short distance to the overlook. Hence, it may be that visitors who commit some time to a particular park experience are likely to be more sensitive to the intrusions of tour aircraft noise than visitors at more accessible sites.

A second important observation is that for a given level of sound exposure, more visitors report interference with natural quiet than annoyance. This difference, reflected in other surveys of park visitors,[2] can be useful for park management purposes. At sites where the experience of natural quiet is a primary management objective, aircraft noise must be more limited if a given percent of the visitors are to be protected. Dose–Response results (Figs. 3 and 5) can provide guidance on setting limits to minimize visitor judgements of interference with natural quiet. For example, to limit the percent of visitors reporting interference with natural quiet to less than about 25% at the ''short-hike'' sites, audible intrusions of aircraft noise should be limited to less than about 5% of the time. For sites where natural quiet is not or cannot be expected, information of the type in Figs. 2 and 4 can be used to limit visitor annoyance to a small percentage of the visitors. (Section 5 provides additional interpretation of this difference between visitor judgements of annoyance and of interference with natural quiet.)

A final observation regarding these results is that the relationship of the sites to each other, in terms of sensitivity (vertical position of the curve on the plots), varies depending on the response (annoyance or interference) and the dose metric. Although this variation is partially due to limited sample sizes, it is probably also due to the fact that the two dose metrics are very weakly correlated (correlation coefficient of 0.26).[1] This lack of correlation is shown graphically in Fig. 6, which plots percent of time audible vs sound level difference for all visitors interviewed. Lack of correlation means that the two doses provide different information about the sound exposure so that it is informative to know the values of *both* metrics for a site. Section 5 suggests a method for using both metrics to evaluate sound intrusions at park locations.

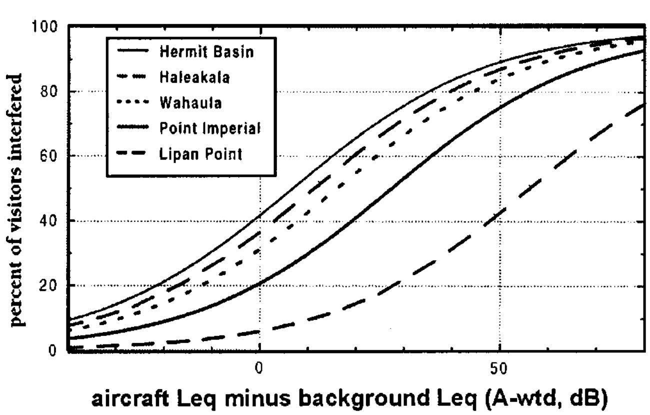

Fig. 3 – Dose–Response relationship, interference vs difference in Leq.

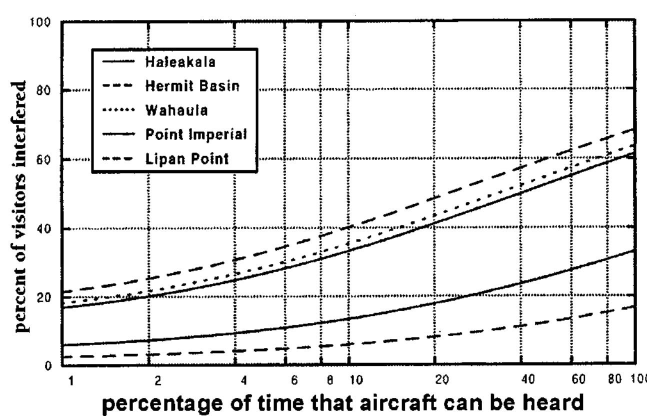

Fig. 5 – Dose–Response relationship, interference vs percent of time audible.

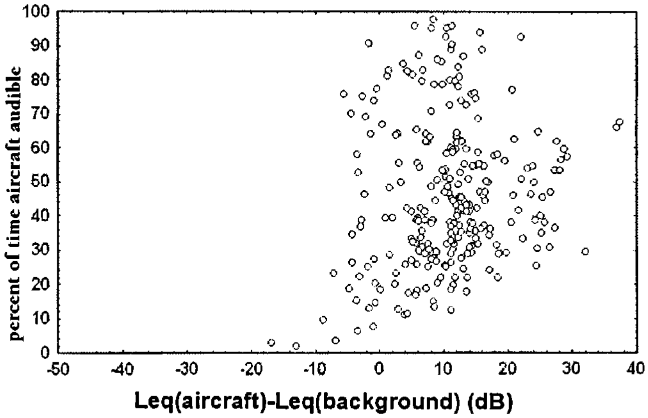

Fig. 6 – Demonstration of lack of correlations between time audible and Leq difference.

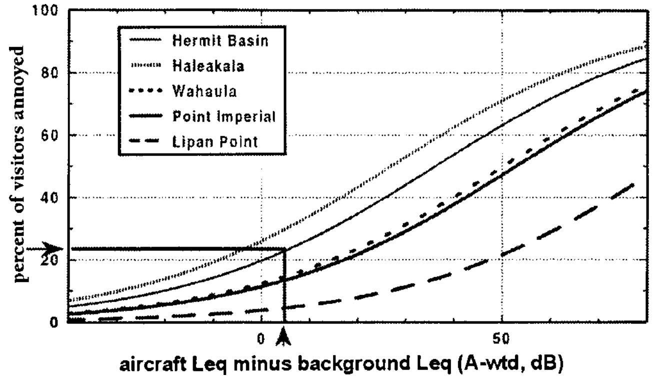

Fig. 7 – Determining difference in Leq that produces annoyance in 25% of visitors.

4. COGNITIVE SURVEY

The consistent differences between visitor judgements of annoyance and interference led to questions about respondents' interpretation of the questions. To better understand visitor responses, cognitive interviews were designed and conducted at White Sands National Monument in conjunction with a U.S. Air Force-sponsored Dose–Response study.[3]

A. Method

Cognitive interviewing is simply asking the respondent additional ''probe'' questions about their interpretation of specific words or phrases used in the basic questionnaire, and exploring how they arrived at the answers they gave. In this case, the standard survey instrument was used in the actual park setting. After obtaining responses to several specific questions of interest, particularly the annoyance and interference questions, additional questions were used to determine visitor interpretations of specific concepts.

B. Results

The cognitive surveys, conducted of 21 individuals during a 3-day period, provided the following five conclusions:

(1) Aircraft noise appears to be a factor that visitors may not consider when asked to evaluate their park experience in an open-ended question format. As a result, open-ended questions, such as ''What did you like the least about your visit to (park)?'' are probably not good indicators of the seriousness of problems from aircraft overflight noise at parks.

(2) Visitors have a clear and widely shared understanding of the concept of ''natural quiet and sounds of nature.'' Natural quiet is viewed as the absence of any human-made sounds, allowing visitors to hear natural sounds.

(3) Most visitors make a distinction between the terms ''interference'' and ''annoyance.'' Interference is perceived as an objective term, describing something that prevents them from doing what they want to do; it is an interruption or a distraction. Annoyance is perceived as having an emotional, evaluative component. For example, many respondents associate a negative reaction ''makes me mad'' or ''causes my blood pressure to rise'' with the term annoyance.

(4) Aircraft noise interference may not always result in annoyance. Aircraft noise generally must exceed a certain level or number threshold before it is perceived as annoying.

(5) Respondents indicate that interference can be a short-term occurrence, such that once the noise source has passed the perceived interference ends. Because of its emotional component, annoyance is longer lasting. It seems reasonable to consider annoyance as the reaction that causes a visitor to evaluate the experience as negative or to consider registering a complaint.

5. JUDGING RELATIVE INTRUSIVENESS

This section proposes a quantitative method that can be used to assist in making judgements about sound intrusions at park sites. The method quantitatively describes a site by using in combination the two sound metrics that have been shown to correlate well with visitor judgements of aircraft sound intrusions—percent of time audible and difference in L_{eq}. Dose–Response results are used to help judge these quantitative descriptions. The two metrics quantify the degree and level of the sound intrusions, and the Dose–Response results tell what values of these metrics cause ''too many'' visitors to register annoyance or interference. The determination of how much annoyance or interference is too much is naturally a policy decision. For the purposes of describing the general method proposed here, we choose to use 25% of visitors annoyed or interfered with as limits of acceptability.

As a first step in developing the method, thresholds of acceptability in terms of both metrics are identified. Figure 7 presents again the Dose–Response relationship for annoyance as a function of difference in L_{eq}, and Fig. 8 shows the annoyance results for percent of time audible. As an example, these figures are used to identify limits on intrusions such that no more than 25% of visitors to a typical or average ''short hike'' site would report annoyance. These figures show that this goal can be met if differences in L_{eq} are no greater than 5 dB, and if percent of time audible is no greater than about 30%. Figure 9 identifies

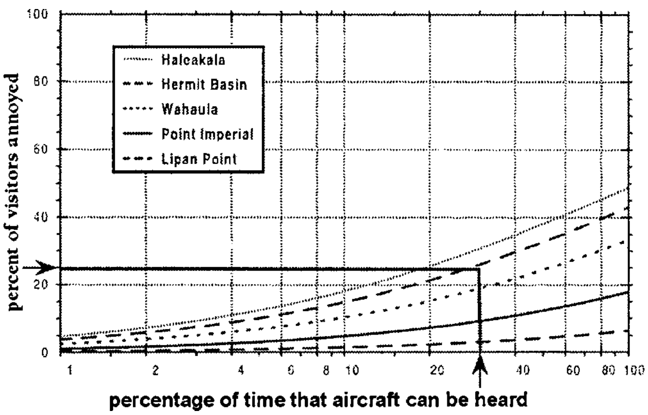

Fig. 8 – Determining percent of time audible that produces annoyance in 25% of visitors.

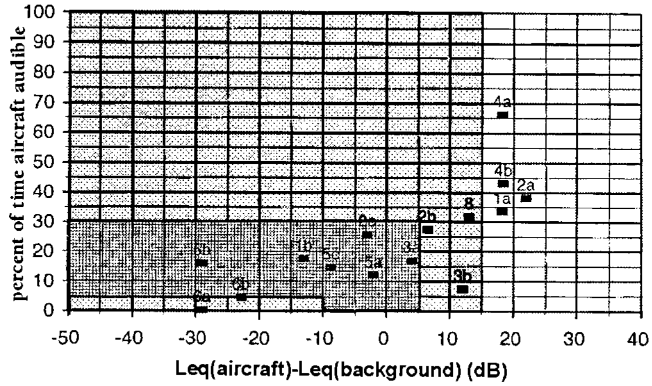

Fig. 10 – Measurements made at sites in Rocky Mountain National Park.

this range on a graph. In other words, sites that meet this criteria should provide a park sound environment which produces annoyance reactions in less than 25% of visitors. Such sites would plot within the shaded area of Fig. 9.

By similarly finding thresholds that limit *interference with natural quiet* to 25% of visitors at short hike sites and that limit annoyance to 25% of visitors at *overlook sites*, two other areas may be identified. All three areas are identified in Fig. 10, along with measurement results from eight sites in Rocky Mountain National Park. (Results at only seven of these sites are shown in Fig. 10.) The small white area in the lower left limits interference with natural quiet to 25% of visitors; the largest shaded area limits annoyance to 25% of visitors at overlooks (visitors at the overlook sites of Point Imperial and Lipan Point proved to be quite insensitive to aircraft noise). The plotted points are numbered by site, and letters distinguish one measurement period from another.

Though the presentation of site information provided by Fig. 10 is certainly not complete, this approach offers one means for quantitatively comparing different sites and different times at a given site. If many measurements are made at a site, for example, the distribution of measured results will suggest the significance of the noise intrusions and indicate whether changes are warranted to meet goals for visitor experiences.

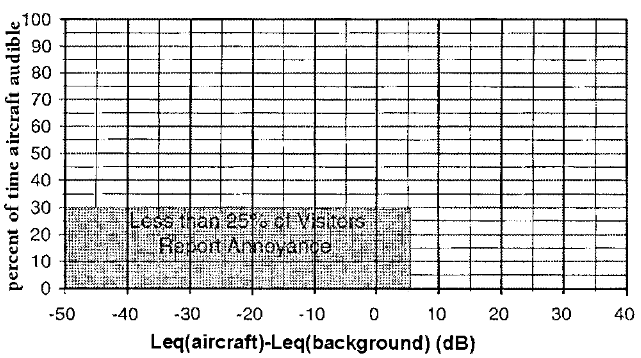

Fig. 9 – Graphic representation of thresholds that limit annoyance to 25% of visitors.

6. SUMMARY OBSERVATIONS

Studies of visitor reactions to aircraft overflights at specific sites in U.S. National Parks have yielded both quantitative and qualitative information that can be used to make park management decisions. The information shows how visitors' sensitivity to tour aircraft noise can vary considerably from site to site, and depends upon whether visitor annoyance is the primary issue or whether visitor perception of interference with natural quiet is the main concern. Quantitative relationships between sound intrusions and visitor reactions should be useful in general assessments of the effects on visitors of different amounts of aircraft noise at specific park sites. Such assessments, however, must consider that visitor sensitivities vary by site as do all aspects of the sound environment. In the end, the type of information provided in this paper provides only one perspective on an issue that has many dimensions. The quantitative information presented gives a starting point for discussion and problem solving, not the complete answer.

7. REFERENCES

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