EFFECTS OF BACKCOUNTRY AVIATION ON DEER (ODOCOILEUS SPP.) STRESS PHYSIOLOGY

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prepared by
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RESEARCH PROGRAMS

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EFFECTS OF BACKCOUNTRY AVIATION ON DEER (*ODOCOILEUS spp.*) STRESS PHYSIOLOGY

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16. Abstract

A study to investigate stress levels on wildlife resulting from backcountry recreational aviation primarily composed of single engine aircraft was conducted in 2014 – 2015 in western Montana and wilderness areas in Idaho. The study focused on white-tailed deer and mule deer because of their ubiquitous distribution and relatively high densities allowing for repeated measures and comparative sampling between airstrip sites and control sites. Fecal deposits were collected from deer and analyzed for fecal glucocorticoid metabolite (FGM) concentrations as an indicator of stress levels. Samples were collected from a suite of airstrip sites that ranged in use from high frequency of visitors to airstrips with very low frequency of use. Airstrip sites were compared with control sites composed of campgrounds and recreational access sites that were selected to mimic the airstrip sites, but without aircraft takeoffs and landings. Visitor day-use varied among airstrip and non-airstrip control sites, but were similar in the range of variation between site types.

There was no significant difference in airstrip and control sites in 2014, with the exception of what we believe to be weather related stress levels expressed by deer at the Schafer Meadow Montana airstrip. In 2015, data analysis suggests that stress levels among deer were higher at the non-aviation, control sites than at the airstrip sites, in spite of the fact that two of the airstrip sites had the highest visitor-use among both airstrips and controls. The lowest FGM concentrations among all sites was found at Fish Lake airstrip, which also had the lowest human presence among both airstrip and control sites. Based on the results of our study, we concluded that there is no significant increase in stress levels among deer due to recreational aviation activity (e.g., takeoffs, landings, prop noise, camping, human presence) at backcountry airstrips compared to that expressed by deer as a result of similar, but non-aviation recreational activity (e.g., camping, motorized access to campground or trailhead, human presence) at campground and recreation access sites.

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Devin Landry is a Masters student in the Wildlife Biology program at the University of Montana. His Major Advisor is Dr. Creagh Breuner. The data presented in this report represents a portion of the data for DL's degree program. Additional data have been collected to investigate specific sound signatures of high performance aircraft at different RPM. DL also conducted a social-ecological study of recreational aviation pilots.

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Abstract

A study to investigate stress levels on wildlife resulting from backcountry recreational aviation primarily composed of single engine aircraft was conducted in 2014 – 2015 in western Montana and wilderness areas in Idaho. The study focused on white-tailed deer and mule deer because of their ubiquitous distribution and relatively high densities allowing for repeated measures and comparative sampling between airstrip sites and control sites. Fecal deposits were collected from deer and analyzed for fecal glucocorticoid metabolite (FGM) concentrations as an indicator of stress levels. Samples were collected from a suite of airstrip sites that ranged in use from high frequency of visitors to airstrips with very low frequency of use. Airstrip sites were compared with control sites composed of campgrounds and recreational access sites that were selected to mimic the airstrip sites, but without aircraft takeoffs and landings. Visitor day-use varied among airstrip and non-airstrip control sites, but were similar in the range of variation between site types.

There was no significant difference in airstrip and control sites in 2014, with the exception of what we believe to be weather related stress levels expressed by deer at the Schafer Meadow Montana airstrip. In 2015, data analysis suggests that stress levels among deer were higher at the non-aviation, control sites than at the airstrip sites, in spite of the fact that two of the airstrip sites had the highest visitor-use among both airstrips and controls. The lowest FGM concentrations among all sites was found at Fish Lake airstrip, which also had the lowest human presence among both airstrip and control sites.

Based on the results of our study, we concluded that there is no significant increase in stress levels among deer due to recreational aviation activity (e.g., takeoffs, landings, prop noise, camping, human presence) at backcountry airstrips compared to that expressed by deer as a result of similar, but non-aviation recreational activity (e.g., camping, motorized access to campground or trailhead, human presence) at campground and recreation access sites.

Introduction

Backcountry aviation is a popular form of recreation throughout the US and Canada, but especially in the Mountain West. However, it is unclear whether the activity of recreational aircraft has adverse effects on wildlife. Numerous studies have sought to understand the effects of human-related activities and disturbances on free-living animal populations, such as human presence and noise (Stankowich 2008, Barber et al. 2010, Chan et al. 2010). Disturbance has been extensively studied across wildlife taxa (Bleich et al. 1994, Cote 1996, Lawler et al. 2005, Goudie 2006); although research on aircraft noise in particular has focused on behavioral responses associated either with military aircraft, high frequency takeoff and landings at commercial airports, or sightseeing aircraft around national parks and wildlife preserves (Pepper et al. 2003). Results from these studies have shown that the effects of human disturbance on observable animal behavior is highly context-dependent, and an animal's decision to avoid or tolerate disturbance is influenced by a suite of factors (Bejder et al. 2009, Shannon et al. 2015). While direct observation of behavioral response remains an invaluable tool, the effects of human disturbance on mammalian wildlife can be investigated very quantitatively using stress physiology and chemical analyses.

Stress physiology metrics in wildlife have been shown to correlate with the relative severity of stress responses across different levels of human disturbance (Wikelski and Cooke 2006, Tarlow and Blumstein 2007). Using stress physiology techniques provides a mechanistic understanding of the effects of disturbance. The basic concept applied in this study is that stress hormones secreted by vertebrates when presented with an environmental "stressor" to heighten awareness or provide some form of short-term survival advantage are released by the stressed individual and then metabolized and excreted in the form of fecal glucocorticoid metabolites (FGM). Thus, the analysis of FGM is a very useful tool in conservation biology by providing a non-invasive measurement of circulating stress hormones released into the blood at the time of stress and then subsequently deposited into the feces (Wasser et al. 2000). The feces are then collected and analyzed for the concentration of FGM.

The primary aim of this project was to evaluate the relationship between disturbance intensity, specifically by backcountry recreational aviation, and stress response by white-tailed deer *(Odocoileus virginianus*) and mule deer (*O. hemionus*). This was done by examining glucocorticoid concentrations in the feces. It is important to note, however, that an animal's physiological response to a stressor often depends on the context in which the stressor occurs (Wright et al. 2007), such as the predictability with which a stressor occurs in an animal's environment or the perception of intensity of the stressor by the organism (e.g., perception of threat or risk).

Background

Cervid Natural History and *Ecology*

White-tailed deer and mule deer are relatively small ruminants in the cervid family. White-tailed deer in particular have undergone one of the most successful population recoveries since the turn of the 20th century and are now distributed throughout the continental U.S. (Foresman 2012). Their behavioral plasticity and general habitat preference—found anywhere from forested, wetter areas to open, drier areas—have been key factors in promoting their current abundance. Both species are largely crepuscular (i.e., highest foraging and movement rates during dusk and dawn). They generally forage in open meadow habitats during these periods and reenter covered habitats, such as riparian woodlands and coniferous forests, during peak daytime hours (Beier and McCullough 1990). The native mule deer is found across habitat types from mixed coniferous forests to sagebrush steppes. When faced with resource competition from white-tailed deer, mule deer tend to prefer drier, more open habitat at higher elevations (Foresman 2012). During the spring and summer seasons, forbs, and grasses are the primary food sources for both white-tailed and mule deer. Both species begin to enter breeding season during late August and are fully "in the rut" by September in the US northern Rocky Mountains.

Organismal Stress Physiology

Organismal stress response in mammals is regulated by the hypothalamic-pituitary-adrenal axis (HPA). The broad effects of HPA activation are meant to facilitate survival in the face of a challenge in which blood glucose concentration and vasodilation increase to transport available energy to muscles while non-essential activities, such as reproduction and growth, are inhibited in order to allocate needed energy for survival of the individual (Romero 2004). While the HPA response is highly adaptive and conserved in most vertebrates, its long-term effects on growth and reproductive effort are considered maladaptive and can decrease individual survivorship and fitness and thus also population-scale viability (Wingfield et al. 1998, Romero and Wikelski 2001).

Glucocorticoids (e.g., vertebrate stress hormones such as cortisol) are secreted by the adrenal gland into the bloodstream. Glucocorticoids circulating in the bloodstream are metabolized in the liver and are excreted as conjugates in urine and feces (Möstl et al. 2002). The analysis of fecal samples provides researchers with a more integrated understanding of the organismal stress response because feces contain concentrations of glucocorticoids that reflect the levels that have been circulating in the bloodstream over a matter of hours, as opposed to the instantaneous measurement of adrenal activity gained from direct plasma (blood) sampling (Sheriff et al. 2011). Fecal sampling is also a non-invasive sampling technique for measuring glucocorticoid concentrations in free-living species (Wasser et al. 1997, Monfort et al. 1998, Harper and Austad 2000, Millspaugh et al. 2001, Von der Ohe et al. 2004, Dantzer et al. 2010) thereby reducing stress potentials that come from capture and blood withdrawals.

Fecal glucocorticoid metabolite analysis from wildlife populations has provided researchers with novel insights into demographic parameters such as survival rates and the effects of status in social animals (Sands and Creel 2004, Cabezas et al. 2007, Van Meter et al. 2009). Validation experiments in other studies have determined that FGM is a particularly good measure of organismal stress in deer, other cervids such as elk and caribou, and other mammals (Dehnhard et al. 2001, Millspaugh et al. 2002, Huber et al. 2003, Ashley et al. 2011). Fecal stress hormone concentrations in white-tailed deer represent the integrated stress response over a timespan of approximately 24 hours, a typical gut-passage time for deer (Millspaugh et al. 2002).

Exposure to noise and the presence of humans in natural settings may elevate stress levels in wild species, which can result in a suite of behavioral changes (Fig. 1). In a recent review, Barber et al (2010) proposed that fixed-wing aircraft noise may have significant negative effects on the size of listening areas experienced by wildlife, potentially leading to altered predator-prey dynamics. Efforts to measure animal stress responses to outdoor recreation and ecotourism has been a growing field of research in recent years (Monfort et al. 1998, Millspaugh et al. 2001, Creel et al. 2002, Barja et al. 2007, Freeman 2008, Zwijacz-Kozica et al. 2012). A handful of studies have looked at the effects of motorized recreation on stress levels in mammals. Creel et al. (2002) measured FGM levels in elk and gray wolves exposed to seasonal snowmobile recreation in three different national parks, and found positive correlations between motorized disturbance and FGM levels. Freeman (2008) measured FGM levels in caribou exposed to backcountry snowmobile and helicopter disturbance, and found higher FGM levels in caribou exposed to both forms of motorized recreation when compared to caribou sampled in non-motorized control sites. Alternatively, simple presence of humans may increase glucocorticoid secretion in ungulates. An animal's behavioral response to human presence is largely dependent on the type of human activity presented to the animal (Frid and Dill 2002).

Also of importance as a potential confounding factor, the secretion of glucocorticoids by the hypothalamic-pituitary-adrenal (HPA) axis serves a primary purpose of energy allocation in vertebrates, a function that is largely unrelated to stress response. Accordingly, glucocorticoids may be elevated due to sex activity, competition, reproductive status, diet, circadian rhythm, or psychophysical condition (Von der Ohe and Servheen 2002, Huber et al. 2003, Millspaugh and Washburn 2004). Environmental factors can also alter the analysis of FGM post-defecation. Experiments with white-tailed deer feces have shown that factors such as time elapsed since defecation and precipitation can alter FGM levels detected by hormone assays (Millspaugh and Washburn 2003).

Fig. 1. Predicted interaction between aircraft activity or number of human visitors and FGM concentration.

The following research question, hypotheses, and alternative hypotheses were developed to address the overall unknown effects of backcountry aviation on white-tailed deer and mule deer stress levels.

Basic Research Question: What is the relationship between backcountry aviation activity and fecal glucocorticoid metabolite (FGM) concentrations as an indicator of mammalian stress levels of deer inhabiting airstrip areas?

Hypotheses and Alternatives

H_1*:* Aviation activity presents a novel stressor to white-tailed and mule deer beyond that of general human presence that produces an elevated physiological stress response.

P_1: 1) FGM concentrations at airstrips will be higher than those at non-airstrip sites and 2) FGM levels will be positively correlated with aircraft activity at airstrip sites.

H_2: General human presence and non-motorized recreational, not aviation activity, elicits the strongest physiological stress response in white-tailed and mule deer.

P_2: FGM concentrations of white-tailed deer will be highest at recreational sites with the greatest overall level of human presence.

H_0: Aviation activity does not contribute to stress levels in white-tailed and mule deer beyond that of general human presence.

P_3: FGM concentrations at airstrips will not be significantly different from those at non-airstrip sites.

It is important to consider the many possible reasons why white-tailed deer and mule deer remain under such conditions as proposed by Hypothesis *H1*, and connecting deer behavior ecology to physiological responses may be helpful to this end. In the tradeoff between elevated stress levels due to aircraft activity and the benefits of abundant edge habitat provided by airfields (i.e., access to forage, access to cover), the relative cost of exposure to disturbance is less than that of relocation to other suitable habitat. Alternatively, plausible reasons for seeing results proposed under the null hypothesis H_0 may have to do with how ungulates, such as deer, have evolved anti-predator cues. Studies investigating the effects of recreational disturbance on ungulate behavior have found that human activities like walking and hiking elicit more intense flight responses than motorized vehicles and other noise-related stimuli (Taylor and Knight 2003, Stankowich 2008). It may be the case that non-motorized recreation and human presence generally evokes stronger anti-predatory behavior in ungulates due to the evolutionary cue of humans as apex predators.

Study Area, Methods, and Analyses

Study Area

This study was conducted in western Montana and northern Idaho at six backcountry airstrips and at six campgrounds or trailheads that served as control sites (Table 1). We quantified aircraft activity and average number of people per day using each airstrip or each control site during the visitation/sample collection interval. All sampling occurred from June to August in 2014 and from late May to August in 2015. Terminating the sample dates to before mid-August was to avoid sample collection overlapping with the breeding season. Each site was visited once during each annual sampling for a period of 72 hours (see Methods Section below). One of the airstrips sampled in 2014, Fish Lake, provided no viable samples that year. Likewise, the control site, Hogback Homestead, provided no viable samples in either research year.

Table 1. Study sampling areas giving the Site Symbols used throughout this report, corresponding site name, site type (airstrip or control), and the year sampled.

Site Symbol	Site Name	Site Type	Years Sampled
EF	East Fork Campground	Control	2015
FL	Fish Lake Airstrip (S92)	Airstrip	2014, 2015
HH	Hogback Homestead	Control	2014, 2015
JC	Johnson Creek Airstrip (3U2)	Airstrip	2014, 2015
KP	Kreis Pond Campground	Control	2014, 2015
MC	Monture Creek Campground	Control	2015
ME	Meadow Creek Airstrip (0S1)	Airstrip	2014, 2015
MO	Moose Creek Airstrip (1U1)	Airstrip	2014, 2015
RF	Ryan Field Airstrip (2MT1)	Airstrip	2014, 2015
SG	Sawmill Gulch	Control	2014, 2015
SM	Schafer Meadow Airstrip (8U2)	Airstrip	2014, 2015
VM	Valley of the Moon Trailhead	Control	2014, 2015

The backcountry airstrips in this study ranged in runway length from 762 m (2500 ft) to 1250 m (4100 ft) with a mean length of 913.5 m (2997 ft). Airstrip site elevations ranged from 748 m (2454 ft) to 1721 m (5646 ft). These airstrip sites were all located in a vegetation type described generally as subalpine, mixed coniferous forest and deciduous woodlands. Each airstrip is enveloped by the surrounding forest with an airfield clearing. Thus, each airstrip provides a large montane meadow-type habitat surrounded by forest. The non-airstrip control sites were selected specifically to mimic the airfield sites by the general habitat features described above including the large meadow. Control sites were also selected to have motorized access and similar human presence to that of the airfield sites, but without the aircraft and propeller noise associated with takeoffs and landings.

Sampling Methods

To minimize the effects of various confounding factors, the sampling protocol was executed at each airstrip or control site focused on two times each day; deer observation periods at the airfield or meadow clearing were done in the mornings during peak foraging hours, beginning approximately one-hour pre-sunrise to one-hour post-sunrise and evenings from approximately 6:00 PM until last available light. Other researchers recommend direct observation of defecation whenever possible, and an experimental study by Huber et al. (2003) reported a significant decrease in FGM concentrations in fecal samples after 6 hours of exposure to the environment. For these reasons, we utilized direct observation in the early mornings and evenings at each site to record behavior and to witness defecation, in order to collect samples that provided the most accurate measurement of FGM concentrations. Additionally, the sampling protocol included actively scouting the area surrounding the airfield site or control site via hiking trails to locate deer and track them until defecation was observed. To augment both of these approaches, *ad libitum* fecal piles that appeared fresh and account for the effects of time since defecation in this analysis were sampled.

Fecal samples were collected and immediately frozen with dry ice (-80°C) and then kept frozen and returned to the laboratory at the University of Montana for analysis. A generalized Iodine-125 radioimmunoassay (RIA) was run on the fecal samples to detect glucocorticoid concentrations (Wasser et al. 2000, Millspaugh et al. 2002). GPS coordinates of all observed deer defecation events were also recorded. Scouting periods on hiking trails in the surrounding area were done simultaneously during observational periods at the airfield or meadow clearing. The primary purpose of this was to sample from individuals near the airfield or meadow, but not necessarily using the open area during these periods. This was done to investigate potential differences in FGM concentrations between deer that use airstrip runways during peak foraging periods versus those farther from the source of human disturbance.

Acoustic data were taken at each site to record the number of landing and takeoff events per day at each airstrip during the 72-hour visitation period. This measurement provided a metric for quantifying both the intensity of noise at a particular airstrip site and the predictability of flight events. A single Roland R-05 MP3 recorder was placed on the edge of the airfield or meadow clearing in the case of control sites. The recorder was then calibrated for engine noise, as well as set to be sensitive to various sources of ambient noise in the surrounding area. The recorder was run continuously throughout the period of time as each site was visited. Daily averages of flight activity over three days of sampling at each airstrip were compared to historical pilot logs when available. Spectrograms of airplane noise at airstrips or motorized vehicles at control sites, as well as other ambient sounds were analyzed in [1]Audacity®, an open-source sound analysis software program. Spectrograms provided visualization of the intensity and timing of aircraft activity over the duration of a visit to a site (Fig. 2).

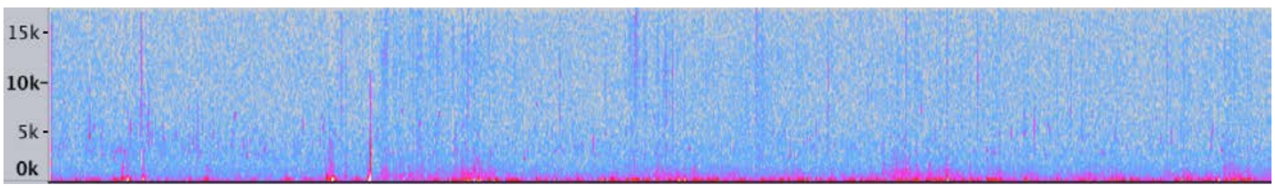

Figure 2. An example spectrogram displaying an 8-hour subsample of ambient noise (kHz); this example is from Schafer Meadow USFS Airfield, Montana, USA. These data, collected at all sites were used to provide a visualization of the timing and intensity of aircraft noise and other ambient noise at airstrips and control sites.

Human presence, as well as aircraft activity, may be a significant factor affecting FGM concentrations. We measured the number of people present at airstrips by total headcounts and by taking hourly averages during two 1-hour sample periods each day to obtain average visitation over the sampling period at each airstrip or control site. By having numbers of humans visiting each site over the duration of the sampling period, we can better measure the particular effect of flight activity within the greater context of human-related disturbance.

Results

For both years, fecal samples were analyzed for FGM concentrations for mammalian feces ($n_{2014} = 36$, $n_{2015} = 115$, $n_{total} = 151$) (Table 2).

Table 2. Breakdown of fecal samples collected for I^{125} RIA across research seasons.

Species	**2014**	**2015**	***Total***
White-tailed deer	12	29	41
Mule deer	1	1	2
Deer (no species ID)	23	85	108
Total	**36**	**115**	**151**

[1]Footnote: http://www.audacityteam.org

2014 Research Year

The mean FGM concentration for airstrip sites versus control sites in 2014 was 190.15 ng/g and 147.78 ng/g, respectively. A two-sample *t*-test suggested a moderately significant difference ($p = 0.044$) with airstrips displaying a higher stress level compared to control sites. However, because of a small sample size ($n_{2014} = 36$), these results were biased toward airstrip sites. Thus, it was difficult to ascertain the relationship in mean FGM levels between airstrips and non-airstrips with a high level of confidence (Fig. 3). In particular, a higher average FGM concentration at Schafer Meadow Airstrip (Site Symbol - SM) was observed compared to other four airstrips and the two control sites, Kreis Pond Campground (KP) and Valley of the Moon Trailhead (VM). When the Schafer Meadow data are removed from the data set, there is no significant difference between the airstrip and control data.

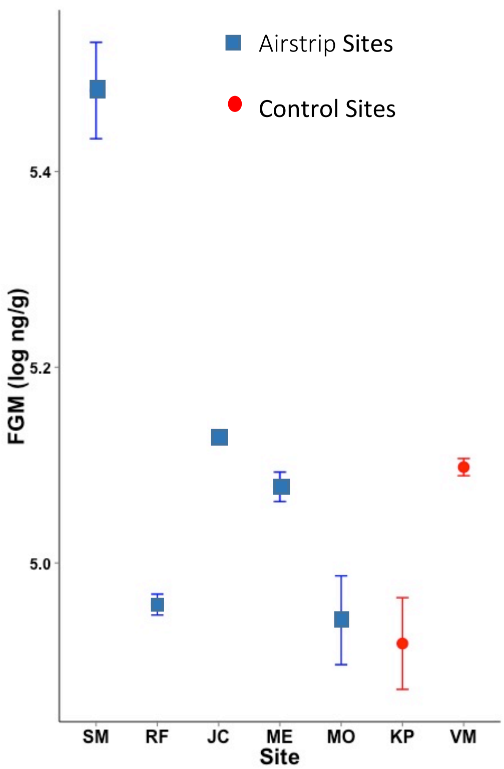

Fig. 3 Mean (± SE) FGM across all airstrip sites and non-airstrip sites sampled in 2014.

2015 Research Year

In 2015, a more robust sample collection protocol was instituted which expanded the number of control sites (see Table 1, above). These modifications in sampling led to a three-fold increase in sample size from 2014 ($n_{2014} = 36$) to 2015 ($n_{2015} = 115$), which allowed for stronger analysis and inference. The mean FGM concentration for airstrip sites versus control sites in 2015 was 122.59 ng/g and 160.04 ng/g, respectively. Further, an approximately equal set of samples came from airstrip sites versus control sites in 2015 ($n_{airstrip} = 61$; $n_{control} = 54$).

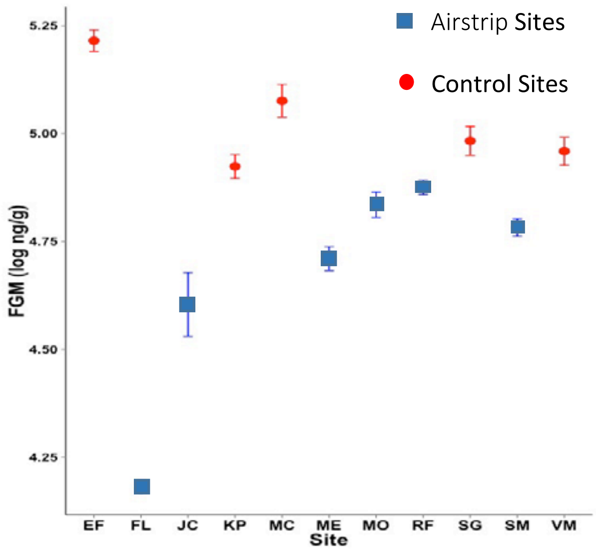

Fig. 4 Mean (± SE) FGM at all airstrips and control sites sampled in 2015.

A two-sample *t*-test of 2015 data indicated a highly significant difference between site types ($p < 0.001$) in which control sites had a higher FGM concentration than airstrip sites (Fig. 4).

Combined Research Years

Combining data across both years of the study, mean FGM concentrations were 144.4 ng/g at airstrips and 158.6 ng/g at non-airstrip sites. A two-sample *t*-test indicated a significant difference between site types when the data were pooled for both years ($p = 0.039$). Of the 6 airstrip sites and 5 control sites (recall one control site, Hogback Homestead, did not produce data), we observed a general pattern of slightly higher FGM concentrations among deer at the control sites than at the airstrip sites (Fig. 5).

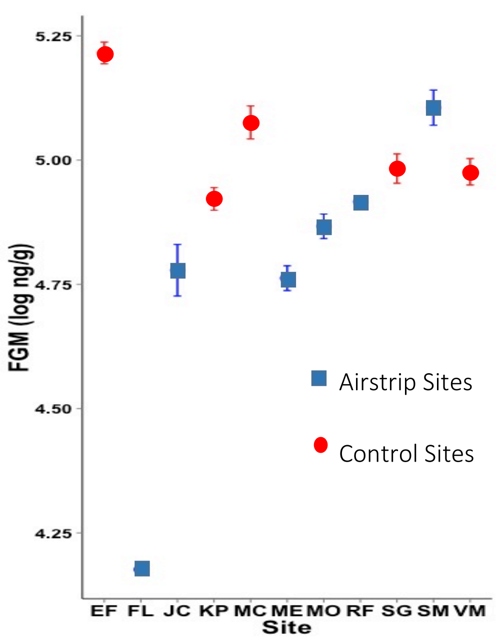

Fig. 5 Mean (±SE) FGM at all airstrip sites and non-airstrip control sites sampled in 2014 and 2015.

Visitor and Airstrip Use

There also existed considerable variation in visitation across all airstrip and control sites, as well as variation in air traffic at airstrip sites. The average volume of human presence at each site from which samples were successfully collected was averaged across both research years (Table 3). We observed the highest average number of daily visitors during our sampling visits at Johnson Creek and Ryan Field airstrips among the airstrip sites (30.97 and 28.97, respectively) and Keis Pond Campground and the Rattlesnake Recreation Corridor among the control sites (22.53 and 14.33, respectively). The lowest average daily visitors were observed at Fish Lake (2.22 visitors/day) among the airstrip sites and Monture Creek Campground (5.39 visitors/day) among the control sites. There was also high variation in daily air traffic among the backcountry airstrips ranging from 27.5 arrivals and departures per day at Johnson Creek to 1.0 at Fish Lake airstrip.

Table 3. Average volume of human presence at airstrip and non-airstrip sites during 2014 & 2015 research seasons.

Site	**Avg. No. of Daily Visitors**	**Daily Air Traffic (avg. no. flights/day)**
East Fork Reservoir USFS Campground	5.83	n/a
Fish Lake USFS Airport	2.22	1.0
Johnson Creek Airport	30.97	27.5
Kreis Pond Campground	22.53	n/a
Monture Creek Campground	5.39	n/a
Meadow Creek USFS Airport	2.67	2.5
Moose Creek USFS Airport	15.33	6.65
Ryan Field	28.97	11.33
Rattlesnake Recreation Corridor	14.33	n/a
Schafer Meadow USFS Airport	10.72	9.33
Valley of the Moon Trailhead	8.55	n/a

Discussion

Our results in the first year of the study showed a higher mean FGM when airstrip sites were aggregated compared to the two control sites. In the second year of the study, non-airstrip control sites had higher mean FGM than airstrip sites. It is notable that the relationship in mean FGM concentrations between airstrips and non-airstrips reversed between 2014 and 2015. However, when these plots are viewed more closely, it can be seen that in 2014 Schafer Meadow USFS Airport (SM) strongly influenced the 2014 airstrip component of the data. Schafer Meadow was not only significantly higher in FGM than the control sites that year, but also significantly higher than the other airstrip sites. Additionally, the high values observed at Schafer Meadow in 2014 were not seen in the Shafer Meadow 2015 data.

Research by others has suggested that many factors can increase FGM concentrations due to environmentally induced stress or specific stress events. Indeed, single weather events may strongly affect stress levels in mammals. In 2014, Schafer Meadow was the first site sampled that year and was preceded by a weeklong weather front with rain and cold weather. We believe there is a real possibility that the noticeably elevated mean FGM concentration at Schafer Meadow in 2014, compared to other airstrip sites in both years and Schafer Meadow the following year, may have been due to the weather event that preceded our sampling visit to the site. We base this conclusion, in part, on the fact that the airstrip had very little air traffic prior to our sampling as low hanging clouds caused marginal flying conditions and extensive mountain obscuration. The USFS flew two flights the day previous to the beginning of our sampling effort in 2014 to drop off ranger station crews and equipment. These data suggest that the environmental challenge of the weather may well have elevated deer FGM at this site largely independent of any aviation or human-related disturbance that might have occurred over this period.

Our expanded number of control sites in 2015, coupled with the fact that we were able to obtain a greater number of samples per site in 2015, affords us a clearer picture of the relationship between airstrip sites and non-airstrip control sites. The finding that non-airstrips had a higher mean FGM than airstrip sites was contrary to our *a priori* Hypotheses. We anticipated one of two possibilities; a) that airstrip sites would have a higher FGM than non-airstrip control sites as a function of aircraft noise, or b) there would be no significant difference between airstrip sites and non-airstrip control sites. Although expressed as an alternative hypothesis, we did not predict that the non-airstrip sites would have higher FGM concentrations than the airstrip sites; yet this is what we observed particularly in 2015. This is even more counter intuitive in that the two highest visitor/day sites were both airstrip sites, Johnson Creek and Ryan Field.

So what could explain this counter-intuitive outcome? First, concerning 2014, as we suggested above the Schafer Meadow airstrip data was skewed, we believe, by the severe weather event just prior to our sampling. When data across both years are aggregated, we observed higher levels of FGM from deer at the control sites than the airstrip sites with the exception of Schafer Meadow. So, what might account for the differences observed between most of the control sites being higher in FGM stress hormone than the airstrip sites in this study? One explanation may be that our non-airstrip control sites (USFS campgrounds and recreation areas) may have experienced an overall greater amount of human-related presence, due to their relative proximity to towns or ease of access. However, the visitor/day data do not support this, as the variation in human presence at control sites was less than what we observed at the airstrip sites. It is also possible that human-altered landscapes and motor vehicle or trail walking access at the control sites results in a higher level of human presence, although this is in general not supported by the visitor-day data. Another explanation may be that the nature of human presence among persons arriving at the control sites, particularly auto arrival, is more stressful than the arrival, presence, and departure of aircraft.

Finally, based on the results, we reject the hypothesis that aviation activity at the backcountry airstrips in this study result in higher levels of fecal glucocorticoid metabolite (FGM) concentrations, as an indicator of stress in our test-case species, white-tailed deer *(Odocoileus virginianus*) and mule deer (*O. hemionus*). Indeed, the data suggest that deer had higher stress levels at the control sites composed of campgrounds and recreational access sites than at the airstrip sites.

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