Acoustical Monitoring in Peregrine Falcon Territories at Bryce Canyon National Park

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Introduction

Bryce Canyon National Park (Bryce Canyon) is located on the Colorado Plateau in southwestern Utah and is known for its outstanding natural beauty and unusual rock formations. Visitors to Bryce Canyon also recognize the soundscape as an important part of experiencing the park. With natural ambient levels that sometimes register below the "noise floor" of acoustic equipment, park staff have measured and recorded moments with no measurable sound. During the spring and summer of 2009 and 2010, Bryce Canyon staff conducted a soundscape monitoring study focused on the acoustic environment at nesting sites of the American peregrine falcon (*Falco peregrinus anatum*)—a species of management concern for the park. Monitoring systems (consisting of a Larson Davis 831 unit, anemometer, and Edirol MP3 recorder) were deployed throughout the park at seventeen front and backcountry locations where peregrine falcon territories were known to occur (Figure 1).

The primary purpose of this study was to gather baseline soundscape data for use in the development of soundscape and air tour management plans, as directed by the National Parks Air Tour Management Act of 2000. In addition to soundscape planning efforts, park staff conducted behavioral observations on nesting peregrine falcons to investigate if low flying aircraft (helicopters and propeller planes) caused negative effects on birds within their breeding territories. Data collection followed protocols developed by the National Park Service (NPS) Natural Sounds Program, and included documenting existing and natural ambient levels and percent-time-audible statistics for sound sources. Peregrine falcon monitoring followed U.S. Fish and Wildlife Service protocols, and also included documenting behavioral responses when aircraft were in close proximity to active nesting areas or perch sites. Acoustic systems were deployed for approximately 30 days at frontcountry locations, and approximately 15 days at backcountry locations, and they logged one-second sound pressure (decibel) levels and continuous audio recordings. Additional information on the acoustic environment was collected at each monitoring location using

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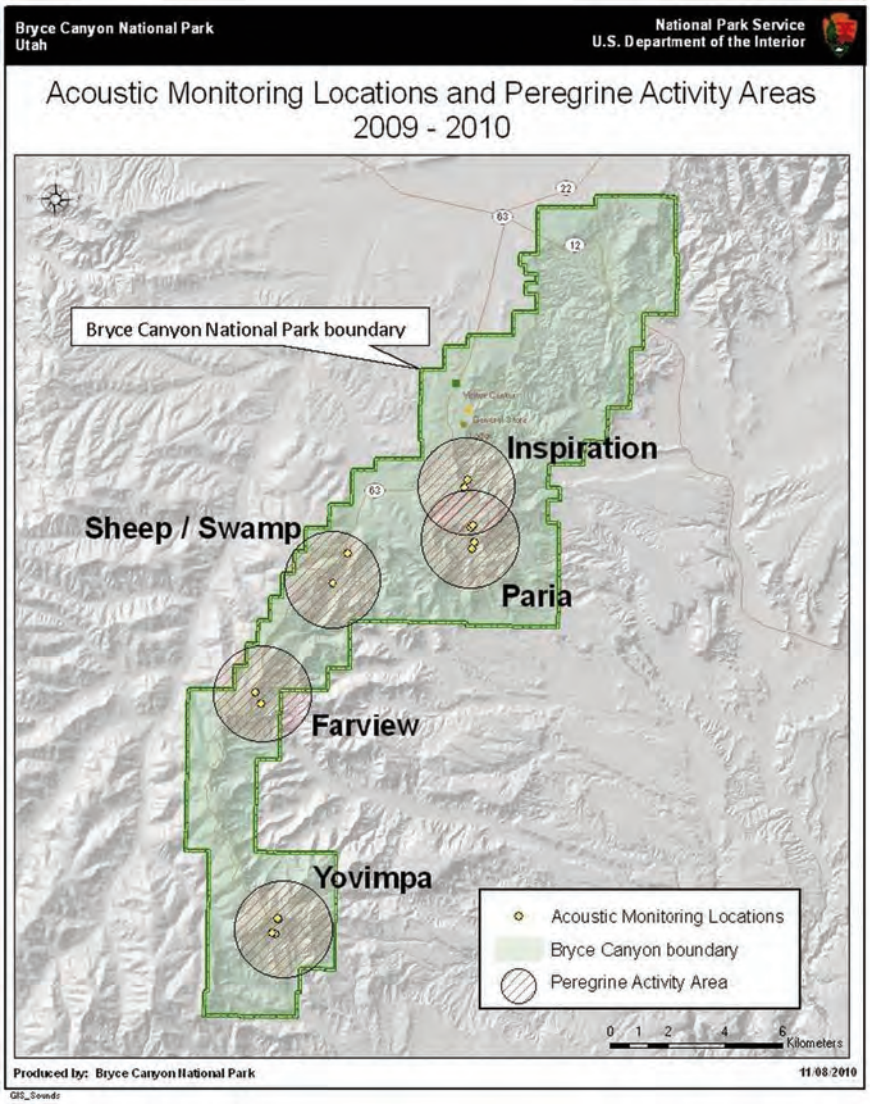

Figure 1. Acoustic monitoring sites and Peregrine Falcon activity areas 2009–2010, Bryce Canyon National Park, Utah.

on-site (attended) listening techniques. Each monitoring location documented existing (L_{50}, or median sound level) and natural ambient (L_{nat}) statistics in A-weighted decibels (dBA) for two time periods, day and night (Table 1). The A-weighted filter accounts for people's limited hearing response to higher and lower frequency sounds, and is frequently used when the primary concern is the effect of sound upon humans.

Natural and existing ambient sound

The natural ambient sound levels at all sites were highest during the day when wind and bird song occurred. The Paria Frontcountry 2010 site proved to have the loudest daytime natural ambient levels (39.0 dBA) where fierce spring winds were common. The quietest natural ambient levels among frontcountry sites (23.7 dBA) occurred at the Inspiration Frontcountry 2010 location. Among backcountry sites, the quietest daytime sound levels occurred at the Inspiration Backcountry 2009 site (18.7 dBA), and were loudest at the Yovimpa Backcountry 2010 site (36.2 dBA), where a small stream elevated sound pressure levels for all hours. Wind was audible over 50 percent of the time at nearly all sites, and likely reduced the percent time extrinsic and natural sounds were audible due to the "masking" of sounds by wind noise.

Across all sites, the existing ambient sound levels during the day were highest at Farview Frontcountry 2010 and Paria Frontcountry 2009/2010, and lowest at Inspiration Backcountry

	Nighttime Ambient (7pm – 7am)				Daytime Ambient (7am – 7pm)			
Site Name	L_{nat}	L_{10}	L_{50}	L_{90}	L_{nat}	L_{10}	L_{50}	L_{90}
FRONTCOUNTRY								
BRCA005	40.3	46.5	40.9	35.1	34.3	45.5	37.8	30.2
BRCA006	38.8	46.4	40.4	34.0	31.8	45.8	37.8	30.0
BRCA007	24.9	33.7	27.1	22.5	32.0	45.0	37.4	31.5
BRCA008	31.0	38.3	32.4	26.8	27.1	37.7	30.6	24.7
BRCA013	20.9	29.0	22.5	18.4	23.7	37.0	28.0	22.0
BRCA015	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BRCA016	39.3	44.5	40.2	35	39.0	46.9	41.0	34.4
BRCA017	40.6	46.5	41.6	37.0	37.4	48.0	42.1	35.8
BRCA018	24.4	32.1	26.0	21.9	27.0	39.7	32.4	25.6
BRCA019	36.1	44.3	38.0	32.0	29.1	40.6	33.4	27.7
BACKCOUNTRY								
BRCA009	25.8	31.0	26.2	21.9	27.9	36.5	28.5	22.0
BRCA012	24.1	31.9	25.0	19.7	24.5	35.1	26.1	20.5
BRCA014	15.3	23.4	16.2	14.7	18.7	31.4	21.7	17.7
BRCA020	22.3	29.2	23.2	18.2	31.2	38.9	32.4	26.9
BRCA021	18.5	26.0	19.0	16.6	28.9	38.7	31.2	24.8
BRCA022	15.8	23.0	16.0	14.6	21.5	33.5	23.7	18.4
BRCA023	36.0	37.9	36.0	35.3	36.2	39.4	36.5	35.0

*The median existing ambient (L_{50}) describes the acoustical environment as is, including both natural and extrinsic (human-caused) sounds. The natural ambient (L_{nat}) offers an estimation of what the acoustical environment would sound like in the absence of extrinsic sounds. Median L_{10} is the sound level exceeded 10% of the sampling period, with 90% of measurements quieter than L_{10}. Median L_{90} is the sound level exceeded 90% of the sampling period, with 10% of measurements quieter than L_{90}.

Table 1. Median natural and existing ambient* for all sites during day and night, Acoustic Monitoring Study 2009–2010, Bryce Canyon National Park, Utah.

2009, Farview Backcountry 2010, and Yovimpa Backcountry 2009. The combination of extrinsic sounds at the frontcountry sites, especially aircraft, vehicle, and visitor noise, as well as the prevalence of strong spring winds at the Paria locations, likely contributed to this result.

Contribution of extrinsic sound

Across all sites, human-caused sounds raised the existing ambient levels more during the daytime hours than at night. Aircraft, especially high altitude jets, were the dominant extrinsic sound source at all backcountry locations. All frontcountry monitoring areas, except Farview and Sheep/Swamp (which were located next to the park roadway and were dominated by vehicle noise) showed aircraft to be the dominant source of extrinsic sounds. Peak aircraft activity occurred at most locations between the hours of 8:00 and 10:00 a.m., with some sites showing minor peaks in the evening between the hours of 7:00 and 10:00 p.m. Aircraft were audible over 50 percent of the time at the Inspiration Frontcountry 2009 site from 8:00 a.m. to 9:00 a.m., and at the Inspiration Backcountry 2009 site from 10:00 to 11:00 a.m. and from 4:00 to 5:00 p.m. Across all sites, low-elevation fixed wing aircraft were audible less than five percent of the time but had a more dramatic effect on L_{10}, which documents acute conditions (90% of all measurements were quieter than L_{10}).

The contribution of extrinsic sound was greatest at Sheep/Swamp Frontcountry 2009, Inspiration Frontcountry 2009/2010, and lowest at Paria Frontcountry 2009/2010, and Yovimpa Frontcountry 2009. This is likely due, in part, to both the combination of aircraft, vehicle, and visitor noise audible at each site, and to the distance of sites from roads, viewpoints, and parking areas. Among the quieter backcountry locations, the contribution of extrinsic sound was by far

greatest at the Inspiration backcountry sites, followed by the Sheep/Swamp and Farview backcountry sites. This finding is likely due to the location of the Inspiration backcountry sites within the heavily visited Bryce Amphitheater, where extrinsic sound sources such as visitors and their vehicles were audible even below the rim.

The backcountry sites with the lowest contribution of extrinsic sound were Paria Backcountry 2009/2010 and Yovimpa Backcountry 2010. During the early morning hours at several of the backcountry sites (Inspiration 2009, Swamp Canyon 2010, and Farview 2010) the existing and natural ambient levels were within 10.0 to 15.0 dBA of the noise floor of the recording equipment, indicating that these sites were, at times, very quiet. In the absence of natural sounds such as wind and flowing water, which led to increased natural and existing ambient levels, it is likely that other backcountry locales would have displayed similar results.

There was considerable variation in the percent time extrinsic sounds were audible across sites. For example, at the Sheep/Swamp Frontcountry 2009 location, extrinsic sounds were audible nearly 54 percent of the time, while they were only audible 11.6 percent of the time at both the 2009 and 2010 Paria Backcountry locations. This variation is largely due to the proximity of roads or trails to the frontcountry locations where visitors and their vehicles are in close proximity. The presence of wind, which was ubiquitous throughout the study area, also reduced the percent time extrinsic sounds were audible.

Table 2 reports the percentage of time that measured sound levels were above those levels that have known negative impacts on human experiences or health (Haralabidis et al. 2008; EPA 1974), for each of the monitoring locations during daylight and nighttime hours. These values should not be construed as thresholds of impact, but rather sound levels which have been identified in scientific literature as having relevance to the human or wildlife experience in parks (e.g., noise levels that can cause increases in blood pressure and heart rate, or interfere with the perception of speech).

Table 2. Percent time above metrics for night and day, Acoustic Monitoring Study 2009–2010, Bryce Canyon National Park, Utah.

	% Time above sound level (7pm - 7am)				% Time above sound level (7am - 7pm)			
Site Name	35 dBA	45 dBA	52 dBA	60 dBA	35 dBA	45 dBA	52 dBA	60 dBA
FRONTCOUNTRY								
BRCA005	76.47	23.11	8.93	0.42	56.49	11.64	3.97	0.39
BRCA006	71.46	27.87	8.05	0.35	55.03	12.31	4.21	0.42
BRCA007	16.82	0.39	0.01	0.00	59.27	14.65	2.70	0.10
BRCA008	32.72	2.66	0.16	0.00	31.95	3.13	0.36	0.02
BRCA013	5.53	0.24	0.02	0.00	20.45	1.79	0.20	0.01
BRCA016	69.41	33.98	4.66	0.02	74.35	27.09	3.55	0.10
BRCA017	72.13	37.38	5.64	0.06	77.48	29.73	3.99	0.11
BRCA018	18.77	0.34	0.01	0.00	33.88	2.81	0.27	0.03
BRCA019	57.18	22.39	2.84	0.03	39.45	7.94	0.79	0.05
BACKCOUNTRY								
BRCA009	61.12	0.80	0.00	0.00	22.51	2.88	0.56	0.01
BRCA012	16.17	0.33	0.01	0.00	18.06	1.01	0.18	0.01
BRCA014	1.51	0.05	0.00	0.00	5.74	0.47	0.07	0.00
BRCA020	5.61	0.20	0.00	0.00	35.57	3.04	0.23	0.00
BRCA021	3.59	0.05	0.00	0.00	29.25	1.82	0.13	0.00
BRCA022	2.30	0.13	0.00	0.00	11.94	1.30	0.18	0.02
BRCA023	95.24	0.25	0.01	0.00	83.72	2.27	0.39	0.06

Peregrine falcon monitoring

Peregrine falcons were detected at all territories over both years of monitoring, with the exception of the Sheep/Swamp territory in 2009. Recruitment (visual or aural identification of juveniles) was recorded for 2 aeries in 2009 (2 juveniles observed), and 2 aeries in 2010 (3 juveniles observed). During over 100 hours of behavioral observations, no incidents of peregrine reacting severely to overflight events were recorded. Difficulty in sighting birds during overflight events, as well as limited aircraft activity (helicopter tours were not in operation during both field seasons due to staffing limitations of those air tour operators) may have affected the monitoring results.

Conclusions and management implications

The results from this study present recent information on the acoustic environment at five peregrine falcon territories at Bryce Canyon. Because of the wide distribution of these territories, detailed records of ambient sound pressure levels throughout the park were documented at both front- and backcountry locations, and are a good representation of the park's overall soundscape. In conjunction with the percent time audible statistics, these data have been used to report existing ambient levels and have helped to estimate natural ambient levels in many areas of the park. As would be expected, frontcountry locations generally have higher existing ambient sound levels compared to backcountry locations. This result is consistent with visitor use patterns and the concentration of visitation at the park's viewpoints in the main Bryce Amphitheater.

Overall, this study found that aircraft, especially high-altitude jets, were the most frequently audible extrinsic sound at nearly all monitoring locations. In backcountry locations, aircraft (jets and propeller planes) were responsible for virtually all extrinsic sound. Extrinsic sounds at frontcountry locations were comprised of varying combinations of aircraft, vehicle, and visitor noise, with aircraft being the dominant extrinsic sound source at nearly all sites. Aircraft sounds were audible on average 21.2 percent of the time at frontcountry locations and 18.2 percent of the time at backcountry locations. Aircraft were audible over 50 percent of the time at the Inspiration monitoring locations during certain hours of the day. Across all sites, low-elevation fixed wing aircraft were audible less than 5 percent of the time, but had a greater impact on the acoustic environment than high-altitude jets.

The effects of noise on wildlife can be difficult to measure and interpret, and can take many forms (Barber, Crooks, and Fristrup 2010; Pater, Grubb, and Delaney 2009; Pepper, Nascarella, and Kendall 2003). Most researchers agree that noise can affect an animal's physiology and behavior, and if it becomes a chronic stress, can be injurious to an animal's energy budget, reproductive success, and long-term survival (Radle 1997). Previous research on the effects of aircraft overflights on peregrine falcon parental behavior detected subtle differences in activity budgets between overflight and control areas, but found no evidence that overall attendance patterns differed, depending on exposure to overflights (Palmer, Nordmeyer, and Roby 2003). While it is unclear if human-caused sounds can impact peregrine breeding success, continuous overflights of breeding territories may represent a chronic stress to animals, and could impact other important life cycle activities, such as inter-specific interactions for breeding-site selection (Sergio et al. 2004). Additionally, analysis of soundscape impacts on human hearing and experience may serve as a proxy for the potential impacts to other vertebrates, because humans have more sensitive hearing at low frequencies than most species (Dooling and Popper 2007).

Based on surveys at Bryce Canyon, a large percentage of park visitors (68%) value natural quiet and indicate that unwanted noise has led to detractions from their experience. Based on this finding and previous research on the effects of noise on humans and wildlife, it is clear that management decisions that attempt to minimize potential negative impacts to both visitors and wildlife are warranted at Bryce Canyon. Future data collection should focus on popular viewpoints such as Sunset and Bryce Points and under-the-rim trails within the Bryce Amphitheater.

Additional soundscape monitoring at the Visitor Center and within the park's historical district (specifically the Bryce Canyon Lodge area) should also be conducted to assess noise impacts in those locations. Impacts on the soundscape from vehicles, especially tour buses and the park's shuttle buses, were not well documented in this study due to the objectives of the research, and placement of the acoustic monitors. Further investigation in the park's heavily used frontcountry locations along Bryce Amphitheater is required to assess this impact to park visitors and wildlife.

Acoustical monitoring efforts at Bryce Canyon have yielded valuable results that will allow park managers to better understand the existing acoustic environment of the park, and plan for the challenges associated with soundscape conservation. Monitoring existing conditions and trends allows managers to take action to move towards desired future conditions. Contributions and impacts to the park's soundscape from aircraft, vehicles, visitors, and park-directed activities will require additional research, and will be influenced by management decisions and NPS directives. The acoustic data collected during this study provides baseline information for the development of acoustical indicators and standards in upcoming soundscape and air tour management plans.

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