

Monitoring the Acoustic Environment of the Ruth Glacier: 2019

Davyd_Betchkal@nps.gov • 2020-01-17 • [Technical Assistance Request #7081](#)

Executive Summary

- The DENARUTH site remains out of compliance with the 2006 Denali Backcountry Management Plan. Measurements in 2019 suggest *overall* conditions have further degraded since 2016 due to Chalet-related noise from generators/construction/stereos, but aviation noise impacts fell between 2002 and 2016 impact levels.
- When focused on the expected change (aircraft) and overlapping dates, change in compliance with the Percent Time audible standard from 2016 to 2019 was accurately predicted in the *Access and Use Request, Ruth Glacier, Mountain House LLC EA*.
- Despite deterioration of the landing strip in early August, many of the seasonal patterns in transportation appear consistent across years. This suggests flight routes pass through – and impact – the amphitheater independent of the ability to land.
- At the daily scale, the acoustic environment of the Sheldon Amphitheatre represents a *saturation process*. In other words, aircraft operations in the area overlap to the degree where substantial reductions in the number of vehicles would be necessary to measurably reduce the duration of noise. Few environments in Alaskan parks have been impacted to this extent.



Figure 1. Acoustic recording system deployed to the amphitheater, 2019.

Background / Summary of Results

As part of the *Access and Use Request, Ruth Glacier, Mountain House LLC EA*, the NPS stated that it “would enhance [acoustic] monitoring efforts during the 2019 summer season to evaluate possible changes to aviation activity levels.” This report is an update on those efforts.

Acoustic monitoring equipment was deployed to the same location sampled in 2002 and 2016 (see NPS 2019 for information on previous deployments). We annotated all varieties of mechanized noise in spectrograms throughout the entire summer season, 05/20/2019 through 09/22/2019. In addition, Concessionaire-reported landing data were gathered/filtered for use as an explanatory covariate.

Important to the context of 2019 measurements are airstrip conditions. Due to heavy rain and snow, landing was difficult during the months of August and September. This placed constraints on the volume and proximity of fixed-wing aircraft operations. The Sheldon Chalet’s Special Use Permit did not go into effect until early August, but extended periods of helicopter use punctuated the season.

Results in Table 2 extend (and *in some cases, correct*) values reported in the EA. Measurements in 2019 suggest conditions have degraded at the DENARUTH site since 2016, even surpassing baseline impacts measured in 2002. This is partly due to newly-observed generator noise, construction, drone use, and stereos at the Sheldon Chalet. A summary considering only aircraft impacts is provided as a footnote to Table 2. It suggests that the aircraft component of noise has degraded towards, but not exceeded 2002 conditions.

Table 2. Noise metrics comparing conditions on the Ruth Glacier to those typical for parks in Alaska. The 2019 Ruth Glacier site is the most recent measurement within audible range of the authorized action.

Measurement Site	Overall Time Noise is Audible	Median Noise Free Interval*	Median Noise Events Per Day
Ruth Glacier 1999** (Van Horn and Valentine 1999)	17 – 21% of sample	-	-
Ruth Glacier 2002	20.5%	12.9 minutes	48.0 per day
Ruth Glacier 2016	17.5%	15.3	34.0
Ruth Glacier 2019***	23.1%	10.3	49.0
Backside Lake 2014	14.5%	4.0	49.5
Toe of the Ruth Glacier 2006	12.8%	4.9	54.0
Toe of the Ruth Glacier 2017	21.8%	5.0	45.0
Median Conditions in Alaskan Parks	3.7%	27.8	14.0

*Median noise free interval describes the typical amount of time between when one noise event ends and when the next begins.

** Results from ranger patrols totaling to ≤ 33 full days of observation. Only time audible was measured in the study.

*** Prior to 2019 all impacts were due to aircraft. Presence of generators, construction, and stereos at the Sheldon Chalet increased aggregate impacts in 2019. Considering *only* aircraft noise, 2019 figures become: 17.9% of sample, 12.7 minutes, 45.0 events per day.

Compliance with Denali Backcountry Management Plan standards

Denali’s Backcountry Management Plan implemented three standards for acceptable condition of the acoustic environment in the vicinity of the Ruth Glacier (NPS 2006, pg. 41):

1. **Time Audible:** “motorized noise may be audible up to 50% of any hour”
2. **Events Per Day:** “up to 50 motorized noise intrusions per day”
3. **Maximum Sound Pressure Level:** “motorized noise does not exceed 60 dBA”*

(*note that this level also corresponds to the maximum level for motorized noise allowed as per Federal Regulation, 36 C.F.R. § 2.12, as well as speech interference at 1 meter as per EPA 1974.)

There is some level of exceedance of every BMP standard in the greater Ruth Glacier area. Table 3 describes the base rate of exceedance for each indicator in the plan. Over the period from 2002 to 2016 conditions improved across every indicator.

In 2019, change *depended on the indicator*. Compliance with the 'Maximum Sound Pressure Level' standard continued to improve. Compliance with the 'Events Per Day' standard remained the same. Compliance with the 'Time Audible' standard decreased. This latter change is due to addition of the mechanized noise sources from the Sheldon Chalet listed above. If the 'Time Audible' standard could be determined with only aircraft noise considered, compliance would have improved in 2019.

Table 3. Exceedance of Denali's BMP standards at measurement sites along the Ruth Glacier. No site sampled in this area was in compliance with the BMP.

Measurement Site	Time Audible Standard	Events Per Day Standard	Sound Pressure Level Standard
Ruth Glacier 2002	21% of hours	31% of days	57% of events
Ruth Glacier 2016	17%	27%	41%
Ruth Glacier 2019**	22%	27%	30%
Backside Lake 2014	9%	48%	14%
Toe of the Ruth Glacier 2006	4%	59%	22%
Toe of the Ruth Glacier 2017	19%	23%	20%

** Prior to 2019 all impacts were due to aircraft. Presence of generators, construction, and stereos at the Sheldon Chalet influenced compliance in 2019. Considering *only* aircraft noise, 2019 figures become: 16% of hours, 27% of days, 34% of aircraft events.

Plots showing the details for each indicator with respect to its standard are included in the section *Supplemental Data* below as Figures 6, 7, 8.

The EA predicted changes in compliance. To test these predictions, we focused on 05/15 – 07/18, which was sampled in both 2016 and 2019. We considered *only* aircraft in the comparison, as they were affected by the management action and present in both years.

Next, we confirmed the change in helicopter noise between 2016 and 2019 was similar to the EA's expectation: 4 minutes per day 3 days per week, averaging to 1.7 minutes per day. In fact, this is almost exactly what was observed: a median increase of 1.7 minutes per day. (Note that this increase may not have anything to do with the activity analyzed by the EA; instead it may just be routine use of the Sheldon Chalet helipad).

We predicted the action would result in an additional +0.9% of hours in this time period being out of compliance with the BMP. The observed change was +0.8% of hours. This suggests stability in human behavior across years such that previous observations can be used as a reliable baseline to

predict changes resulting from management action (Figure 2). The monitoring approach used in the EA was novel, and may be worth carefully applying elsewhere.

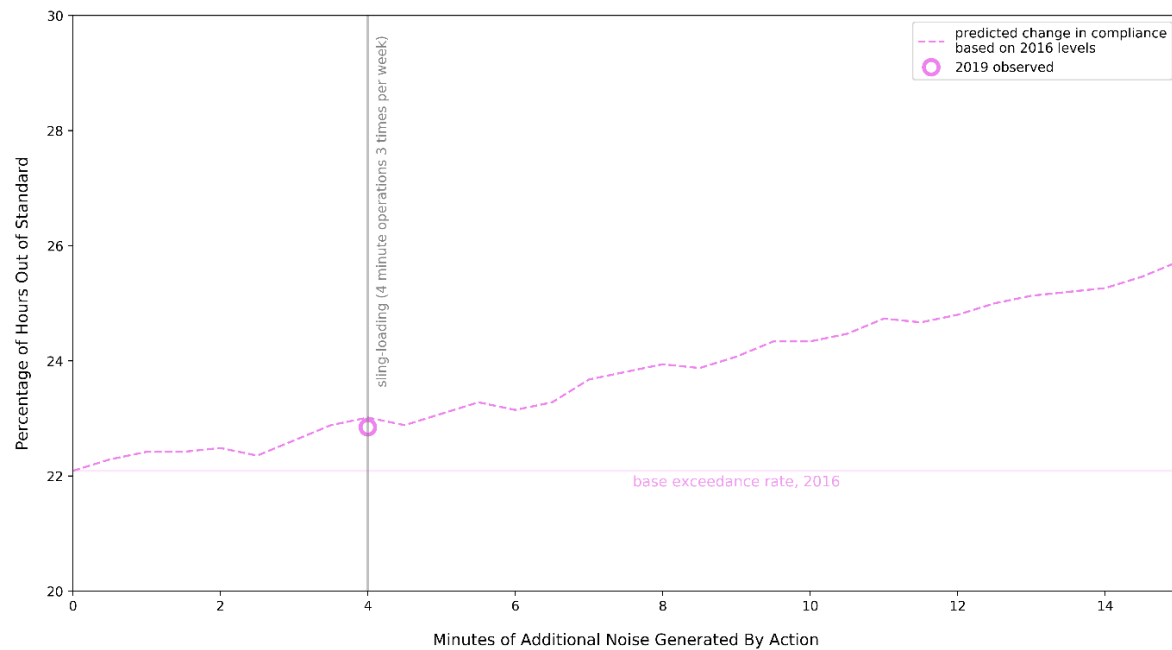


Figure 2. Predicted effect of varying the duration of cargo transport noise on compliance with the Denali BMP Percent Time Audible standard at the Ruth Glacier site (modified from Figure 2 in the EA). Vertical line indicates the expected duration of authorized cargo transport activities. The horizontal line indicates the level of exceedance in 2016, and the hollow circle indicates the level of exceedance observed in 2019.

Seasonal Patterns

In this section we take a closer look at how noise conditions change throughout a season. Denali is strongly seasonal – and understanding that should inform monitoring considerations. For example: daily durations of helicopter noise are relatively similar across years (Figure 3), but pronounced episodes of intense noise (three to six times greater in duration than a ‘normal’ day) have increased in frequency since the Sheldon Chalet construction began in mid-summer 2016. These intense impacts are spaced approximately 25 days apart, as if part of scheduled operations.

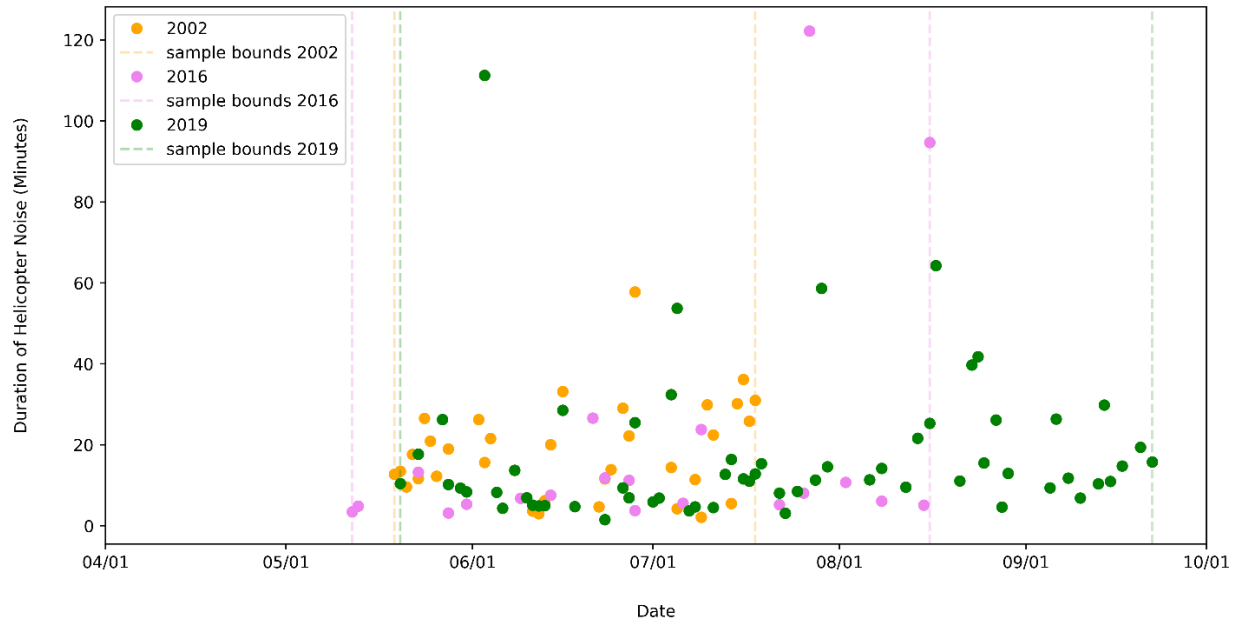


Figure 3. Duration of helicopter noise per day, in minutes at the Ruth Glacier monitoring site. Temporal sampling bounds are indicated by dashed lines. Days with very intense helicopter noise have increased in frequency since the Sheldon Chalet was built in mid-summer 2016.

Measurements that relate the causes of change to their effects are also pivotal to a successful monitoring program. Concessionaire landing data are reported to Denali on a regular basis throughout the summer season. Full-season records for each operator were merged to arrive at total counts for each day. These data can inform the linkage between a cause (landings) and the effect (noise), as shown in Figure 4.

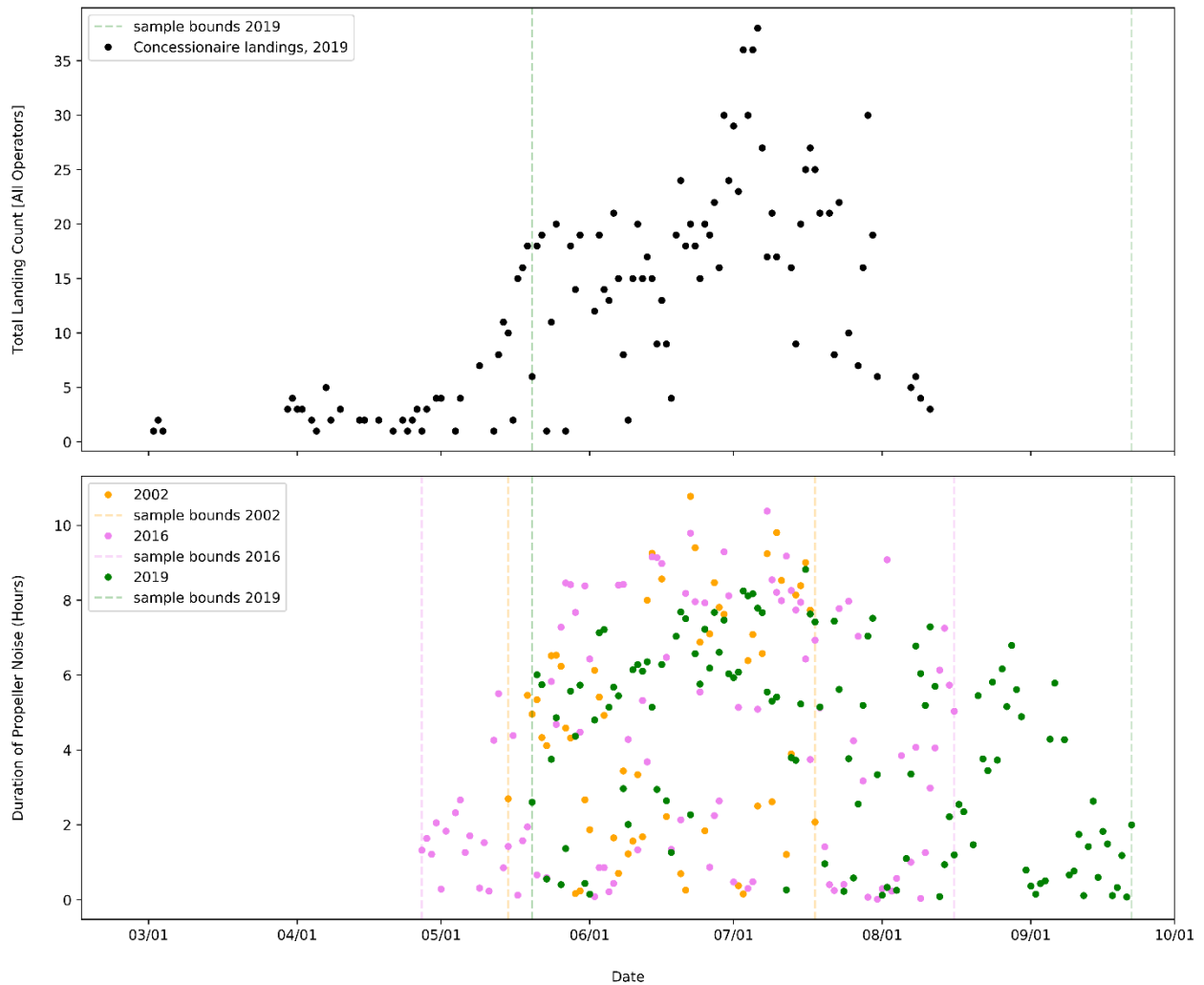


Figure 4. Two time series of propeller aircraft activity. The upper plot shows the number of Concessionaire-reported landings at the Ruth Glacier airstrip on each day. The lower plot shows the audible duration of propeller aircraft noise on each sampled day in 2002, 2016, and 2019. Vertical lines indicate sampling bounds for each year. Since the landing data are from 2019, the corresponding sample bounds are extended across both plots. Note that unusual deterioration of the landing strip in 2019 curtailed the landing season to early August, but noise impacts persist at similar levels to 2016 beyond this date.

It is apparent that landings and aircraft noise correspond in time. How do they correspond in magnitude? To explore this, we create a *phase space* plot of the system – disregarding time and plotting the two magnitudes against one another as if they were independent (Figure 5.) The plot immediately reveals strong correlation between daily landing counts and total time audible.

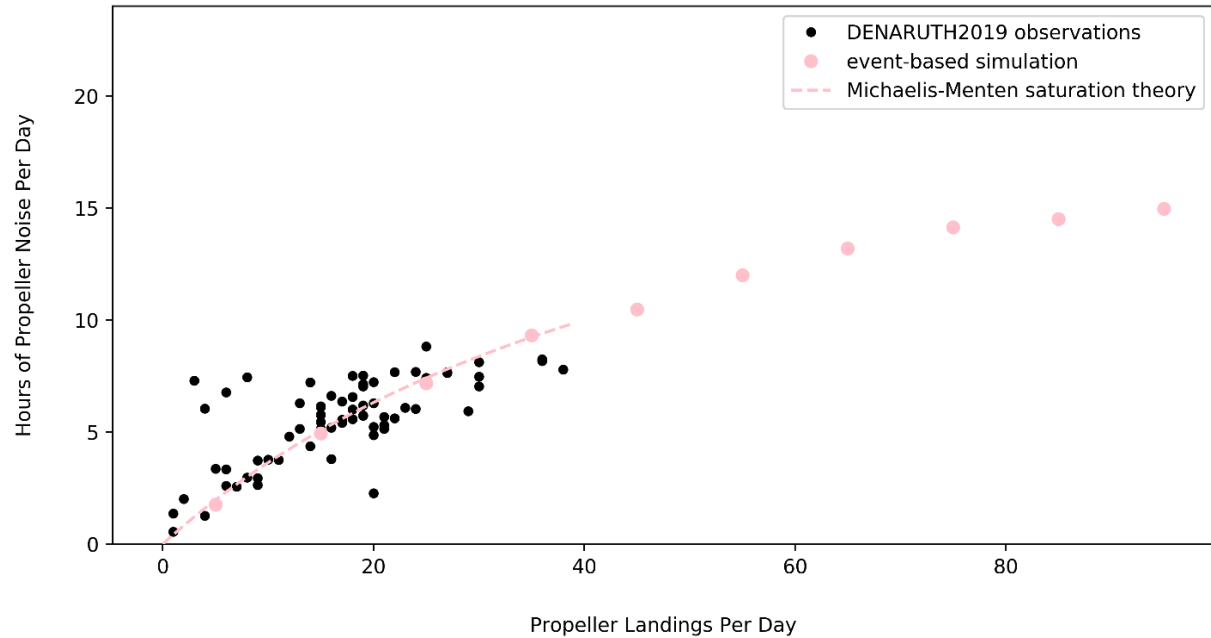


Figure 5. Propeller aircraft landings versus total time audible. Superposed are event-based simulation results using typical parameters from DENARUTH2019 (pink dots), and a fit using saturation theory (pink dashed line). Vertical axis is scaled to 24 hours to show the number of landings required to truly saturate the system.

Aggregate properties of the Ruth Glacier transportation system can be simulated using a flexible event-based modelling tool written in Python (<https://github.com/dbetchkal/AcousticRecord>). This allows us to extend our understanding beyond a single season of observations to make more general predictions about how the system will respond to management action.

To create the model three input parameters are required: an $L_{Aeq, 1s \max}$ distribution (equivalent to the *Maximum Sound Pressure Level* standard, above), a distribution of durations, and daily timing probabilities. We used data from DENARUTH2019 to inform our choices, as described in Table 4. We then compute the total duration of noise given the number of landings. Model results are shown as pink dots in Figure 5.

Table 4. Input settings for event-based model of propeller aircraft noise at DENARUTH.

Parameter	Lower Bound	Upper Bound
$L_{Aeq, 1s \max}$ [uniform distribution]	10 th percentile observed	90 th percentile observed
Duration [uniform distribution]	10 th percentile observed	90 th percentile observed
Event Timing [sinusoidal distribution]	maximum probability at 12:00, minimum at 00:00	

An analogous numerical expression of saturation is found in enzyme kinetics (Michaelis and Menten 1913). Expressed here in terms of the acoustic environment:

$$TA = \frac{TA_{max} L}{K_{sat} + L}$$

Where L is the number of landings TA is total time audible, TA_{max} is the maximum time audible for the system (24 hours), and K_{sat} is a constant which represents the number of landings at which the system is half-saturated (12 hours of audible noise).

For the Ruth Glacier system, K_{sat} was found to be 56 landings. Such a level of use would subvert the purpose of the Ruth Major Landing Area as stated (NPS 2006, pg. 36):

"Provide high-use airplane landing areas that are suitable for both day use and expedition drop-off and pick-up. Seasonal, May – September."

These two lines of evidence (empirical + theoretical) together support the premise that on a daily scale, the acoustic environment of Sheldon Amphitheatre represents a *saturation process*. As landings increase, impacts increase more and more slowly. This is due to greater and greater overlap in noise events. The more saturated an area is allowed to become, the more difficult noise is to mitigate. In other words, *desaturation costs are also non-linear*: small reductions in aircraft numbers will cause little or no improvement. Knowledge of this property is critical for management purposes. In fact, it may be the most important message of this document to highlight that the area is already experiencing saturation effects.

Supplemental Data

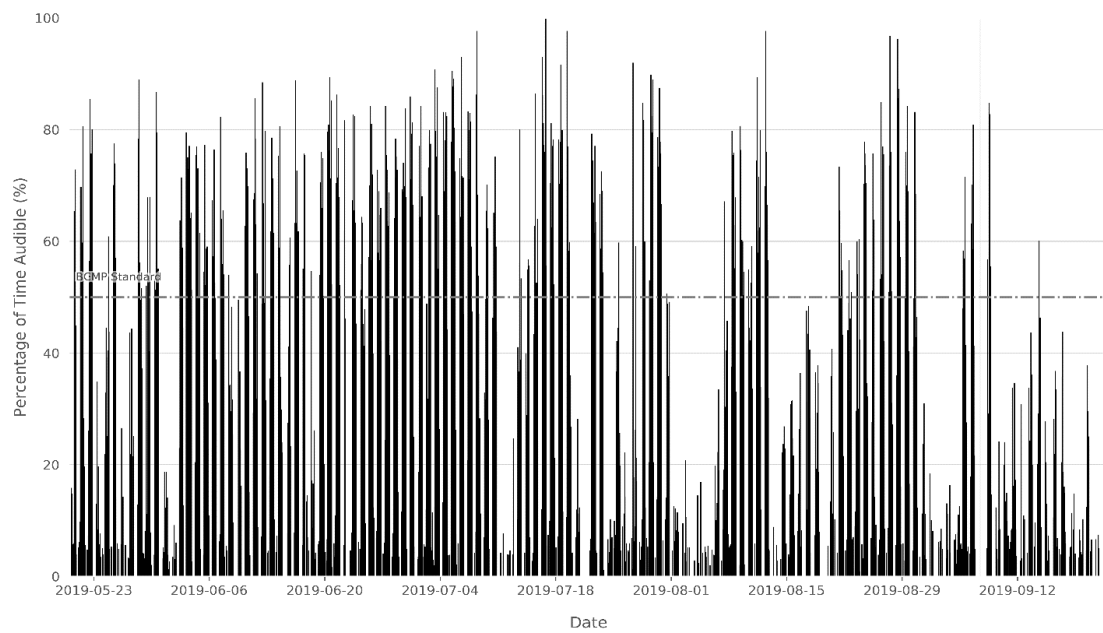


Figure 6. Audibility of aircraft noise at Ruth Glacier, 2019.

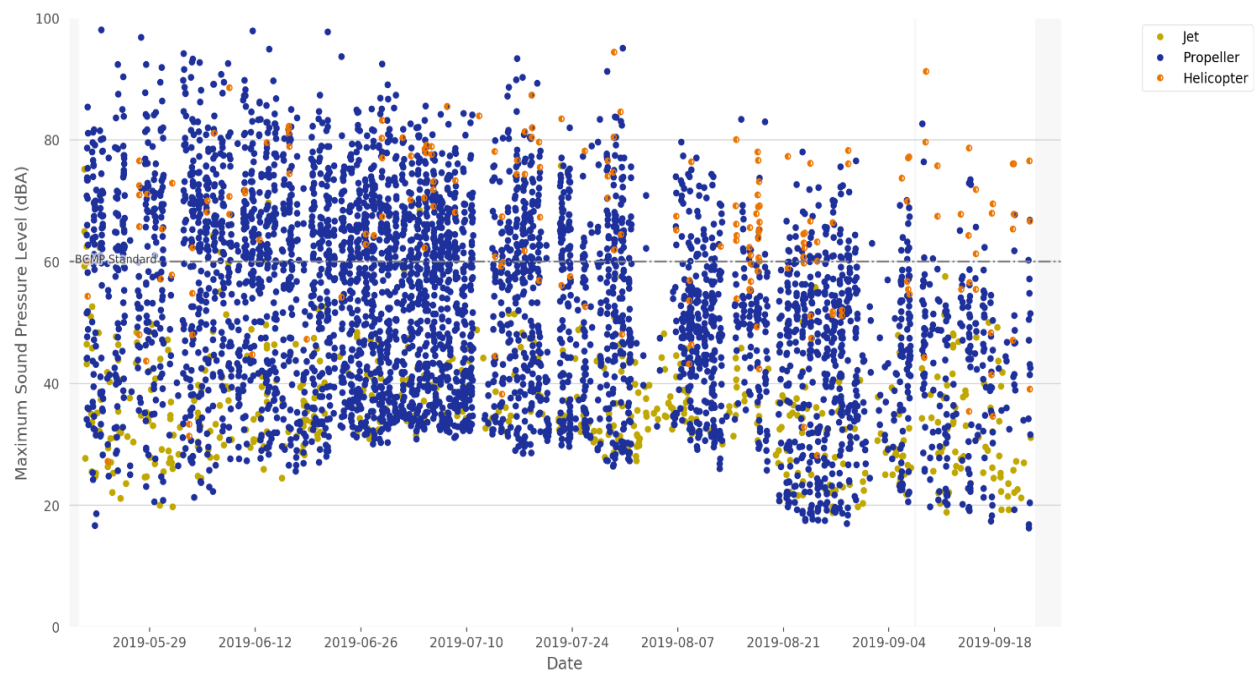


Figure 7. Maximum one-second sound pressure level for each aircraft event detected at Ruth Glacier, 2019.

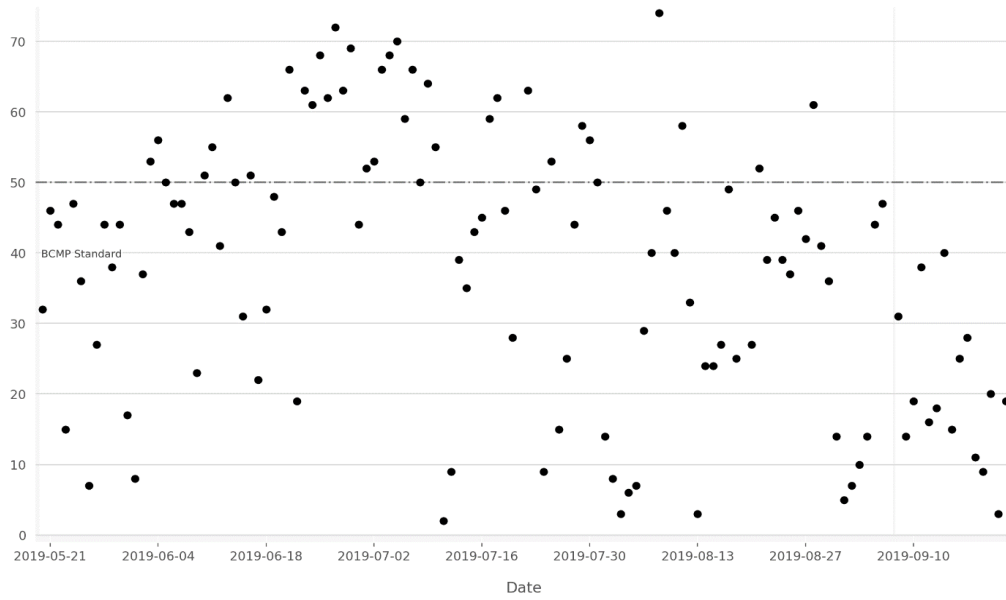


Figure 8. Number of aircraft noise events detected per day at Ruth Glacier, 2019.

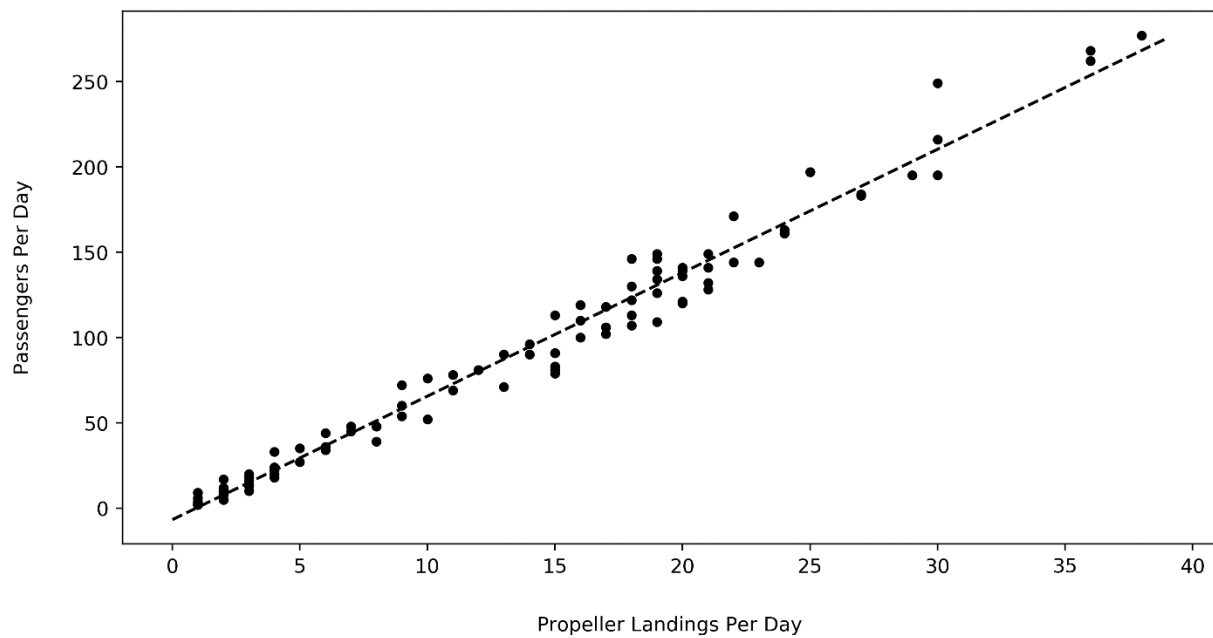


Figure 9. Landing counts and passenger counts are strongly correlated, $r^2 = 0.98$, $m = 7.2$ passengers per landing.

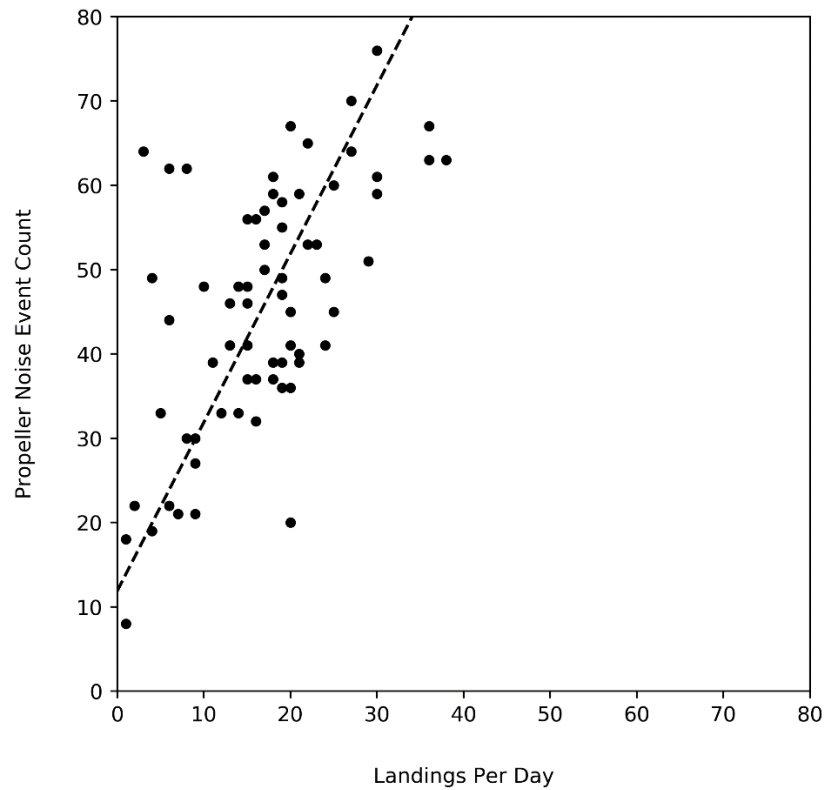


Figure 10. One arrival/departure pair should theoretically result in two noise events. Fitting a line with $m = 2$ shows that landing counts and noise event counts are moderately correlated. The fit suggests a y-intercept of 11.9 noise events per day. This simple linear model has an RMSE of ± 14.2 noise events.

References

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