2016

IMPACTS OF RECREATIONAL AVIATION ON WILDLIFE: THE PHYSIOLOGICAL STRESS RESPONSE IN WHITE-TAILED DEER (Odocoileus virginianus) AND ASSOCIATED USER PERCEPTIONS

Devin W. Landry

University of Montana

IMPACTS OF RECREATIONAL AVIATION ON WILDLIFE: THE PHYSIOLOGICAL STRESS RESPONSE IN WHITE-TAILED DEER (*Odocoileus virginianus*) AND ASSOCIATED USER PERCEPTIONS

By

DEVIN WILLIAM LANDRY

Bachelor of Arts, Skidmore College, Saratoga Springs, NY, 2009

Thesis

Presented in partial fulfillment of the requirements
for the degree of

Master of Science
in Wildlife Biology

The University of Montana
Missoula, MT

May 2016

Approved by:

Scott Whittenburg, Dean of the Graduate School
Graduate School

Dr. Creagh W. Breuner, Chair
Wildlife Biology, Division of Biological Sciences

Dr. Elizabeth C. Metcalf, Co-Chair
Parks, Tourism, and Recreation Management

Dr. Michael S. Mitchell
Montana Cooperative Wildlife Research Unit

Dr. F. Richard Hauer
Center for Integrated Research on the Environment

Dr. Erick Greene
Wildlife Biology, Division of Biological Sciences

Landry, Devin, M.S., May 2016 *Wildlife Biology*

Recreational aviation and wildlife impacts: the physiological stress response in white-tailed deer (*Odocoileus virginianus*) and associated user perceptions

Chairperson: Creagh W. Breuner

Co-Chairperson: Elizabeth C. Metcalf

Abstract

Recreational aviation on public lands may negatively impact wildlife. However, land-use decisions need to balance user need with wildlife impact. We know very little about 1) how back country airstrip use affects local wildlife, or 2) attitudes and perceptions of recreational pilots toward possible management actions. For my Master's research, I investigated how aircraft activity influenced physiological measures of stress in white-tailed deer, while also modeling how psychometrics such as wildlife attitudes and place attachment predict the willingness of recreational pilots engage in impact-mitigating behaviors. I measured physiological stress through non-invasive sampling of stress hormones in fecal samples (fecal glucocorticoid metabolites: FGM). My results suggest that neither air traffic rates nor amount of human presence at recreation sites explained variation in FGM; however, much of the variation in deer FGM can be explained by abiotic factors such as wind velocity and precipitation. A quantitative survey of recreational pilots revealed that more positive attitudes toward wildlife were associated with greater support for impact-mitigating behaviors, while stronger place attachment to airstrips resulted in more negative attitudes toward these behaviors. Viewing recreation areas as socio-ecological systems calls for a multi-disciplinary approach, and employing biological and social science to study anthropogenic impacts on wildlife is the conceptual basis for integrative wildlife planning. By investigating organismal responses of wildlife to recreational aviation and attitudes of this user group, my aim was to provide an initial look into the impacts of recreational aviation within the framework of integrative wildlife planning.

Dedication

To Charlotte, who constantly supported me in this pursuit, and patiently endured the lack of a negative feedback loop in my own physiological stress response.

Acknowledgements

This research would not have been possible without the continued support of the American Owners and Pilots Association, the Recreational Aviation Foundation, the Montana Department of Transportation, and onXmaps.

I would like to first acknowledge Dr. Creagh Breuner, who gave me the opportunity to pursue a Master's degree in Wildlife Biology through this project. Beyond her accomplished career in behavioral endocrinology and inquisitive ecological mind, she always supported my often half-baked ideas for this project. I am truly grateful for the ways in which she taught me how to think about big questions and complex relationships in the natural world, and for the chance she took on me.

I would also like to acknowledge Dr. Elizabeth Metcalf, whose willingness to sign on as a co-advisor enriched the substance of this project, and my overall experience of graduate school, in a way that words cannot capture. She put me through a crash course in the human dimensions of wildlife and a slew of social theory, and I consider myself truly fortunate that she was my teacher. Without her guidance, I would not have been able to pursue topics in conservation and wildlife management that are of the utmost importance to me.

To my committee, Drs. F. Richard Hauer, Michael Mitchell, and Erick Greene, I extend the deepest thanks and appreciation. Their individual and collective contributions to my development as a scientific researcher and thinker have been of the utmost value.

To my fellow Breuner Lab members: thank you for always lending time to brainstorm and hash out ideas, and for always having my back.

I would also like to thank my graduate cohort and various faculty at the University of Montana, specifically Paul Lukacs, Art Woods, Josh Nowak, Joe Smith, and Will Janousek. I would not have succeeded without their willingness to provide insight, technical advice, and, at times, a healthy dose of commiseration. To that end, I want to acknowledge the support of the Wildlife Biology staff, Jeanne Franz and Robin Hamilton, who keep all things afloat and moving.

I am beyond grateful for my field technicians, Chad White, Zach Jones, and Tucker Costain. They endured long hours, unpredictable flight schedules, and the occasional run-in with large predators in the backcountry. The Bryant family was gracious enough to let us onto their land for observation while at Johnson Creek Airport.

Many thanks to Rebecca Booth at the Center for Conservation Biology, University of Washington, for running the assays on my fecal samples. Her help on this project was absolutely critical. Thanks also goes to Dulaney Miller, Seth Smith, Jenna Schabacker, and Steve Amish at the Luikart Lab at the University of Montana, who analyzed my fecal samples for genetic identification.

Lastly, I would like to thank the volunteer pilots—Larry Ashcraft, Ric Hauer, Chuck Jarecki, John McKenna, Alan Metzler, Carmine Mowbray, Mike Perkins, Chuck Schroll, and Steve Thompson—who took time out of their day to safely fly us in and out of airstrip sites. Without them, none of this would have been possible.

Table of Contents

List of Tables

List of Figures

1 Introduction

1.1 Socio-Ecological Systems and Integrative Wildlife Planning

Recreation on public lands in the United States continues to grow in popularity, as changing societal values and increases in leisure time emphasize alternative uses of natural resources besides extraction (Knight and Gutzwiller 1995). As a result, the field of recreation ecology has emerged over the last two decades to research the myriad impacts of recreation on natural resources (Liddle 1991, Hammitt et al. 2015). Areas of concern include, but are not limited to, soil compaction and vegetation trampling (Cole and Fichtler 1983, Cole 1995), degradation of water sources (Merriam et al. 1973, Larson and Hammitt 1981), and the alteration of behavior in wildlife (Borkowski et al. 2006, Griffin et al. 2007). The increasing popularity of recreation presents challenges for managers in charge of monitoring the status of natural resources. For example, "soundscape conservation" is one of the most contemporary areas of recreation ecology that deals with the pervasive impacts of anthropogenic noise in protected areas, positing that soundscapes themselves are natural resources that must be managed (Dumyahn and Pijanowski 2011, Hammitt et al. 2015).

At its core, the topic of recreation demands both ecological and social considerations. Any one form of recreation may not only have adverse impacts on wildlife, but conflict between user groups often arises when different activities overlap in the same area. Furthermore, the U.S. Forest Service (USFS) is obligated to meet their mandate of providing recreation opportunities to the public while preserving the integrity of our natural resources. This mandate derives in part from the Multiple-Use Sustained-Yield Act of 1960, in which national forests were said to exist "for outdoor recreation, range, timber, watershed, and wildlife and fish purposes." A recent planning rule by the USFS identifies the need for monitoring recreation activity on national forest lands in order to meet agency goals for sustainable recreation (USFS 2012). Monitoring recreation on USFS lands is a tripartite effort that includes meeting objectives for ecological, social, and economic conditions. By establishing monitoring questions that address both bio-ecological and social conditions, managers can assess the impacts of recreation on natural resources, such as wildlife populations, as well as the attitudes and behaviors of user groups that routinely interact with wildlife through their recreation.

However, biological and social analyses of recreation tend to be executed in isolation, sometimes making an integrated understanding of recreational impacts elusive. Employing a multi-disciplinary approach to investigate recreation issues recognizes the complexities of socio-ecological systems (SESs), a concept that views systems (e.g., recreation areas) in terms of their biophysical and social attributes (Berkes and Folke 1998, Young et al. 2006). A related idea has been theorized in the context of wildlife management using the concepts of integrative wildlife planning or adaptive impact management (Bright et al. 2000, Riley et al. 2003). This sort of approach to wildlife management recognizes the contribution of biological and social science to inform conservation efforts, and argues for their integration when investigating anthropogenic impacts on free-living animals.

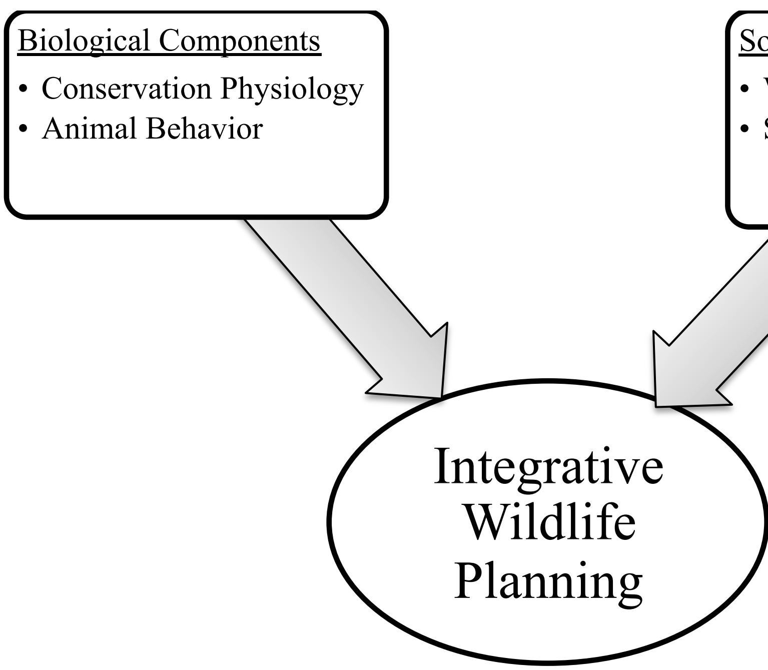
However, a recent literature review by Marzano and Dandy (2012) notes a lack of research into impacts of recreation on wildlife that links ecological and social conditions. An example of such work comes from Taylor and Knight (2003), where researchers collected data on ungulate flight distances to various forms of recreation and surveyed recreationists on site about their perceived impacts on wildlife. A similar study from Stalmaster and Kaiser (1998) measured flight distance of wintering bald eagles (*Haliaeetus leucocephalus*) in response to boating activity while surveying recreationists about their perceived impacts and support for management actions. In concert with monitoring the ecological impacts of recreation, management agencies can produce more effective land use plans by understanding the predominant attitudes and desired recreational experiences of different user groups.

1.1.1 Thesis Objectives

The integration of biological and social science tools represents a robust but underutilized approach that provides a more comprehensive look into recreation issues, and forms the main thrust of my Master's research. This thesis utilizes an integrative approach to better understand biological and social components of recreational aviation on public lands throughout Montana and Idaho, USA. Despite the increased attention given to recreation on public lands, there is a lack of information on participation in recreational aviation (Boyle and Samson 1985, Cordell 2010). Additionally, recreational aviation on public lands carries with it sources of conflict between pilots and other user groups, where the latter may have negative perceptions of this form of motorized recreation. Indeed, it is not uncommon for recreational pilot groups to be accused of altering wildlife behavior and affecting reproductive success of populations due to noise disturbance (communication with the Recreational Aviation Foundation).

This project measured the stress physiology responses of white-tailed deer (*Odocoileus virginianus*) exposed to low-flying, single-propeller aircraft at backcountry airstrips and evaluated the human dimensions associated with recreational pilots who access these airstrips. For the biological component, I collected fecal samples to model how fecal glucocorticoid metabolite (FGM) levels in white-tailed deer correspond to varying rates of aircraft activity and weather conditions at different backcountry airstrips, and assessed the relative contribution of aircraft activity on deer FGM by sampling from recreational sites lacking aviation disturbance. For the social component, I modeled how psychometrics such as wildlife attitudes and place attachment predict the willingness of recreational pilots to engage in impact-mitigating behaviors. By investigating both wildlife responses to recreational aviation and attitudes of this associated user group, my aim was to provide an initial look into the impacts of recreational aviation within the framework of integrative wildlife planning (Fig.1-1). I have outlined my research hypotheses in section 1.8, after covering the relevant background across the different areas of my thesis.

Figure 1-1. Conceptual model of integrative wildlife planning and theoretical foundation of Master's research into biological and social components of recreational aviation and wildlife impacts.



1.2 Recreational Aviation

Recreational aviation occurs throughout the contiguous United States and Alaska, where multiple federal and state agencies manage public-access grass airstrips. This form of recreation is typified by the use of single-propeller, fixed-wing aircraft. It is a popular form of recreation in the Northern Rockies region of Montana and Idaho, where there are approximately 52 airstrips located on public lands (e.g., national forest lands, national monuments), with several more that directly border public lands (www.airnav.com).

Of these 52 airstrip sites located on various public lands designations, 16 airstrips are located in federally designated Wilderness areas (Meyer 1999). The Wilderness Act of 1964 (TWA) explicitly prohibits motorized travel within Wilderness areas. However, language within TWA includes special-use exceptions that allow for motorboat and aircraft travel "where these practices have already become established." Aircraft travel was also legislated as a special use in some Wilderness areas that were designated after TWA. An example of this is the Great Bear Wilderness of Montana established in 1978, where aircraft can access Schafer Meadows, an airstrip that existed prior to Wilderness designation (Meyer 1999).

1.3 Issue of Aviation Noise in Protected Areas

Federal agencies such as the U.S. Forest Service manage many active backcountry airstrips on public land, where multiple user groups besides pilots can access the area, such as floaters and hikers. Motorized noise in protected areas present managers with unique challenges, namely mediating conflict between recreationists with divergent views on appropriate use (Meyer 1999). Studies looking at the effects of aircraft noise on visitor experiences in protected areas show an inverse relationship between both intensity and frequency of air traffic noise and a visitor's appreciation of landscape characteristics and other aesthetic qualities, such as perceived tranquility (Tarrant et al. 1995, Mace et al. 2013, Weinzimmer et al. 2014). Unlike flyover traffic in national parks, for example, recreational aviation in protected areas compounds the issue with active landings and takeoffs, a source of disturbance that likely increases the potential for conflict between pilots and other user groups (Jacob and Schreyer 1980).

1.4 Deer Ecology of the U.S. Northern Rockies

The white-tailed deer (*Odocoileus virginianus*) is a member of Family Cervidae in the Order Artiodactyla (even-toed ungulates). White-tailed deer are recognized as habitat generalists, but thrive in edge habitat between forested and open areas (Putnam 1988). When disturbed or threatened, white-tailed deer tend to exhibit a long, bounding gait while “flashing” the conspicuous white underside of their tail, and will often head for dense cover (Mackie et al. 1998).

In the summer season, white-tailed deer follow a crepuscular activity pattern, with highest foraging rates during pre-dawn and dusk. They generally forage in open meadow habitats during these periods and reenter covered habitats, such as riparian woodlands and coniferous forests, during daytime hours (Beier and McCullough 1990). The use of edge habitat by white-tailed deer makes them good candidates for occupying human-altered habitats such as backcountry airstrips, which often require a grass clearing upwards of a kilometer in length in the midst of extensive forest habitat. Backcountry airstrips are often located near water sources, resulting in riparian areas that deer can also utilize. Through a combination of these factors, backcountry airstrips inadvertently provide suitable habitat for deer. In addition, anecdotal evidence from pilots attests to the presence of white-tailed deer at airstrips during the flying season (communication with the Recreational Aviation Foundation), making them the focal species of this study.

1.5 Endocrinology of the Vertebrate Stress Response

The stress response in vertebrates is a highly conserved physiological system that generally allows organisms to regulate environmental challenges (e.g., predation risk, adverse weather). Two classes of hormones, the catecholamines (epinephrine and norepinephrine) and glucocorticoids, are responsible for the mobilization and progression of the response (Sapolsky et al. 2000, Romero and Butler 2007). Upon sensing a stressor, epinephrine and norepinephrine are immediately secreted through the sympathoadrenal system (consisting of the sympathetic nervous system and the adrenal medulla). The catecholamines are produced and stored preemptively, allowing for an organism-wide response to a potential threat within milliseconds of detecting it; this is more commonly called the "fight or flight" response. Some facets of this initial response include increased blood flow and vasodilation, increased oxygen flow, and enhanced visual capabilities, while also inhibiting non-essential processes such as digestion (Romero and Butler 2007).

Unlike the catecholamines, glucocorticoids (GCs) are steroid hormones that must be produced as needed (they cannot be stored), meaning that their secretion does not typically occur until several minutes after the onset of epinephrine and norepinephrine (Sapolsky et al. 2000). Secretion of GCs is the end of result of actions orchestrated by the hypothalamic-pituitary-adrenal (HPA) axis: the hypothalamus activates the anterior pituitary, signaling increased secretion of adrenocorticoptropic hormone (ACTH). ACTH then stimulates production and secretion of GCs in the adrenal cortex. Once in the bloodstream, GCs are bound to corticosteroid binding globulins (CBG). It is thought that CBG inhibits GCs from entering target tissues (Breuner et al. 2013); however, during a stress response there is a notable increase in GCs that remain unbound and are free to reach target tissues.

The primary role of GCs in the organismal stress response is to mobilize glucose stores and provide needed energy for the animal to meet an environmental challenge (Wingfield et al. 1998). This response increases organismal fitness in the short term, an idea first proposed by physiologist Hans Selye in the early twentieth century, who termed the stress response the "general adaptation syndrome" (Selye 1937). Indeed, the broad effects of HPA activation are meant to facilitate survival in the face of a challenge: blood glucose concentration increases to transport available energy to muscles, while non-essential activities such as reproduction and growth are inhibited in order to further allocate needed energy for survival (Romero 2004). While the HPA response is highly adaptive, long-term activation of the response suppresses growth and reproductive effort to an extent that can be deleterious, decreasing organismal fitness and population viability (Wingfield et al. 1998, Romero and Wikelski 2001).

Applied research must take into account the multi-faceted functions of the vertebrate stress response in order to better interpret stress levels in free-living animals. As previously mentioned, environmental challenges acting on an organism can be acute (e.g., predation) or gradual (e.g., transitions between life history stages). This latter example causes GCs to fluctuate naturally, depending on the metabolic requirements of a given seasons or life history stage (Wingfield et al. 1998, Landys et al. 2006). In this way, GC secretion is instrumental to overall organismal function, playing an integral part in preparing an animal to survive immediate threats to survival as well as optimizing fitness across its lifetime.

1.6 Application of Stress Physiology in Conservation

Measuring physiological responses of wildlife to anthropogenic disturbance has become more prevalent in recent years (Walker et al. 2005, Wikelski and Cooke 2006, Tarlow and Blumstein 2007, Busch and Hayward 2009, Dantzer et al. 2014). Of the biological sampling techniques available, measuring fecal glucocorticoid metabolites (FGM) has been widely applied to mammalian and avian taxa, and provides notable benefits for conservation research. Collecting fecal samples is non-invasive, eliminating any additional stress due to animal handling. In addition, FGM represent an integrated average of circulating GCs in an organism over a known time period. This integrated measure allows for a wider scope of inference into the endocrine profile of animals exposed to anthropogenic disturbance (Sheriff et al. 2011). The time it takes to metabolize GCs into the conjugate form of FGM is commonly referred to as gut passage time. Gut passage time is species-specific, and for ungulates such as deer it is approximately 12 to 24 hours in duration, depending on season (Millspaugh et al. 2002).

The opportunities afforded to conservation biology through the use of non-invasive stress measures has driven an emerging field known as conservation physiology (Wikelski and Cooke 2006, Cooke et al. 2013). The basic tenet of conservation physiology is to use physiological assessments to identify the mechanisms that drive wildlife responses to anthropogenic disturbance. The utility of non-invasive sampling through FGM, for example, has led to numerous studies of the effects of recreation and ecotourism on wildlife (Creel et al. 2002, Arlettaz et al. 2007, Barja et al. 2007, Zwijacz-Kozica et al. 2012). However, research on uncontrolled, free-living animals should consider the ways in which other factors affecting the physiological stress response act independently of or interact with anthropogenic sources of disturbance. Some confounding factors include differences between sexes, the effects of diet change across seasons, and the ways gut bacterial communities might differ across individuals, thus changing the process of metabolizing GCs into FGM (Goymann 2012). Given the fact that the primary function of the glucocorticoid-driven stress response is energy mobilization, it is important to account for potential effects beyond anthropogenic disturbance (Dantzer et al. 2014). Research that takes samples from unmarked populations or across multiple seasons, for instance, may be faced with increased systematic and random noise in FGM concentrations if these covariates are not included in the analysis (Millspaugh and Washburn 2004, Goymann 2012).

1.7 Social Science and the Human Dimensions of Wildlife

HDW is a branch of wildlife conservation and management that applies social-psychological theory to explore facets of human-wildlife relationships. One of the earliest instances of HDW work in the U.S. came from the Outdoor Recreation Resources Commission, a government-sanctioned survey of recreationists started in 1958 that continues to the present day (Brown 2009). Over this time, HDW grew to incorporate various fields of social science interested in researching recreation and other forms of human-wildlife interactions (Hendee and Schoenfeld 1973; Brown 2009).

Due to the fact that the feasibility of wildlife management efforts is partly driven by social parameters (e.g., tolerance for certain species, support for management actions), incorporating social science into wildlife management and conservation can provide information that improves management decisions. With the growing prevalence of HDW research, natural resource managers are able to make more informed decisions by combining well-established knowledge from biophysical research with surveys of people using the resource. This resulted in many agencies establishing their own HDW divisions (Manfredo 2008). Indeed, the role of HDW in forming management plans has become more central in the last two decades. For instance, results from an on-going study of wildlife values across the western U.S., sponsored by the Western Association of Fish and Wildlife Agencies, indicate a fundamental shift at the societal level in the ways people perceive and appreciate wildlife (Manfredo and Zinn 1996, Teel et al. 2005, Manfredo et al. 2009, Teel and Manfredo 2010). This information has become invaluable for management agencies that oversee vast areas of public land, interact with stakeholders, and need to justify their decision-making to the public.

The application of HDW in nature-based recreation is especially pertinent because of the potential for human-wildlife interaction. Numerous studies have measured motivations and attitudes of different recreationist groups to better understand recreationist behavior in outdoor settings (Manfredo et al. 1996, Andereck et al. 2001, Bright and Porter 2001, Thapa and Graefe 2001, Teisl and Brien 2003). Cognitive Hierarchy Theory is a foundational psychological concept that underlies much of the research into how attitudes predict behaviors. An individual's cognitive evaluation of an object is structured hierarchically, such that their fundamental values influence more emergent cognitive traits, such as attitudes, in a "bottom-up" manner (Rokeach 1973, Homer and Kahle 1988, Fulton et al. 1996) (Fig. 1-2).

Values develop early in life, serve as the foundation for basic beliefs and attitudes, and are instrumental in guiding an individual's cognitive and emotional assessment of an issue. Values differ from higher-order attitudes in that the former apply to a variety of situations, whereas the latter are more context-dependent and can change given a situation or when presented with new information. Due to the difference in specificity between values and attitudes, researchers have theorized that *value orientations* serve as the cognitive connection between values and attitudes (Schwartz 2006). Value orientations are basic beliefs that provide meaning and direction for an individual to apply their values in a given situation. By doing so, consistent patterns of attitude assessment and behavioral intentions regarding an issue (e.g., reintroducing once-extirpated predators in the western U.S.) begin to emerge across individuals with divergent values. Decades of theory construction have led to the application of cognitive hierarchy theory into the realm of natural resource and wildlife management (Purdy and Decker 1989, Fulton et al. 1996, Vaske and Donnelly 1999), allowing agencies to broaden their understanding of local, regional, and national trends regarding the public's relationship to natural resources.

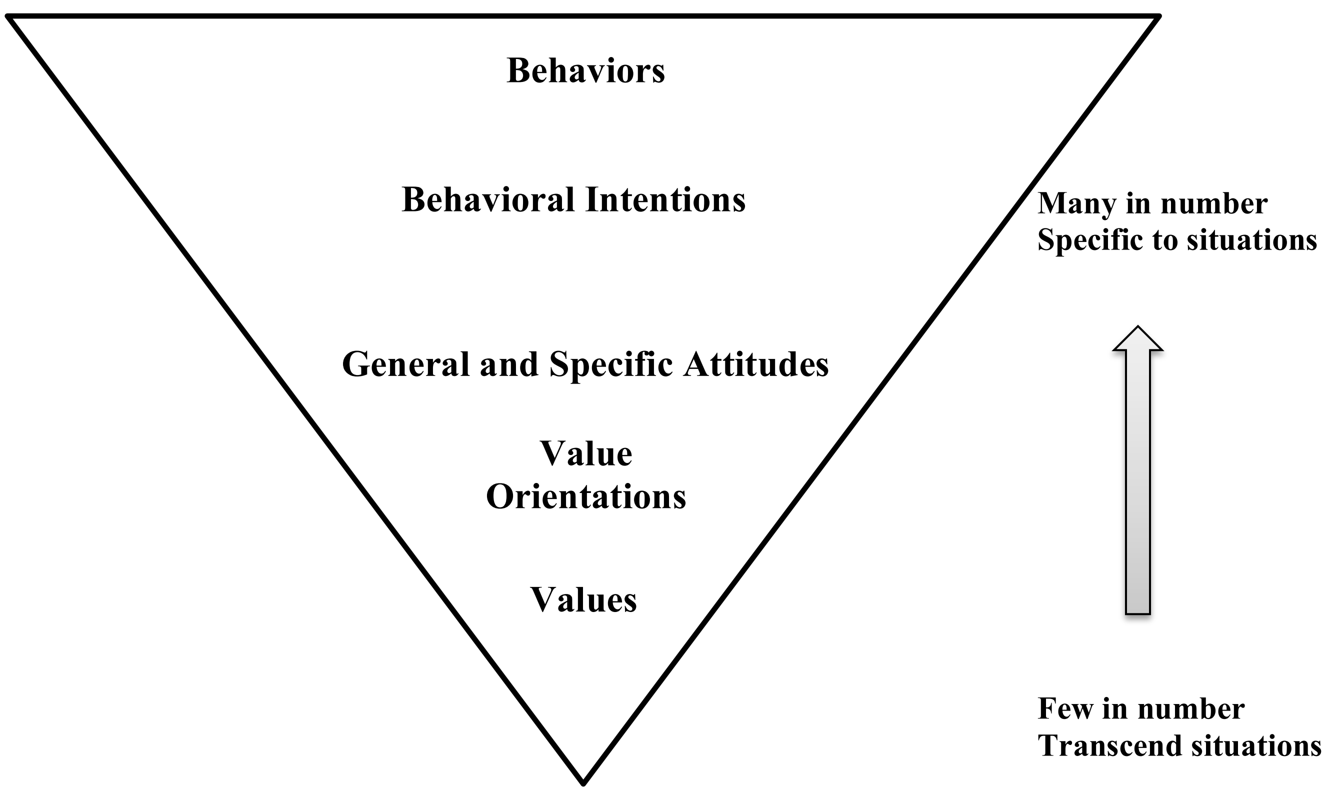


Fig. 1-2. Conceptual model of Cognitive Hierarchy Theory (borrowed from Vaske and Donnelly 1999)

Additionally, the concept of place attachment has become increasingly useful in recreation management. Psychological connections to place are a defining characteristic of self-identity, and there has been a growing recognition that recreation management needs to consider sense of place in order to understand different user groups' claims to the use of an area (Williams et al. 1992, Williams and Stewart 1998). As a cognitive measure, place attachment measures two components that theoretically inform the person-place relationship: place identity and place dependence (Williams and Roggenbuck 1989). Place identity is the emotional component that represents a recreationist's experiences with or memories of a place, while place dependence is the functional component that represents how well a place meets the needs of a recreationist. In this way, it is designed to not only capture variation in the overall level of importance individuals ascribe to a place, but also differences in the manner in which this attachment occurs for a given individual. By understanding psychometrics such as values, attitudes, and sense of place, management agencies can engage user groups and increase experiential satisfaction on public lands.

1.8 Research Hypotheses

For the stress physiology component of my thesis, I tested the relative contributions of anthropogenic, abiotic and intrinsic factors that may influence the organismal stress response in white-tailed deer. For anthropogenic sources of disturbance, I formulated three hypotheses as to how recreational disturbance influences organismal stress response beyond the effects of abiotic and intrinsic factors. First, the amount of aircraft activity at a site drives variation in deer FGM levels, due to air traffic noise serving as an additional stressor to general human presence in the form of camping and other non-motorized uses. Alternatively, FGM levels vary primarily due to the volume of human use at a site, regardless of the amount of aircraft activity occurring at a site. Lastly, recreation disturbance may not influence variation in FGM levels beyond the effects of abiotic and intrinsic factors, and FGM levels do not vary with changes in disturbance intensity. To account for abiotic and intrinsic factors thought to influence ungulate FGM through an animal's normal physiological processes, I formulated two hypotheses. First, I hypothesized that factors such as mean or maximum temperature and wind speed act as environmental challenges, and increases in these covariates would increase deer FGM. Second, I hypothesized that FGM would vary by sex, with females exhibiting higher FGM levels than males due to the metabolic requirements of parturition and lactation that occur during the early period of the sample season.

For the human dimensions component, I hypothesized that wildlife-related attitudes and place attachment influence attitudes toward impact-mitigating behaviors. The attitudes toward impact-mitigating behaviors I was interested in included (1) the acceptability of a management action that limited the number of allowable flights to an airstrip due to displayed elevated stress levels in wildlife and (2) the importance of reducing noise output of aircraft when flying in the backcountry. For attitudes toward the first behavior measured, limiting access to impacted airstrips, I hypothesized that attitudes toward viewing wildlife at airstrips, place attachment and visitation history to backcountry airstrips in the Northern Rockies determine the acceptability of this management action. In particular, more positive attitudes toward viewing wildlife would be associated with more positive attitudes toward limiting flight access, while higher levels of place attachment, longer visitation histories, and the interaction between these two variables would be negatively associated with attitudes toward limiting flight access. For attitudes toward the second behavior measured, reducing noise output of aircraft, I hypothesized that attitudes toward viewing wildlife would largely determine the importance a respondent placed on reducing noise when accessing backcountry airstrips.

1.9 References

Andereck, K. L., C. a Vogtisan, K. Larkin, and K. Freye. 2001. Differences between motorized and nonmotorized trail users. Journal of Park & Recreation Administration 19:62–77.

Arlettaz, R., P. Patthey, M. Baltic, T. Leu, M. Schaub, R. Palme, and S. Jenni-Eiermann. 2007. Spreading free-riding snow sports represent a novel serious threat for wildlife. Proceedings of the Royal Society B 274:1219–1224.

Barja, I., G. Silván, S. Rosellini, A. Piñeiro, A. González-Gil, L. Camacho, and J. C. Illera. 2007. Stress physiological responses to tourist pressure in a wild population of European pine marten. The Journal of Steroid Biochemistry and Molecular Biology 104:136–42.

Beier, P., and D. R. McCullough. 1990. Factors influencing white-tailed deer activity patterns and habitat use. Wildlife Monographs 109:3–51.

Berkes, F. and C. Folke, editors. 1998. Linking social and ecological systems: management practices and social mechanisms for building resilience. Cambridge University Press, UK.

Borkowski, J. J., P. J. White, R. A. Garrott, T. Davis, and A. R. Hardy. 2006. Behavioral responses of bison and elk in Yellowstone to snowmobiles and snow coaches. Ecological Applications 16:1267–1276.

Boyle, S. A., and F. B. Samson. 1985. Effects of non-consumptive recreation on wildlife: a review. Wildlife Society Bulletin 13:110–116.

Breuner, C. W., B. Delehanty, and R. Boonstra. 2013. Evaluating stress in natural populations of vertebrates: Total CORT is not good enough. Functional Ecology 27:24–36.

Bright, A. D., M. J. Manfredo, and D. C. Fulton. 2000. Segmenting the public: An application of value orientations to wildlife planning in Colorado. Wildlife Society Bulletin 28:218–226.

Bright, A. D., and R. Porter. 2001. Wildlife-related recreation, meaning, and environmental concern. Human Dimensions of Wildlife 6:259–276.

Brown, P.J. 2009. Perspectives on the past and future of human dimensions of fish and wildlife. Pages 1-13 *in* Manfredo, M.J., J.J. Vaske, P.J. Brown, D.J. Decker, and E.A. Duke. Wildlife and society: the science of human dimensions. Island Press, Washington, D.C., USA.

Busch, D. S., and L. S. Hayward. 2009. Stress in a conservation context: A discussion of glucocorticoid actions and how levels change with conservation-relevant variables. Biological Conservation 142:2844–2853.

Cole, D. N., and R. K. Fichtler. 1983. Campsite impact on three western Wilderness areas. Environmental Management 7:275–288.

Cole, D. N. 1995. Experimental Trampling of Vegetation. I . Relationship between trampling intensity and vegetation response. Journal of Applied Ecology 32:203–214.

Cooke, S. J., L. Sack, C. E. Franklin, a. P. Farrell, J. Beardall, M. Wikelski, and S. L. Chown. 2013. What is conservation physiology? Perspectives on an increasingly integrated and essential science. Conservation Physiology 1:1–23.

Cordell, H. K. 2010. Outdoor recreation trends and futures: a technical document supporting the forest service 2010 RPA assessment. U.S. Forest Service, Southern Research Station, Asheville, North Carolina, USA.

Creel, S. R., J. E. Fox, A. Hardy, J. Sands, B. O. B. Garrott, and R. O. Peterson. 2002. Snowmobile activity and glucocorticoid stress responses in wolves and elk. Conservation Biology 16:809–814.

Dantzer, B., Q. E. Fletcher, R. Boonstra, and M. J. Sheriff. 2014. Measures of physiological stress: a transparent or opaque window into the status, management and conservation of species? Conservation Physiology 2:1–18.

Dumyahn, S. L., and B. C. Pijanowski. 2011. Soundscape conservation. Landscape Ecology 26:1327–1344.

Foresman, K. 2012. Mammals of Montana. Second edition. Mountain Press, Missoula, Montana, USA.

Goymann, W. 2012. On the use of non-invasive hormone research in uncontrolled, natural environments: The problem with sex, diet, metabolic rate and the individual. Methods in Ecology and Evolution 3:757–765.

Griffin, S. C., T. Valois, M. L. Taper, and L. Scott Mills. 2007. Effects of tourists on behavior and demography of Olympic marmots. Conservation Biology 21:1070–81.

Hammitt, W.E., D.N. Cole, and C.A. Monz. 2015. Wildland recreation: Ecology and management. Third edition. John Wiley & Sons, Ltd., Oxford, UK.

Hendee, J.C. and C. Schoenfeld, editors. 1973. Human dimensions in wildlife programs. Wildlife Management Institute, Washington, D.C., USA.

Jacob, G. R., and R. Schreyer. 1980. Conflict in outdoor recreation: A theoretical perspective. Journal of Leisure Research 12:368 – 380.

Keay, J. M., J. Singh, M. C. Gaunt, and T. Kaur. 2006. Fecal glucocorticoids and their metabolites as indicators of stress in various mammalian species: a literature review. Journal of Zoo and Wildlife Medicine 37:234–244.

Knight, R.L. and K.J. Gutzwiller. 1995. Wildlife and recreationists: Coexistence through management nad research. Island Press, Washington, D.C., USA.

Landys, M. M., M. Ramenofsky, and J. C. Wingfield. 2006. Actions of glucocorticoids at a seasonal baseline as compared to stress-related levels in the regulation of periodic life processes. General and Comparative Endocrinology 148:132-139.

Larrison, E.J. and D.R. Johnson. 1981. Mammals of Idaho. University Press of Idaho, Moscow, USA.

Larson, G. L., and W. E. Hammitt. 1981. Management concerns for swimming, tubing, and wading in the Great Smoky Mountains National Park. Environmental Management 5:353–362.

Liddle, M. J. 1991. Recreation ecology: Effects of trampling on plants and corals. Trends in Ecology and Evolution 6:13–17.

Mace, B. L., G. C. Corser, L. Zitting, and J. Denison. 2013. Effects of overflights on the national park experience. Journal of Environmental Psychology 35:30–39.

Mackie, R. J., D. F. Pac, K. L. Hamlin, and G. L. Dusek. 1998. Ecology and management of mule deer and white-tailed deer in Montana. Montana Fish, Wildlife and Parks, Wildlife Division, Helena, Montana, USA.

Madliger, C. L., S. J. Cooke, E. J. Crespi, J. L. Funk, K. R. Hultine, K. E. Hunt, J. R. Rohr, B. J. Sinclair, C. D. Suski, C. K. R. Willis, and O. P. Love. 2016. Success stories and emerging themes in conservation physiology. Conservation Physiology 4:1–17.

Manfredo, M. J., B. L. Driver, and M. Tarrant. 1996. Measuring leisure motivation: A meta-analysis of the recreation experience preference scales. Journal of Leisure Research 28:188–213.

Manfredo, M.J. 2008. Who cares about widllife? Social science concepts for exploring human-wildlife relationships and conservation issues. Springer-Verlag, New York, New York, USA.

Manfredo, M. J., T. L. Teel, and K. L. Henry. 2009. Linking society and environment: A multilevel model of shifting wildlife value orientations in the western United States. Social Science Quarterly 90:407–427.

Manfredo, M. J., and H. C. Zinn. 1996. Population change and its implications for wildlife management in the New West: A case study of Colorado. Human Dimensions of Wildlife 1:62–74.

Marzano, M., and N. Dandy. 2012. Recreationist behaviour in forests and the disturbance of wildlife. Biodiversity and Conservation 21:2967–2986.

Merriam, L.C., J., C. K. Smith, D. E. Miller, C. tiao Huang, I. Tappeiner, J.C., K. Goeckermann, J. A. Bloemendal, and T. M. Costello. 1973. Newly developed campsites in the boundary waters canoe area: a study of 5 years' use. Minnestoa Agricultural Experiment Station Bulletin 511.

Meyer, S. 1999. The role of legislative history in agency decision-making: a case study of wilderness airstrip management in the United States. International Journal of Wilderness 5:9-12.

Millspaugh, J. J., B. E. Washburn, M. a Milanick, J. Beringer, L. P. Hansen, and T. M. Meyer. 2002. Non-invasive techniques for stress assessment in white-tailed deer. Wildlife Society Bulletin 30:899–907.

Millspaugh, J. J., and B. E. Washburn. 2004. Use of fecal glucocorticoid metabolite measures in conservation biology research: Considerations for application and interpretation. General and Comparative Endocrinology 138:189–199.

Multiple-Use Sustained-Yield Act of 1960. 16 U.S.C. §§ 528-531.

Putnam, R. 1988. The natural history of deer. Comstock Publ Association, Ithaca, New York, USA.

Riley, S.J., W.F. Siemer, D.J. Decker, L.H. Carpenter, J.F. Organ, and L.T. Berchielli. 2003. Adpative impact management: An integrative approach to wildlife management. Human Dimensions of Wildlife 8:81-95.

Romero, L. M., and L. K. Butler. 2007. Endocrinology of stress. International Journal of Comparative Psychology 20:89–95.

Romero, L. M., and M. Wikelski. 2001. Corticosterone levels predict survival probabilities of Galapagos marine iguanas during El Nino events. Proceedings of the National Academy of Sciences of the United States of America 98:7366-7370.

Romero, M. L. 2004. Physiological stress in ecology: Lessons from biomedical research. Trends in Ecology and Evolution 19:249–255.

Sapolsky, R. M., M. L. Romero, and A. U. Munck. 2000. How do glucocorticoids influence stress responses? Integrating permissive, suppressive, stimulatory, and preparative actions. Endocrine Reviews 21:55–89.

Selye, H. 1937. The significance of the adrenals for adaptation. Science 85:247–248.

Sheriff, M. J., B. Dantzer, B. Delehanty, R. Palme, and R. Boonstra. 2011. Measuring stress in wildlife: techniques for quantifying glucocorticoids. Oecologia 166:869–87.

Stalmaster, M. V., and J. L. Kaiser. 1998. Effects of recreational activity on wintering bald eagles. Wildlife Monographs 1–46.

Tarlow, E. M., and D. T. Blumstein. 2007. Evaluating methods to quantify anthropogenic stressors on wild animals. Applied Animal Behaviour Science 102:429–451.

Tarrant, M. a., G. E. Haas, and M. J. Manfredo. 1995. Factors affecting visitor evaluations of aircraft overflights of wilderness areas. Society & Natural Resources 8:351–360.

Taylor, A. R., and R. L. Knight. 2003. Wildlife responses to recreation and associated visitor perceptions. Ecological Applications 13:951–963.

Teel, T., A. Dayer, M. Manfredo, and A. Bright. 2005. Wildlife Values in the West. Western Association of Fish and Wildlife Agencies, Fort Collins, Colorado, USA. 1-307.

Teel, T. L., and M. J. Manfredo. 2010. Understanding the diversity of public interests in wildlife conservation. Conservation Biology 24:128–139.

Teisl, M. F., and K. O. Brien. 2003. Who cares and who acts: Outdoor recreationists exhibit different levels of environmental concern and behavior. Environment and Behavior 35:506–522.

Thapa, B., and A. R. Graefe. 2001. Environmental attitude-behavior correspondence between different types of forest recreationists. Ethnicity 5:20–27.

The Wilderness Act of 1964. 16 U.S.C §§ 1131-1136.

Forest Service, USDA. 2012. National forest system land management planning. 36 CFR Part 219.

Walker, B. G., P. D. Boersma, and J. C. Wingfield. 2005. Field endocrinology and conservation biology. Integrative and comparative biology 45:12–18.

Weinzimmer, D., P. Newman, D. Taff, J. Benfield, E. Lynch, and P. Bell. 2014. Human responses to simulated motorized noise in national parks. Leisure Sciences 36:251–267.

Wikelski, M., and S. J. Cooke. 2006. Conservation physiology. Trends in Ecology and Evolution 21:38–46.

Williams, D. R., M. E. Patterson, J. W. Roggenbuck, and A. E. Watson. 1992. Beyond the commodity metaphor: Examining emotional and symbolic attachment to place. Leisure Sciences 14:29-46.

Williams, D. R., and J. W. Roggenbuck. 1989. Measuring place attachment: some preliminary results. Outdoor Planning and Management NRPA Symposium on Leisure Research 1–7.

Williams, D. R., and S. I. Stewart. 1998. Sense of place: an elusive concept that is finding a home in ecosystem management. Journal of Forestry 96:18–23.

Wingfield, J. C., D. L. Maney, C. W. Breuner, J. D. Jacobs, S. Lynn, M. Ramenofsky, and R. D. Richardson. 1998. Ecological bases of hormone—behavior interactions: the "emergency life history stage." Integrative and Comparative Biology 38:191–206.

Young, O. R., F. Berkhout, G. C. Gallopin, M. a. Janssen, E. Ostrom, and S. van der Leeuw. 2006. The globalization of socio-ecological systems: An agenda for scientific research. Global Environmental Change 16:304–316.

Zwijacz-Kozica, T., N. Selva, I. Barja, G. Silván, L. Martínez-Fernández, J. C. Illera, and M. Jodłowski. 2012. Concentration of fecal cortisol metabolites in chamois in relation to tourist pressure in Tatra National Park (South Poland). Acta Theriologica 58:215–222.

2 Effects of Recreational Fixed-Wing Aircraft on the Physiological Stress Response of White-tailed Deer (*Odocoileus virginianus*) in the U.S. Northern Rockies

2.1 Introduction

Recreation on public lands in the United States has garnered an increasing amount of research attention due to its potential impacts on wildlife populations. The field of recreation ecology has produced numerous studies on the effects of recreation and ecotourism on wildlife behavior, stress physiology, and demography (Boyle and Samson 1985, Knight and Gutzwiller 1995, Hammit et al. 2015). Much of this research has focused on the impacts of motorized recreation on ungulates, with special consideration given to snowmobiling (Dorrance et al. 1975, Richens and Lavigne 1978, Creel et al. 2002, Borkowski et al. 2006). At the same time, research suggests that non-motorized activity such as hiking elicits even stronger responses in these species (Freddy et al. 1986, Stankowich 2008). Overall, research into the effects of motorized and non-motorized recreation raises important questions about the fitness consequences of noise disturbance (Barber et al. 2010, 2011, Shannon et al. 2015) and the ways in which recreation acts as a form of perceived predation in prey species (Frid and Dill 2002, Beale and Monaghan 2004).

Recreational aviation is a particular form of motorized recreation that has garnered little attention (Boyle and Samson 1985, Cordell 2010). Typified by the use of single-propeller, fixed-wing aircraft, it occurs throughout the contiguous United States and Alaska, where multiple federal and state agencies manage public-access, grass airstrips. White-tailed deer (*Odocoileus virginianus*) are one of the most prevalent ungulate species observed at backcountry airstrips in the U.S. Northern Rockies during the summer months (communication with the Recreational

Aviation Foundation). The use of edge habitat by white-tailed deer makes them good candidates for occupying human-altered habitats such as backcountry airstrips, which require a grass clearing upwards of a kilometer in length in the midst of extensive forest habitat. Backcountry airstrips are also often located near water sources, resulting in riparian areas that deer can also utilize. Through a combination of these factors, backcountry airstrips inadvertently provide good habitat for deer, thereby increasing the potential for human-wildlife interactions.

Research on the effects of fixed-wing and jet aircraft has not considered recreational aviation, and has largely investigated ungulate fleeing behavior (Calef et al. 1976, Krausman et al. 1986, 1998, Frid 2003) and calving success (Harrington and Veitch 1992, Lawler et al. 2005). The majority of these studies focus on boreal caribou (*Rangifer tarandus*), with one study that investigated the effects of aircraft disturbance on desert mule deer behavior (*O. hemionus crooki*) (Krausman et al. 1986). Results are variable across and within species, with ungulates such as desert mule deer and bighorn sheep (*Ovis canadensis*) showing no strong behavioral responses, while studies on caribou (*Rangifer tarandus*) provide contradictory evidence for the effects of aircraft disturbance on calf survival (Harrington and Veitch 1992, Maier et al. 1998, Lawler et al. 2005).

While behavioral studies are informative, measures of stress physiology can provide a mechanistic understanding of how free-living animals perceive and respond to perturbations. The glucocorticoid-driven stress response in vertebrates is a highly conserved physiological system that generally allows organisms to cope with environmental challenges (e.g., predation risk, adverse weather) (Wingfield et al. 1998). Secretion of glucocorticoids (GCs) is the end result of actions orchestrated by the hypothalamic-pituitary-adrenal (HPA) axis. The primary role of GCs is to mobilize glucose stores and send needed energy to target tissues, while non-essential activities such as reproduction and growth are inhibited in order to further allocate energy toward survival (Sapolsky et al. 2000, Romero 2004). The vertebrate stress response is highly adaptive in this way, but long-term activation of the HPA axis suppresses growth and reproductive effort to an extent that can be deleterious, decreasing organismal fitness and population viability (Wingfield et al. 1998, Romero and Wikelski 2001).

The analysis of GC concentrations has become prevalent in conservation biology, where insights into the physiological stress response of species of concern can improve management plans (Walker et al. 2005, Tarlow and Blumstein 2007, Busch and Hayward 2009, Sheriff et al. 2011, Madliger et al. 2016). Indeed, the last decade has witnessed the advancement of conservation physiology (Wikelski and Cooke 2006, Cooke et al. 2013), a field of research that uses physiological traits to assess the impacts of anthropogenic disturbance on free-living populations. The use of non-invasive measures of GCs such as fecal glucocorticoid metabolites (FGM) has enhanced conservation efforts over the last two decades. Besides eliminating the potential for additional stress due to handling animals, FGM provide an integrated average of circulating GCs over a known time period. This integrated measure allows for a wider scope of inference into the endocrine profile of animals exposed to anthropogenic disturbance (Sheriff et al. 2011). The time it takes to metabolize GCs into the conjugate form of FGM is commonly referred to as gut passage time. Gut passage time is species-specific, and for ungulates such as deer it is approximately 12 to 24 hours in duration, depending on season (Millspaugh et al. 2002).

Measuring FGM has proven especially useful for investigating the effects of recreation on various mammalian and avian species. Previous studies have reported increases in FGM due to motorized recreation such as snowmobiling (Creel et al. 2002), non-motorized recreation such as skiing (Arlettaz et al. 2007, Thiel et al. 2008), and tourist visitation rates in national parks and other protected areas (Barja et al. 2007, Zwijacz-Kozica et al. 2012). These studies have established that areas with higher volumes of recreation activity have elevated FGM compared to areas with lower volumes of disturbance. A recent review of the literature reports that all forms of human disturbance tend to elicit increases in FGM across taxa (Dantzer et al. 2014), which poses the question of how to parse out the relative effects of different human activities on wildlife stress levels. My aim, then, is to determine the effects of recreational aviation on deer FGM and to compare these stress responses to deer at other recreational sites that only allow non-motorized forms of recreation (e.g., camping, hiking). I consider whether disturbance associated with motorized recreation is the major mechanism behind FGM increases, or if it can be attributed more to overall volumes of human-related disturbance, regardless of the form of recreation involved. In doing so, my intention is not to compare areas with high levels of recreational disturbance to undisturbed areas, but to place the impacts of recreational aviation within the greater context of recreation on public lands and protected areas.

Additionally, research on the stress response of uncontrolled, free-living animals should consider the ways in which other environmental challenges act independently of or interact with anthropogenic sources of disturbance. Some confounding factors include differences between sexes, the effects of diet change across seasons, and the ways gut bacterial communities might differ across individuals, thus changing the process of metabolizing GCs into FGM (Goymann 2012). Given the fact that organisms regulate their physiology to numerous challenges (e.g., life history stages, weather events) via the glucocorticoid-driven stress response, it is important to account for factors beyond anthropogenic disturbance when researching uncontrolled, free-living populations (Dantzer et al. 2014). Weather events such as increasing temperature or precipitation may serve as environmental challenges to an ungulate that needs to meet energetic needs through foraging while minimizing energetic costs due to exposure to such weather.

This project measured the stress physiology profile of white-tailed deer (*Odocoileus virginianus*) exposed to low-flying, fixed-wing aircraft at backcountry airstrips in Montana and Idaho, USA. Here, I ask how FGM levels in deer correspond to varying rates of aircraft activity at different backcountry airstrips versus recreational sites lacking this form of disturbance. I tested the relative effects of anthropogenic disturbance on the organismal stress response after accounting for variation in FGM due to abiotic (e.g., temperature, wind velocity) and intrinsic (e.g., sex) factors. For anthropogenic sources of disturbance, I formulated three hypotheses as to how recreational disturbance influences organismal stress response beyond the effects of abiotic and intrinsic factors. First, the amount of aircraft activity at a site drives variation in deer FGM levels, due to air traffic noise serving as an additional stressor to general human presence in the form of camping and other non-motorized uses. Alternatively, FGM levels vary primarily due to the volume of human use at a site, regardless of the amount of aircraft activity occurring at a site. Lastly, recreation activity may not influence variation in FGM levels beyond the effects of abiotic and intrinsic factors, and FGM levels do not vary with changes in disturbance intensity. To account for abiotic and intrinsic factors thought to influence ungulate FGM through an animal's normal physiological processes, I formulated two hypotheses. First, I hypothesized that factors such as mean or maximum temperature and wind speed act as environmental challenges, and increases in these covariates would increase deer FGM. Second, I hypothesized that FGM would vary by sex, with females exhibiting higher FGM levels than males due to the metabolic requirements of parturition and lactation that occur during the early period of the sample season.

2.2 Study Area

The study area spanned a portion of the U.S. Northern Rockies between northwestern Montana and north-central Idaho (Fig. 2-1). Twelve recreational sites were visited: six public-access airstrips and six U.S. Forest Service (USFS) campgrounds that allowed non-motorized recreational opportunities and prohibited aviation. Management of airstrips was split between federal and state agencies, namely the USFS, the Montana Department of Transportation, and the Idaho Division of Aeronautics. Airstrip sites included Schafer USFS Airport, MT (48°07', -113°24'), Fish Lake USFS Airport, ID (46°33', -115°06'), Moose Creek USFS Airport, ID (46°12', -114°92'), Meadow Creek USFS Airport, MT (47°84', -113°41'), Johnson Creek Airport, ID (44°91', -115°48'), and Ryan Field, MT (48°48', -113°95'). Of these, three airstrips are located within designated Wilderness areas (Schafer USFS Airport, Fish Lake USFS Airport, and Moose Creek USFS Airport), two are located within national forest lands (Meadow Creek USFS Airport, Johnson Creek Airport), and one is located on private land deeded to the public for recreational aviation access (Ryan Field). Non-airstrip recreational sites included Monture Creek Campground, MT (47°12', -113°14'), Kreis Pond Campground, MT (47°09', -114°42), Rattlesnake Recreation Corridor, MT (46°93', -113°98'), Valley of the Moon Trailhead, MT (46°69', -113°67'), Hogback Homestead, MT (46°41', -113°70'), and East Fork Campground, MT (46°13', -113°38').

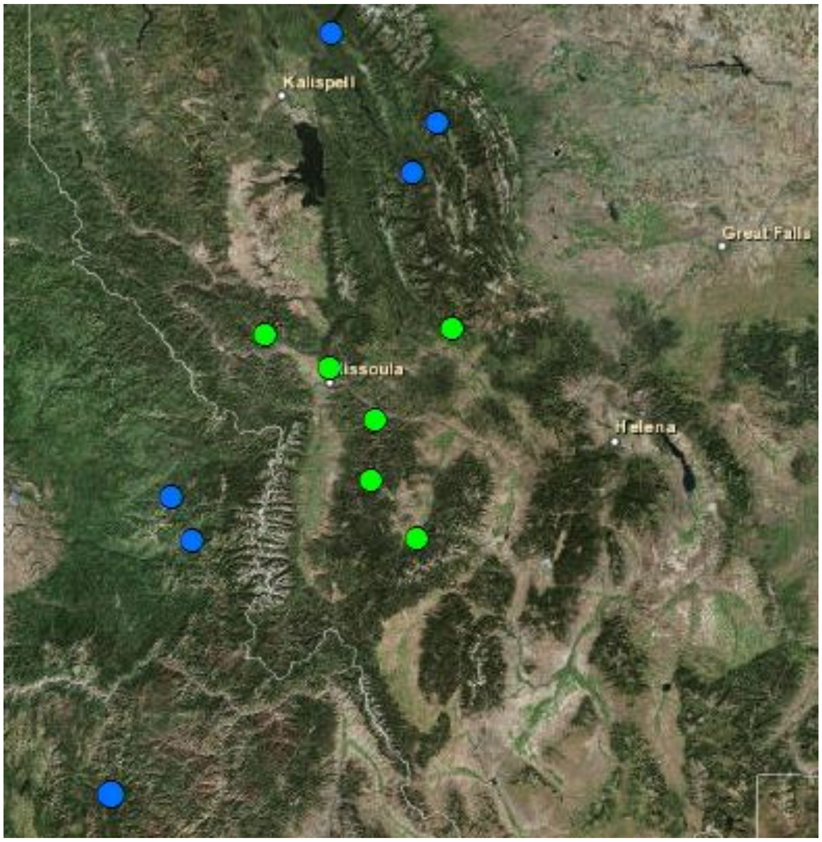


Fig. 2-1. Map of study area displaying locations of airstrip (blue) and non-airstrip sites (green).

Airstrip runways range in length from approximately 762 m to 1250 m, with a mean length of 913.5 meters (2997 feet). Airstrip sites range in elevation from 748 m to 1721 m, with a mean elevation of 1297 meters (4255 feet). Non-airstrip sites range in elevation from 1097 m to 1829 m, with a mean elevation of 1300 meters (4267 feet). Both airstrip and non-airstrip sites are described generally by subalpine, mixed coniferous forests, deciduous woodland, and riparian habitat that envelop a meadow clearing, which itself provides considerable edge habitat. Meadow clearings at non-airstrip sites were consistently smaller and varied more topographically than runway clearings at airstrips.

2.3 Methods

2.3.1 Fecal Sample Collection

Fecal samples were collected for FGM analysis from June to August 2014 and from May to August 2015. The location of every sample was marked via GPS and species and sex were recorded when known. Sample collection was conducted with approval from the University of Montana Institutional Animal Care and Use Committee protocol No. 030-15. Each site was visited once each summer for a period of approximately 72 hours. In 2014, direct observation periods took place in the evening during the last 3 hours of sunlight each day. In 2015, 3-hour observation periods occurred twice daily (early dawn and evening), resulting in a total of 6 observation periods. All observation periods took place during peak foraging activity (i.e., early dawn and dusk) and lasted for three hours. The purpose of these observation periods was to collect fecal samples through observing defecation and scanning areas for fecal samples post-observation where deer had foraged extensively. A stationary observation point was chosen at the airstrip or meadow clearing prior to the observation period. An observer remained at this location and monitored the clearing continuously with binoculars for the three-hour period. When a defecation event was observed during this period, the sample was immediately collected. Toward the end of the observation period, the observer scanned areas of the clearing where animals were foraging consistently during that time. To minimize the likelihood of collecting feces from different defecation events as a single sample, I only collected piles that were sufficiently isolated from others.

Concurrent with these observation periods in 2015, a second observer sampled from the area surrounding the clearing. For this sample effort, three sections around the airstrip were defined prior to the first sampling period at a site. The order in which these sections were sampled was chosen randomly in such a way that each section was sampled twice over the 72-hour visit to a site. While looking for ungulate scats in these sections, the observer also recorded the presence of carnivore scats as a rudimentary metric of predator presence at each site.

As opposed to conducting direct observation in the morning during the 2014 season, samples were taken systemically in the following manner. Ten 30x30 meter transects were set up across the length of the airstrip or meadow clearing such that transects lined the edges of the clearing, where deer are known to defecate during daily movement patterns to and from foraging bouts (Loft and Kie 1988). These ten transects were scanned once daily following peak foraging periods (2 hours post-sunrise) for three consecutive days, and all fresh fecal samples were collected for radioimmunoassay.

An experimental study of red deer (*Cervus elaphus*) by Huber et al. (2003) showed significant changes in FGM concentrations from samples collected > 6 hours post-defecation. Accordingly, fecal masses known to be or that appeared to be ≤ 6 hours post-defecation were collected into a Falcon 50 ml polypropylene conical tube and placed in a dry ice container (~ -80°C) on site until storage in a laboratory freezer was possible. Due to our method of collecting samples during set observation periods, many of our samples fell within 3 hours post-defecation. However, because samples from direct observation as well as unobserved defecation events, a proportion of samples from both years collected were likely older than this suggested timeframe.

2.3.2 Measuring Recreation Activity and Abiotic Factors

I used a Roland R-05 MP3 recorder (Roland Corp. US, Los Angeles, CA, USA) to gather audio recordings at each site for the duration of the 72-hour period. The purpose of audio recordings was to measure the number of takeoff and landing events that occurred at each airstrip site. The daily average number of takeoff and landing events served as the variable for measuring volume of aircraft activity at a site.

I also measured human presence at each site. In 2014, I estimated the number of people at each site by counting all individuals on site daily for three days, not recounting individuals already present on previous days. These daily counts were then averaged over the 72-hour period. In 2015, I measured various aspects of human presence daily during two 1-hour periods at 1000h and 1400h for three consecutive days. Depending on the site, I counted the number of people, planes, vehicles, established campsites, and domestic dogs present. These counts took place at the beginning, middle, and bottom of the hour, and then averaged. If a site had secondary roads adjacent to the site, vehicular traffic rates were also recorded during these periods. These different methods both resulted in achieving a measure of average visitation rates at each site over the three days I visited the site.

I gathered weather data for each site from the nearest remote weather access stations (RAWS Climate Archive). Information selected from RAWS reports included daily mean and maximum temperature (degrees C), daily precipitation (cm), and daily mean wind velocity (m/s).

2.3.3 I^{125} Radioimmunoassay

Samples were sent to the Center for Conservation Biology at the University of Washington. Glucorticoid metabolites were extracted using a 125-I corticosterone radioimmunoassay (RIA) kit (MP Biomedicals, Solon, OH, USA, Cat. No. 07-120103). The manufacturer's protocol was followed except that the volume of all reagents was halved (Wasser et al. 2000). This assay was previously validated for captive white-tailed deer via ACTH challenge and parallelism studies

(Millspaugh et al. 2002). Inter-assay variation for 2014 and 2015 was 3.5% and 1.9%, respectively, and intra-assay variation was 6.5% and 6.1% (R. Booth, Center for Cons. Bio).

2.3.4 Fecal Genetics Analysis

I used genetic analysis to determine individual sex for each sample. For all samples, 3-4 pellets were placed into a Falcon 10 ml polypropylene conical tube and 90% ethanol (EtOH) was added. Samples were sent to the lab of Dr. Gordon Luikart at the University of Montana for the purposes of DNA extraction and amplification via polymerase chain reaction (PCR). DNA extraction was performed using Qiagen QIAamp stool extraction kits (QIAGEN Corp., Germantown, MD, USA, Cat. No. 51504). The manufacturer's protocol was followed except initial ASL buffer amount was increased from 1.6 to 2.0 mL, and the amount of InhibitEx added to each sample was halved.

PCR was done using the Kompetitve Allele Specific PCR genotyping system (LGC genomics, Beverly, MA, USA). The manufacturer's protocol was followed with the following modifications to the thermal cycling conditions in the final stage of PCR: for sex ID, the number of PCR cycles was increased from 26 to 36, and for species ID was the number of cycles increased from 26 to 32.

2.3.5 Statistical Analyses

Fecal glucocorticoid metabolite concentrations were natural log-transformed to improve normality of residuals. First, I used an exploratory approach to evaluate variation in FGM across all sites sampled in both years of the study (ANOVA), and also investigated differences in mean FGM to account for possible variation due to sex, circadian rhythms, and the effects of degradation over time (independent t-test) (Huber et al. 2003, Millspaugh and Washburn 2004, Goymann 2012, Dantzer et al. 2014).

I then used linear mixed effects models to evaluate how well anthropogenic, abiotic and intrinsic factors explained variation in deer FGM. Model performance was assessed using an information theoretic framework with Akaike's Information Criterion adjusted for small sample sizes (AIC_c). I constructed candidate models based on the idea that anthropogenic factors (e.g., aircraft activity) must be considered only in addition to abiotic factors (e.g., weather events) that may already be responsible for natural fluctuations of glucocorticoid secretion in free-living deer. To compare models, I chose the top supported models that fell within $\Delta AIC_c < 2.0$ (Burnham and Anderson 2002). Prior to modeling, I used linear regression to gain insight into which anthropogenic and abiotic factors correlated with FGM better than others, thus minimizing the number of uninformative parameters in the models. I also assessed collinearity of covariates using a variance inflation factor (VIF) threshold of < 2.0 (Zuur et al. 2010). Anthropogenic variables set as fixed effects included average number of people at a site/hour ('visitors') and the frequency of aircraft activity/hour ('air traffic'). Abiotic variables set as fixed effects included mean wind velocity ('wind') and precipitation ('precip') from the day prior to sample collection, in order to account for the approximately 24-hour gut passage time in white-tailed deer. Additionally, I included interaction terms between the number of visitors and type of recreational site ('visitors*type'), the effect of visitors and seasonal period ('visitors*period'), and the effect of air traffic and seasonal period (air traffic*period). All models contained recreational site ID as a random effect, unique to the year the site was visited or revisited, which allowed us to account for observed variation in mean FGM across all sites in both years of the study. However, I did not use year explicitly as a random effect because there were only two years of the study, raising statistical concerns over how to reliably gain an estimate and variance of a random effect given a sample size of two (Gelman and Hill 2007, Kéry 2010). All analyses were performed in R v.3.0.2 with packages "lme4" and "runjags" (R Core Team 2012, www.r-project.org).

Due to a proportion of samples that did not amplify during PCR to determine sex, the dataset contained missing values. To address the potential effect of sex on FGM, I created a generalized linear mixed model in a Bayesian framework (Kéry and Schaub 2012). The inclusion of sex as a covariate, however, did not improve model performance. Thus, I excluded sex from the models reverted back to using AICc as a model selection framework.

2.4 Results

2.4.1 Exploratory Data Analysis

I collected 149 deer fecal samples viable for RIA across both study years (n_{2014} = 34, n_{2015} = 115). Across both years of the study, mean FGM concentrations were 142.9±5.4 ng/g at airstrips and 158.8±4.5 ng/g at non-airstrip sites (t=-2.21, p=0.03). There was notable variation in FGM between recreation site types (airstrip vs. non-airstrip) as well as across all sites sampled within and between years (Fig 2-2). The difference in mean FGM between recreation site types changed direction between years, such that 2014 showed higher FGM at airstrips and 2015 showed higher FGM at non-airstrips. Much of the difference between airstrips and non-airstrips in 2014 appears to be driven by one site, Schafer Meadows USFS airport. When I removed this site from the analysis, mean FGM concentrations were 128.3±4.5 ng/g and 158.77±4.5 ng/g at non-airstrip sites (t=-3.27, p=0.001).

I did not see differences in daily visitation rates between recreation site types across both years of the study (t = 0.47, p=0.64) (Table 2-1b). However, I did see significant variation in air traffic rates among the airstrip sites visited across both years of the study (ANOVA: F=1.15[30], p < 0.001) (Table 2-1).

Fig. 2-2. Mean FGM (±SE) of individual airstrip and non-airstrip sites sampled in 2014-2015 and mean FGM (±SE) of all airstrip and non-airstrip sites across both years of the study.

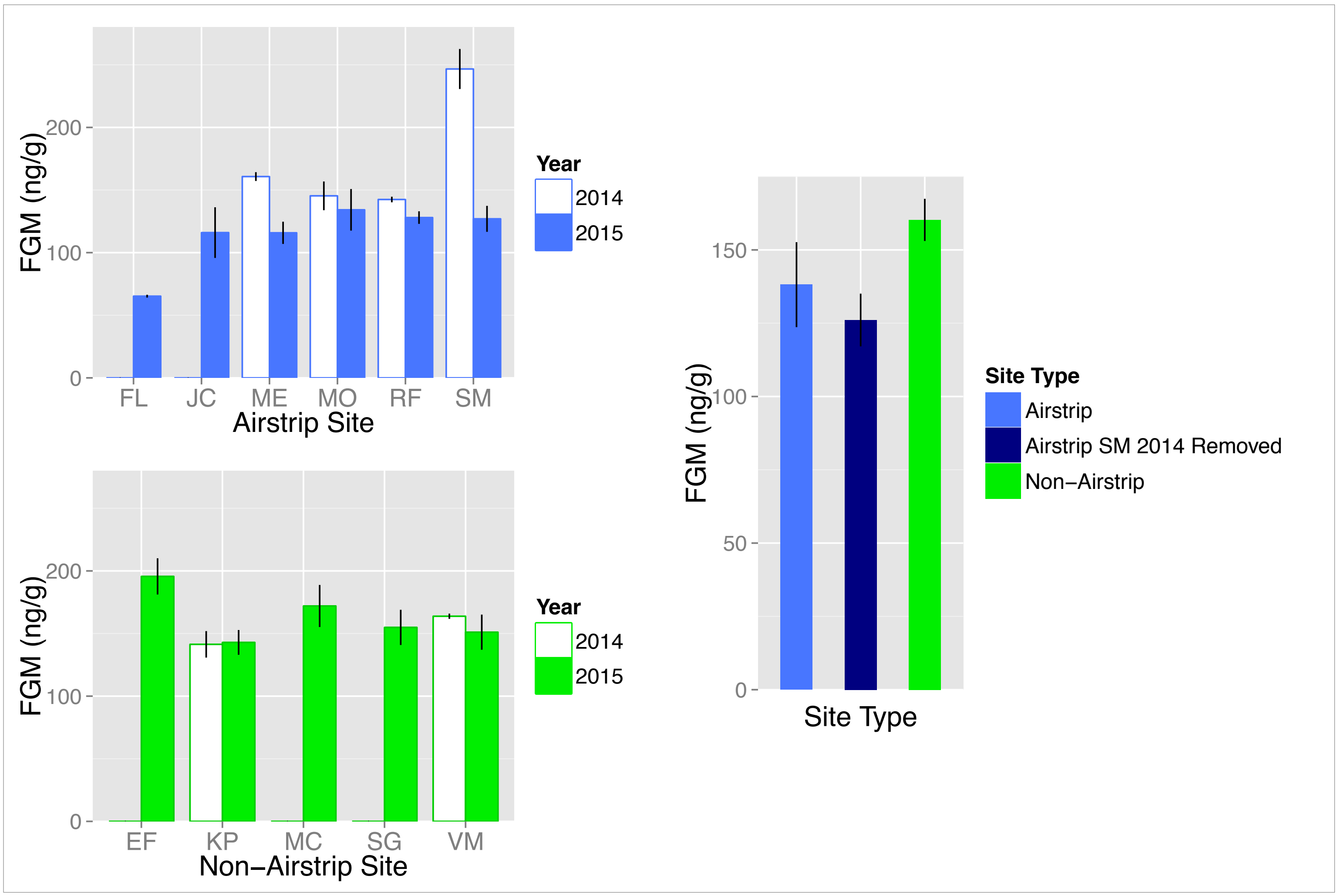


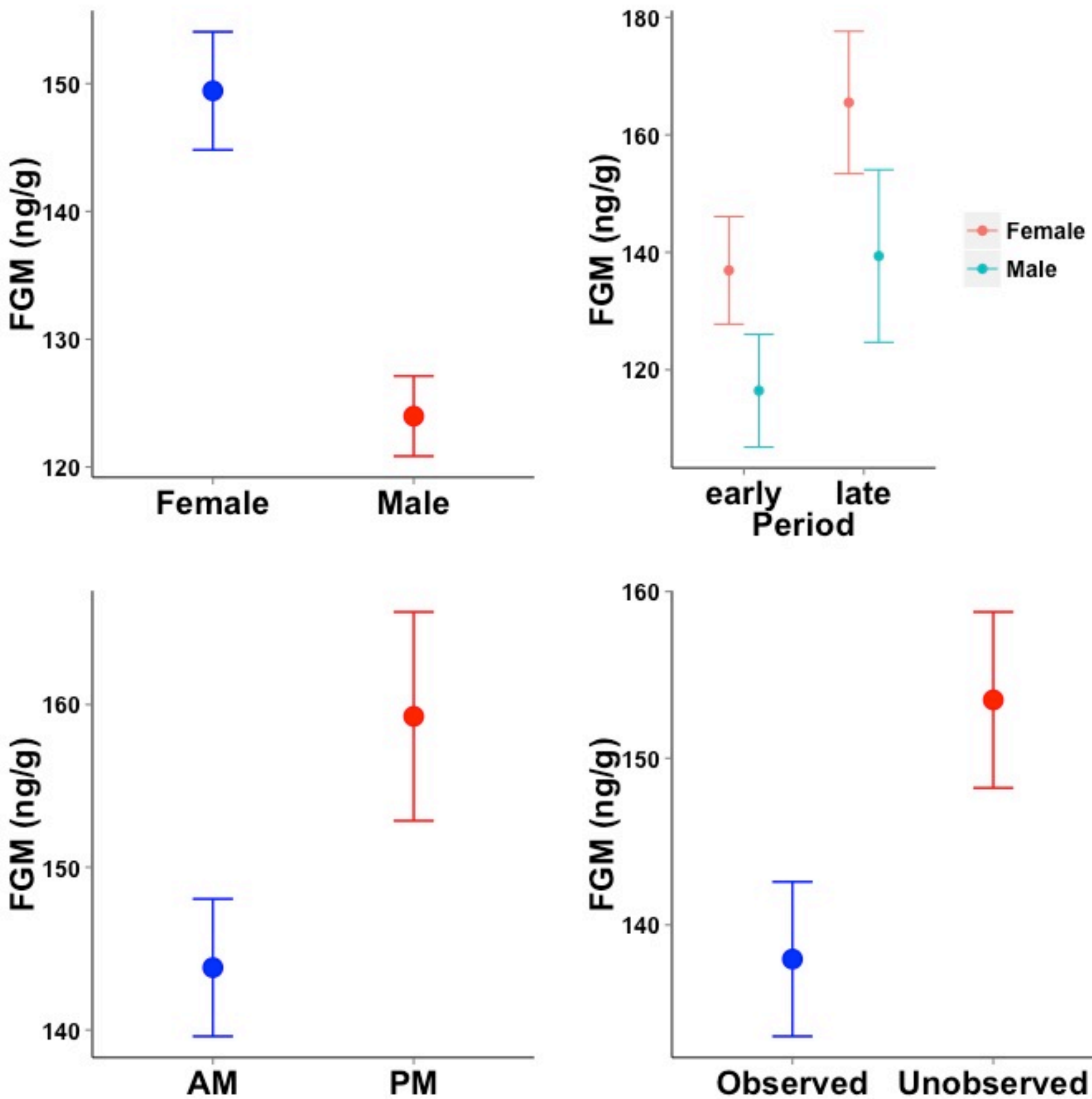
Table 2-1. Average visitation rates and daily air traffic rates at airstrip and non-airstrip sites sampled during 2014 & 2015.

Recreation Site	Year	Average No. of Daily Visitors	Daily Air Traffic Rates (average no. flight events/day)
East Fork Campground[a]	2015	5.83	N/A
Fish Lake USFS Airport[b]	2015	2.22	1.0
Johnson Creek Airport[b]	2015	11.95	15.33
Kreis Pond Campground	2014	12.5	N/A
	2015	25.05	N/A
Monture Creek Campground[a]	2015	5.39	N/A
Meadow Creek USFS Airport	2014	5.5	5
	2015	2	0
Moose Creek USFS Airport	2014	21	11
	2015	14.67	2.33
Ryan Field Airport	2014	53.83	11.67
	2015	27.28	11
Sawmill Gulch (Rattlesnake Rec Corridor)[b]	2015	14.33	N/A
Schafer Meadow USFS Airport	2014	5.5	7
	2015	10.45	11.67
Valley of the Moon Trailhead	2014	5.33	N/A
	2015	8.55	N/A

[a] Site was visited in 2015 only.
[b] Site was visited in 2014 and revisited in 2015, but viable fecal samples were collected in 2015 only.

I analyzed additional sources of variation in FGM (e.g., sex, circadian rhythm), finding that females had higher mean FGM (149.4 ±4.6 ng/g) compared to males (124.0 ±3.1 ng/g) (*t*=2.41, p=0.01) (Fig 2-3a). Mean FGM of known females (n=68) also increased from the early period (May-June) to the late period (July-August) of the season (*t*=-2.29, p=0.02), while there was no difference observed in males (n=25) (*t*=-1.44, p=0.16) (Fig. 2-3b). There is also no effect of circadian rhythms on FGM levels in white-tailed deer (*t*= -0.86, p=0.39). (Fig. 2-3c), nor was there a difference detected in mean FGM between samples collected from observed defecations (n=30) and unobserved defecations (119) (*t*=1.44, p=0.15) (Fig. 2-3d).

Fig. 2-3 A-D. Comparison of mean FGM (±SE) across numerous factors thought to influence FGM variation: (a) sex (b) sex and seasonal period (early=May-June, late=July-August (c) circadian rhythm (AM=sample collected during morning observation, PM=sample collected during evening observation) (d) degradation of fecal samples from unobserved defecation events due to environmental exposure.



2.4.2 AIC Model Selection

The top three models within $\Delta AIC_C < 2.0$ indicate that much of the variation in deer FGM can be explained by abiotic factors that largely override any effects due to anthropogenic disturbance, accounting for 54% (or 69%) of the model weights (Table 2-2). Of these, estimates and confidence intervals for daily precipitation and mean wind velocity are consistently positive, suggesting increases in precipitation and wind velocity elevate glucocorticoid secretion (Table 2-3). The anthropogenic parameters of interest appear in moderately supported models, but confidence intervals for these parameter estimates overlap zero (air traffic: β=-0.001, 95CI=-0.50—0.47; visitors: β=0.001, 95CI=-0.01—0.01). Linear regression showed no relationship between mean or max temperature and white-tailed deer FGM, and thus was excluded as a weather covariate from the model selection process. VIF analysis of the remaining anthropogenic and abiotic factors revealed no collinearity between explanatory variables.

Table 2-2. Linear mixed-effect candidate models for anthropogenic and abiotic effects on deer FGM at all recreational sites sampled in 2014 and 2015 (natural log-transformed).

Model (fixed-effects)[a,b]	k[c]	log likelihood	AIC_C	ΔAIC_C [d]	w_i [e]
precip + wind + period	**6**	**-44.23**	**101.1**	**0.00**	**0.25**
precip + wind	**5**	**-45.67**	**101.8**	**0.71**	**0.18**
precip + period	**5**	**-46.20**	**102.8**	**1.77**	**0.11**
precip + wind + period + visitors	7	-44.19	103.2	2.13	0.09
precip + wind + period + air traffic	7	-44.23	103.3	2.20	0.08
precip + wind + period + air traffic + air traffic*period	8	-43.52	104.1	3.01	0.06
wind + period	5	-47.16	104.7	3.70	0.04
period	4	-48.28	104.8	3.79	0.04
precip	4	-48.36	105.0	3.95	0.03
wind	4	-48.37	105.0	3.96	0.03
visitors + precip + wind + period + visitors*period	8	-44.11	105.3	4.20	0.03
precip + wind + period + visitors + air traffic	8	-44.19	105.4	4.35	0.03
random-intercept only	3	-50.15	106.5	5.41	0.02
precip + wind + period + visitors + type + vistors*type	9	-44.04	107.4	6.32	0.01

[a] Explanation of predictor variable abbreviations provided in Methods section.
[b] All models contain recreational site ID as a random intercept effect.
[c] Number of parameters in model.
[d] Difference in AIC_C value from the top supported model.
[e] The probability that the model is the best fit model given the data available (Akaike weight).

Table 2-3. Model-averaged parameter estimates and 95% confidence intervals for strongly-supported models ($\Delta AIC_C < 2.0$) for all recreational sites in 2014 and 2015.

Model Parameter	**Model-averaged Estimate**[a]	**Back-transformed Estimate**[b]	**95% CI**
intercept	4.68	108.10	(85.98, 135.92)
daily precipitation (cm)	**0.15**	**1.16**	**(1.02, 1.31)**
daily mean wind velocity (m/s)	**0.11**	**1.12**	**(1.02, 1.30)**
seasonal period (late)	0.11	1.12	(0.98, 1.44)

[a] Model-averaged parameter estimates are natural log transformed.
[b] Parameters were back-transformed by taking the natural logarithm and raising it to the power of the original estimate. Values above 1.0 indicate a positive effect, values below 1.0 indicate a negative effect.

2.5 Discussion

These findings suggest that neither recreational aviation nor non-motorized forms of recreation account for variation in deer FGM beyond the abiotic factors of precipitation and wind velocity, a result that corresponds with my third hypothesis. Such findings are not unique to research on the stress response of free-living mammals to recreation and ecotourism. For instance, a study of Alaskan brown bears (*Ursus arctos*), found that human presence explained little variation in FGM relative to factors such as diet and date sampled (Von der Ohe et al. 2004). Still, several possible explanations should be considered to address the apparent lack of anthropogenic effects on deer FGM at my study sites.

The fact that backcountry airstrips provide abundant edge habitat with access to water is perhaps a benefit that overrides any negative impacts of recreation disturbance on deer. Therefore, the benefits provided by the habitat at backcountry airstrips relative to the costs associated with exposure to anthropogenic disturbance may help explain the lack of an elevated stress response of deer to recreational aviation.

Furthermore, the high level of temporal and spatial predictability may help explain why deer at airstrips do not show evidence of FGM increases in response to recreational aviation disturbance (Miller et al. 2001, Von der Ohe and Servheen 2002, Francis and Barber 2013). Flights tend to occur in the early morning and evening, when winds are often calmer and density altitude is lower than at the heat of midday, making conditions safer for flying. Recreational aviation also necessitates spatially concentrated use on the ground, limiting fixed-wing aircraft to operating in relatively small areas (~ 1 km). White-tailed deer in the western, mountainous parts of Montana have an estimated home range of 0.5-1.2 km^2 (Foresman 2012). In spite of a home range size that presumably overlaps with airstrip clearings, deer sampled in this study did not display elevated FGM due to air traffic disturbance, suggesting that perhaps deer utilizing the area surrounding backcountry airstrips are able to negotiate the high level of spatial predictability characteristic of takeoffs and landings.

Backcountry airstrips may also serve as a potential predator refuge or human shield (Berger 2007) in the summer seasons. With the sudden and relatively short-lived influx in human disturbance that occurs at these sites over a period of several months, it is plausible that predators in the backcountry of Montana and Idaho move farther from these concentrated areas of human use. If this were the case, it would relieve deer at airstrips of this stressor and replace it with the more predictable event of recreational disturbance.

Individual personality or temperament may also provide insights into the lack of a response in deer to recreational aviation. An increasing body of theoretical and empirical work suggests that personality—whether an individual is proactive/reactive, or bold/shy—should be mirrored in an individual's physiological traits. That is, "bold" individuals are expected to be more proactive in their behavior relative to "shy," or reactive, individuals. Accordingly, bold individuals are expected to mount less severe stress responses compared to shy individuals when faced with environmental stimuli such as recreation and ecotourism (Sih et al. 2004, Cockrem 2007). In a study comparing behavioral and physiological traits of Eastern chipmunks (*Tamias striatus*), Martin and Réale (2008) found that individuals whose burrows were located closer to where humans frequented exhibited more proactive (or "explorative") behavior, and hair cortisol samples from these individuals showed no relationship to amount of human presence. In a study involving free-living Richardson's squirrels (*Urocitellus richardsonii*), Clary et al. (2014) found a positive relationship between an individual's vigilance in response to a novel object and their corresponding FGM concentrations. If individuals who forage in airstrip clearings, regardless of aircraft disturbance level, were on the proactive end of the behavioral spectrum, then it could help to explain lowered FGM responses to this form of disturbance. Conversely, reactive individuals may not enter the airstrip clearing or frequent the general airstrip area.

The consistently positive effect of both wind and precipitation on deer FGM in the models provides strong evidence for environmental challenges at these sites that override effects of recreational disturbance. The discovery of a strong predictive effect of wind velocity on deer FGM was unexpected. This effect may be explained by the fact that deer largely use auditory and olfactory senses to assess threat level, and increases in wind velocity could result in the masking of predator cues (Muller-Schwarze 1994, Barber et al. 2010). This masking effect would reasonably lead to higher vigilance levels and inhibit foraging activity (Lima and Dill 1990). While anthropogenic disturbance at these recreational sites does not directly drive FGM concentrations in deer, the need for these foraging ungulates to determine sources of perceived predation risk from recreationists may begin to have indirect effects on deer FGM when abiotic factors such as wind mask an individual's capacity to gain reliable information from its listening area (Frid and Dill 2002). In a recent study of mule deer in northwestern Colorado, Lynch et al. (2015) investigated the interplay between auditory and visual vigilance behaviors in deer. They concluded that not only do deer rely on auditory vigilance more when visual scanning capabilities are reduced (e.g. during nighttime or in forested habitats), but that an increased reliance on auditory cues result in increased pausing bouts during foraging activity. Part of this increase in pausing during foraging is because the act of mastication inherently reduces the ability of mammals to receive auditory signals (Pang and Guinan 1997). This behavioral tradeoff between energy allocation and assessing predation risk is compounded in a situation with increased wind velocities masking auditory cues, where receiving reliable information is now curtailed by wind noise in addition to mastication. The role of wind velocity as an ecological factor that inhibits perception of predation risk and increases auditory vigilance rates, and the effects this has on organismal stress responses, should be studied further.

As for the effects of precipitation on deer FGM, it may be harder to parse out its role on the physiological stress response versus the artificial effects of moisture on FGM. While precipitation may act as an environmental challenge that alters foraging behavior or increases thermogenesis in foraging ungulates, experimental studies have shown that exposure to precipitation results in increases of FGM in fecal masses post-defecation that is detected during radioimmunoassay (Washburn and Millspaugh 2002). However, I did not detect a difference between fecal samples that were collected from unobserved defecation events and those that were observed (Fig.2-3d). Nonetheless, I acknowledge the possibility of precipitation artificially elevating FGM levels in my samples, and urge future studies to approach sampling in moist environments with caution.

Lastly, the findings regarding differences in endocrine profile between sexes are consistent with some previous research, but the interactions between sex and seasonal change are inconsistent with other deer studies. The finding that females had significantly higher mean FGM compared to males is most likely due to the effects of reproductive state in the summer season, where parturition and lactation act to increase GC secretion. This supports similar findings in North American red squirrels (Dantzer et al. 2010) and spotted hyenas (Goymann et al. 2001), which both showed pregnant and lactating females having higher FGM than non-breeding females and males. However, in a study of red deer (*Cervus elaphus*) in Europe, Huber et al. (2003) saw no difference in FGM between pregnant females, non-breeding females, and males. Additionally, the finding that mean FGM increased for females from the early to late period of the season differs from experimental studies in deer that show a spike in female FGM during parturition and a subsequent decline into the later part of the summer season (Jachowski et al. 2015). It is unlikely that this overall increase in FGM in the later part of the season is attributable to recreational impacts becoming more severe over time, since interaction terms between the effects of recreation and seasonal period were not supported in the models. Rather, I hypothesize that, unlike captive individuals that are fed *ab libitum*, free-living populations in the Northern Rockies are faced with decreasing forage quality as the season progress and becomes increasingly arid. This decrease in forage quality, especially for females experiencing lactation, could result in increased metabolic output via increases in foraging effort, resulting in higher GC secretion.

Exploratory tests of mean FGM revealed that non-airstrip sites displayed significantly higher deer FGM, although this finding was not supported by AIC model selection. However, this difference between recreation site types does support previous research where increased ungulate FGM is correlated with greater volumes of human disturbance (Millspaugh et al. 2001, Garcia Pereira et al. 2006, Wasser et al. 2011, Zwijacz-Kozica et al. 2012, Jachowski et al. 2015). While there was no difference in average visitation rates between airstrips and non-airstrips (Airstrip = 15.44 people/hr, Non-Airstrip= 11.56 people/hr, df=15, $p = 0.55$) (Table 2-1), visitation at these non-airstrip sites is likely to occur over more of the calendar year than at airstrip sites, where access is restricted during much of the winter. Furthermore, non-airstrip sites tended to be in closer proximity to human settlements and major roads than their airstrip counterparts, which are typically located in remote parts of the national forest system and Wilderness areas. These additional sources of anthropogenic disturbance at non-airstrip sites may well account for the increased FGM displayed there.

Numerous limitations of the study that could bias results should be acknowledged. There is a substantial amount of variability in the sample size collected from airstrips over both years, with some sites providing over 20 viable samples (Moose Creek, Schafer Meadows) and others less than five (Fish Lake, Johnson Creek). Similar variability in sample size attained occurred at non-airstrip sites. Furthermore, it is unclear how the average visitation rates I observed over a 72-hour period match that of overall visitation rates at a given site (e.g., monthly or seasonal visitation rates), primarily due to a lack of accurate record keeping at these remote, backcountry airstrips. Gaining an understanding of long-term trends in visitation at these airstrip sites may help to explain differences in mean FGM from these sites. Differences in methodologies between study years, namely the absence of a morning observation period in 2014, may have also biased results.

While various conservation successes can be attributed to the growing field of conservation physiology (Madliger et al. 2015), fundamental questions persist as to how physiological insights are optimized for the purposes of effective management. These outstanding questions point out the need to consider how increases in GCs serve to increase fitness parameters of disturbed populations, and for more studies to measure demographic rates in order to make conclusive statements about the role that increased GCs play in survival and reproduction rates (Blickley et al. 2012, Dantzer et al. 2014). Previous research suggests the relationship between GCs and fitness is highly context-dependent (Breuner et al. 2008, Bonier et al. 2009). For instance, while mean FGM concentrations from this study are higher than baseline values taken from captive white-tailed deer (Millspaugh et al. 2002), the biological relevance of this difference and its impact on organismal fitness is unclear. While it is beyond the scope of the current study, I reiterate the call for conservation physiology research to measure demographic rates when possible, as this is inarguably the foundation for conservation planning.

2.6 Management Implications

Recreational aircraft activity and other, non-motorized forms of recreation did not contribute to physiological stress responses in white-tailed deer, as measured by fecal glucocorticoid metabolite concentrations. However, abiotic factors of wind velocity and daily precipitation both accounted for increases in FGM from deer sampled. Since high wind velocities and precipitation tend to ground much recreational aviation activity due to safety concerns, there is likely no need to address limiting flight activity during such weather events.

2.7 References

Arlettaz, R., P. Patthey, M. Baltic, T. Leu, M. Schaub, R. Palme, and S. Jenni-Eiermann. 2007. Spreading free-riding snow sports represent a novel serious threat for wildlife. Proceedings of the Royal Society B 274:1219–1224.

Barber, J. R., C. L. Burdett, S. E. Reed, K. a. Warner, C. Formichella, K. R. Crooks, D. M. Theobald, and K. M. Fristrup. 2011. Anthropogenic noise exposure in protected natural areas: estimating the scale of ecological consequences. Landscape Ecology 26:1281–1295.

Barber, J. R., K. R. Crooks, and K. M. Fristrup. 2010. The costs of chronic noise exposure for terrestrial organisms. Trends in Ecology & Evolution 25:180–9.

Barja, I., G. Silván, S. Rosellini, A. Piñeiro, A. González-Gil, L. Camacho, and J. C. Illera. 2007. Stress physiological responses to tourist pressure in a wild population of European pine marten. The Journal of Steroid Biochemistry and Molecular Biology 104:136–42.

Beale, C. M., and P. Monaghan. 2004. Human disturbance: People as predation free predators? Journal of applied ecology 41:335–343.

Berger, J. 2007. Fear, human shields and the redistribution of prey and predators in protected areas. Biology Letters 3:620–623.

Blickley, J. L., D. Blackwood, and G. L. Patricelli. 2012. Experimental evidence for the effects of chronic anthropogenic noise on abundance of greater sage-grouse at leks. Conservation Biology 26:461–471.

Bonier, F., P. R. Martin, I. T. Moore, and J. C. Wingfield. 2009. Do baseline glucocorticoids predict fitness? Trends in Ecology and Evolution 24:634–642.

Borkowski, J. J., P. J. White, R. A. Garrott, T. Davis, and A. R. Hardy. 2006. Behavioral responses of bison and elk in Yellowstone to snowmobiles and snow coaches. Ecological Applications 16:1267–1276.

Boyle, S. A., and F. B. Samson. 1985. Effects of non-consumptive recreation on wildlife: a review. Wildlife Society Bulletin 13:110–116.

Breuner, C. W., S. H. Patterson, and T. P. Hahn. 2008. In search of relationships between the acute adrenocortical response and fitness. General and Comparative Endocrinology 157:288–295.

Brown, C. L., A. R. Hardy, J. R. Barber, K. M. Fristrup, K. R. Crooks, and L. M. Angeloni. 2012. The effect of human activities and their associated noise on ungulate behavior. PLoS ONE 7:38–40.

Burnham, K.P and D.R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer-Verlag, New York, New York, USA.

Busch, D. S., and L. S. Hayward. 2009. Stress in a conservation context: A discussion of glucocorticoid actions and how levels change with conservation-relevant variables. Biological Conservation 142:2844–2853.

Calef, G. W., E. a. DeBock, and G. M. Lortie. 1976. The reaction of barren-ground caribou to aircraft. Arctic 29:201–212.

Ciuti, S., J. M. Northrup, T. B. Muhly, S. Simi, M. Musiani, J. a. Pitt, and M. S. Boyce. 2012. Effects of humans on behaviour of wildlife exceed those of natural predators in a landscape of fear. PLoS ONE 7:1-13.

Clary, D., L. J. Skyner, C. P. Ryan, L. E. Gardiner, W. G. Anderson, and J. F. Hare. 2014. Shyness-boldness, but not exploration, predicts glucocorticoid stress response in Richardson's ground squirrels (Urocitellus richardsonii). Ethology 1101–1109.

Cockrem, J. F. 2007. Stress, corticosterone responses and avian personalities. Journal of Ornithology 148.

Cooke, S. J., L. Sack, C. E. Franklin, a. P. Farrell, J. Beardall, M. Wikelski, and S. L. Chown. 2013. What is conservation physiology? Perspectives on an increasingly integrated and essential science. Conservation Physiology 1:1–23.

Creel, S. R., J. E. Fox, A. Hardy, J. Sands, B. O. B. Garrott, and R. O. Peterson. 2002. Snowmobile activity and glucocorticoid stress responses in wolves and elk. Conservation Biology 16:809–814.

Dantzer, B., Q. E. Fletcher, R. Boonstra, and M. J. Sheriff. 2014. Measures of physiological stress: a transparent or opaque window into the status, management and conservation of species? Conservation Physiology 2:1–18.

Dantzer, B., A. G. McAdam, R. Palme, Q. E. Fletcher, S. Boutin, M. M. Humphries, and R. Boonstra. 2010. Fecal cortisol metabolite levels in free-ranging North American red squirrels: Assay validation and the effects of reproductive condition. General and Comparative Endocrinology 167:279–286.

Dorrance, M. J., P. J. Savage, and D. E. Huff. 1975. Effects of snowmobiles on white-tailed deer. The Journal of Wildlife Management 39:563–569.

Foresman, K. 2012. Mammals of Montana. Second edition. Mountain Press, Missoula, Montana, USA.

Francis, C. D., and J. R. Barber. 2013. A framework for understanding noise impacts on wildlife: an urgent conservation priority. Frontiers in Ecology and the Environment 11:305–313.

Freddy, D. J., W. M. Bronaugh, M. C. Fowler, S. Wildlife, S. Bulletin, and N. Spring. 1986. Responses of mule deer to disturbance by persons afoot and snowmobiles. Wildlife Society Bulletin 14:63–68.

Frid, A., and L. M. Dill. 2002. Human-caused disturbance stimuli as a form of predation risk. Conservation Ecology 6:11.

Frid, A. 2003. Dall's sheep responses to overflights by helicopter and fixed-wing aircraft. Biological Conservation 110:387–399.

Garcia Pereira, R. J., J. M. Barbanti Duarte, and J. A. Negrão. 2006. Effects of environmental conditions, human activity, reproduction, antler cycle and grouping on fecal glucocorticoids of free-ranging Pampas deer stags (Ozotoceros bezoarticus bezoarticus). Hormones and behavior 49:114–22.

Gelman, A. and J. Hill. 2007. Data analysis using regression and multilevel/hierarchical models. Cambridge University Press, New York, New York, USA.

Goymann, W., M. L. East, B. Wachter, O. P. Höner, E. Möstl, T. J. Van't Hof, and H. Hofer. 2001. Social, state-dependent and environmental modulation of faecal corticosteroid levels in free-ranging female spotted hyenas. Proceedings of the Royal Society B 268:2453–2459.

Hammitt, W.E., D.N. Cole, and C.A. Monz. 2015. Wildland recreation: Ecology and management. Third edition. John Wiley & Sons, Ltd., Oxford, UK.

Harrington, F. H., and a. M. Veitch. 1992. Calving success of woodland caribou exposed to low-level jet fighter overflights. Arctic 45:213–218.

Huber, S., R. Palme, and W. Arnold. 2003. Effects of season, sex, and sample collection on concentrations of fecal cortisol metabolites in red deer (Cervus elaphus). General and Comparative Endocrinology 130:48–54.

Huber, S., R. Palme, W. Zenker, and E. Möstl. 2003. Non-invasive monitoring of the adrenicorticol response. Journal of Wildlife Management 67:258–266.

Jachowski, D., S. McCorquodale, B. Washburn, and J. Millspaugh. 2015. Human disturbance and the physiological response of elk in eastern Washington. Wildlife Biology in Practice 11:12–25.

Jachowski, D. S., B. E. Washburn, and J. J. Millspaugh. 2015. Revisiting the importance of accounting for seasonal and diel rhythms in fecal stress hormone studies. Wildlife Society Bulletin 39:738–745.

Keay, J. M., J. Singh, M. C. Gaunt, and T. Kaur. 2006. Fecal glucocorticoids and their metabolites as indicators of stress in various mammalian species: a literature review. Journal of Zoo and Wildlife Medicine 37:234–244.

Kéry, M. 2010. Introduction to WinBUGS for ecologists: a Bayesian approach to regression, ANOVA, mixed models and related analyses. Academic Press, Waltham, Massachusetts, USA.

Kéry, M. and M. Schaub. 2012. Bayesian population analysis using WinBUGS: a hierarchical perspective. First edition. Academic Press, Waltham, Massachusetts, USA.

Knight, R.L. and K.J. Gutzwiller. 1995. Wildlife and recreationists: Coexistence through management and research. Island Press, Washington, D.C., USA.

Krausman, P. R., B. D. Leopold, and D. L. Scarbrough. 1986. Desert mule deer response to aircraft. Wildlife Society Bulletin 14:68–70.

Krausman, P. R., M. C. Wallace, C. L. Hayes, and D. W. Deyoung. 1998. Effects of jet aircraft on mountain sheep. Journal of Wildlife Management 62:1246–1254.

Lawler, J. P., A. J. Magoun, C. T. Seaton, C. L. Gardner, R. D. Boertje, J. M. Ver Hoef, and P. A. Del Vecchio. 2005. Short-term impacts of military overflights on caribou during calving season. Journal of Wildlife Management 69:1133–1146.

Lawler, J. P., A. J. Magoun, C. T. O. M. Seaton, C. L. Gardner, R. D. Boertje, J. Hoef, and P. A. Vecchio. 2005. Short-term impacts of military overflights on caribou during calving season. Journal of Wildlife Management 69:1133–1146.

Lima, S. L., and L. M. Dill. 1990. Behavioral decisions made under the risk of predation: a review and prospectus. Canadian Journal of Zoology 68:619–640.

Lynch, E., J. M. Northrup, M. F. McKenna, C. R. Anderson, L. Angeloni, and G. Wittemyer. 2015. Landscape and anthropogenic features influence the use of auditory vigilance by mule deer. Behavioral Ecology 26:75–82.

Maier, J.A.K., S.M. Murphy, R.G. White, M.D. Smith. 1998. Responses of caribou to overflights by low-flying jet aircraft. Journal of Wildlife Management 62:752-766.

Martin, J. G. A., and D. Réale. 2008. Animal temperament and human disturbance: Implications for the response of wildlife to tourism. Behavioural Processes 77:66–72.

Miller, S., R. Knight, and C. Miller. 2001. Wildlife responses to pedestrians and dogs. Wildlife Society Bulletin 29:124–132.

Millspaugh, J. J., B. E. Washburn, M. a Milanick, J. Beringer, L. P. Hansen, and T. M. Meyer. 2002. Non-invasive techniques for stress assessment in white-tailed deer. Wildlife Society Bulletin 30:899–907.

Millspaugh, J. J., R. J. Woods, K. E. Hunt, K. J. Raedeke, C. Brundige, B. E. Washburn, S. K. Wasser, J. Kenneth, and G. C. Brundige. 2001. Fecal glucocorticoid assays and the physiological stress response in elk. Wildlife Society Bulletin 29:899–907.

Mullet, T. C. 2014. Effects of snowmobile noise and activity on a boreal ecosystem in southcentral Alaska. Disseration, University of Alaska, Fairbanks, USA.

Von der Ohe, C. G., and C. Servheen. 2002. Measuring stress in mammals using fecal glucocorticoids : opportunities and challenges. Wildlife Society Bulletin 30:1215–1225.

Von der Ohe, C. G., S. K. Wasser, K. E. Hunt, and C. Servheen. 2004. Factors associated with fecal glucocorticoids in Alaskan brown bears (Ursus arctos horribilis). Physiological and Biochemical Zoology 77:313–320.

Pang, X. D., and J. J. Guinan. 1997. Effects of stapedius-muscle contractions on the masking of auditory-nerve responses. The Journal of the Acoustical Society of America 102:3576–3586.

Richens, V. B., and G. R. Lavigne. 1978. Response of white-tailed deer to snowmobiles and snowmobile trails in Maine. Canadian Field Naturalist 92:334–344.

Romero, L. M., and M. Wikelski. 2001. Corticosterone levels predict survival probabilities of Galapagos marine iguanas during El Nino events. Proceedings of the National Academy of Sciences of the United States of America 98:7366–7370.

Romero, M. L. 2004. Physiological stress in ecology: Lessons from biomedical research. Trends in Ecology and Evolution 19:249–255.

Sapolsky, R. M., M. L. Romero, and A. U. Munck. 2000. How do glucocorticoids influence stress responses? Integrating permissive, suppressive, stimulatory, and preparative actions. Endocrine Reviews 21:55–89.

Shannon, G., M. F. McKenna, L. M. Angeloni, K. R. Crooks, K. M. Fristrup, E. Brown, K. a. Warner, M. D. Nelson, C. White, J. Briggs, S. McFarland, and G. Wittemyer. 2015. A synthesis of two decades of research documenting the effects of noise on wildlife. Biological Reviews doi:10.111/brv.12207.

Sheriff, M. J., B. Dantzer, B. Delehanty, R. Palme, and R. Boonstra. 2011. Measuring stress in wildlife: techniques for quantifying glucocorticoids. Oecologia 166:869–87.

Sih, A., A. M. Bell, J. C. Johnson, and R. E. Ziemba. 2004. The Quarterly Review of Biology 79:241–277.

Stankowich, T. 2008. Ungulate flight responses to human disturbance: a review and meta-analysis. Biological Conservation 141:2159–2173.

Tarlow, E. M., and D. T. Blumstein. 2007. Evaluating methods to quantify anthropogenic stressors on wild animals. Applied Animal Behaviour Science 102:429–451.

Thiel, D., S. Jenni-Eiermann, V. Braunisch, R. Palme, and L. Jenni. 2008. Ski tourism affects habitat use and evokes a physiological stress response in capercaillie (Tetrao urogallus): a new methodological approach. Journal of Applied Ecology 45:845–853.

Walker, B. G., P. D. Boersma, and J. C. Wingfield. 2005. Field endocrinology and conservation biology. Integrative and Comparative Biology 45:12–18.

Washburn, B. E., and J. J. Millspaugh. 2002. Effects of simulated environmental conditions on glucocorticoid metabolite measurements in white-tailed deer feces. General and Comparative Endocrinology 127:217–222.

Wasser, S. K., K. E. Hunt, J. L. Brown, K. Cooper, C. M. Crockett, U. Bechert, J. J. Millspaugh, S. Larson, and S. L. Monfort. 2000. A generalized fecal glucocorticoid assay for use in a diverse array of nondomestic mammalian and avian species. General and Comparative Endocrinology 120:260–275.

Wasser, S. K., J. L. Keim, M. L. Taper, and S. R. Lele. 2011. The influences of wolf predation, habitat loss, and human activity on caribou and moose in the Alberta oil sands. Frontiers in Ecology and the Environment 9:546–551.

Wikelski, M., and S. J. Cooke. 2006. Conservation physiology. Trends in Ecology and Evolution 21:38–46.

Wingfield, J. C., D. L. Maney, C. W. Breuner, J. D. Jacobs, S. Lynn, M. Ramenofsky, and R. D. Richardson. 1998. Ecological bases of hormone—behavior interactions: the "emergency life history stage." Integrative and Comparative Biology 38:191–206.

Zuur, A. F., E. N. Ieno, and C. S. Elphick. 2010. A protocol for data exploration to avoid common statistical problems. Methods in Ecology and Evolution 1:3–14.

Zwijacz-Kozica, T., N. Selva, I. Barja, G. Silván, L. Martínez-Fernández, J. C. Illera, and M. Jodłowski. 2012. Concentration of fecal cortisol metabolites in chamois in relation to tourist pressure in Tatra National Park (South Poland). Acta Theriologica 58:215–222.

3 Recreational User Attitudes Toward Impact-Mitigating Behaviors at Backcountry Airstrips in the Northern Rockies

3.1 Introduction

In the past several decades, social science research has expanded the potential for effective natural resources management. With guiding principles such as the Public Trust Doctrine framing contemporary debates surrounding wildlife conservation (Blumm and Paulsen 2013), there is an increasing awareness of the need to measure public sentiment and support when considering management plans. Due to the fact that the feasibility of management plans is partly affected by social parameters (e.g., tolerance for certain species, support for management actions), incorporating cognitive measures such as stakeholders' values and attitudes can improve decision-making and implementation of management plans (Manfredo 2008). For example, results from an on-going study of wildlife values across the western states of the U.S. highlight a fundamental shift at the societal level in the ways people perceive and appreciate wildlife (Manfredo and Zinn 1996, Teel et al. 2005, Manfredo et al. 2009, Teel and Manfredo 2010). This information is useful for management agencies that oversee vast areas of public land, interact with stakeholders often, and need to justify their decision-making to the public.

The concept of values and attitudes is central to recreation management on public lands, where various user groups may have fundamentally different perceptions of how to relate to nature and what constitutes appropriate behavior. The analysis of values, attitudes, and how these cognitive measures ultimately influence behavior can shine light on various aspects of the recreation experience (Henderson 1994, Henderson et al. 2004). For instance, identifying predominant attitudes of various user groups toward natural resources such as wildlife can elucidate the causes of conflict between different user groups, or provide information on the predicted support for a proposed wildlife management plan on public lands (Manfredo 2008).

An equally important concept in recreation research is sense of place, or place attachment (Proshansky et al. 1983, Williams and Roggenbuck 1989). Psychological connections to place are a defining characteristic of self-identity, and there has been a growing recognition that recreation management needs to consider sense of place in order to understand different user groups' claims to the use of an area (Williams et al. 1992, Williams and Stewart 1998).

This study focuses on wildlife-related attitudes and place attachment of recreational pilots who access backcountry airstrips in the Northern Rockies region, defined here as the states of Montana and Idaho as well as the provinces of Alberta and British Columbia. Recreational aviation occurs throughout the contiguous United States and Alaska, where multiple federal and state agencies manage public-access grass airstrips. Discounting public-access, backcountry airstrips located in national forests, 16 airstrips between Montana and Idaho are located within federally designated Wilderness areas (Meyer 1999). The Wilderness Act (TWA) of 1964 explicitly prohibits motorized travel within Wilderness areas. However, language within TWA includes special-use exceptions that allow for motorboat and aircraft travel "where these practices have already become established." Aircraft travel was also legislated as a special use in some Wilderness areas that were designated after TWA. An example of this is the Great Bear Wilderness of Montana established in 1978, where aircraft can access Schafer Meadows, an airstrip that existed prior to Wilderness designation (Meyer 1999).

Motorized noise in the Wilderness areas of the Northern Rockies present managers with unique challenges, namely mediating conflict between recreationists with divergent views on appropriate use (Jacob and Schreyer 1980, Meyer 1999). Studies looking at the effects of aircraft noise on visitor experiences in protected areas show an inverse relationship between both intensity and frequency of air traffic noise and a visitor's appreciation of landscape characteristics and other aesthetic qualities, such as perceived tranquility (Tarrant et al. 1995, Mace et al. 2013, Weinzimmer et al. 2014). Unlike flyover traffic in national parks, for example, recreational aviation in protected areas compounds the issue with active landings and takeoffs, a source of disturbance that likely increases the potential for conflict between pilots and other user groups (Jacob and Schreyer 1980). Indeed, it is not uncommon for recreational pilot groups to be accused of altering wildlife behavior and impacting reproductive success of populations due to noise disturbance (communication with Recreational Aviation Foundation).

3.1.1 Theoretical Framework

Theory of Reasoned Action and Theory of Planned Behavior

Analyzing the relationship between attitudes and behaviors is central to social science research, and is especially pertinent to understanding aspects of nature-based recreation. Attitudinal surveys are so widely used because of their interpretability and, more importantly, their usefulness in predicting behaviors of interest to researchers or managers (Manfredo 2008). They can also aid effective management of public lands, where understanding attitudes of a user group can help managers predict behavior, or even attempt to encourage changes in behavior that could lead to impact mitigation.

To this end, the Theory of Reasoned Action (TRA) has been highly influential in understanding the relationship between attitudes and behavior (Fishbein and Ajzen 1975, Ajzen and Fishbein 1980) (Fig. 3-1b). Due to its efficacy in predicting behavior, TRA was initially applied to public health initiatives such as smoking-cessation programs (Babrow et al. 1990), exercise promotion (Godin et al. 1993), and numerous other behaviors of interest such as voting intention (Fishbein and Manfredo 1992). TRA and its theoretical extension, Theory of Planned Behavior (TPB), have also been central in understanding the mechanisms behind public attitudes toward natural resource issues (Pate et al. 1996, Garel et al. 2006) and participation in consumptive and non-consumptive forms of recreation (Ajzen and Driver 1991, Rossi and Armstrong 1999, Hrubes et al. 2001, Shrestha et al. 2012). TRA and TPB differ in that the TPB accounts for behaviors that may be outside the control of an individual, measured as perceived behavioral control (Ajzen 1985, 1991), while TRA assumes that the behavior in question is within the control of an individual to enact. For this reason, TPB has become more prevalent in outdoor recreation research, in order to account for activities in which an individual's participation may be constrained due to numerous factors (e.g., expense, amount of available leisure time).

A central concept of both of these attitude-behavior theories is the cognitive connection between an individual's attitude toward performing a behavior and their intention to actually perform that behavior. Quantifying the intention to behave in a particular way is the ultimate utility behind applying TRA and TPB to survey instruments and forming subsequent management plans. Another central tenet of both is that an individual's intention to perform a behavior is ostensibly identical to measuring the likelihood that an individual will actually perform the behavior. The process of forming a behavioral intention may include thoughts or feelings toward the target of the behavior in question (e.g., feelings toward a particular animal that may influence food consumer behavior). Besides behavioral intention, TRA and TPB also incorporate subjective norms into predicting an individual's course of action. The concept of subjective norm measures the extent to which an individual is compelled to behave according to the perceived expectations of people or groups that are important to them.

Attitude-behavior theory has been employed extensively over the last two decades to understand public perceptions related to natural resource issues. For instance, a study of Colorado residents that measured general attitudes about wolves (*Canis lupus*), as well as specific attitudes toward reintroducing wolves, was shown to strongly predict behavioral intentions to vote on a ballot initiative aimed at wolf reintroduction (Bright and Manfredo 1996). In a similar study again focused on a population of voters in Colorado, attitudes and behavioral intention predicted voting behavior toward Wilderness preservation initiatives (Vaske and Donnelly 1999). A more recent study examined attitudes toward beaver (*Castor canadensis*) among Massachusetts residents, finding that respondents' attitudes became increasingly negative as experiences with beaver-related property damage increased (Garel et al. 2006).

Numerous studies have also used TRA and TPB to measure the attitude-behavior relationship in outdoor recreation settings. One of the earliest applications of TPB to recreation research comes from Ajzen and Driver (1991), who surveyed over 100 college students in Colorado and found that a respondent's level of participation in five different recreation activities was predicted by the tripartite structuring of TPB: attitudes about performing a particular sort of recreational activity, subjective norms held about the activity, and the amount of perceived control over performing the activity.

The use of TRA/TPB in recreation and natural resource issues has continued steadily for the last two decades. A study of a population of individuals in Vermont showed that attitudes toward the behavior of interest (hunting), as well as perceived behavioral control over actualizing the desire to participate in hunting, accurately predicted the intention to go hunting the following season (Hrubes et al. 2001). Furthermore, there is evidence to suggest that wildlife-related attitudes differ among user groups. For example, researchers used components of TRA to show that non-consumptive recreationists had more positive attitudes than consumptive users toward applying wildlife protection measures such as the Endangered Species Act (ESA) (Tarrant et al. 1997). Attitudinal surveys can also measure additional parameters of interest to managers, such as support for wildlife management actions (Zinn et al. 1998, Aipanjiguly et al. 2003, Garel et al. 2006). A study of boaters' attitudes toward manatees (*Trichechus manatus*) in south Florida, found wide support for general conservation measures, such as education initiatives, but less support for restrictive actions such as speed reduction zones or no-entry areas (Aipanjiguly et al. (2003). Furthermore, increased knowledge of manatees was positively associated with support for management action. In the aforementioned study of beaver management in Massachusetts, negative attitudes toward beaver increased with more frequent negative experiences, respondents' became more supportive of proactive management scenarios, such as lethal control (Garel et al. 2006). By highlighting the processes and relationships underlying cognitive processes such as attitudinal assessments of issues, TRA and TPB can measure the effects of general attitudes on pursuant attitudes toward performing a behavior and the intention to perform that behavior, both of which are valuable sources of information to recreation management.

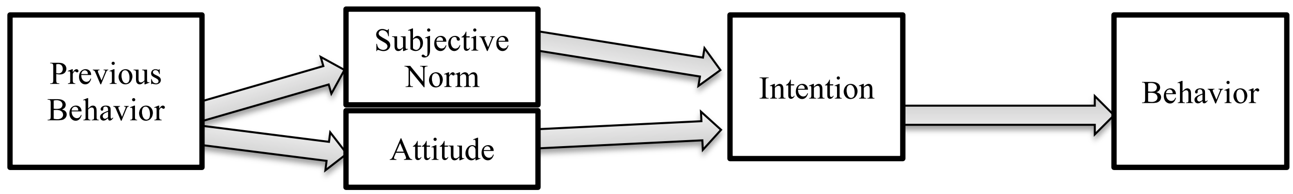


Fig. 3-1 Conceptual models of Theory of Reasoned Action (borrowed from Vaske and Donnelly 1999, Rossi and Armstrong 1999).

Place Attachment Theory

Place attachment is a concept derived from human geography that has become increasingly useful in recreation studies. Initial theorizing about "place" viewed the concept as a geographical space onto which people bestow value through individual or collective knowledge and memory (Tuan 1975). The concept of "place identity" is a subset of self-identity that incorporates cognitions held about one's physical surroundings into their overall sense of identity (Proshansky et al. 1983). Foundational theories such as these posit that individuals seek to alleviate disharmony between their sense of place identity and those attributes their physical surroundings provide. This fundamental idea has direct ramifications for understanding recreationists' place-based decisions and subsequent place attachment to particular recreation settings and sites.

The foundation for quantifying place attachment in recreation settings can be attributed to Williams and Roggenbuck (1989), who theorized that recreationists may continue to utilize a site because of the degree to which it meets the needs of a recreationist and also because it symbolizes aspects of their self-identity. The former type of attachment is functional in nature and is termed place dependence; the latter is an emotional attachment termed place identity. In this way, the dual components of place attachment are designed to not only capture variation in the overall level of importance individuals ascribe to a place, but also differences in the manner in which attachment occurs. Since the onset of place attachment research in natural resource issues, including recreation on public lands, there has been a greater call for incorporating the concept of place into management strategies (Williams and Stewart 1998, Cheng et al. 2003).

This two-dimensional framework for conceptualizing and measuring place attachment has been the predominant theoretical approach utilized by recreation researchers over the last two decades (Williams et al. 1992, Moore and Graefe 1994, Williams and Vaske 2003, Lewicka 2011). In a study of place attachment in several Wilderness areas in the U.S. by Williams et al. (1992), stronger sense of place was hypothesized to be inversely related to the substitutability of a place. Furthermore, they hypothesized that several other factors predict level of place attachment: the length of association a person has with a site, how their motivation for visiting a site is oriented (e.g., to enjoy natural surroundings or to reaffirm social bonds with family/friends) and trip characteristics (i.e., activities performed during a visit). To illustrate this, interviews of visitors were conducted at several Wilderness areas, two of which were in the southeast U.S., one in Texas, and one in Montana. Their results indicate that willingness to substitute for another Wilderness area was indeed associated with lower levels of place attachment. To illustrate this relationship, they pointed out that Texas showed the highest place attachment values, presumably because it is the only Wilderness area within the state, and therefore was non-substitutable in the minds of Wilderness users (Williams et al. 1992).

The first study to directly test the two-dimensional place attachment framework examined place attachment dimensions in recreation user groups on rail-trail systems (Moore and Graefe 1994). Similar to previous research, they found that individuals who scored higher on place attachment scales had been recreating at rail-trail sites for a longer duration of time when compared to those with lower place attachment scores. From studies such as the ones outlined here, there is consistent evidence that history of visitation and frequency of visitation have an effect on place attachment for recreationists.

Like attitudinal surveys, place attachment theory has become increasingly useful in measuring how sense of place predicts the amount of support proposed or current management actions receive among user groups (Kyle et al. 2003, Smaldone et al. 2005). For instance, a survey of visitors to the Mono Basin Scenic Area in California measured how differences in the level of place attachment predicted support for fee increases and allocation of spending (Kyle et al. 2003). They found that the emotional component of place attachment, place identity, had a significant effect on strengthening the relationship between attitudes toward paying fees and support for using the revenue toward improving on-site capacities, notably increasing environmental education about the natural history of the recreation area.

Conceptual Model

My proposed model derives from conceptual components of Theory of Reasoned Action. Specifically, my purpose is to show how antecedent cognitions, measured by recreational experience preferences, influence attitudes of recreational pilots toward viewing wildlife while recreating (the target of an attitude, e.g., deer), and whether these attitudes toward wildlife predict an individual's attitude toward performing behaviors aimed at mitigating negative impacts on wildlife. My decision to apply TRA rather than TPB is based on the assumption *a priori* that perceived behavioral control is not likely a significant factor in this recreation user group, as expendable income and leisure time were thought to be characteristic demographic parameters of recreational pilots. I am also interested in how Place Attachment Theory informs my capacity to predict attitudes toward impact-mitigating behaviors, one of which is more restrictive than the other. In doing so, my aim is to (1) gain an understanding of relative support for management scenarios at recreational airstrips by measuring attitudes toward impact-mitigating behaviors and (2) examine the ways in which symbolic importance and functional importance of airstrips in the Northern Rockies region might influence these attitudes.

I predicted that attitudes toward viewing wild ungulates at airstrips would be positively associated with attitudes toward performing impact-mitigating behaviors. For the first model, this would result in higher levels of support for the hypothetical management action of limiting flights to an impacted airstrip. For the second model, this would result in noise reduction being perceived as an important aspect of recreational aviation. Additionally, I predicted that an individual's level of place attachment to airstrips in the Northern Rockies would be negatively associated with support for management actions that limit flying opportunities to airstrips in that region. Lastly, I predicted that visitation history to airstrips in the Northern Rockies region would have a moderating effect on the degree of place attachment formed to airstrips in the area, thereby decreasing support for restrictive management scenarios.

3.2 Methods

3.2.1 Sampling and Data Collection

I conducted a quantitative, web-based survey of the membership of a non-profit recreational aviation group based in western Montana that has a national presence (N=6154). The group advocates for recreational aviation opportunities by maintaining existing and creating new public-access airstrips across the United States.

I used a tailored-design approach to meet numerous conditions set by the executive board of the aviation group. The concept of tailored design methods allows researchers to build surveys in a customizable fashion that takes into account the needs of the survey sponsor (e.g., survey length limitations) while encouraging maximum participation from survey respondents (Dillman 2014). An initial sample of 15 recreational pilots was systemically chosen in order to capture respondents from the major geographical regions of the United States. Response trends from this initial survey provided insights into the consistency and clarity of question types and overall efficacy of the survey instrument, while respondents submitted open-ended commentary on perceived length and relevance of portions of the survey. The final survey instrument consisted of 21 to 24 questions, a difference in length that depended on a respondent's level of experience flying in backcountry settings.

Prior to sending the survey, I sent notification e-mails to potential respondents describing the purpose of the survey, the main topics covered, and estimates for completion time. Follow-up techniques involved a single e-mail sent ten days after the initial survey request, reminding members to respond to the survey. A total of 1,072 questionnaires were returned, 830 of which were completed responses (17% response rate, 77% completion rate). While a second e-mail reminder might have increased response rate (Vaske 2008, Dillman 2014), the survey sponsor handled the proliferation of the survey to the membership list and wished to limit the number of contacts with potential respondents.

For the purposes of this analysis, I subset the respondents to include only those recreational pilots who have experience flying into backcountry recreational airstrips in the northern Rockies region (512), defined as the U.S. states of Montana and Idaho, and the Canadian provinces of Alberta and British Columbia. I defined the term "backcountry" in the question item header per the National Park Service's 2002 definition of backcountry as "a primitive, remote, or Wilderness area" that is accessible by foot, horseback, or watercraft, modifying the definition for respondents to include aircraft access.

3.2.2 Measurement of Questionnaire Items

In order to gauge respondents' different motivations for participating in recreational aviation in the backcountry, I listed eight statements based on established recreational experience preferences which were rated on a 5-point Likert scale, with 1 = "Not at all Important," 3 = "Neither," and 5 = "Very Important" (Driver 1983, Manfredo et al. 1996). REP can be useful in measuring a number of relevant aspects of recreational behavior, such as why an individual engages in a particular recreational activity or why they take trips to particular recreational sites. To measure attitudes toward the target of the behavior (i.e., free-living ungulates inhabiting backcountry airstrip areas), respondents were asked, "How important is viewing ungulates (deer, elk, moose) to your recreational experience?". This question was scaled from 1 to 5, with 1 = "Not At All Important," 3 = "Neither," and 5 = "Very Important". To measure recreational pilots' perceptions of their impact on wildlife, namely ungulates such as deer, respondents were asked, "To what extent do you think recreational aviation impacts ungulate stress levels (deer, elk, moose)?". Responses were scaled from 1 to 5, with 1 = "Strong Negative Impact," 3 = "Neither," and 5 = "Strong Positive Impact."

To measure place attachment, I employed an eight-question item to measure these components of place attachment, as proposed by Williams and Roggenbuck (1989) and validated by Williams and Vaske (2003). Respondents were asked to evaluate each item on a 1 to 5 Likert scale, with 1 = "Strongly Disagree" and 5 = "Strongly Agree." Following the results from Moore and Graefe (1994), I also measured the visitation history of those pilots who answered in the affirmative to whether they had ever accessed public recreational airstrips in the Northern Rockies region. To this end, I included a write-in question that asked respondents "Approximately how many trips in the last 5 years have you made to public-access, recreational airstrips in the Northern Rockies (Montana, Idaho, Alberta, British Columbia)?".

Lastly, to measure attitudes toward impact-mitigating behaviors, respondents were asked to consider a scenario in which wildlife at a public-access, backcountry airstrip displayed elevated stress levels. They were then asked, "How acceptable would it be to limit flights to mitigate stress levels in ungulates (deer, elk, moose)?". Their reported level of acceptability was scaled from 1 to 7, with 1 = "Highly Unacceptable," 4 = "Neither Unacceptable nor Acceptable", and 7 = "Highly Acceptable." A separate series of question items asked respondents to rank the importance of various aspects of recreational aviation, including "How important is it to you to reduce propeller noise?" and "How important is it to you to reduce engine noise?". The importance of these behaviors was scaled from 1 to 5, with 1 = "Not At All Important," 3 = "Neither," and 5 = "Very Important."

3.2.3 Statistical Analyses

I determined reliability within items used to measure survey domains using Cronbach's alpha (Nunnally and Berstein 1994). Items whose incorporation reduced the overall α coefficient were excluded from the dimension, and any dimension that did not have an α coefficient of at least 0.70 was excluded from further analyses.

Recreational Experience Preferences (REP) items were reduced into three motivational groups using Exploratory Factor Analysis (EFA): nature appreciation/relaxation, challenging skills, and socializing with family/friends. These motivational groups served as predictors of attitudes toward viewing wildlife at recreational airstrips in subsequent path analysis. Place attachment measures were also reduced using EFA to separate the emotional (place identity) and functional (place dependence) dimension. These dual dimensions underwent univariate analysis separately as well as together to measure to predictive strength of Place Attachment on my two dependent variables (attitudes toward impact-mitigating behavior). In addition to these recoded independent variables, I included perceptions of impact and visitation history to Northern Rockies airstrips to analyze the relative contribution of these variables in predicting attitudes toward impact-mitigating behaviors. In order to control for the possible effects of demographic variables on my models, I included demographic information such as age, annual income, and level of education achieved. I also included a moderating effect of visitation history on the relationship between place attachment and attitude toward impact-mitigating behavior (Baron and Kenny 1986).

For each model of attitudes toward impact-mitigating behavior, two path analyses were conducted. First, attitudes toward wildlife were regressed on REP items that had been reduced into motivational groupings. Next, attitudes toward impact-mitigating behaviors were regressed on independent variables such as attitudes toward wildlife, place attachment components, and demographics. Both path analysis models consisted of the same set of independent variables and used multivariate linear regression in order to reliably compare the relative contributions of each independent variable in predicting attitudes toward impact-mitigating behaviors. All factors were deemed statistically significant at the $p < 0.05$-level.

3.3 Results

3.3.1 Descriptive Statistics

Among recreation motivations, measured from the established Recreation Experience Preferences (REP), respondents showed the strongest agreement with statements identifying being outdoors (4.40 ± 0.69) and experiencing natural surroundings (4.33 ± 0.74), as well as relaxation (4.14 ± 0.85) (Table 3-1).

For items measuring place attachment, respondents showed higher levels of emotional attachment to recreational airstrips (4.19 ± .72) relative to functional attachment (3.70 ± .86) (Table 3-1).

Mean response values indicate that, on average, respondents had slightly negative attitudes toward viewing wildlife at recreational airstrips (2.61 ± 1.06), with the response becoming more neutral toward viewing ungulates (2.91 ± 1.16) (Table 3-1). Across all wildlife species presented, respondents had largely neutral perceptions of recreational impact (i.e., that recreational aviation has neither a negative nor a positive impact on wildlife) (2.87 ± 0.61), with a similar evaluation of impacts on ungulates in particular (2.91 ± 0.68) (Table 3-1).

In regards to the independent variables in my models, respondents on average reported slightly negative to neutral attitudes toward impact-mitigating behaviors. There were slightly low levels of acceptability toward management plans that limit flight access to mitigate stress levels in all wildlife species presented (3.43 ± 1.89), with acceptability increasing, but still negative, toward ungulates (3.73 ± 1.98) (Table 3-1).

For items dealing with noise reduction of aircraft, respondents on average had negative attitudes toward the personal importance of reducing propeller noise (2.64 ± 1.12) and reducing engine noise (2.41 ± 1.08) (Table 3-1).

The majority of respondents were male (95.3%), with an average reported age of 62 (Table 3-2). Respondents tended to complete higher levels of education, with 66.5% reporting receiving an undergraduate or graduate degree (Table 3-2). A majority of respondents (90.3%) reported making over 100,000USD annually, with 35.2% reporting an annual income over 140,000USD (Table 3-2).

In terms of piloting experience, over half of respondents (60.6%) reported logging at least 50 flying hours annually, with 31.1% of those reporting upwards of 200 flying hours logged annually (Table 3-2). Out of all respondents who completed a survey (n=938), 75.9% reported having accessed a backcountry, public-access airstrip (Table 3-2). Of those, 71.9% reported to have accessed this type of airstrip in the Northern Rockies region. Pilots visiting these airstrips spent an average of two nights camping on site. These 512 respondents who reported accessing backcountry airstrips in the northern Rockies region comprised the sample with which I ran the path analysis models.

Table 3-1. Questionnaire Items, Mean Response Values, and Reliability Coefficients

Survey Domain and Items Used to Construct Domain	Mean Response (±SD)	Reliability Coefficient (Cronbach's α)
Recreational Motivations *How important to you are each of the following factors when deciding to fly to a recreational airstrip?*		
Nature Appreciation / Relaxation	**4.20 (.65)**	**.79**
…To get away from my regular routine	**3.91 (1.04)**	
…To be outdoors	**4.40 (.69)**	
…For relaxation	**4.14 (.85)**	
…To experience the natural surroundings	**4.33 (.74)**	
Socializing with Family / Friends	**3.60 (.93)**	**.59**
…For family recreation	**3.40 (1.23)**	
…To spend time with friends	**3.81 (.99)**	
Challenging Skills	**3.70 (1.03)**	**.90**
…To challenge myself	**3.69 (1.1)**	
…To develop skills	**3.72 (1.07)**	

Table 3-1 (Continued). Questionnaire Items, Mean Response Values, and Reliability Coefficients

Survey Domain and Items Used to Construct Domain	Mean Response (±SD)	Reliability Coefficient (Cronbach's α)
<u>Place Identity</u>	**4.19 (.72)**	**.89**
Backcountry recreational airstrips in the Northern Rockies mean a lot to me	**4.58 (.65)**	
I am very attached to backcountry recreational airstrips in the Northern Rockies	**4.37 (.79)**	
Visiting backcountry airstrips in the Northern Rockies says a lot about who I am	**3.93 (.93)**	
I feel backcountry recreational airstrips in the Northern Rockies are a part of me	**3.88 (.92)**	
<u>Place Dependence</u>	**3.70 (.86)**	**.89**
Backcountry recreational airstrips in the Northern Rockies are the best places for what I like to do	**3.96 (.94)**	
I get more satisfaction out of visiting backcountry recreational airstrips in the Northern Rockies than any other destination	**3.77 (1.0)**	
I wouldn't substitute flying to any other destination for flying to a backcountry recreational airstrip in the Northern Rockies	**3.47 (1.06)**	
Flying to backcountry recreational airstrips in the Northern Rockies is more important than flying to any other destination	**3.62 (.96)**	

Table 3-1 (Continued). Questionnaire Items, Mean Response Values, and Reliability Coefficients

Survey Domain and Items Used to Construct Domain	**Mean Response (±SD)**
<u>**Attitudes toward viewing wildlife at airstrips**</u> ***How important is viewing wildlife to your recreational experience?***	**2.61 (1.06)**
…Ungulates (deer, elk, moose)	**2.91 (1.16)**
…Canids (coyotes, wolves)	**2.35 (1.22)**
…Bears (black, grizzly)	**2.41 (1.23)**
…Birds (songbirds, birds of prey)	**2.79 (1.2)**
<u>**Perception of Impacts on Wildlife**</u> ***To what extent do you think recreational aviation impacts wildlife stress levels?***	**2.87 (.61)**
…Ungulates (deer, elk, moose)	**2.91 (.68)**
…Canids (coyotes, wolves)	**2.85 (.67)**
…Bears (black, grizzly)	**2.85 (.66)**
…Birds (songbirds, birds of prey)	**2.89 (.64)**

Table 3-1 (Continued). Questionnaire Items, Mean Response Values, and Reliability Coefficients

Survey Domain and Items Used to Construct Domain	**Mean Response (±SD)**	**Reliability Coefficient (Cronbach's α)**
Personal Importance of Noise Reduction ***How important to you are the following aspects of recreational aviation in the backcountry?***	**2.28 (.90)**	**.86**
…Reducing propeller noise	**2.64 (1.12)**	
…Propeller design	**2.22 (1.11)**	
…Reducing engine noise	**2.41 (1.08)**	
…Reducing noise while camping	**1.90 (.96)**	
Acceptability of Proposed Management Action ***How acceptable would it be to limit flights to mitigate stress levels in the following wildlife?***	**3.43 (1.89)**	**n/a**
...Ungulates (deer, elk, moose)	**3.73 (1.98)**	
…Canids (coyotes, wolves)	**3.01 (2.01)**	
…Bears (black, grizzly)	**3.53 (2.04)**	
…Birds (songbirds, birds of prey)	**3.50 (2.04)**	

Table 3-2. Demographic Information and Piloting Experience

Demographic Variable	Percentage
Age	
18-30	0.7
31-50	16.8
51-70	61.8
71-90	20.1
invalid response	0.6
Gender	
Female	4.7
Male	95.3
Level of Education	
High School/GED	4.6
Some College	15.8
Associate's Degree	13.2
Bachelor's Degree	35.7
Graduate Degree	30.8
Annual Income (USD)	
10,000-19,999	0.3
20,000-39,999	2.7
40,000-59,999	5.8
60,000-79,999	8.1
80,000-99,999	10.7
100,000-119,000	11.3
120,000-139,999	8.6
140,000 or more	35.2
Piloting Experience	
Approximately how many flying hours do you log annually?	
<20	7.2
21-49	19.6
50-99	29.5
100-200	31.1
>200	12.6

3.3.2 Model Results for Impact-Mitigating Behaviors

Standardized beta coefficients were used to indicate effect size of each independent variable on the dependent variable being modeled. Of the three recreational motivation groups used, only nature appreciation and relaxation reliably predicted attitudes toward viewing ungulate wildlife at recreational airstrips (β =.25, R^2 = *.06*, p <.001) (Figs. 3-3a, 3-3b). These recreational motivations only explained 6% of the variance in attitudes toward viewing wildlife at airstrips, a limitation of the study addressed in the next section.

Limiting Flight Activity

The strongest predictor of attitude toward limiting flights to mitigate stress levels in ungulates was attitude toward viewing wild ungulates at recreational airstrips (β = .21, p < .001) (Fig. 3-3a). Other predictors included the functional component of place attachment (i.e., place dependence, β = -.18, p = .04), level of education (β = .16, p = .002), and whether the respondent was female (β = .12, p < .001) (Fig 3-2).

Reducing Noise Output

Again, the strongest predictor of attitudes toward reducing noise output of aircraft was attitude toward viewing wild ungulates at recreational airstrips (β = .22, p < .001) (Fig 3-3b). No other independent variables in this model were significant predictors of attitude toward reducing noise output.

Fig. 3-2. Conceptual model for attitudes toward impact-mitigating behavior at recreational backcountry airstrips in the Northern Rockies.

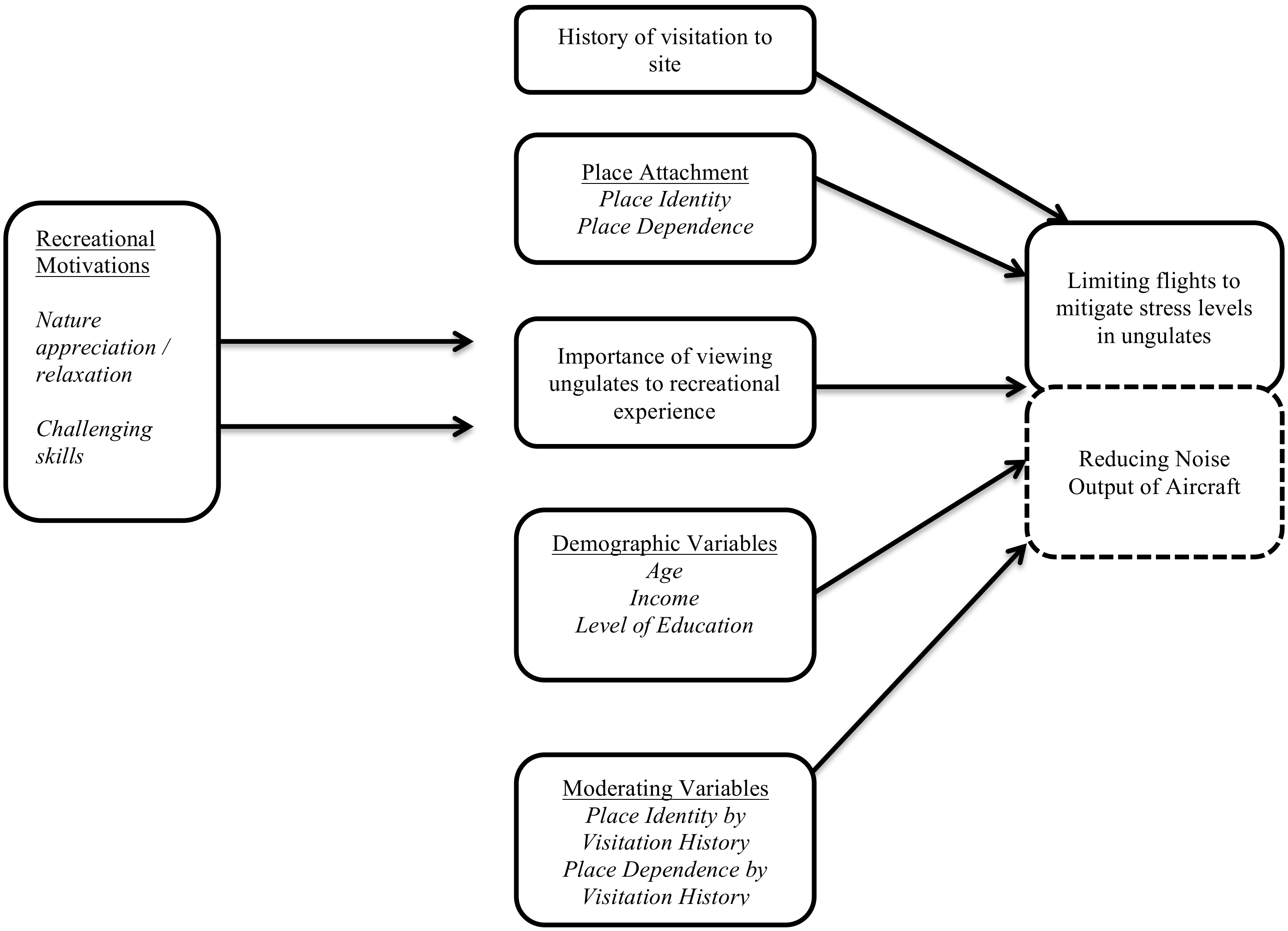


Fig. 3-3a. Reduced model for attitudes toward limiting flights to backcountry airstrips (all variables significant at p < .05).

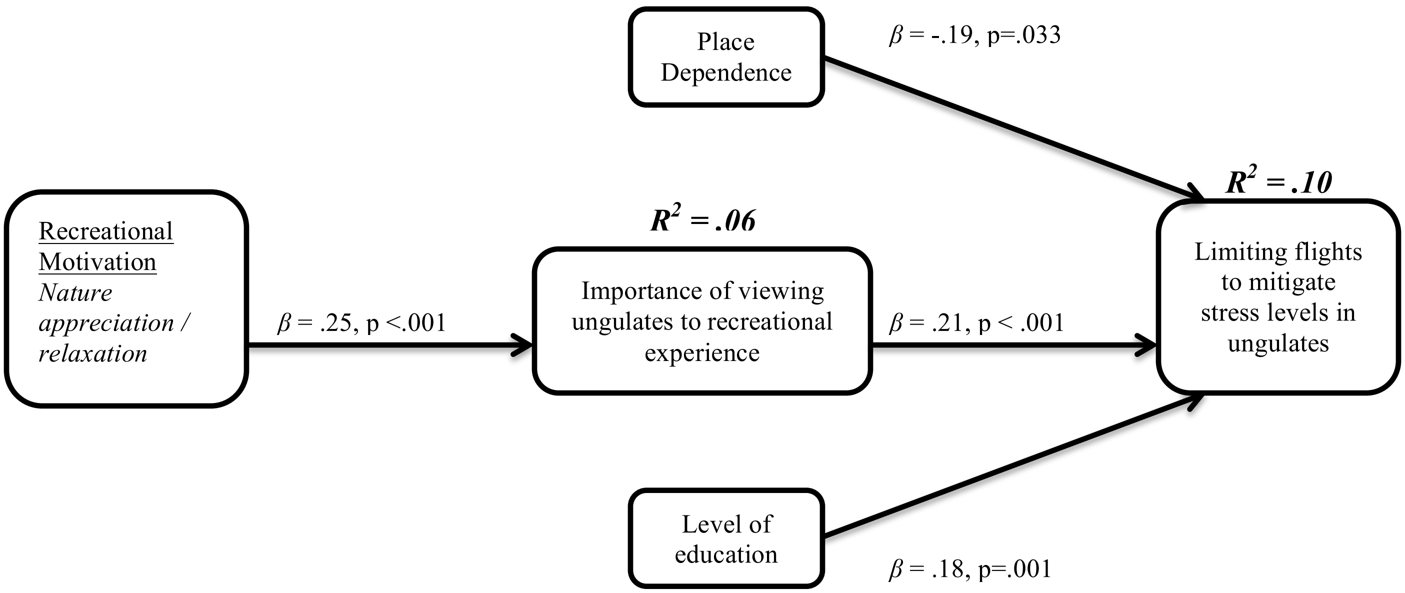
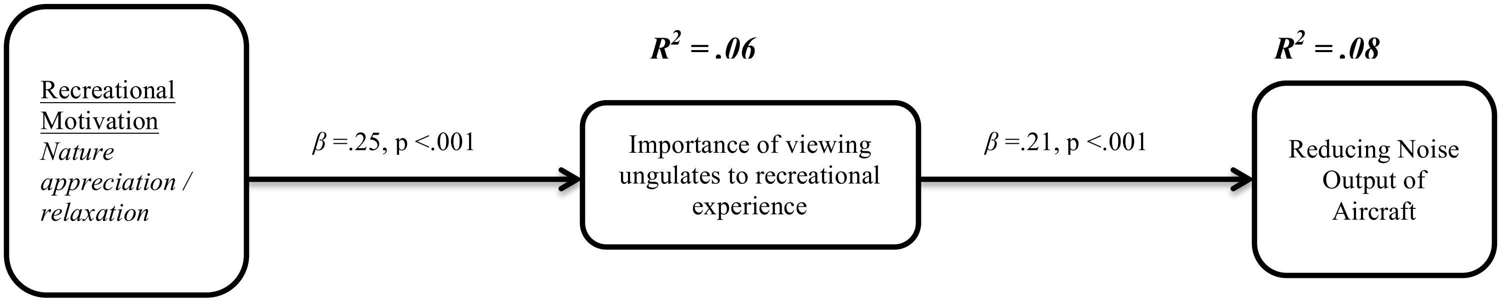


Fig. 3-3b. Reduced model for attitudes toward reducing aircraft noise output (all variables significant at p < .05)



3.4 Discussion

For both models, there was a consistently positive relationship between nature-based recreational motivation and wildlife-related attitudes, as well as a positive relationship between wildlife-related attitudes and attitudes toward engaging in impact-mitigating behaviors. As predicted, there was a negative influence of place attachment on attitudes toward impact-mitigating behaviors, indicating that those respondents who are more functionally attached to backcountry airstrips in the Northern Rockies region are less likely to support management actions that reduce recreational opportunities. Additionally, higher levels of education were positively associated with support for impact-mitigating management actions, suggesting that those respondents with more education may be more sensitive to the potential of ecological impacts of recreation. Taken together, these results support previous research and the utility of using components of TRA in better understanding the influence of motivations, attitudes, and place attachment on acceptability of management actions in a recreational context.

REP and their Relationship with Attitudes toward Aspects of Recreational Experience

Respondents who scored high on the nature appreciation and relaxation REP dimensions were more likely to report viewing wild ungulates at airstrips as an important aspect of their recreational experience. In the case of some recreational pilots, the chance to view wildlife while recreating is a subset of their goal-state to enjoy the natural surroundings. This finding is in line with research that showed an individual's stated motivations for participating in recreation influence the nature of their involvement and value they place on their recreational experience (Kyle et al. 2006, Prebensen et al. 2013). Previous research has also successfully linked different segments of recreational motivations to varying support for management actions that are restrictive in nature. For instance, Hall et al. (2010) grouped Wilderness visitors into three different motivation clusters and showed that Wilderness enthusiasts differed significantly from generalists and escapists in their willingness to see more restrictive use and visitation limits if it meant preserving Wilderness solitude. However, I was unable to directly associate any recreational motivation group with either differing levels of acceptability toward proposed management actions that would limit flying to a site or personal importance of reducing noise output of aircraft. Moreover, even with respondents having higher evaluations of the nature REP dimension than any other, this did not correspond to them having positive attitudes on average toward an aspect of nature appreciation, namely wildlife viewing.

Object Attitudes and their Relationship to Attitudes Toward Impact-Mitigating Behavior

Attitudes toward an object—in this case wild ungulates such as deer, elk and moose inhabiting backcountry airstrip areas—were a strong and consistent predictor of subsequent attitudes toward engaging in impact-mitigating behaviors. Those who deemed viewing these wildlife species as important to their recreational experience (a) were more willing to limit their flight activity if management deemed it necessary and (b) reported reducing noise from their aircraft as an important aspect of recreational aviation. This finding supports theory that an attitude toward an object can be used to evaluate numerous other scenarios under which that object attitude might lead to corresponding behavior (Eagly and Chaiken 1993, Manfredo 2008). In this study, those with positive attitudes toward wildlife viewing may use that attitude toward wildlife as a filter through which the merit of different behavioral choices are assessed, such as restricting recreation activity or reducing the scale of impact due to noise.

Place Attachment and its Relationship to Attitudes Toward Impact-Mitigating Behavior

Respondents showed more agreement with statements aimed at the emotional dimension of place identity than the ones measuring the functional component of attachment characterized by place dependence (Table 3-1). However, only the functional component of place attachment was a significant predictor of support for limiting flight access to backcountry airstrips, and neither dimension of place attachment was predictive of attitudes toward noise reduction. The finding that place dependence was a significant predictor of attitudes provides interesting insights into the perceived status of recreational aviation on public lands. I initially predicted that place identity would play a bigger role in predicting how acceptable an individual finds restrictive management action, whereas place dependence would be less of a factor in the path analysis. This prediction was due in large part to the assumption that pilots' can more easily recreate at numerous other sites compared to other recreationists, who may be spatially and temporally limited in their access to public lands. However, my path analysis results suggest that pilots perceive any management action aimed at reducing the number of flights allowable as limiting overall recreational opportunities for an activity that is already highly specialized and relegated to a handful of sites across the backcountry of the Northern Rockies region.

Neither of the models showed a significant moderating effect of visitation history to airstrips in the Northern Rockies region on the degree to which dimensions of place attachment affect this attitude. This lack of a moderating effect is contrary to several studies that have established that degree of participation at a site is positively associated with either the level of place identity or place dependence for that site (Williams et al. 1992, Moore and Graefe 1994, Williams and Vaske 2003). Given these results, my measure of place attachment may have had limitations in its operationalization. I suggest that my attempt to measure place attachment at a regional rather than site-specific scale may have detracted from its explanatory power, although other studies have found no difference in place attachment of respondents when statements were posed at a regional versus site-specific scale (Ardoin et al., in review).

Influence of Demographic Variables on Attitudes Toward Impact-Mitigating Behavior

After controlling for the effects of age and income, a respondent's level of education was a significant predictor of whether they found limiting flights as a management option acceptable. Previous research has shown that higher levels of education are positively associated with concern for the health of wildlife populations (Kellert and Berry 1987) and with "biocentric" value orientations toward natural resource issues (Vaske et al. 2001). This finding supports this relationship by showing that more educated respondents are more willing to engage in impact-mitigating behaviors.

Survey Limitations

Numerous limitations surround the survey instrument and conceptual model that merit discussion. The degree to which I could operationalize key theoretical concepts, and an ensuing lack of attitude-strength in some domains, led to the models leaving more unexplained variation than would be desirable. The lack of attitude-strength regarding perceptions of impact may have reduced the predictive power of this variable on support for management action (Bright and Manfredo 1995, Bright 1997). Similarly, the somewhat neutral response toward acceptability of management scenarios that mitigate stress levels in ungulates might show a slight preference for game species over the other wildlife listed in the survey, but it may also indicate a limitation of the survey in trying to assess attitudes about a topic that requires a more thorough understanding of stress physiology than the questionnaire items could provide. Theory suggests that attempts to measure attitudes about topics that require some level of technical knowledge can be ineffective (Manfredo 2008).

More importantly, my survey was substantially limited by the exclusion of Wildlife Value Orientations (WVO) (Fulton et al. 1996). First, my ability to test cognitive hierarchy theory was inhibited by the lack of a standardized measurement of wildlife values, which ostensibly underlies higher-order cognitions such as wildlife attitudes and attitudes toward behaviors that might mitigate negative impacts on wildlife. Theoretical development and operationalization of WVO have shown that they are accurate predictors of wildlife-related attitudes, and further that WVO predicted behavioral intentions as mediated by attitudes (Fulton et al. 1996). The utility of WVO lies in its ability to provide organization at the more fundamental level of values which, in turn, groups individuals at each subsequent level of the cognitive hierarchy: basic beliefs, motivations, attitudes, and behavioral intentions (Fulton et al. 1996, Bright et al. 2000). Furthermore, WVO have been shown to adequately predict acceptability of wildlife-related management decisions (Zinn et al. 1998), the testability of which in my own models would have potentially strengthened inference. While I was able to utilize REP dimensions as an organizational construct to classify individuals across different motivations, and showed that REP predict attitudes toward facets of the recreational experience (i.e., viewing wildlife), I suspect that using WVO would have explained more of the variance amongst attitudes.

3.5 Management Implications

The use of attitude surveys in recreation and wildlife management on public lands is a central component to the development of comprehensive planning that considers the status of free-living animals alongside other mandated uses of these areas. The conceptual model developed here lends support to components of Theory of Reasoned Action, such that specific attitudes toward viewing wild ungulates at recreational airstrips predicts higher-order attitudes toward behaviors that could mitigate negative impacts on wild ungulates.

This relationship, however, only holds for a small proportion of the population that has strong, positive attitudes toward viewing and, by extension, the very presence of wild ungulates at backcountry airstrips. For managers, results of this study indicate that the prevailing attitude of this recreation user group toward wildlife and impact-mitigating behaviors are neutral to somewhat negative. This negative assessment is likely due to the fact that wild ungulates represent a safety risk to pilots when the former utilizes airstrip runways for forage during summer months. Therefore, any management plan aimed at impact mitigation that is restrictive in approach is predicted to be largely unsupported.

Furthermore, a physiological assessment of wild ungulate stress responses at backcountry airstrips in the Northern Rockies that is part of this study revealed no evidence of negative impacts due to recreational air traffic. From this perspective, then, there is arguably little incentive from the outset to alter recreation planning for the purposes of wildlife management.

Rather, I posit that the issue of aviation disturbance on public lands in national forests and Wilderness areas may be relevant to social conflict between user groups. To this end, a more feasible alternative to reducing the impact signature of recreational aviation would be to regulate the noise output of aircraft. Such regulation could occur through mechanical means, such as setting a maximum allowable propeller length or recommending certain propeller designs to reduce noise propagation. This could also occur through behavioral or “etiquette” standards, such as recommending maximum allowable engine output inside protected areas, to be exceeded only to ensure pilot safety. However, this study reveals that noise reduction is not perceived as very important, and regulatory measures to that end may lack support amongst this user group.

3.6 References

Ajzen, I. and M. Fishbein. 1980. Understanding attitudes and predicting social behavior. Prentice Hall, Englewood Cliffs, New Jersey, USA.

Ajzen, I., and B. L. Driver. 1991. Prediction of leisure participation from behavioral, normative, and control beliefs: An application of the theory of planned behavior. Leisure Sciences 13:185–204.

Ajzen, I. 1991. The theory of planned behavior. Organizational Behavior and Human Decision Processes 50:179–211.

Aipanjiguly, S., S.K. Jacobson, and R. Flamm. 2003. Conserving manatees: Knowledge, attitudes, and intentions of boaters in Tampa Bay. Conservation Biology 17:1098-1105.

Ardoin, N., J. Thomsen, C. Sponarski, and R. Gould. When scale matters: Scale of place among urban dwellers. In review.

Babrow, A. S., D. R. Black, and S. T. Tiffany. 1990. Beliefs, attitudes, intentions, and a smoking-cessation program: a planned behavior analysis of communication campaign development. Health Communication 2:145–163.

Baron, R. M., and D. a Kenny. 1986. The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. Journal of Personality and Social Psychology 51:1173–1182.

Blumm, M. C., and A. Paulsen. 2013. The public trust in wildlife. Utah Law Review 1437–1504.

Bright, A. D., M. J. Manfredo, and D. C. Fulton. 2000. Segmenting the public: an application of value orientations to wildlife planning in Colorado. Wildlife Society Bulletin 28:218–226.

Bright, A. D., and M. J. Manfredo. 1995. The quality of attitudinal information regarding natural resource issues: the role of attitude-strength, importance, and information. Society and Natural Resources 8:399–414.

Bright, A. D. 1997. Attitude-strength and support of recreation management strategies. Journal of Leisure Research 29:363–379.

Cheng, A. S., L. E. Kruger, and S. E. Daniels. 2003. “Place” as an integrating concept in natural resource politics: Propositions for a social science research agenda. Society & Natural Resources 16:87–104.

Dillman, D.A., J.D. Smyth, and L.M. Christian. 2014. Internet, phone, mail and mixed-mode surveys: the tailored design method. John Wiley & Sons, Inc., Hoboken, New Jersey, USA.

Eagly, A.H. and S. Chaiken. 1993. The psychology of attitudes. Harcourt, Fort Worth, Texas, USA.

Fishbein, M. and I. Ajzen. 1975. Belief, attiude, intention, and behavior: an introduction to theory and research. Addison-Wesley, Reading, Massachusetts, USA.

Fishbein, M., & Manfredo, M.J. (1992). A theory of behavior change. *In* M.J. Manfredo (Ed.), Influencing human behavior: Theory and applications in recreation, tourism, and natural resource management. Sagamore Publishing Inc., Champain, Illinois, USA.

Fulton, D. C., M. J. Manfredo, and J. Lipscomb. 1996. Wildlife value orientations: a conceptual and measurement approach. Human Dimensions of Wildlife 1:24–47.

Garel, M., J. M. Cugnasse, a J. M. Hewison, and D. Maillard. 2006. Experiences with beaver damage and attitudes of Massachusetts residents toward beaver. Wildlife Society Bulletin 34:300–306.

Godin, G., P. Valois, and L. Lapage. 1993. The pattern of influence of perceived behavioural control upon exercise behaviour: an application of Ajzen's theory of planned behaviour. Journal of Behavioural Medicine 16:81–102.

Hall, T. E., E. Seekamp, and D. Cole. 2010. Do recreation motivations and Wilderness involvement relate to support for Wilderness management? A segmentation analysis. Leisure Sciences 32:109–124.

Henderson, K. A., J. Presley, and M. D. Bialeschki. 2004. Theory in recreation and leisure research: Reflections from the editors. Leisure Sciences 26:411–425.

Henderson, K. A. 1994. Theory application and development in recreation, parks, and leisure research. Journal of Park and Recreation Administration 12:51-64.

Homer, P. M., and L. R. Kahle. 1988. Value attitude behavior hierarchy. Journal of Personality and Social Psychology 54:638–646.

Hrubes, D., I. Ajzen, and J. Daigle. 2001. Predicting hunting intentions and behavior: an application of the theory of planned behavior. Leisure Sciences 23:165–178.

Jacob, G. R., and R. Schreyer. 1980. Conflict in outdoor recreation: a theoretical perspective. Journal of Leisure Research 12:368 – 380.

Kellert, S. R., and J. K. Berry. 1987. Attitudes, knowledge, and behaviors toward wildlife as affected by gender. Wildlife Society Bulletin 15:363–371.

Kyle, G. T., J. D. Absher, W. E. Hammitt, and J. Cavin. 2006. An examination of the motivation —involvement relationship. Leisure Sciences 28:467–485.

Lewicka, M. 2011. Place attachment: How far have we come in the last 40 years? Journal of Environmental Psychology 31:207–230.

Mace, B. L., G. C. Corser, L. Zitting, and J. Denison. 2013. Effects of overflights on the national park experience. Journal of Environmental Psychology 35:30–39.

Manfredo, M. J., B. L. Driver, and M. Tarrant. 1996. Measuring leisure motivation: a meta-analysis of the recreation experience preference scales. Journal of Leisure Research 28:188–213.

Manfredo, M.J. 2008. Who cares about widllife? Social science concepts for exploring human-wildlife relationships and conservation issues. Springer, New York, New York, USA.

Manfredo, M. J., T. L. Teel, and K. L. Henry. 2009. Linking society and environment: A multilevel model of shifting wildlife value orientations in the western United States. Social Science Quarterly 90:407–427.

Manfredo, M. J., and H. C. Zinn. 1996. Population change and its implications for wildlife management in the new west: A case study of Colorado. Human Dimensions of Wildlife 1:62–74.

Manfredo, M., T. Teel, and A. Bright. 2003. Why are public values toward wildlife changing? Human Dimensions of Wildlife 8:287–306.

Meyer, S. 1999. The role of legislative history in agency decision-making: a case study of wilderness airstrip management in the United States. International Journal of Wilderness 5:9–12.

Moore, R. L., and A. R. Graefe. 1994. Attachments to recreation settings: The case of rail‐trail users. Leisure Sciences 16:17–31.

Pate, J., M. J. Manfredo, A. D. Bright, and G. Tischbein. 1996. Coloradans' attitudes toward reintroducing the gray wolf into Colorado. Wildlife Society Bulletin 24:421–428.

Prebensen, N. K., E. Woo, J. S. Chen, and M. Uysal. 2013. Motivation and involvement as antecedents of the perceived value of the destination experience. Journal of Travel Research 52:253–264.

Proshansky, H. M., A. K. Fabian, and R. Kaminoff. 1983. Place-identity: Physical world socialization of the self. Journal of Environmental Psychology 3:57–83.

Purdy, K. G., and D. J. Decker. 1989. Applying wildlife values information in management: the wildlife attitudes and and values scale. Wildlife Society Bulletin 17:494–500.

Rokeach, M. 1973. The nature of human values. The Free Press, New York, New York, USA.

Rossi, A. N., and J. B. Armstrong. 1999. Theory of reasoned action vs. theory of planned behavior: Testing the suitability and sufficiency of a popular behavior model using hunting intentions. Human Dimensions of Wildlife 4:40–56.

Schwartz, S. H. 2006. A theory of cultural value orientations: Explication and applications. Comparative Sociology 5:137–182.

Shrestha, S. K., R. C. Burns, J. Confer, A. R. Graefe, and E. A. Covelli. 2012. The role of elements of theory of planned behavior in ediating the effects of constraints on intentions: a study of Oregon big game hunters. Journal of Park & Recreation Administration 30:41–62.

Tarrant, M. A., A. D. Bright, and H. Ken Cordell. 1997. Attitudes toward wildlife species protection: Assessing moderating and mediating effects in the value‑attitude relationship. Human Dimensions of Wildlife 2:1–20.

Tarrant, M. A., G. E. Haas, and M. J. Manfredo. 1995. Factors affecting visitor evaluations of aircraft overflights of wilderness areas. Society & Natural Resources 8:351–360.

Teel, T., A. Dayer, M. Manfredo, and A. Bright. 2005. Wildlife values in the west. Western Association of Fish and Wildlife Agencies, Fort Collins, Colorado, USA. 1–307.

Teel, T. L., and M. J. Manfredo. 2010. Understanding the diversity of public interests in wildlife conservation. Conservation Biology 24:128–139.

Tuan, Y.F. 1975. Place: an experiential perspective. Geographical Review 65:151–165.

Vaske, J. J., and M. P. Donnelly. 1999. A Value – attitude – behavior model predicting wildland preservation voting intentions. Society & Natural Resources 12:523–527.

Vaske, J.J. M. P. Donnelly, and J. Dani 2001. Demographic influences on environmental value orientations and normative beliefs about national forest management. Society & Natural Resources 14:761–776.

Vaske, J.J. 2008. Survey research and analysis: application in parks, recreation, and human dimensions. Venture Publishing, Inc., State College, Pennsylvania, USA.

Weinzimmer, D., P. Newman, D. Taff, J. Benfield, E. Lynch, and P. Bell. 2014. Human responses to simulated motorized noise in national parks. Leisure Sciences 36:251–267.

Williams, D. R., M. E. Patterson, J. W. Roggenbuck, and A. E. Watson. 1992. Beyond the commodity metaphor: Examining emotional and symbolic attachment to place. Leisure Sciences 14:29-46.

Williams, D. R., and J. W. Roggenbuck. 1989. Measuring place attachment: Some preliminary results. Outdoor Planning and Management NRPA Symposium on Leisure Research 1–7.

Williams, D. R., and S. I. Stewart. 1998. Sense of place: an elusive concept that is finding a home in ecosystem management. Journal of Forestry 96:18–23.

Williams, D. R., and J. J. Vaske. 2003. The easurement of place attachment: Validity and generalizability of a psychometric approach. Forest Science 49:830–840.

Zinn, H. C., M. J. Manfredo, J. J. Vaske, and K. Wittmann. 1998. Using normative beliefs to determine the acceptability of wildlife management actions. Society & Natural Resources 11:649–662.