

Aircraft noise-dose, visitor-response relations for national parks

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Overview



Dose – Response Data: Aircraft noise exposure metrics, subject response, and meta-data

Model Development: Multi-level logistic regression

Model application and interpretation

1992-2011: Studies by National Park Service and Federal Aviation Administration



Aircraft-noise exposure vs park-visitor response:

- Project Goal: Predict impacts to visitor experience based on noise exposure
- Mandated by National Park Overflight Act of 1987⁽¹⁾
- Began by NPS in 1990
- Continued by FAA in 1998
- Studies coordinated by multi-disciplinary team:
 - Experts on park management, recreational sociology, psychology, and acoustics
 - NPS, FAA

(1) <http://www.nps.gov/grca/naturescience/upload/PL100-91.pdf>

Information Collected

- 10 front country sites within 4 scenic national parks
- Data:
 - 2,600 visitor questionnaires
 - Visitor-by-visitor aircraft noise exposure, separately by aircraft type:
 - Aircraft LAeq, SEL, LMax
 - Noise-free intervals: longest, number of
 - Number of aircraft, aircraft-type percentages
 - Percent time audible, percent time above various ambient thresholds
 - Same protocols, questionnaire format
- Core response questions:
 - Were you bothered or annoyed by aircraft noise?
 - Did aircraft noise interfere with natural quiet and the sounds of nature?



Development

- Multi-level logistic regression accounts for:
 - Visitor-to-visitor variability, using the proper underlying statistical distribution
 - Site-to-site variability, using Site as the sampling “level” above Visitor
- Therefore sampling uncertainty contains the site-to-site standard deviation:

$$z = C_0 + N(0, \sigma_{Site}^2) + \sum_{i=1}^n C_i x_i$$

$$R = \frac{1}{1 + e^{-z}}$$
$$= \text{Prob}[\text{"yes" for the dichotomized response}].$$

Development

Final regression equation:

$$\begin{aligned} z = & C_0 + C_1 (M_{SiteType}) + C_2 (L_{eqAll}) \\ & + C_3 (P_{EnHelos}) + C_4 (P_{EnProps}) + C_5 (P_{EnHelos}) (P_{EnProps}) \\ & + C_6 (M_{ImpNQ_VorMore}) + C_7 (M_{AdultsOnly}) + C_8 (M_{SiteVisitBefore}) \end{aligned}$$

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

where

$M_{SiteType} = 1$ for ShortHike, 0 for Overlook

$$L_{eqAll} = 10 \log \left(10^{L_{eqHelos}/10} + 10^{L_{eqProps}/10} + 10^{L_{eqJets}/10} \right)$$

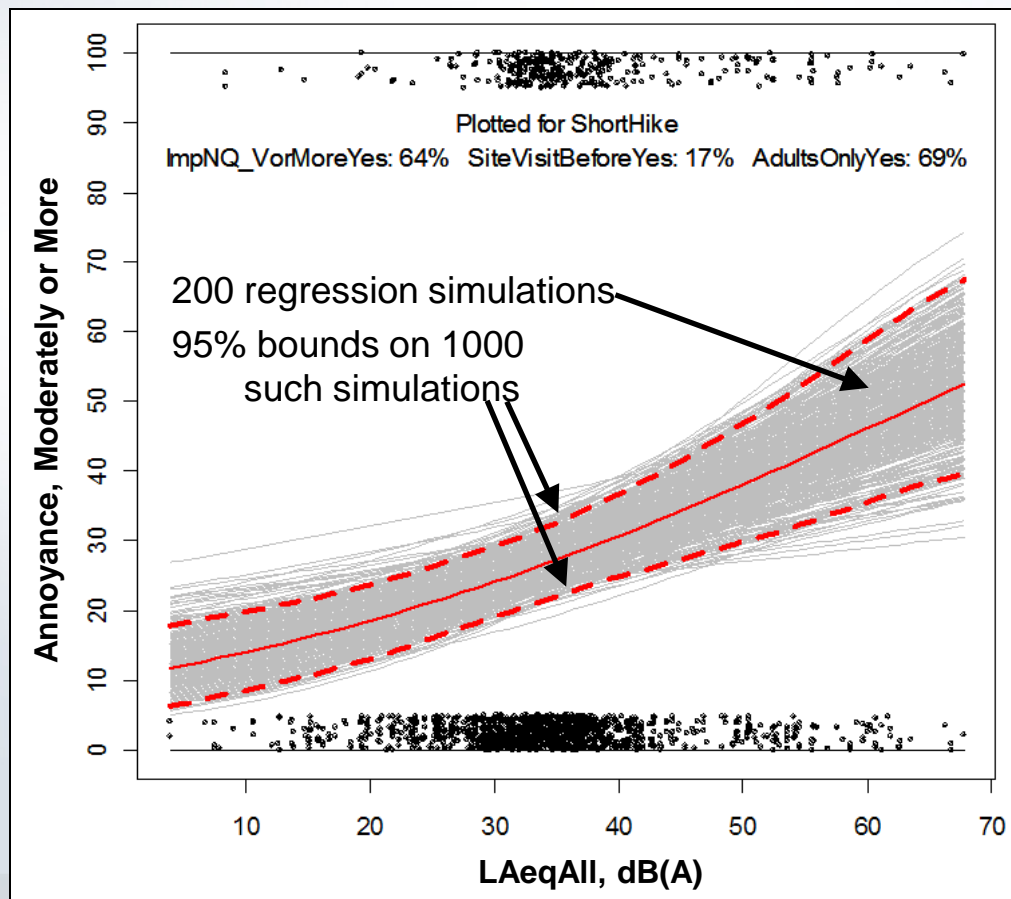
$$P_{EnHelos} = 100 \left(\frac{10^{L_{eqHelos}/10}}{10^{L_{eqAll}/10}} \right)$$

$$P_{EnProps} = 100 \left(\frac{10^{L_{eqProps}/10}}{10^{L_{eqAll}/10}} \right)$$

* For brevity LAeq is abbreviated as Leq in equations

Development

Sample dose-response graph:



Development

Residuals:

Response	Dichotomization	Residual size (percentage points above, or below, the predicted response)		
		minimum	average	maximum
Annoyance	Slightly or more	-1.6	-0.006	3.9
	Moderately or more	-1.1	-0.008	6.4
	Very or more	-0.8	-0.005	10.4
Interference with Natural Quiet	Slightly or more	-2.4	-0.002	3.6
	Moderately or more	-1.6	-0.004	4.5
	Very or more	-1.1	-0.003	6.7

Development

Field data

Individual noise exposure

Visitor questionnaires

- How much annoyed by aircraft noise?
- How much interfered with your appreciation of Natural Quiet?
- Context questions / observations



Exposure / Response

Six relations

- Annoyed
- Interference with Natural Quiet
- Both of these:
 - Slightly or more
 - Moderately or more
 - Very or more

Context increases response

- Short hike vs. overlook
- Natural Quiet very important
- Only adults in group
- Visit site before

Application

Input

Noise exposure

- Compute with FAA's INM
- How many, by aircraft type?
- Distances?
- Intervening hills?

Context

- Short hike or overlook?
- Relevant visitors believe Natural Quiet very important?
- Percent groups: Adults only
- Percent visitors: First time at site



Percent of visitors

Annoyed

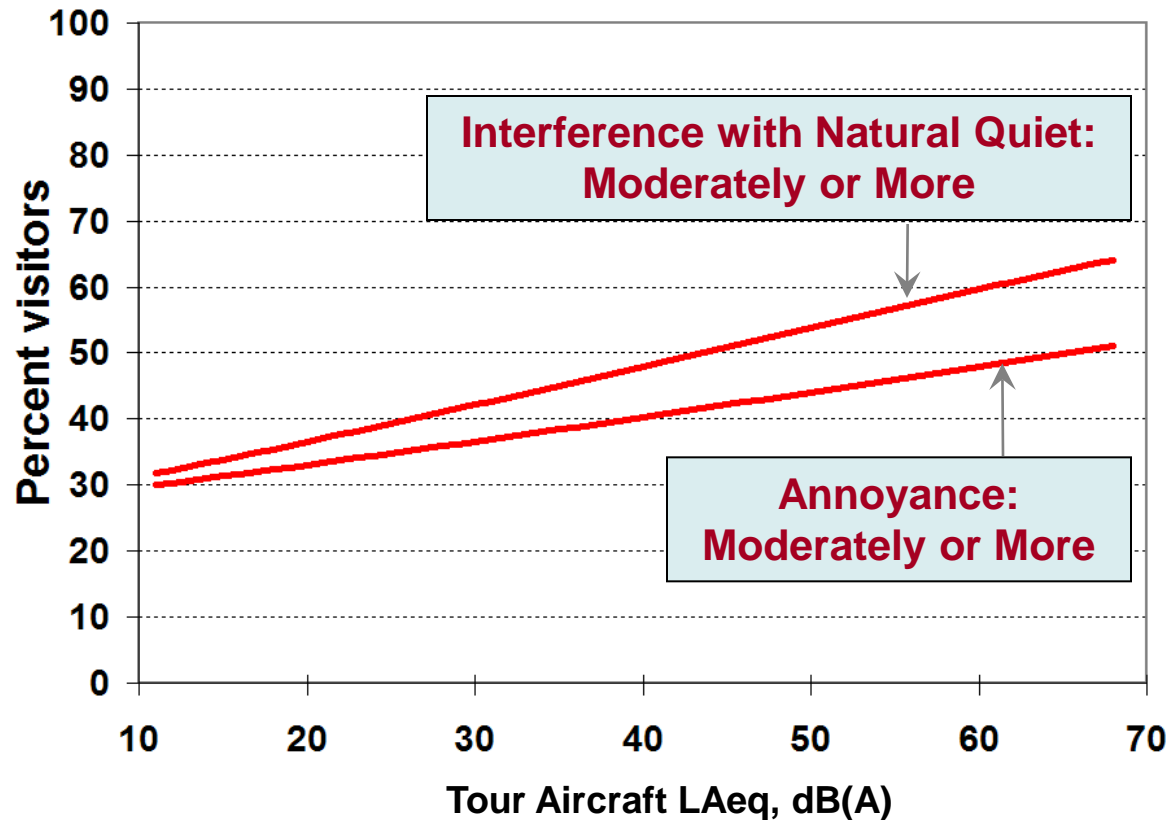
- Slightly or more
- Moderately or more
- Very or more

Interference with Natural Quiet

- Slightly or more
- Moderately or more
- Very or more

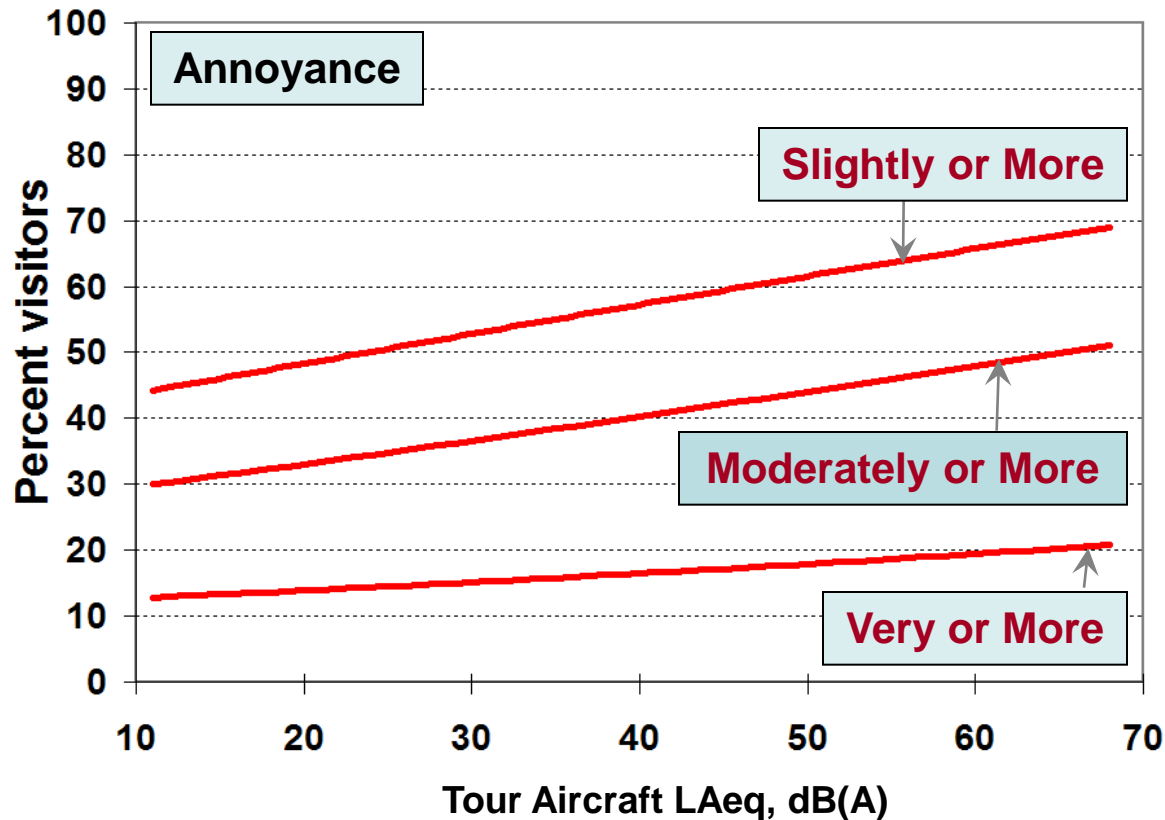
Results:

Interference with Natural Quiet vs Annoyance



- Short hikes
- Natural Quiet very important: Yes
- Equal helicopters and fixed-wing

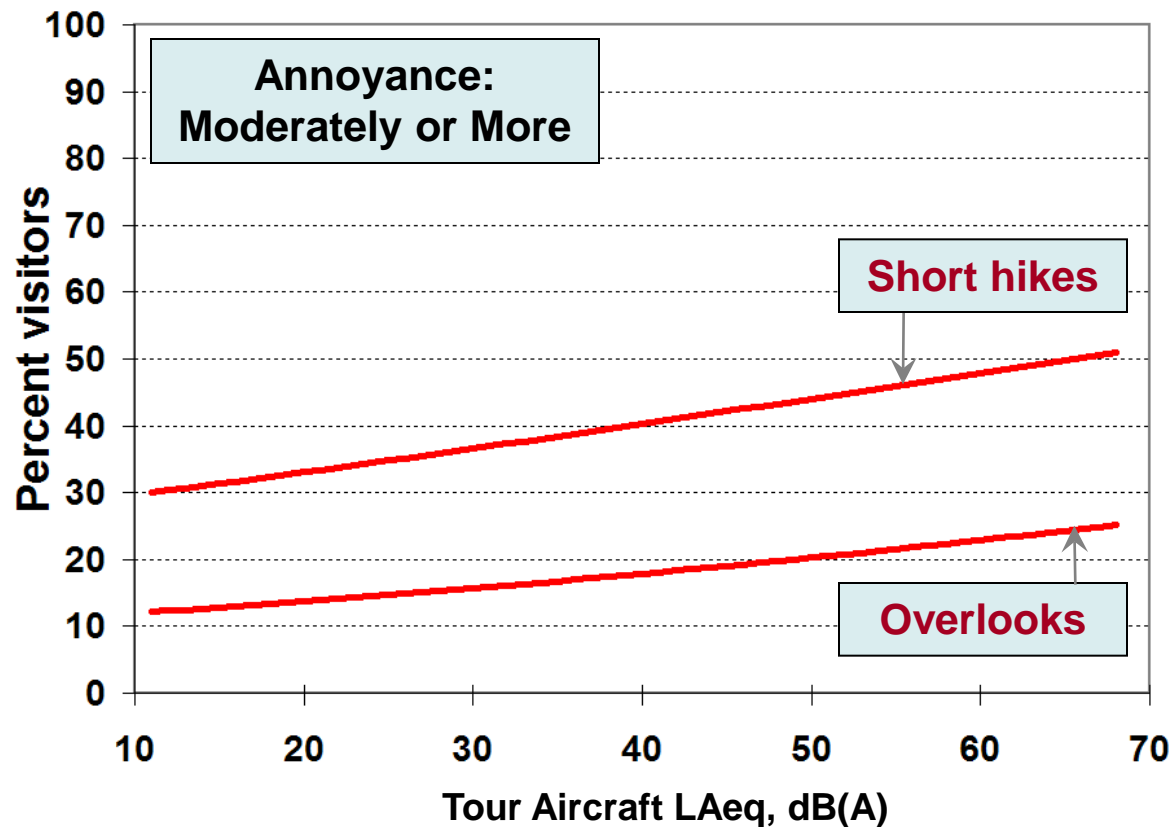
Results: Slightly vs Moderately vs Very



- Short hikes
- Natural Quiet very important: Yes
- Equal helicopters and fixed-wing

Results:

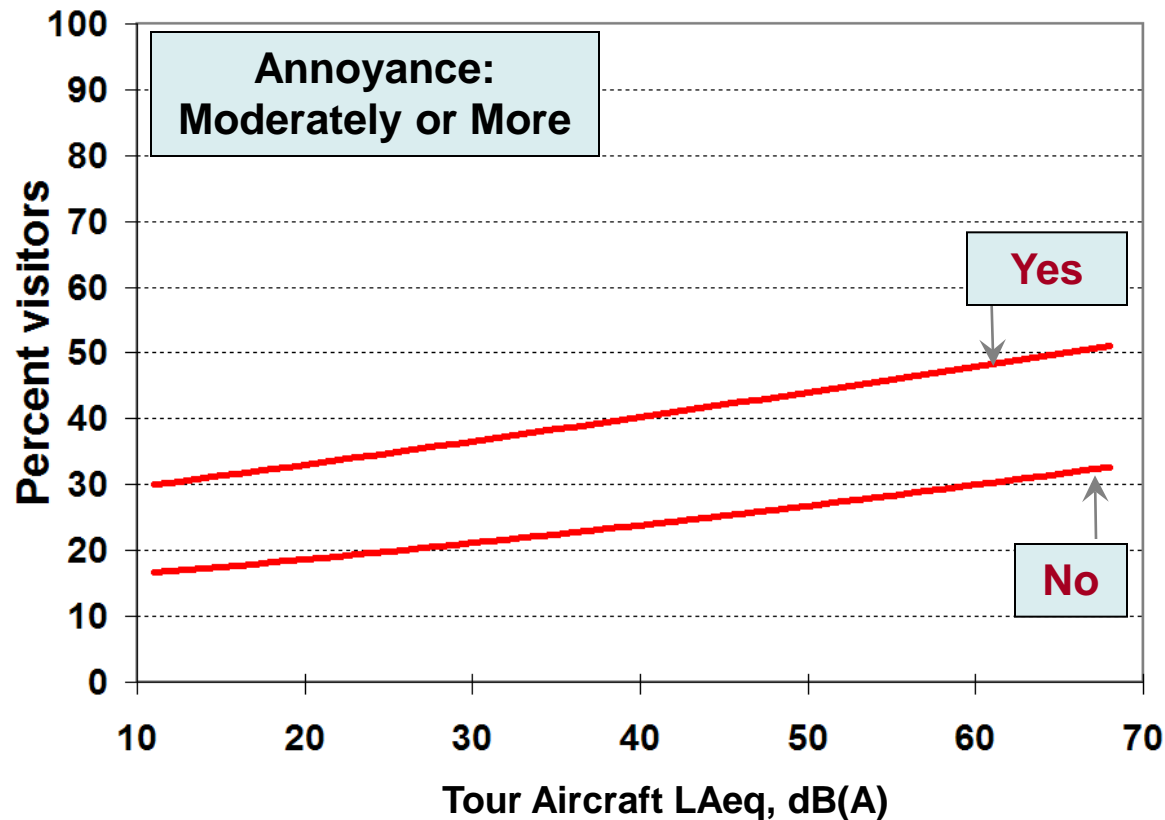
Short Hikes vs Overlooks



- Natural Quiet very important: Yes
- Equal helicopters and fixed-wing

Results:

Natural Quiet very important

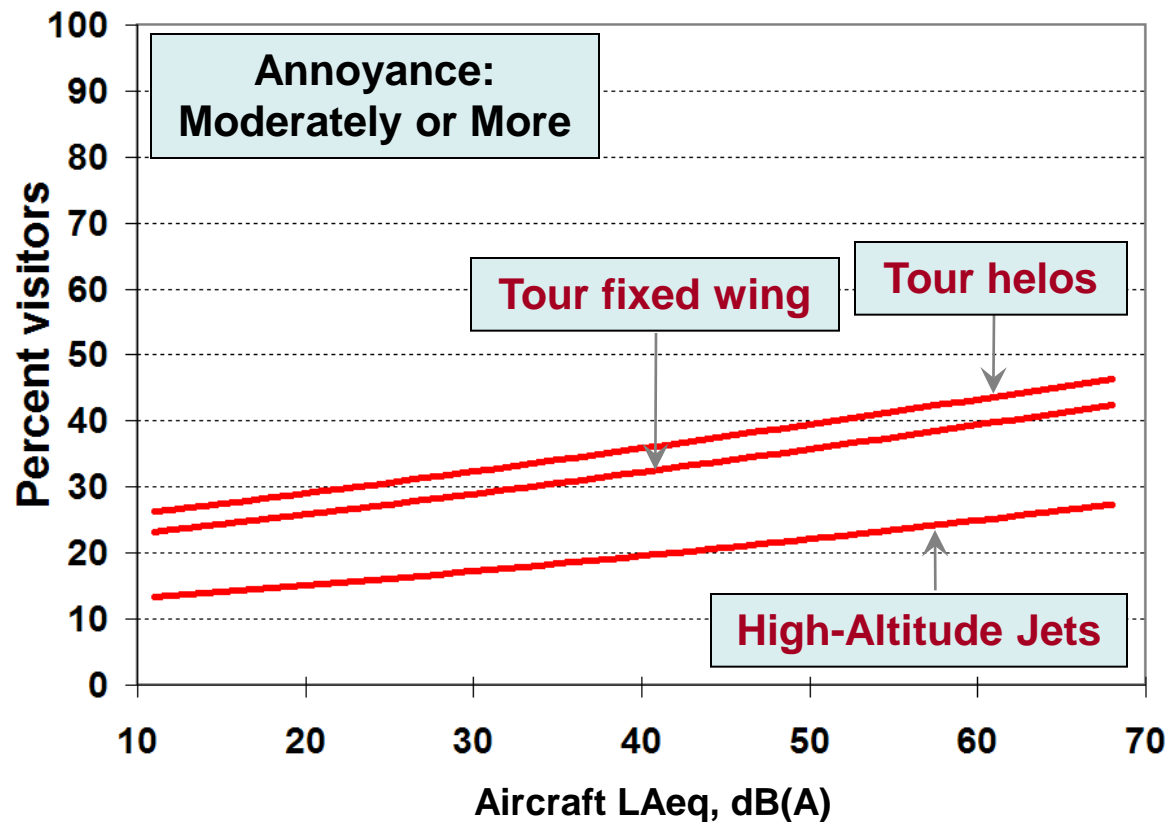


- Short hikes

- Equal helicopters and fixed-wing

Results:

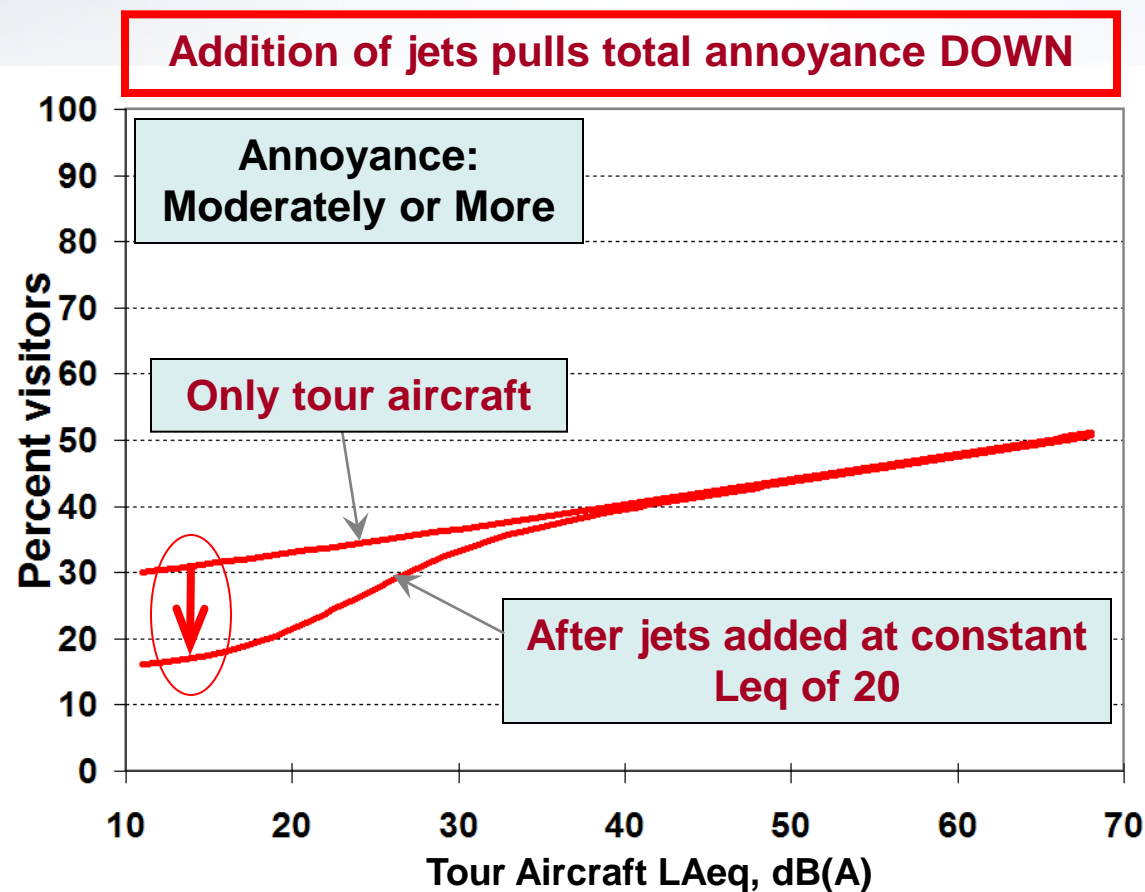
Tours vs High-Altitude Jets



- Short hikes
- Natural Quiet very important: Yes

Results:

Both Tours and Jets



- Short hikes
- Natural Quiet very important: Yes
- Equal helicopters and fixed-wing



Conclusions

- **Visit-context variables are important:**
 - Site type: Visitors on short hikes are 30 to 70 dB more sensitive than at overlooks
 - Familiarity with site: First-time visitors are 20 to 40 dB more sensitive
 - Children: Visitors without children are 10 to 20 dB more sensitive
 - Visitors who consider natural quiet very important are 10 to 50 dB more sensitive
- **Noise source is important:**
 - % helicopter sound energy
 - % propeller sound energy
 - % jet sound energy



Conclusions

- **Other:**
 - Equivalent A-weighted sound level (LAeq) provides the most explanatory power
 - Incorporates both sound level and duration of exposure
 - Other summary acoustic metrics tested, but none performed better
 - Composite doses (such as LAeq + %Time Audible) offered no improvement
- **Presence of high-altitude jets reduces total annoyance:**
 - Depends upon jet LAeq relative to air-tour LAeq

New Measurements

Fill-in data gaps:

- Aim for 5,600 additional visitors
- Back country (2625 visitors):
 - Multi-day hikes and campgrounds
- Front country:
 - Day hikes and historical sites (1750 visitors)
 - Short hikes and overlooks (1225 visitors)



Measurements for 2011:

- 7 National Parks (Bryce, Rainbow Bridge, Glacier, Grand Canyon, Montezuma, Walnut Canyon, Zion)
- 3 New Survey Instruments: one modernization of the late 1990s survey used in the present analysis and two new surveys used by more recent social sciences studies by the National Park Service⁽²⁾

⁽²⁾ OMB control number: 2120-0744. Documentation available at <http://www.reginfo.gov/public/do/PRASearch>

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Questions / Discussion

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