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Letter to the Editor

Airplane noise: a pervasive disturbance in Pennsylvania Parks, USA ☆

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1. Introduction

An often overlooked and ubiquitous form of pollution in our environment is noise. Noise can be defined as unwanted or undesired sound. Noise may have been first reported as pollution in the early 1800s when townspeople complained about church bells ringing every hour during the night [1]. Today, researchers estimate that world noise levels are doubling every 10 years, and in the United States alone, unacceptable noise (as perceived by humans) has increased nearly 40% since 1970 [2].

Noise can disturb ecosystems by altering animal behavior and physiology. Animals have been reported to experience chronic stress, marked by changes in metabolism and hormone levels, and increased heart rate, in the presence of unnatural noise [3–5]. Calving mortality rates can increase in woodland caribou (*Rangifer tarandus*) [6] and some birds will abandon their eggs when exposed to periods of aircraft noise [7]. In humans, aircraft noise can raise blood pressure [8], cause stress [9] and induce fatigue [10]. When aircraft noise is prevalent near schools, a decrease in learning among students has been reported [10].

Our society may accept noise in our communities, seeing it as the necessary price we pay for modern conveniences (e.g., cars, trains, and construction noise). Yet, when we seek peace and solitude in our state and national parks, noise is an unwanted disturbance [7]. Indeed the National Park Service has declared that natural quiet is a resource that should be preserved [7].

The Noise Control Act of 1972 and several other laws require the federal government to establish and enforce noise control standards in aircraft, workplace activities, rural areas, and

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National Parks. Additional legislation has been enacted in US National Parks such as the Grand Canyon and Hawaii Volcanoes to limit air tours and enforce a minimum flight altitude over parklands [7]. Legislation introduced in the 108th Congress include one bill that aims to curtail snowmobile use in Yellowstone National Park and snowplane use in Grand Teton National Park (H.R. 1130). Another bill introduced would provide for the development of new technologies that will lead to future aircraft with significantly lower noise, emissions and fuel consumption (H.R. 586).

Before creating legislation and restrictions on aircraft noise and overflights in state and national parks, it is important to quantify and document aircraft use over these areas. The objective of this study was to record the number of aircraft overflights and the audible duration of aircraft noise in state parks in Central Pennsylvania, USA. In addition, the hypothesis that the audible duration of aircraft noise in state parks is related to the density of the number of surrounding skyways and airports was tested.

2. Methods

2.1. Study sites

Eighteen out of a possible 106 Pennsylvania state parks were selected for this study (Fig. 1). All parks were located in central Pennsylvania. An array of parks was desired—some remote (i.e., one or no airports close by), some semi-remote (i.e., some small airports in the vicinity), and others semi-urban (i.e., close to several airports).

2.2. Pilot study

A pilot study was conducted in two central Pennsylvania state parks to evaluate the variation in aircraft noise from hour-to-hour during the workday (i.e., from 9 a.m. to 6 p.m.) for 1 day in each park. One of the parks, R.B. Winter State Park, was remote (only one small airport close by) and the other, Black Moshannon State Park, had four airports in the vicinity. The data was collected on weekdays. In both sites, little variation was found in the percentage of each hour during which aircraft noise could be heard during the day. The average percent of each hour aircraft noise could be heard in the more remote park was 22.5% ($n = 8$ h; Standard deviation (SD) = 3.3) vs. 64.0% ($n = 8$ h; SD = 5.12) for the less remote park. These results indicated that measuring aircraft noise during the day, on a weekday, would give a reasonable estimate of aircraft noise duration in a park.

2.3. Noise measurements

Aircraft noise was measured in 18 state parks selected throughout the state from 1999 to 2000. Aircraft noise was measured for 3 h in each park between 09:00 and 15:00 on weekdays. Listening stations in parks were isolated from other sources of noise (automobile and pedestrian traffic) and were at least 15 m from trees (to avoid interference). Temperature varied between 10°C and 21°C during the sampling periods. Noise was expressed as the percent of time an observer heard aircraft noise during the hour of sampling.

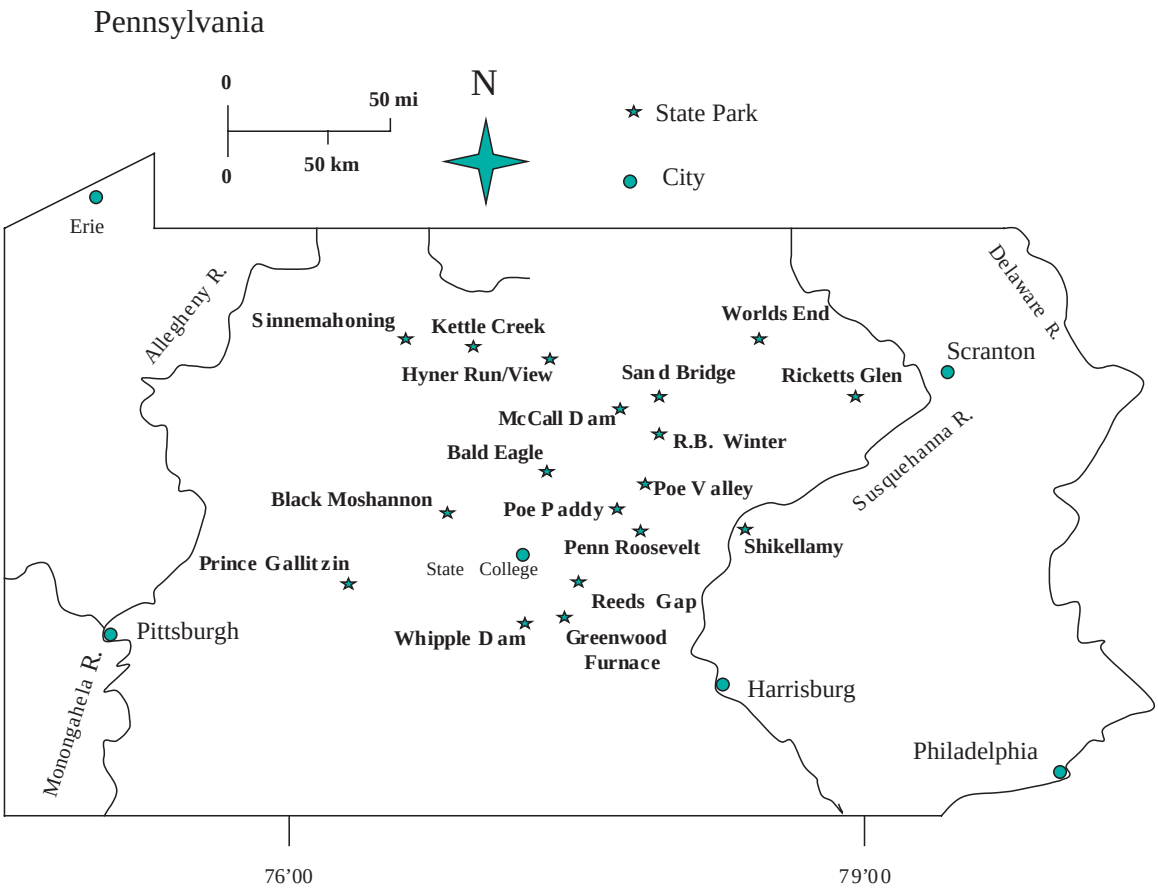

Fig. 1. The locations of the Pennsylvania State Parks monitored for aircraft noise in this study.

Four people were involved in taking the noise measurements. At the onset of the study, the consistency of human hearing was tested as a recording tool. Four listeners simultaneously monitor aircraft noise for 1 h in one of the parks. They heard aircraft noise for an average of 24 min; SD = 0.6.

Each aircraft noise event was designated as originating from either a jet or propeller-driven plane. In cases where more than one plane was heard at the same time, one noise event was recorded; and the duration of total noise from this event was evenly divided among the two plane types.

2.4. Data analysis

To determine if a relationship existed between audible airplane noise and the number of airports near each part, regression analyses were done. Regression analyses were done between the percent of sample time airplane noise was heard in each state park and the number of airports within a distance of 8.1, 16.1 and 24.2 km from the listening stations. The distances between airports and listening stations were measured from the Pennsylvania Aeronautical Chart [11].

Hard and soft surfaced runway based airports, and military airports were included in the analyses. Data used in the regression were normally distributed and were not transformed. All statistical analyses were done in SYSTAT Version 8.0 [12] and a p-value of $\leqslant 0.05$ was considered a significant difference.

Regression analyses were done between the percent noise heard in each park and the density of "skyways" overlying each park. A skyway is a prescribed route in the sky that aids navigation between locations and enables pilots to create flight plans [13]. Commercial planes follow skyways, however general aviation flights are not restricted to skyways and can follow customized flight plans. Skyway density around each park was calculated by summing the total skyway miles within each circle (8.1, 16.1 and 24.2 km radius). Skyway measurements were taken from the Pennsylvania Aeronautical Chart [11], Detroit and New York Sectional Aeronautical Charts, and the Low Altitude Enroute Chart, Sections 23 and 24. Each skyway was treated as having equal air traffic volume, since data on skyway traffic were not available.

3. Results

There was an average of 14 overflights recorded per hour (SD = 3.3) in the eighteen state parks studied. Eleven parks had between 10 and 20 overflights in the sampling period, and only four parks had less than 10 overflights (Fig. 2). Noise was sampled from more jet (61% of the planes, $n = 141$ planes) than propeller (39%, $n = 106$ planes) aircraft in all parks combined.

Aircraft noise was heard an average of 40% (SD = 10.1) of the sampling period in the 18 state parks and ranged from a minimum of 18% (11 noise events) to a maximum of 71% (34 noise events) (Fig. 3). The average duration recorded for each noise event was 1 min and 36 s (SD = 22 s). Propeller planes were heard, on average, slightly longer (average of 1 min and

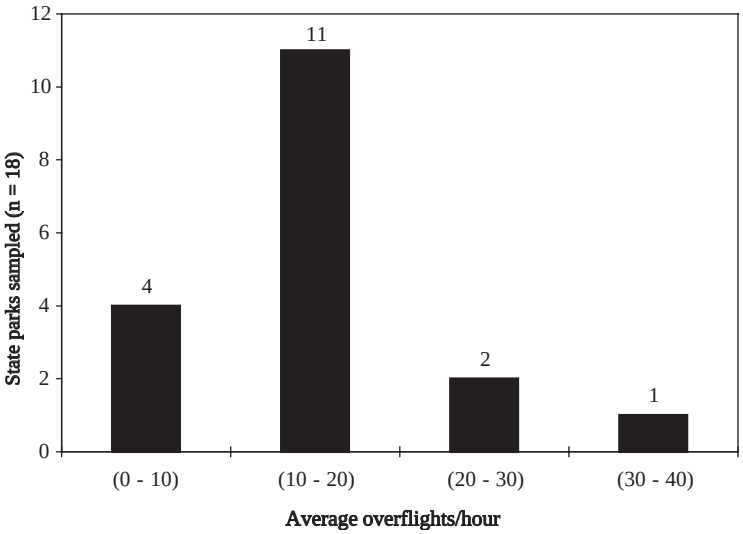

Fig. 2. The number of overflights recorded per hour on a weekday morning in 18 state parks in central Pennsylvania.

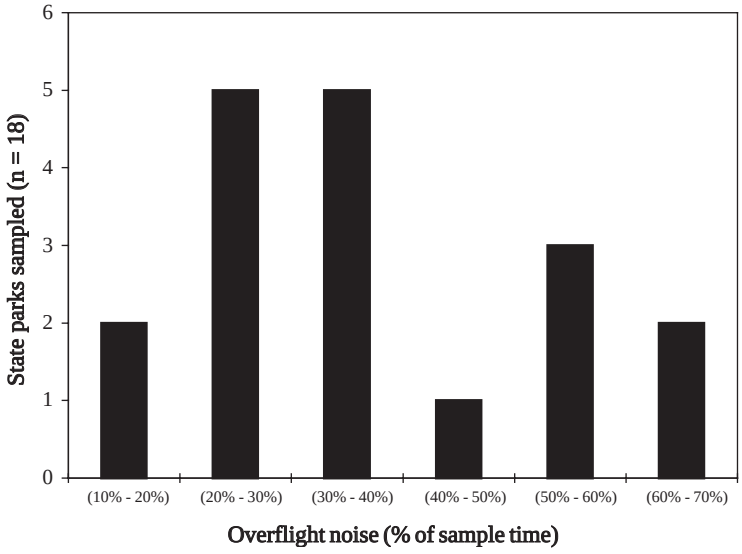

Fig. 3. The percentage of sample time during which aircraft noise could be heard overhead in 18 state parks in central Pennsylvania.

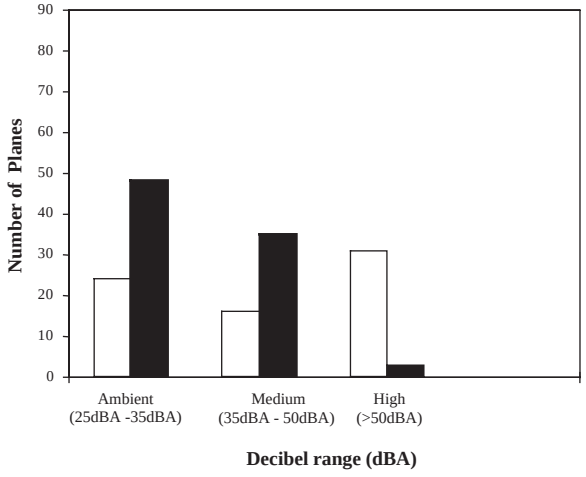

Fig. 4. The intensity of propeller and jet aircraft noise over a 7-h period in Black Moshannon State Park, central Pennsylvania (□ propellers, ■ jets).

39 s/overflight; $n = 106$ overflights; SD = 19) than jets (average of 1 min and 35 s per overflight; $n = 141$ overflights; SD = 26).

Noise intensity was measured in Black Moshannon State Park over a 7-h period to compare the range of aircraft noise to ambient noise. Propeller planes were louder, on average, than jets. Less than 5% of jet planes sampled ($n = 86$ planes) generated noise over 50 dB (e.g., equivalent to a vacuum cleaner 5 m away), yet nearly 20% of the propeller planes sampled ($n = 71$ planes) were louder than 50 dB (Fig. 4). The noise from most planes ($n = 78$ planes), although fully discernable

Table 1
The relationship between aircraft noise (% of sample time) and airport and skyway density in 8.1 and 24.2 km radius circles centered on listening stations in central Pennsylvania state parks

Relationship between aircraft noise and:	r^2 value	p-value
Airports within a 8.1 km radius	0.250	0.034*
Airports within a 24.2 km radius	0.571	0.000*
Skyway density within a 8.1 km radius	0.250	0.035*
Skyway density within a 16.1 km radius	0.332	0.012*
Skyway density within a 24.2 km radius	0.012	0.159

Starred p-values indicate significance at the 0.05 level ($n = 18$ for all analyses).

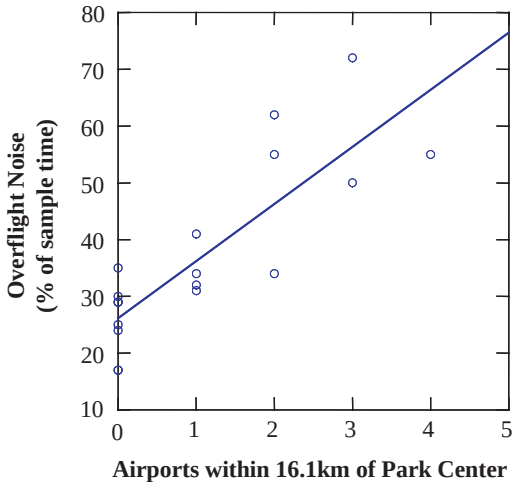

Fig. 5. The relationship between the number of airports within a 16.1 km radius of 18 state parks in central Pennsylvania and aircraft noise duration ($p = 0.000$; $r^2 = 0.693$).

to the human ear, was not picked up by a decibel meter (i.e., below ambient noise level −25 to −35 dBA) at the time of recording.

The density of "skyways" within a radius of 8.1 and 16.1 km of park centers was weakly correlated with aircraft noise duration (Table 1). However, a stronger relationship was found between noise duration in parks and airport density within set distances from parks (Table 1). For example, the relationship between aircraft noise and the number of airports located within 16.1 km of the 18 study parks was $r^2 = 0.693$ ($p = 0.000$) (Fig. 5). If the relationship between airport proximity and noise in state parks in Central Pennsylvania is similar to state parks and airports in the entire state (a reasonable assumption), it is predicted that the majority of state parks in Pennsylvania will have audible aircraft noise for over 40% of the time during the day ($n = 126$ total parks) (Fig. 6).

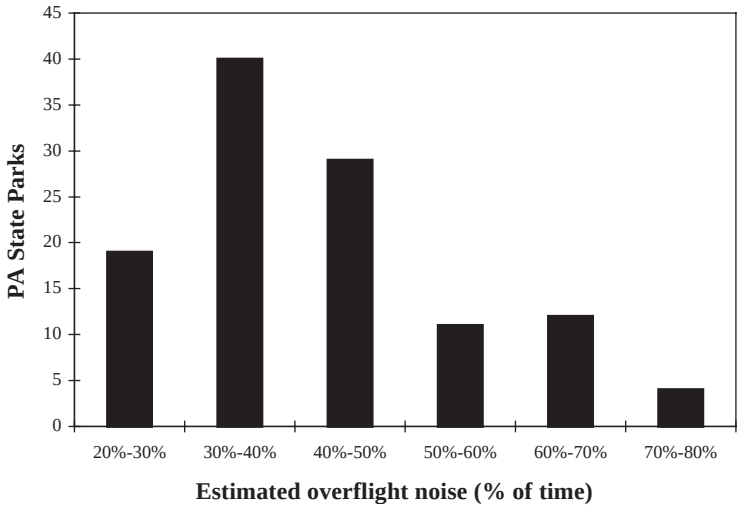

Fig. 6. The estimated percentage of time visitors are likely to hear aircraft noise in Pennsylvania's state parks.

4. Discussion

A disturbance in ecological terms is defined as a "discrete event that disrupts community structure and changes available resources, substrate availability or the physical environment" [14]. Aircraft noise masks the natural sounds in park areas and might be considered as a disturbance to the ecosystem. In state parks of Pennsylvania, aircraft noise was heard from 18% to 70% of the sampling period.

Aircraft noise duration in state parks of Pennsylvania is probably typical of much of the US For example, in Cumberland Island and Mount Rushmore National Park, aircraft noise was heard 55% and 40% (respectively) of the time [7]; and in the Grand Canyon, noise from overflying aircraft was recorded from 5% to 80% of the time, depending on the location and time [7].

One way to put our Pennsylvania results into context is to consider Federal Aviation Association (FAA) data on the average number of aircraft operations/km^2/day (either takeoffs or landings). In the case of Pennsylvania, there are 15 operations/km^2/year, a value similar to the national average for all states (13 ± 4.6 operations/km^2/year) [13]. If comparisons are restricted to Northeastern States (average of 27 ± 12.6 operations/km^2/year), it appears that aircraft noise intrusion into Northeastern parks may be even more prevalent than in Pennsylvania.

Aircraft-generated noise has increased dramatically in the past 25 years in the US Jets have expanded their fleet by 200% and increased passenger load by 177% since 1975. Meanwhile, at the national level, the number of airports has increased sharply in the last 20 years (Table 2), affecting noise levels in state and national parks.

Noise in parks is a greater disturbance than similar noise in human communities because of lower ambient noise levels in parks. In urban communities' humans expect noise. Studies show that the intensity of ambient noise can be as much as 55 dBA in neighborhoods and 60 dBA near streets [2], making it difficult to hear overflying aircraft in communities. But in parks people are

Table 2
Changes in aircraft and airport usage in the United States in recent years [13]

National statistics	1975	1984	1996	% Change 1975–1996
Number of airports[a]	13,251	16,079	18,292	38%
Takeoffs and landings[b]	NA	32,063,058	40,419,365	26%
Enplaned passengers[c]	194,538,351	344,831,718	538,394,000	177%
Total aircraft in operation[d]	2495	4371	7478	200%

[a] Total number of US Civil and Joint Use Airports on record.
[b] Total IFR air traffic activity (number of take-offs and landings) recorded at air traffic control centers.
[c] Number of passengers traveling on commercial airlines.
[d] Total aircraft (with a capacity of greater than 30 seats) reported in operation by air carriers.

accustomed to natural sounds and lower ambient noise levels. Ambient noise in national parks has been reported as low as 21 dBA [15].

Noise regulations associated with land areas (e.g., city and county area) are established by state and local governments. The federal government; however, regulates aircraft noise according to the noise aircraft types make and noise emitted from airports as measured in surrounding residential, public use, industrial and recreational areas. The Environmental Protection Agency in 1972 issued a statement outlining their suggestions for minimum noise levels in rural and outdoor areas. They recommended *average* day and night noise level to be between 45 and 55 dBA in rural and outdoor areas. Using this scale, large periodic noise events can be averaged out if they are followed by relative silence. In our study of Black Moshannon Park, 22% ($n = 157$ planes) of the planes generated noise above 50 dBA and only low-flying propeller planes generated noise above 65 dBA. Nonetheless, a DNL of 55 dBA would never be reached in any of the state parks studied, even with aircraft noise heard over 70% of the time. This example shows how measuring average noise levels can mask the occurrence of large, periodic noise events that may be as annoying as a constant stream of noise.

Using sound intensity to create guidelines for noise pollution in park areas would underestimate the disturbance of aircraft noise. Aircraft overflight events and the duration of aircraft noise heard per hour have been correlated to human annoyance [16,17]. In three National Parks, 50% of park visitors were annoyed when aircraft noise could be heard for more than 40% of the time [16]. Using this figure and our data and projections, it is expected that a majority of visitors will be annoyed by aircraft noise in about half of all Pennsylvania State Parks (Fig. 6).

Reducing aircraft activity in airports near parks and eliminating low flying aircraft over parks might limit aircraft noise in state and national parks. This can be done by

1. Directing take-offs and landings away from parks [18].
2. Creating ''noise budgets'' for airports based on the number of state parks within the vicinity of the airport. An airport noise budget is the sum of noise emission units (calculated using the mass of the plane and type of engine used) from planes taking off from an airport per day. Establishing a maximum noise budget would limit aircraft activity and encourage aircraft owners to invest in technologies that would lower aircraft noise.

3. Creating a curfew on plane activity to reduce nighttime aircraft noise [2].
4. Establishing a minimum altitude for aircraft to reduce noise penetration as has been done in national parks in Tennessee and Hawaii [7,19].
5. Encouraging the use of noise-reduction technology in aircraft through incentives or penalties.

State Park designated natural areas should receive priority in the formulation of sound abatement policy. Natural areas in the state of Pennsylvania are by definition "unique ecological areas that are maintained in their natural condition to allow natural biological and physical processes to operate without human intervention" [20]. Reducing aircraft noise in natural areas around the country would strengthen the definition of a natural area and set an example for further aircraft noise reduction policies.

In our society, it is now impossible to find a natural area that is free from the noise of our machine-mediated world. Indeed, it is impossible to create just 1 in^2 of lasting natural quiet in our parks because of freely roaming aircraft [21]. Banning all aircraft from every park entity might be unrealistic today considering our dependence on air travel and the additional fuel costs that would be associated with re-routing planes. Yet creating restrictions on the frequency of overflights in park areas and establishing noise-free periods may be an achievable goal that would give us limited opportunities to hear the sounds of nature uninterrupted.

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