A HUMAN-ENVIRONMENT SYSTEMS APPROACH TO OUTDOOR RECREATION, HUMAN BIOLOGICAL STRESS, AND LANDSCAPE AESTHETICS

by

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ABSTRACT

Outdoor recreation, as the intersection between physical exercise and nature, provides a multitude of psychological and physiological benefits to human well-being. Though many studies have reported qualitative stress reduction from outdoor recreation, few have focused on quantitative measurements of stress across recreational activity types, intrapersonal differences, and environmental variables. To determine whether outdoor recreation affects physiology, we collected 190 paired salivary cortisol and testosterone samples and 157 surveys from 88 hikers, 81 mountain bikers, and 44 off-highway vehicle (OHV) motorists. After recreation, cortisol concentrations were significantly reduced in hikers and OHV motorists, but cortisol and testosterone concentrations increased in mountain bikers. These three recreational activity types also significantly differed in motivation and wildlife observations, which could be additional mechanisms of physiological change. Out of all three recreation types, hikers were most motivated by environmental variables. To test how the environment could be affecting hikers, we evaluated the impact of landscape aesthetic perceptions and land cover types on hiker spatial movement and stress relief. Using data from 58 GPS tracks, we found that salivary cortisol was significantly reduced when hikers walked through riparian areas. Hiker cortisol also decreased after recreating in areas they perceived as aesthetically pleasing. Aesthetic quality influenced hiker spatial movement, with hikers choosing to recreate in high-aesthetic high-wildlife observance riparian areas. Though hiker movement and stress were not related to the intensity of visitor use, wildlife

observations decreased with greater recreational utilization. Hikers, however, did not perceive any negative impact from their recreational activities. Despite the different forms of recreational activity, outdoor recreation has potential to benefit human well-being. In addition, managing recreational land for ecosystem health and wildlife may enhance well-being benefits, as well as serving a role in the conservation of wildlands.

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BACKGROUND INTRODUCTION

Outdoor recreation provides opportunity for green exercise and reconnection with nature that is believed to have many psychological and biological benefits for human well-being (Pretty et al., 2005; Barton & Pretty, 2010; Bratman et al., 2015). As human stress levels continue to rise in response to urbanization, outdoor recreation is becoming increasingly researched as a potential strategy for reducing urban-related stress and improving the quality of city life (Ulrich et al., 1991; Bolund & Hunhammar, 1999; Takayama et al., 2014). While diverse studies have found that outdoor recreation can reduce self-reported stress, few studies have used direct, quantitative, biological measurements to determine the effect of outdoor recreation on human stress. Though the use of salivary biomarkers for tracking changes in biological stress is becoming more utilized within the field of outdoor recreation, these studies have been limited by small sample sizes and a focus on forested landscapes (Tsunetsugu, Park & Miyazaki, 2010; Ward Thompson et al., 2012; Kabisch et al., 2015; Song et al., 2016). To better understand how outdoor recreational activity is impacting human stress, it is necessary to compare stress biomarkers across a large sample size to account for different recreation types, intrapersonal variation, and environmental variables.

Differences in outdoor recreational activity type, demographics, time of day, weather, and individual variation in environmental knowledge, motivations, and experiences can all affect how stress changes (Cauter, Leproult & Kupfer, 1996;

Brownlee, Moore & Hackney, 2005; Kudielka et al., 2008; Stewart, 2009; Bratman et al., 2012). While many different factors are known to affect the stress response in humans, it is unknown how these factors may change by recreational activity type. Recreational activities may differ in intensity, physical exertion, motivations, and environmental valuation that can affect the recreational experience. These differences can in turn impact human stress and the potential management for ecosystem service benefits.

It is also important to know how the environment can impact stress and the outdoor recreational experience. Landscape aesthetics and outdoor recreation are closely related, and landscape aesthetics can often be a driver of recreational spatial movement (Gobster et al., 2007). Despite differences in individual aesthetic preference, specific land cover types are also thought to be especially beneficial to human physical and mental well-being (Ewert et al., 2005; Tsunetsugu et al., 2010; Lee et al., 2011; Nutsford et al., 2016).

How landscape aesthetics alter visitor use and movement in an urban green space is especially important to consider in terms of wildlife health. If human stress benefits and aesthetic preference are related to recreational spatial movement, this could have direct consequences for wildlife if preferred trails border or intersect high-quality habitat. Wildlife are an important component to ecological health and the outdoor recreational experience, yet higher visitation rates are associated with increased wildlife stress and other negative responses (Thiel et al., 2008; Zwijacz-Kozica et al., 2012). Thus, understanding the environmental and intrapersonal factors important to human stress benefits, recreationist movement, and environmental perceptions are critical for effective land management.

In this thesis, I first focus on measuring the change in biological cortisol concentrations across three different recreation types and exploring potential differences in motivation, ecosystem service valuation, ecological familiarity, and wildlife observance. I then focus on evaluating hiker stress benefits within a human-environment systems framework, investigating the impact of landscape aesthetics on hiker stress, spatial movement, and wildlife observance.

CHAPTER ONE: DOES OUTDOOR RECREATION DECREASE STRESS? INVESTIGATING THE BIOLOGICAL RESPONSES FROM THREE TYPES OF OUTDOOR RECREATIONISTS IN SOUTHWEST IDAHO

Abstract

Outdoor recreation can benefit human well-being by promoting mental and physical health. Many studies have reported reductions in qualitative stress from outdoor recreation. While the connection between self-reported stress and outdoor recreation has been well documented, there has been little research on quantitative, biological measurements of stress and physiology across recreational activity types. To determine the physiological effect of recreational activity, we collected 190 paired saliva samples and 157 surveys of hikers, mountain bikers, and off-highway vehicle (OHV) motorists. We found that hikers and OHV motorists had significant reductions in cortisol after recreating. Conversely, mountain bikers had a significant increase in both cortisol and testosterone after recreating, most likely due to increased physical exertion. The three recreation types significantly differed in motivations and the number of wildlife they observed, which may contribute to changes in stress physiology. We also tested self-stress scores against biological cortisol measurements and found no significant relationship, suggesting that perceived and biological stress are not correlated. Our results suggest that outdoor recreation can decrease biological stress, but this depends on the type of recreation. Land managers should consider more than one form of recreation

when making management decisions. Consideration of different motivations will also ensure that management and human well-being benefits are effective across different recreation types.

Introduction

Outdoor recreation, as the intersection between physical activity and nature, can provide diverse psychological and biological benefits that are important for human well-being (Pretty, 2004; Berto, 2005; Pretty et al., 2005). Specifically, outdoor recreation has been associated with reduced risk of chronic disease and disorders, improving mental health, increasing cognition, and decreasing stress (Pretty, 2004; Pretty et al., 2005; Warburton et al., 2006; Barton & Pretty, 2010; Bratman et al., 2015). Stress can impact a variety of bodily systems and functions; and greater and extended periods of stress experienced in modern society can negatively impact human well-being (Baum et al., 1982; McCarty et al., 2003; Lloyd et al., 2005; Bozovic et al., 2013; Steptoe & Kivimäki, 2013). Understanding ways to reduce stress has the potential to increase human well-being, both physically and mentally, especially in high-stress areas such as urban spaces (Ulrich, 1981; Ulrich et al., 1991; Bolund & Hunhammar, 1999; Kuo & Sullivan, 2001; Pacione, 2003; Gidlöf-Gunnarsson & Öhrström, 2007; Park et al., 2007; Tsunetsugu et al., 2007; Godbey, 2009; Park et al., 2010; Lee et al., 2011; Takayama et al., 2014).

Though researchers have found that outdoor recreation can reduce self-reported stress, few studies have focused on quantitative measurements of biological stress. While there has been a recent advancement in the use of direct and systemic physiological measurements, these studies have been limited by small sample sizes and focus largely on forested landscapes (Tsunetsugu et al., 2010; Ward Thompson et al., 2012; Kabisch et al., 2015; Song et al., 2016). Consequently, there is a need to perform more diverse research using biological indicators of stress across larger sample sizes, recreation types and individual variation.

Salivary steroid concentrations are a useful biomarker for physiology research as it is easy to collect, is non-invasive and significantly correlates with circulating hormone concentrations (Kirschbaum & Hellhammer, 1994; Hellhammer et al., 2009; Salimetrics, 2014). Both salivary cortisol and testosterone can be used to measure physiological changes from outdoor recreation. The impact of daily stressors, indicators of biological stress, feelings of aggression, anger, and dominance as well as response to exercise can all be captured using salivary cortisol and testosterone (Dabbs, 1990; van Eck et al., 1996; Smyth et al., 1998; van Honk et al., 1999; Mastorakos et al., 2005; Almeida et al., 2009).

Since outdoor recreational activities differ in intensity and physical exertion, cortisol and testosterone measurements may vary widely between activity types. To our knowledge, the use of both cortisol and testosterone to evaluate biological responses from outdoor recreation has not yet been done. Using both cortisol and testosterone would provide more information on how stress changes with respect to differences in duration, intensity, and type of outdoor recreational exercise (Adlercreutz et al., 1986; Hloogeveen & Zonderland, 1996; Brownlee et al., 2005). While outdoor recreational activities may differ in physical intensity, they may also differ in individual motivation, valuation of ecosystem services, ecological knowledge, and wildlife interactions (Frey, *in prep*). These differences could feedback into possible mechanisms for stress relief. Exploring differences between recreation types could provide additional connections between outdoor recreation and stress, as well as better inform management decisions for individual activities.

Salivary cortisol can also be compared to self-reported stress scores. While many outdoor recreational studies use self-reported stress measurements or mood indices, previous research has found that there is not a clear association between biological and self-reported measurements of stress (Hjortskov et al., 2004; Carlsson et al., 2006). Since stress can manifest psychologically, behaviorally, and biologically, there is a need to triangulate stress research. Integrating both individual perceptions and biological responses of stress may better elucidate the relationship between outdoor recreation and stress (Baum et al., 1982; Kompier, 2002).

We hypothesize that (1) the recreational activity type will be a key predictor of the biological stress response, (2) motivation, ecosystem service valuation, ecological knowledge, and wildlife observance will differ between recreation types and (3) biological and self-reported stress measurements will not be related. To test our hypotheses, we investigated the physiological response to outdoor recreation across three different recreation types: hiking, mountain biking, and off-highway vehicle (OHV) motoring. We accounted for factors that may influence hormone concentrations such as time of day, gender, age, and weather (Cauter et al., 1996; Brownlee et al., 2005; Kudielka et al., 2008; Stewart, 2009). Additionally, we characterized how recreation types differed in motivation, valuation of ecosystem services, ecological knowledge, and interactions with the environment. These descriptive analyses identified potential mechanisms for stress relief, as well as key differences among recreation types that may be important for land management (Bird, 2004; Bratman et al., 2012).

Methods

Study Areas

We collected survey and salivary hormone data from people at two recreation areas: the Murphy Subregion of the Owyhee Front Management Area (OFMA) in Southwest Idaho, USA, and Camel's Back - Hulls Gulch Reserve of the Ridge to Rivers Management Area in Boise, Idaho, USA (Figure 1.1). The two study sites differed by the type of recreation activities offered and variation in urbanity and physiography.

Murphy Sub region: Owyhees Front Management Area

We collected data from OHV recreationists in the Murphy sub region. The Murphy sub region, managed by the Bureau of Land Management (BLM), is 94,290 hectares of predominantly sagebrush-steppe habitat. The area is characterized by a 1,350 km complex trail system designated for OHV use such as dirt bikes, ATVs, and UTVs. There are eight official OHV trailheads with parking and access to trail networks. We primarily collected data at Hemingway Butte, a trailhead associated with a "play area" for practice, hill climbing, and unstructured recreation, as well as the Rabbit Creek trailhead.

We collected OHV-rider data between March 24 and April 1, 2017. OHV-rider samples were primarily collected on weekends (Sat-Sun) because of lower recreational activity during weekdays. Weather data, consisting of average wind speed and average air temperature were taken from RENI1 station in Uscrn Site at Watershed Research Center (Murphy, ID) and RYCI1 station at Reynolds Creek (Murphy, ID). All participants were asked to participate in salivary cortisol and testosterone collection, as well as a written survey. We did not collect data from hikers or mountain bikers at Murphy due to lower activity use.

Camel's Back: Ridge to Rivers Management Area

Stretching from North Boise to Boise Ridge, the Ridge to Rivers management area offers over 305 km of trails that connect city neighborhoods to the Boise Foothills. Designated trails are available for multiple recreation types ranging from horseback, hiking, and mountain biking. We collected data on mountain bikers and hikers from the Camel's Back trailhead located near Camel's Back Park. The Camel's Back and Hulls Gulch Reserve area are comprised of sagebrush-steppe as well as important riparian areas that support a diversity of wildlife within the city limits.

We collected mountain biker and hiker data between April 8 and May 18, 2017. All mountain biking and hiking samples from Camel's Back were collected on both weekend (Sat-Sun) and weekdays (Mon-Fri). Weather data was obtained from Crestline Trail Idaho (Boise, ID). All participants were asked to participate in both salivary hormone collection and a written survey.

Data Collection

Participants

Recreationists over the age of 18 who were participating in OHV motoring, mountain biking, or hiking were recruited to participate in this study (n=213). We recruited participants at prominent trail heads associated with each recreational area, and the purpose and protocols of the study were explained. Upon agreeing to participate, participants were asked to read an additional written statement of the project and sign a consent form. Each recruited individual was minimally required to participate in either the saliva collection or survey, although all participants were encouraged to participate in each part of the study. Any recreationists who had already been recreating for more than

10 minutes were not recruited. All participants were given an anonymous identifier which was used throughout the study. This research project was reviewed and approved by the IRB at Boise State University, Idaho, USA under #006-SB17-061.

Salivary Cortisol and Testosterone Collection

We restricted all sampling until late morning (generally around 10:00am) to control for diel patterns in hormone concentrations (Dabbs, 1990; Pruessner et al., 1997; Edwards et al., 2001; Salimetrics, 2014; Salimetrics, 2015). To further account for any variations due to time of day, the time of collection was recorded for each saliva sample and factored into analysis.

Saliva samples were collected from recreationists using a pre-post paired design. Participants were asked to give at least 0.25 mL of saliva using a saliva collection aid (2 mL cyrovial, Salimetrics PA, USA) via the passive drool method (Granger et al., 2007; Salimetrics, 2014; Salimetrics, 2015). The passive drool method allows for the collection of large samples for multiple assays, reduces the risk of contamination by collection substances, and allows samples to be frozen without interfering with assay protocols (Granger et al., 2007). Saliva was immediately stored in a portable cooler with ice until frozen at -10°C. Cortisol and testosterone concentrations were assessed using a Salimetrics Cortisol Enzyme Immunoassay kit and a Salimetrics Testosterone Enzyme Immunoassay kit following the manufacturer's protocols and design (Salimetrics, PA, USA). All assay plates were read using the Gen5 software and Biotek EL800 Plate Reader. Hormone concentrations were then calculated from the optical densities using a standard curve and the online elisaanalysis interface.

Survey Collection

After recreating, all participants were asked to take a survey (Appendix A). The survey included questions pertaining to variables that could affect stress levels and be further used to categorize and differentiate between recreation types. Questions included the following: familiarity with plant identification (as a measure of ecological knowledge), observation of wildlife, motivations for recreation (ranging from social, personal challenge, wildlife, and solitude), and basic demographics including age and gender. In addition, participants were asked to rate how stressed they felt after their recreational activity to compare self-reported and biological stress. Participants also had the opportunity to note any negative experiences they had while recreating that could have affected their biological stress (Appendix A).

Statistical Analyses

We used a backward stepwise approach to create a linear model with the following predictor variables: recreation type, start time, duration, gender, age, average temperature, baseline cortisol, baseline testosterone, and all interaction variables with recreation type. We checked for collinearity among variables and considered pairwise $r > |0.70|$ to indicate a correlation. Temperature and duration were removed from all models due to high correlations with recreational activity type where hikers and mountain bikers recreated in higher temperatures compared to OHV motorists, and hikers also recreated for less time (Appendix A). Baseline cortisol concentration did not differ between recreation types, though baseline testosterone concentration was higher in OHV recreationists due to the propensity for male OHV riders (Appendix A).

Non-significant interaction variables were removed first based on lowest SS values, followed by main effect variables with the lowest SS value until only statistically significant variables remained. The response cortisol and testosterone variables were evaluated as the change in concentration from recreational activity (Post-collection - Pre-collection). Negative changes correspond to a decrease and positive changes to an increase in hormone concentration after recreating. To meet normality assumptions, the change in both cortisol and testosterone were transformed using a square root function taken at absolute value. After data transformation, all original signs were returned to maintain the negative-positive spectrum of hormone change. We used a Bon Feronni correction when evaluating all p-values to compensate for any correlational effect between cortisol and testosterone measurements.

To explore differences in motivation, ecosystem service valuation, ecological knowledge, and wildlife observance across recreation types, we conducted a series of best models using the backward step approach with the following predictor variables: recreational activity type, gender, age, and all recreation type interactions. No variables were correlated with each other ($r < |0.70|$) and all variables were included in the models. Non-significant interaction variables with the lowest SS or Chisq values were removed first, followed by main effect variables with the lowest SS or Chisq values until only significant variables remained. Models with significant interaction terms were subset by recreation type and rerun to look at differences in parameter estimates. Response variables included motivation principal component PC1 and PC2 scores, PC1 and PC2 scores for ecosystem service valuations, ordinal plant identification skills (as a measure of ecological knowledge), and total number of wildlife seen while recreating. Linear regression models were used to model motivation and ecosystem service valuation, a multinomial logistic regression was used to evaluate plant identification skills, and a generalized linear model with a poisson distribution was used to model total wildlife seen.

Last, a one-way ANOVA was used to evaluate the relationship between self-reported stress scores and the change in cortisol. We converted the five-scale self-stress score to binary variables of “Not Stressed” (1-2 score) and “Stressed” (4-5 score) due to the lack of “stressed” self-reported responses.

All analyses were conducted in R (R x64 3.3.1) and variables were standardized for parameter estimate comparisons. The entire dataset (n=213) was used for all analyses, though the sample size for each best model may differ due to unequal saliva collection and survey response.

Results

Out of 213 participants, we collected 190 (89.21%) saliva samples and 157 (73.71%) survey samples. We collected 80 (90.91%) saliva samples and 63 (71.59%) surveys from 88 hikers. We collected 80 (98.77%) saliva samples and 57 (70.37%) surveys from 81 mountain bikers, and out of 44 OHV motorists, we collected 30 (68.18%) saliva samples and 37 (84.09%) surveys (Table 1.1). A total of 6 saliva samples (all hikers) were not used due to unusually high (> 2 SD) cortisol and testosterone concentrations, though baseline cortisol was the same across all three recreation types.

Does outdoor recreation decrease stress?

The best model for change in cortisol included both recreational activity type and baseline cortisol concentration as important predictors. Recreation type had a significant effect on the change in cortisol concentration ($p<0.001$) such that both OHV motorists and hikers had decreased cortisol (OHV: -0.212 – -0.00695; Hike: -0.225 – -0.0968) and bikers had increased cortisol (0.156 – 0.284) after recreating (Figure 1.2). Higher baseline cortisol resulted in a significant decrease in cortisol (β= -0.142, $p<0.001$) after recreating (Figure 1.3). The removal of any outliers did not change the interpretation of the results and were kept across analyses.

The best model for change in testosterone only included recreational activity type as a predictor. Recreation type significantly affected change in testosterone ($p<0.001$). After recreating, bikers had increased testosterone (2.698 – 4.630), and both OHV motorists and hikers had no significant change in testosterone (OHV: -1.660 – 1.436; Hike: -1.258 – 0.674) (Figure 1.2).

<u>How do recreational activity types differ?</u>

Recreational types were evaluated based on survey results for motivation, ecosystem service valuation, ecological knowledge, and wildlife observations. The loading for motivation PC1 and PC2 scores was 0.372 and 0.168 respectively such that PC1 scores explained more of the variance. PC1 scores suggest that all motivational variables are equally correlated, whereas PC2 scores suggest motivation is primarily correlated with challenge/develop skills and view wildlife (Table 1.2). The loading for PC1 and PC2 scores for ecosystem service valuation was 0.558 and 0.1859 respectively, and PC1 scores explained more of the variance. PC1 scores suggest equal correlation of ecosystem service variables whereas PC2 scores suggest that recreation place is most correlated with valuation of ecosystem services (Table 1.2).

The best model for both motivational PC1 and PC2 scores included recreational activity type as a predictor variable. While recreation activity type did not impact PC1 scores ($p=0.0576$, 95% CI: -0.308 – 0.310), activity type significantly affected motivational PC2 scores ($p<0.01$) such that hikers were more motivated by viewing wildlife and enjoying both nature and solitude (-0.398 – -0.000560). OHV motorists and mountain bikers were more motivated to challenge themselves/develop skills, meet new people, and spend time with friends/family (OHV: 0.0386 – 0.600; Bike: 0.0496 – 0.464) (Figure 1.4).

The best model for ecosystem service PC1 scores included the interaction and main effect predictor variables for recreational activity type by age. The best model for PC2 scores only included recreational activity. While there was no significant difference by recreation type for PC2 scores ($p= 0.076$), there was a significant interaction effect between recreational activity type and age for PC1 scores ($p<0.05$). Older hikers had decreased valuation of ecosystem services compared to younger hikers (Hike: $\beta=0.697$, $p<0.01$; OHV: $\beta= -0.389$, $p=0.176$; Bike: $\beta=0.0991$, $p=0.761$) (Figure 1.4).

The best model for plant identification skills only included gender as a predictor variable. Males reported significantly higher plant identification skills compared to females ($p<0.01$) (Table 1.3).

Last, the best model for total wildlife seen included recreational activity type as a predictor variable. Recreational activity type significantly affected the total number of wildlife seen while recreating ($p<0.001$). Hikers saw significantly more wildlife (0.309 – 0.699) and OHV motorists saw significantly less wildlife (-0.939 – -0.0831) compared to bikers (-0.147 – 0.347) (Figure 1.5).

Relationship Between Self-Reported Stress and Biological Cortisol

There was no difference in cortisol change with respect to self-reported ratings of "not stressed" or "stressed" ($F_{1,124}$=0.184, p=0.668, 95% CI= -0.345 – 0.222) (Figure 1.6). Across recreation types, self-reported stress measurements were not associated with biological changes in cortisol levels.

Discussion

This study investigated the relationship between the change in biological stress and outdoor recreation across three distinct activity types. The use of direct, biological measurements of stress provided a quantifiable measurement of human well-being benefits from outdoor recreation. Further, the paired design of this study accounted for much of the individual, demographic, and biological variation inherent in endocrine responses (Foley & Kirschbaum, 2010). Overall, the results confirmed our hypotheses that stress response to outdoor recreation depends on the recreational activity type, that activity types differ across interpersonal and ecological variables, and that biological and self-reported stress measurements were not correlated.

Recreational Activity on Biological Stress Response

Recreation type significantly affected the biological stress response. Both hiking and OHV recreationists had decreased cortisol after recreating, whereas mountain bikers experienced an increase in both cortisol and testosterone after recreating.

Mountain biking, as the more physically exertive activity, resulted in higher cortisol and testosterone concentrations relative to the other recreation types. Increased cortisol and testosterone in mountain bikers may not be surprising, however, as we only focused on the short-term effects from recreational activity. Previous research has demonstrated that even moderate, prolonged exercise can induce heightened cortisol and testosterone secretion, especially when measuring free, unbound concentrations rather than total concentration (Galbo et al., 1977; Väänänen et al., 2002; Brownlee et al., 2005). It should be stressed, however, that the heightened cortisol change in mountain bikers should not be misconstrued as a negative effect from outdoor recreation. Rather, the short-term nature of our sampling technique highlights the physical stress induced by vigorous exercise (arousal), rather than any potential decrease in stress experienced after the stressor has ceased.

It is unknown whether biking in outdoor recreational or urban areas would reveal differences in biological stress. Previous research on exercise has shown that viewing pleasant, natural scenery can reduce blood pressure compared to viewing urban scenes which increased blood pressure when compared to control groups (Pretty et al., 2005). It is possible that outdoor recreational areas provide a backdrop for green exercise practices that could promote human well-being benefits regardless of physical exercise induced stressors. Thus, mountain bikers in an outdoor recreational setting may still experience lowered cortisol and testosterone compared to mountain bikers recreating in an urban area.

Our results suggest that outdoor recreation, especially recreation emphasizing leisure and non-strenuous activity, can have short-term beneficial human well-being benefits. In our study, hikers and OHV riders both experienced lower cortisol concentrations after recreating, suggesting that outdoor recreation can provide quantitative stress reduction benefits when not confounded by vigorous exercise.

Though hikers and OHV motorists had significantly reduced cortisol after recreating, the two recreation types may not be equally effective at stress reduction. OHV cortisol measurements had greater variability, which could be due to differences among vehicle types and recreational intent. We did not differentiate between the types of OHV activity (ie. ATV, dirtbikes), nor did we discriminate between individuals who were primarily intent on adrenaline rush (characterized by using the “play” area to develop skills and perform tricks), and those who were more intent on leisure riding. Thus, it is possible that adrenaline seekers may be contributing to the larger variation seen in cortisol change. While separating OHV riders into different categories based on type and intent could have resulted in more detailed analysis of hormone response, we were primarily interested in classifying OHV riders as a single management unit.

It is also worth noting that baseline cortisol concentration affected the change in cortisol across all recreation types. Individuals with higher starting cortisol had greater stress reductions after recreating. Since baseline testosterone and time of day did not significantly affect cortisol or testosterone after recreating, the relationship between baseline cortisol and cortisol change may not be due to diurnal effects. Rather, it is possible that this relationship highlights the potential for greater alleviation of stress in individuals experiencing a heightened stress response. Outdoor recreational activity may then have the potential to significantly alleviate biological stress, especially in individuals who may be experiencing greater amounts of stress.

How do outdoor recreational activities differ across motivation, ecosystem service valuation, ecological knowledge, and wildlife observation?

Recreational groups differed significantly by motivation and wildlife observation, but not by ecological knowledge (which only differed by gender) or ecosystem service valuation (which only differed by hiker age). In most cases, hikers were significantly different from both mountain bikers and OHV motorists, and these differences could be important indicators for managing well-being benefits by recreation type.

Hikers were more motivated by ecological variables such as viewing wildlife and interacting with nature, whereas bikers and OHV motorists were more motivated by variables related to physically challenging oneself and sociality. The higher motivation to develop skills in mountain bikers and OHV motorists could be related to the increase in cortisol and testosterone in mountain bikers, and the increased cortisol variability in OHV motorists. The desire to push oneself, resulting in either increased physical exertion or adrenaline rush, can affect the biological stress response, especially in short-term paired measurements. Conversely, the fact that hikers were primarily motivated by variables such as viewing wildlife suggests that the ecological backdrop for outdoor recreation could be important for hiker well-being and stress reduction. In turn, the differences in motivation among recreation types could have profound effects on management. For instance, the ecological management of recreational areas for biodiversity and species conservation may be aligned to hiker human well-being benefits, but not to well-being benefits experienced by OHV motorists or mountain bikers.

Hikers were also the only group in which overall ecosystem service valuation had any significant effect. While bikers and OHV motorists had no difference in ecosystem service valuation, younger hikers had significantly higher valuation for ecosystem services when compared to older hikers. Since hikers seem to value and be motivated by the environment, younger hikers may be a prime target for cooperative management strategies and participant-mediated conservation efforts.

Last, hikers saw significantly more wildlife than either mountain bikers or OHV motorists, with OHV recreationists seeing significantly less wildlife. Wildlife observation could be an additional potential mechanism for stress reduction, especially in hikers who are highly motivated to view wildlife and who have high valuation of ecosystem services. While many empirical studies have focused on biophilia - the hypothesized desire for humans to connect with nature - few have focused on the relationship between nature and humans via wildlife (Grinde & Patil, 2009). It is possible that wildlife may be an indicator of environmental health, which could heighten the outdoor recreational experience and increase the perception of ecosystem service benefits. While the differences in recreation site may have contributed to the lack of wildlife observation by OHV motorists – thus making comparisons among recreation types difficult – wildlife could still be a possible mechanism for stress relief. To understand the relationship between wildlife and human well-being, wildlife need to be incorporated into future research efforts to make more informed management and land use policy decisions.

Biological Cortisol and Self-Reported Stress

Similar to previous research, we did not find an association between cortisol change and self-reported stress scores (Hjortskov et al., 2004). While perceived and biological stress mechanisms are connected, it is important to note that perceived and biological stress measurements do not reveal synonymous results.

In this study, self-reported stress scores and cortisol change may differ due to the short-term nature of biological data collection. Cortisol release, and consequently, its gradual decline after a stressor, has a lag time compared to other non-biological measures of stress (Qi et al., 2016). Higher cortisol levels seen in mountain bikers may be accentuating the rise and peak of cortisol release due to exertive physical activity rather than any decrease in cortisol individuals may experience after biking has ceased. Self-reported stress scores, on the other hand, may anticipate the feeling of relaxation after exercise, resulting in a disparity between individuals with higher cortisol and low self-reported stress scores after recreating. Within our total analytical dataset, the majority (94.44%) of individuals reported a low stress response despite only half (51.59%) experiencing a reduction in cortisol after recreating. Thus, both physical exertion, as well as the short-term sampling period, may be confounding any associations between perceived and biological stress measurements and affecting their comparisons. Future research should distinguish between self-reported and biological stress measurements and interpret them in their appropriate contexts.

Implications for Ecosystem Services and Management

Ecosystem service research primarily focuses on monetary benefits, but it should not be ignored that outdoor recreation can also provide seemingly non-monetary and intangible benefits such as stress reduction. Though including cultural services for policy and land use decisions can be difficult, it is possible to obtain quantitative measurements of stress. Incorporating previously underrepresented benefits of outdoor recreation as a cultural ecosystem service could help increase the valuation of outdoor recreation to society. Evidence from our study suggests that outdoor recreational areas could help alleviate stress and increase human well-being and quality of life (Bolund & Hunhammar, 1999). We hope that this information can be used to inform land use, city planning, and policy decisions as well as encourage future support for land allocation to green spaces for outdoor recreation.

We also found that recreationists had different motivations depending on their preferred recreational activity type. These differences in motivation and their potential influence on stress suggest that land and trail management practices may not be equally beneficial across recreation types. Understanding the needs and benefits of recreational activities and the implications for wildlife management are necessary to consider for future management plans and assessing areas for intervention. Doing so can help maintain a sustainable balance between the human and natural systems without compromising service benefits (Ballantyne et al., 2009). Rather than advocating for win-win strategies, in-depth trade-off analyses may be better suited for determining sustainable management actions in multi-use recreational areas (McShane et al., 2011).

Limitations

The short-term sampling effort limited this study such that long-term effects of outdoor recreation on biological stress are still unknown. In addition, there may be inherent bias associated with participants having complete knowledge of the proposed methodology and research questions involved. While this bias may have affected our self-reported stress measurements, the variability in the physiological response suggests that the effect of bias was minimal. Last, we did not incorporate measurements of baseline fitness into our results. It is possible that fitness and health may impact the physiological response, and future studies should endeavor to include this.

Future Directions

Understanding the potential mechanisms of stress reduction in outdoor recreationists is complex. While this study begins to differentiate stress response by outdoor recreational activity types, future research should endeavor to perform more complex analyses such as a PATH analysis. A day-long salivary cortisol analysis should also be conducted to see the longer-term effect of outdoor recreation on biological stress. Doing so could investigate the possible stress benefits of more physically exertive activities that may require a longer sampling period to avoid the effect from physical induced stress. Future studies should also focus on collecting both ecological and sociological data and interpreting results within an interdisciplinary human-environment systems context.

Conclusion

Using a paired design, we quantitatively measured stress using salivary cortisol and testosterone biomarkers across three different recreation types. We found that both hikers and OHV motorists had significant reductions in cortisol, and bikers had a significant increase in both cortisol and testosterone after recreating. Across all three recreational activity types, increased baseline cortisol concentrations were significantly associated with lowered cortisol. These results suggest that while outdoor recreation may decrease stress, stress relief is dependent on the type of recreational activity. Recreational activity types also significantly differed among motivation and wildlife observances. While these differences could be possible mechanisms for stress relief, future studies should endeavor to construct a mechanistic approach that could evaluate these differences more effectively. Regardless, the recreational differences described in our study have important implications for management, pinpointing hiking groups as possible conservation targets for participant-mediated management. Last, we also recommend that studies on human well-being differentiate between self-reported and biological stress benefits as they are not synonymous.

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Cited Chapter One Tables and Figures Listed in Order of Reference

Table 1.1. Summary statistics of all predictor variables

	All Recreation Types (n=213)			**Hikers (n=88)**			**Bikers (n=81)**			**OHV (n=44)**		
	Median	*Range*	*SD*	*Median*	*Range*	*SD*	*Median*	*Range*	*SD*	*Median*	*Range*	*SD*
Start Time	11:55	09:13 – 18:31	--	12:20	9:13 – 18:31	--	11:34	10:14 – 17:56	--	12:06	9:55 – 14:56	--
Duration (min)	77	13 – 241	51.8	50	13 – 151	26.6	102	21 – 214	46.9	110	25 – 241	63.9
Temperature (°C)	13.93	2.25 – 20.6	5.33	15.9	7.80 – 20.6	4.05	15.9	7.20 – 19.6	4.03	4.84	2.25 – 9.43	1.65
Age	38	18 – 70	12.8	33.5	18 – 67	13.8	42	21 – 62	11.2	34	19 – 70	12.9
Baseline Cortisol	0.147	0.009 – 1.02	0.160	0.136	0.009 – 1.02	0.188	0.150	0.021 – 0.552	0.109	0.139	0.020 – 0.851	0.191
Baseline Testosterone	61.1	7.66 - 375	53.2	44.6	16.5 - 375	59.9	55.0	7.66 - 297	47.9	99.4	50.5 – 190	36.5

Table 1.2. PC1 and PC2 scores for motivation and ecosystem service principal component analyses. Motivation PC1 scores explain 0.372 of the variance, and PC2 scores explain 0.168 of the variance. Ecosystem service PC1 scores explain 0.558 of the variance and PC2 scores explain 0.186 of the variance. Larger PC values refer to greater correlation, and signs refer to the direction of correlation (ie. negative suggests less motivation and positive higher motivation).

Motivation (n=155)	**PC1**	**PC2**
Meet new people	-0.4620638	0.2893966
Enjoy nature	-0.4171346	-0.3383749
Challenge yourself and develop skills	-0.3831960	0.5645795
Solitude	-0.3965182	-0.3733321
View Wildlife	-0.4415107	-0.4364770
Spending time with friends/family	-0.3368949	0.3912965
Ecosystem Service (n=148)		
Recreation Place	-0.2123777	-0.6674090
Contact Nature	-0.4254320	-0.2300718
Culture	-0.4184087	-0.1549248
Education	-0.3978989	0.2067765
Aesthetics	-0.4029120	-0.2400315
Wildlife Habitat	-0.3927570	0.3779760
Species Conservation	-0.3520196	0.4841415

Table 1.3. Multinomial regression results for plant identification skills (1: Uncomfortable with identification – 6: Comfortable with identification) by gender with a reference level of 3. Male recreationists were more likely to feel comfortable with plant identification at skill level 5 than female recreationists (n=154).

	Plant ID Skill Level	Counts		Coefficients		95% CI		p
		Female	*Male*	*Female*	*Male*	*Female*	*Male*	
Gender	1	16	16	-0.318	0.147	-0.962 – 0.326	-0.779 – 1.073	0.00646
	2	17	28	0.258	-0.646	-0.891 – 0.375	-0.214 – 1.506	
	3	22	19	--	--	--	--	
	4	11	10	0.693	0.0516	-1.42– 0.030	-1.00 – 1.12	
	5	1	10	-3.09	2.45	**-5.10 – -1.09**	**0.305 – 4.601**	
	6	4	0	-1.70	-8.40	**-2.77 – -0.640**	-78.7 – 61.9	

Figure 1.1. **Study site boundaries and trail systems. The yellow circles refer to trailheads at which data was collected for each site. (A) Camel's Back Park and Camel's Back – Hulls Gulch Reserve of the Ridge to Rivers Management Area in Boise, Idaho. The Ridge to Rivers trail system extends beyond the park and reserve boundaries and are not all depicted. (B) The Murphy Subregion of the Owyhee Front Management system (OFMA) in Southwest, Idaho.**

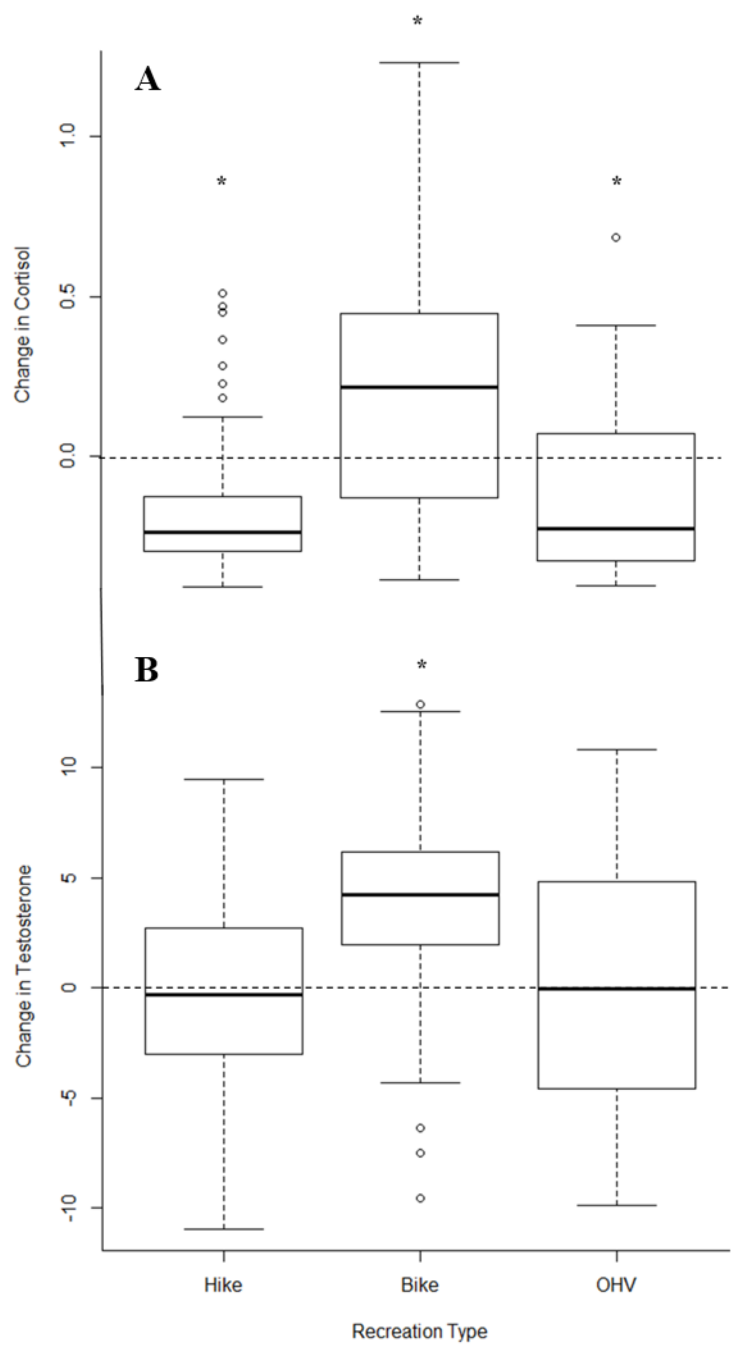

Figure 1.2. **The relationship between (A) the change in salivary cortisol (µg/dL) and (B) the change in salivary testosterone (µg/dL) concentration by recreation type (n=184). Plot A is plotted against the residual change in cortisol when controlling for baseline cortisol concentration. * denotes significance.**

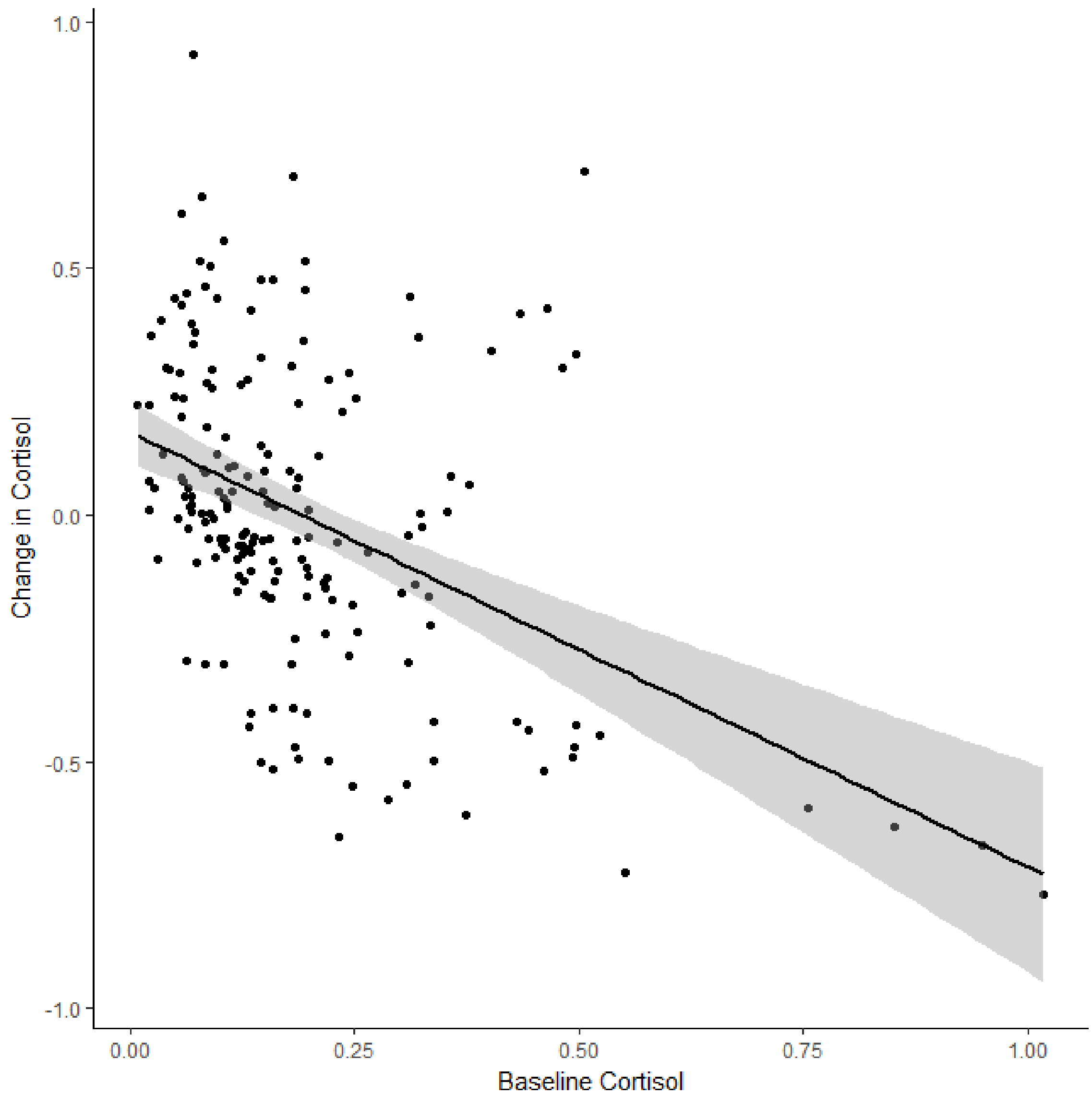

Figure 1.3. Increased baseline cortisol (µg/dL) is associated with greater decreases in cortisol after recreating (n=184). Baseline cortisol is plotted against the residual change in cortisol when controlling for the effect of recreational activity type.

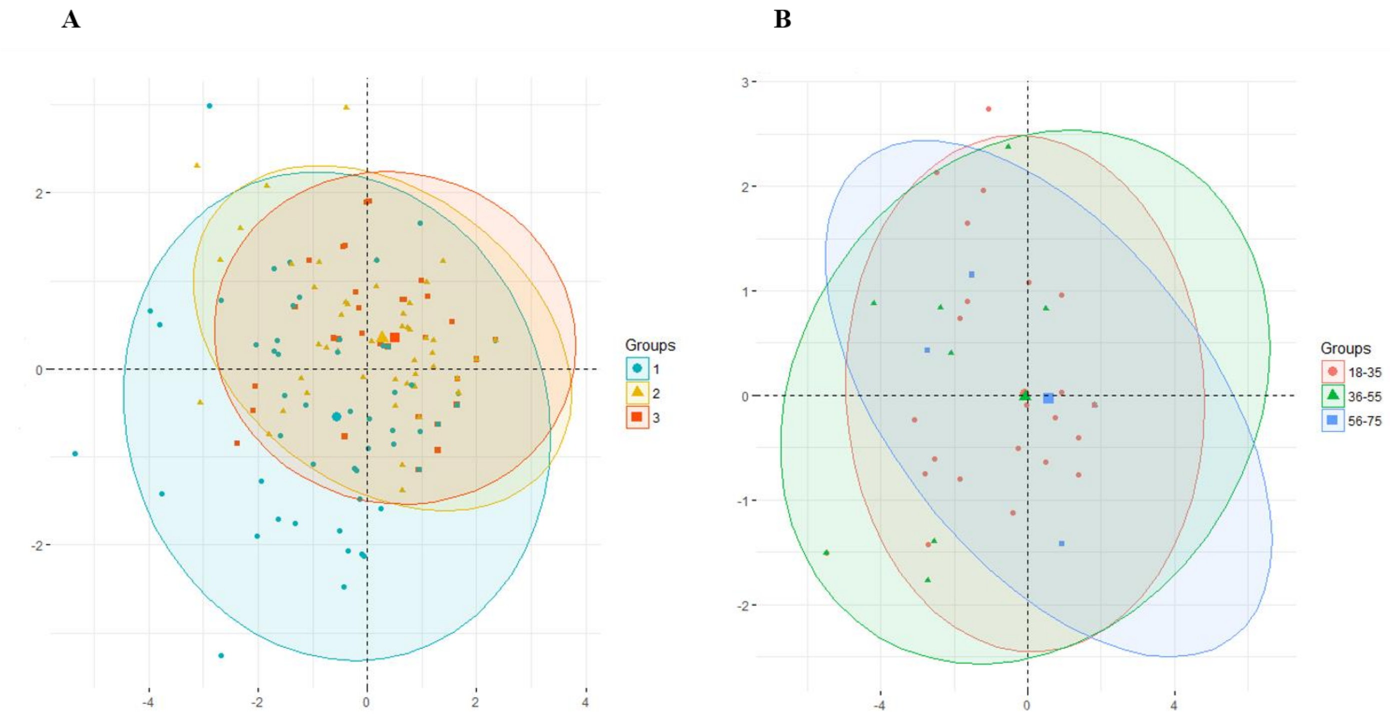

Figure 1.4. **PC1 and PC2 scores plotted by (A) recreational activity type for motivation and (n=155) (B) three hiker age group classifications for ecosystem service valuation (n=62). (A): Group 1 (Hikers) are significantly different from Groups 2 (Bikers) and 3 (OHV) such that hikers are more motivated by ecological variables and bikers and OHV recreationists are more motivated by developing skills and sociality variables. (B): Older hikers significantly value all ecosystem services less than younger hikers.**

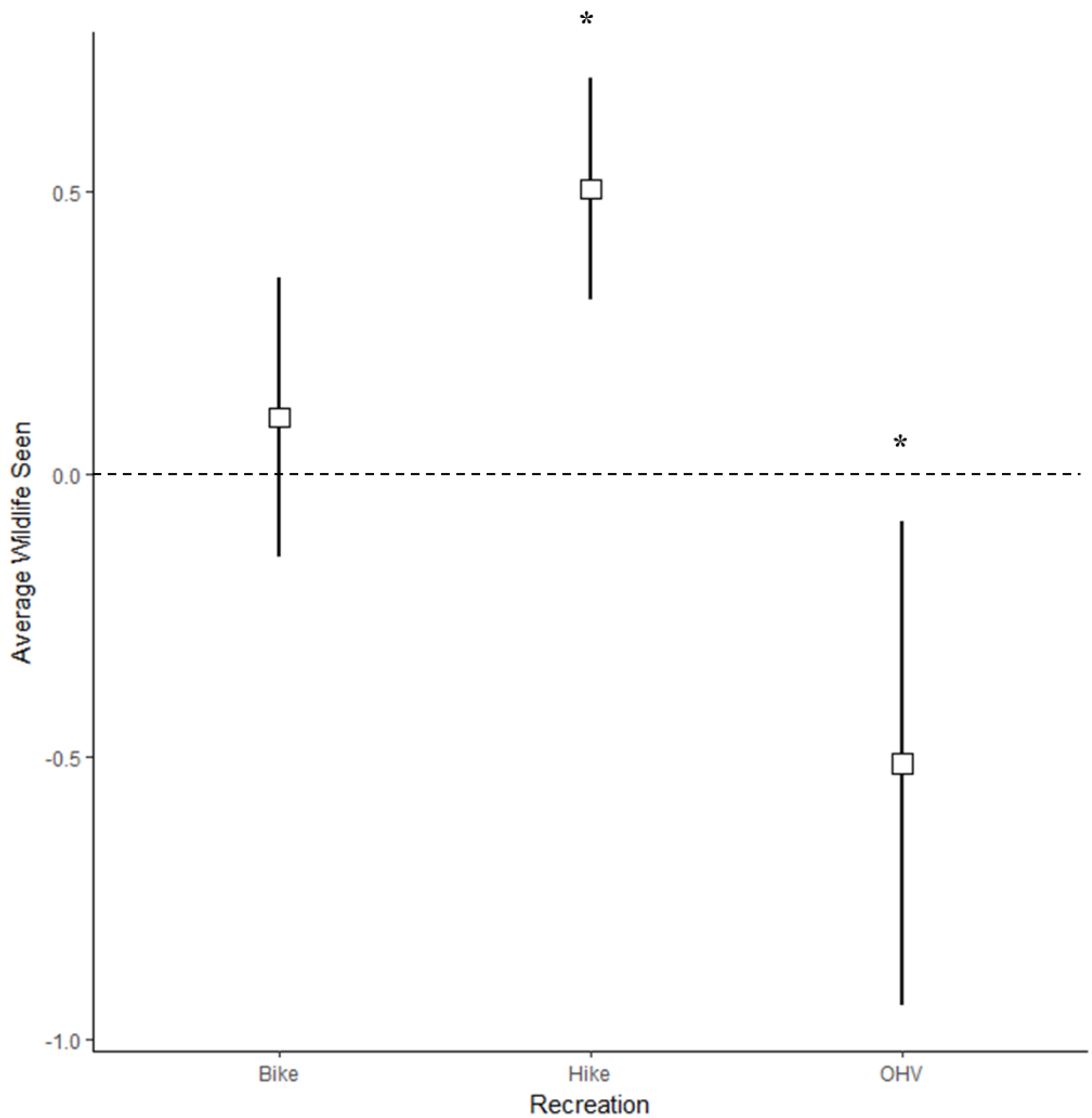

Figure 1.5. Least-square means and 95% confidence intervals of total wildlife seen while recreating by recreational activity type (n=153). Hikers saw significantly more wildlife, and OHV motorists saw significantly less wildlife than bikers. * denotes significance.

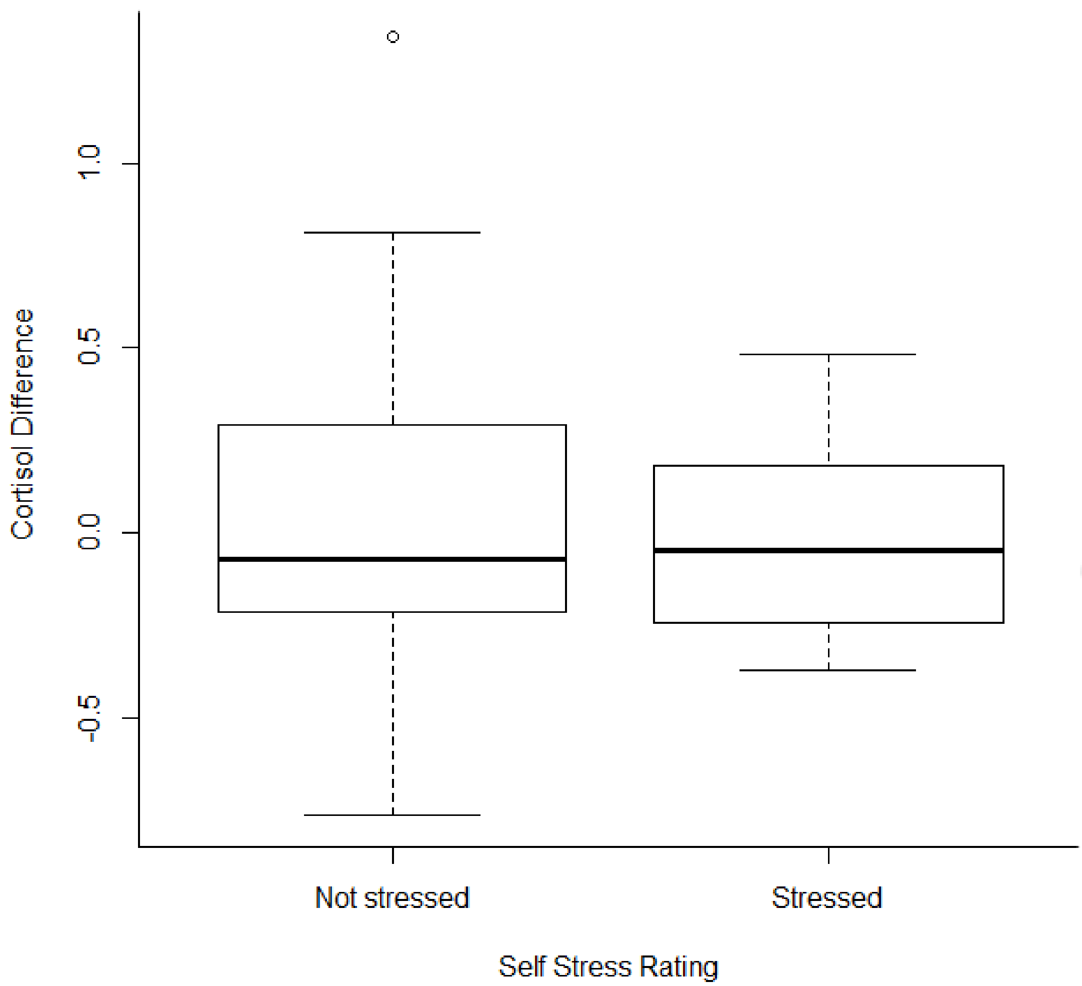

Figure 1.6. A boxplot of self-stress ratings compared to the change in cortisol concentration (μg/dL) after recreating (n=126). There was no significant difference in cortisol change when individuals reported feeling stressed or not stressed after recreating.

CHAPTER TWO: LANDSCAPE AESTHETIC PERCEPTION AND HIGH BIODIVERSITY RIPARIAN AREAS PREDICT HIKER SPATIAL MOVEMENT AND STRESS BENEFITS WITHIN A SIMPLE HUMAN-ENVIRONMENT SYSTEMS FRAMEWORK

Abstract

Aesthetic preference and perception of the landscape can alter visitor flow and potential stress reduction benefits from outdoor recreation. In this study, we investigated the relationships between land cover types, aesthetic perceptions, human stress reduction, visitor use, and wildlife within a human-environment systems framework. We compared spatial, physiological, and survey data from 88 hikers in a high-use peri-urban recreational area. From 77 paired salivary cortisol samples, 63 surveys, and 58 GPS tracks, we found that hiker cortisol levels decreased after recreating in greater amounts of riparian area and in high aesthetically perceived landscapes. Hikers also preferentially visited high aesthetic riparian areas that were characterized by having greater wildlife sightings. The high utility of riparian zones for recreation, coupled with a significant reduction in wildlife sightings during high visitation days, suggests that riparian areas may be at risk for wildlife disturbance. Regardless, many recreationists did not perceive any negative impact on wildlife. Based on our results, we suggest that multi-dimensional visitor monitoring, especially in high-use biodiverse riparian zones, will be important for identifying areas for future management intervention.

Introduction

To date, little work has been done examining landscape variables as the mechanism by which outdoor recreation decreases stress and increases human well-being. Stress, defined as a change in homeostasis due to physical, biological, or psychological stressors, can impact well-being by exacerbating health issues and increasing the risk of cardiovascular disease and diabetes (McCarty et al., 2003; Lloyd et al., 2005; Bozovic et al., 2013; Steptoe & Kivimäki, 2013). Urban stressors, such as overcrowding and noise pollution, can overly stimulate physiological pathways resulting in both mental and biological stress. In comparison, outdoor recreation, especially in urban green spaces, can provide urban stress relief by improving mental health and lowering biological measurements of stress such as salivary cortisol (Ulrich, 1981; Ulrich et al., 1991; Bolund & Hunhammar, 1999; Kuo & Sullivan, 2001; Pacione, 2003; Gidlöf-Gunnarsson & Öhrström, 2007; Tsunetsugu et al., 2007; Godbey, 2009; Park et al., 2010; Lee et al., 2011; Takayama et al., 2014; Bratman et al., 2015).

Previous research has found that salivary cortisol is a useful biomarker and indicator for stress. Easy to collect and non-invasive, salivary cortisol is also correlated with blood serum cortisol and is thought to reliably reflect fluctuations in cortisol concentrations due to daily stressors (van Eck et al., 1996; Smyth et al., 1998; Hellhammer et al., 2009; Salimetrics, 2014). Salivary cortisol has been successfully used to gage changes to biological stress from outdoor recreation, and previous work found that hiker cortisol measurements decreased in response to outdoor recreational activity (Opdahl, *in prep*). While outdoor recreation is associated with a decrease in cortisol, it is still uncertain how attributes of the recreational landscape (both physical and perceived) are also associated with decreases in biological stress.

There is some literature to suggest that certain outdoor recreational landscapes, specifically those near water, may have pronounced effects on human well-being. Water bodies, or “blue spaces,” are associated with increased self-esteem and mood as well as lowered psychological stress (Barton & Pretty, 2010; Nutsford et al., 2016). Water is additionally associated with positive impacts to human perceptions of aesthetics, increased biodiversity, and increased urban quality of life (Völker & Kistemann, 2011; Cooper et al., 2017). Other studies on human well-being have focused on forested landscapes, suggesting recreational areas with high amounts of “greenness” may be associated with higher human well-being benefits (Park et al., 2007; Tsunetsugu et al., 2007; Tsunetsugu et al., 2010; Lee et al., 2011, Ochiai et al., 2015).

The perception of aesthetics may also be an important component for human well-being. Individuals differentially perceive landscapes due to personal background, culture, and experiences (Lyons, 1983; Ewert et al., 2005). To account for intrapersonal differences, more research needs to be conducted on landscape preferences as they are related to social needs, human well-being, and the outdoor recreational landscape (Abraham et al., 2010). Biodiversity and species richness can also affect landscape aesthetics and human well-being (Ulrich, 1993; Dallimer et al., 2012). Water and riparian areas are associated with heightened human well-being, increased aesthetics, and greater wildlife viewing. Thus, riparian areas may be an important interface between outdoor recreation, human stress relief benefits, and wildlife management (Burmil et al., 1999; Völker & Kistemann, 2011).

Landscape aesthetics can drive environmental change and outdoor recreational behavior, resulting in increased recreational traffic and impact in areas of high aesthetic value (Gobster et al., 2007). Identifying high aesthetic landscapes in recreational areas can also be informative for management, especially when such landscapes correspond with areas of high sensitivity and wildlife value (Parsons, 1995). Despite the possible human well-being benefits from recreating in areas of both high aesthetic and wildlife value, recreational crowding can decrease the aesthetic and acceptability value of an area. Recreational perceptions of crowding are subjective and depend on several complex variables tied to the social carrying capacity of recreational land. Consequently, higher visitation rates tend to be associated with lower visitor experience quality and increased habitat degradation (Manning, 1999; Manning et al., 2000).

In addition, recreational crowding is associated with a rise in negative wildlife response. Recreational disturbance is associated with elevated wildlife biological stress, and impacts population distributions, reproductive behavior, and energy budgets (Stalmaster & Newman, 1978; Stalmaster & Kaiser, 1998; Gander & Ingold, 1997; Thiel et al., 2008; Zwijacz-Kozica et al., 2012; Strasser & Heath, 2013; Webber et al., 2013; Arlettaz et al., 2015). Many recreationists are unaware of their own negative impact on wildlife, choosing to blame any negative consequences on other recreational activities over their own (Taylor & Knight, 2003). Thus, understanding how biodiversity and landscape aesthetics contribute to human well-being within the context of wildlife health is important for developing management strategies that can reduce trade-offs and promote sustainable recreation in wildlife rich areas.

Both landscape aesthetics and outdoor recreation are considered cultural ecosystem services that provide strong incentives for the support of environmental conservation efforts (Schaich et al., 2010). Cultural ecosystem services have been little studied compared to regulating, provisioning, and supporting services, and have yet to be fully integrated within the ecosystem services framework (Daniel et al., 2012). Surprisingly, despite many similarities, there has been little integration between landscape and cultural ecosystem service research. Connecting landscape aesthetics with cultural ecosystem services has the potential to provide quantitative spatial connections between human well-being benefits and landscape characteristics.

This paper seeks to associate biological cortisol measurements with landscape aesthetic variables and determine hiker aesthetic preferences and perceptions. To address our objectives, we aim to answer four research questions within a simple human-environment systems diagram (Figure 2.1). We hypothesize that (1) riparian land cover, aesthetic perceptions, visitor use, and wildlife observation will affect hiker cortisol levels. We further postulate that (2) aesthetic ratings will be associated with land cover and visitor use and that (3) wildlife observations will also be impacted by land cover types and visitor use patterns. We are additionally interested to see whether interpersonal differences in motivation and familiarity are associated with a change in cortisol, perception of aesthetics, and wildlife observation, though we hypothesize that these variables will not be as impactful as physical measurements of the landscape. Last, we hypothesize that (4) motivation, familiarity, and observance of wildlife metrics will be related to perceptions of recreational impact on wildlife.

Methods

Study Area

Data was collected from Camel's Back- Hull's Gulch Reserve, a recreational area within the Ridge to Rivers Management Area in Boise, Idaho, USA that seeks to connect the Boise Foothills to public land and city neighborhoods (Figure 2.2). The Ridge to Rivers trails, which span 305 km over an area of 344 km^2, has one million visitations per year by 112,000 users, the bulk of which are hikers and mountain bikers (A 10-Year Management Plan for Ridge to Rivers, 2016). Using trail count data from 2015, most visitation and use was estimated to occur on the weekends, with Saturdays having highest use and Mondays having lowest use across different trails. While many users reside in local communities, overall visitation and trail popularity is increasing in conjunction with the frequency of out-of-state and out-of-county users. The variability in trail activity use and diversity of visitors makes the Ridge to Rivers trail system a natural choice for sampling across a wide range of individuals. The Camel's Back - Hull's Gulch reserve area is a hotspot for hikers due to its car accessibility and proximity to urban neighborhoods.

The Lower Hulls Gulch area is largely composed of sagebrush steppe habitat as well as key riparian areas that support a diversity of wildlife. In addition, the mixture of arid and riparian habitat types creates a unique recreational landscape with contrasting differences in biodiversity and vegetative cover.

Data Collection

We collected data from hikers between April 8 and May 18, 2017 throughout the week (Mon-Sun) between the hours of 9:30-17:00. Based on previous trail counts conducted by Ridge to Rivers, data collection days were categorized as “high recreational use” if taken during the weekends when trail visitation was higher (Sat-Sun), or “low recreational use” if taken during the weekdays when trail visitation was lower (Mon-Fri). Since Mondays had the lowest trail visitation of any day of the week, preference was given to collect weekday data on Mondays whenever possible. Saliva samples, surveys, GPS tracks, and volunteer-employed photography data were then collected from consenting hikers.

Participants

Hikers over the age of 18 were approached and recruited for participation at the Camel’s Back Park trailhead. Any individuals who had been recreating for more than 10 minutes prior to being approached were not recruited. After the purpose and protocols of the study were explained, recruited participants were asked to read over and sign a written consent form as well as given an anonymous numeric identifier. Each participant was asked to minimally participate in either the saliva collection or survey, although all participants were strongly encouraged to participate in as many parts as possible. This research project was approved by the Institutional Review Board (IRB) at Boise State University, Idaho, USA under #006-SB17-061.

Salivary Cortisol Collection

Due to cortisol’s diurnal cycle, we restricted taking saliva samples until the late morning to avoid sampling during the rapid cortisol decline after awakening. Though the diurnal activity does not affect the reliability for assessing cortisol concentrations, we endeavored to try and restrict the influence such diurnal activities could have on any interpretations of the data (Dabbs, 1990; Edwards et al., 2001). All data was subsequently taken between late morning and early evening (~10:00 - 17:00). To further account for any variations in cortisol concentration due to time of day, the time of saliva collection was recorded for each sample and included in analyses.

We collected a saliva sample from each recreationist immediately before, and after, their recreational activity. For each collection, participants were asked to give at least 0.25 mL of saliva using a saliva collection aid via the passive drool method as described by Salimetrics (Salimetrics, PA, USA). Saliva was collected in a 2 mL cyrovial, labeled with the participant's anonymous identifier, and placed in a portable cooler to reduce sample deterioration and bacterial growth until frozen at -10°C. Cortisol was analyzed using the Salimetrics Cortisol Enzyme Immunoassay kit following the manufacturer's protocol and design (Salimetrics, 2014). Assay plates were read using Gen5 software and the Biotek EL800 Plate Reader at 450 nm. Hormone concentrations were calculated from their optical densities using a standard curve and online support from elisaanalysis.

Survey Collection

Participants were asked to complete a survey after returning from their recreational activity (Appendix B). Variables such as aesthetic perception, motivation, familiarity with the landscape, and total wildlife seen were collected. All survey questions were related to either physical or perceived observations of the recreational landscape and were hypothesized to impact biological stress or perceptions of landscape aesthetics. Participants also answered questions about the perceived impact of outdoor recreation on wildlife.

Spatial Data Collection

Portable GPS receivers (Globalsat dg-100) were given to participants to assess recreationist spatial distribution. GPS spatial data has been previously utilized to link survey data and ecological variables to outdoor recreation (Beeco & Brown, 2013). Any data from GPS devices that were found to have turned off prior to returning were not used in analysis. The Globalsat dg-100 model recorded position, time, date, speed, and altitude on five-second intervals with a mean precision of 6.7 meters, and a battery life lasting 20+ hours (Hallo et al., 2012; DG-100 Data Logger User Manual Version 1.2). All GPS tracks were converted from KML files and were processed and analyzed in ESRI 10.2 ArcGIS.

Volunteer-Employed Photography

Volunteer employed photography (VEP) is a cost-efficient and effective method to investigate on-site visitor perceptions of landscape aesthetics and visual scenery. Participants were asked to take a digital camera (Nikon Coolpix) and take photographs of landscapes they found “beautiful.” After returning, participants were asked to choose their favorite photograph which was labeled with the participant identifier along with the time the photograph was taken.

VEP methods can provide social perception data of the outdoor recreational experience that can be useful for trail and land management decisions (Dorwart et al., 2007). In addition, VEP information can be analyzed spatially by collecting photographic and GPS data simultaneously. A spatial analysis approach can tie recreational experiences to spatial characteristics of the site and provide quantifiable measurements of visitor landscape preferences (Sugimoto, 2011). Participants were highly encouraged to participate in both the GPS and digital photography portions of the study, and the coordinates of photo-taking locations was determined by matching the time in which the photograph was taken to the corresponding time logged by the GPS device.

Geographic Information System (GIS) Analyses

Land cover types were measured in ESRI 10.2 ArcGIS. The Lower Hulls Gulch area was digitized using aerial and orthoimagery from ArcGIS Online to create seven layers of land cover: high vegetation, medium vegetation, low vegetation, no vegetation, water, riparian and urban (Table 2.1). Land cover was chosen as a proxy for measuring landscape aesthetics because of its tangible and measurable morphological qualities.

To analyze spatial variables in conjunction with social data, a 100m buffer was created around each GPS track and intersected with the land cover layer. We then calculated the proportion of each land cover type within the 100m buffer. 100m was chosen as a standardized distance to account for variable visibility depending on vegetation cover, elevation, and other environmental factors.

Both GPS track and VEP data were also analyzed in ArcGIS. Photo points were created by matching GPS X and Y coordinates and analyzed using kernel density estimates (KDE) similar to Sugimoto (2011). GPS tracks of participants who had large ($\geq$0.05µg/dL) decreases in cortisol after recreating were additionally analyzed using line density estimates (LDE). LDEs were compared between cortisol reduced individuals and those whose cortisol increased or did not change. Both the KDE and LDE rasters for photo and GPS track data were then analyzed in R (R x64 3.3.1) to extract the median densities of each individual land cover type.

Statistical Analyses

RQ1: What landscape aesthetic variables are associated with decreased hiker cortisol levels?

To look at the relationship between landscape aesthetics and change in salivary cortisol, we created a best linear model of all hypothesized variables using the backward step approach. Predictor variables included the following: principal component PC1 scores of perceived aesthetics, model competition results for land cover metrics, start time, duration, total wildlife observance, plant identification skills (as a metric of ecological familiarity), and all aesthetic interaction terms. Land cover metrics were competed rather than using a low PC1 score to explain the variability among cover types. Due to high correlation between start time and duration, duration was removed from all models (Appendix B). Non-significant interaction effects were removed first by the lowest SS value, followed by lowest SS valued main effect variables until only statistically significant variables remained. Results were interpreted using the change in cortisol (Post-collection - Pre-collection). A negative change in cortisol relates to a decrease in cortisol after recreation, and a positive change with an increase in cortisol. Cortisol concentrations were transformed using a 0.47 exponential transformation to achieve normality. All signs were kept, retaining the negative-positive distribution of cortisol change.

RQ2: What variables are associated with higher aesthetic perceptions?

To investigate perceptions of aesthetics, we created a best linear regression model using the backward step approach for the following predictor variables:

weekday/weekend as a recreational use metric, total wildlife observance, number of years spent in Boise, ID, plant identification skills, gender, age, duration, and all interaction terms. No variables were correlated, and all interaction terms were removed first followed by main effects by lowest SS value until only significant variables remained.

RQ3: Are wildlife observations associated with areas of high aesthetic preference and affected by visitor use?

To understand the relationship between wildlife observations, land cover, recreational use, and ecological familiarity, we created a best generalized linear model with a poisson distribution using the backward step method by lowest Chisq value. No variables were correlated, and all interaction terms were included.

RQ4: How do perceptions of recreational impact on wildlife change with respect to individual motivations, landscape familiarity, and wildlife observation?

Spearman correlations were conducted to see whether perceptions of recreational impact (ordinal ranking from positive impact to negative impact) were related to the motivation to view wildlife, familiarity with animal identification, and total wildlife observations. These variables were chosen due to their direct link to wildlife within the motivation, familiarity, and wildlife hypothesized categories.

All variables across research questions were standardized to compare parameter estimates. All analyses were conducted within the entire dataset (n=88), though the sample size for each best model may differ due to unequal saliva collection, survey response, and GPS track collection.

Results

From a total of 88 hikers, we collected 77 salivary cortisol samples, 63 surveys, and 58 GPS tracks. Overall, hikers recreated through a variety of land cover types dominated by low lying shrub vegetation, perceived their surroundings to have high aesthetic quality, and were variable in their motivations, familiarity, and observance of wildlife (Table 2.2).

Do landscape aesthetics affect salivary cortisol?

The best model for cortisol change after recreating included aesthetic PC1 scores and the proportion of total riparian area travelled through. Hiker cortisol concentration significantly decreased after recreating in higher proportions of riparian cover ($\beta = -0.0965$, $F_{1,52}=8.575$, $p<0.01$). After recreating in areas of low aesthetic quality, we observed a significant increase in salivary cortisol concentration ($\beta=0.0781$, $F_{1,52}=6.069$, $p<0.05$) (Figure 2.3). Perceived aesthetic PC1 scores had a high proportion of variance (0.6634) and higher PC1 scores refer to a general lack of aesthetic quality across all variables (Table 2.3).

GPS tracks of individuals with a large decrease in salivary cortisol ($\geq 0.05 \mu g/dL$) were compared to the GPS tracks of all other individuals using line density estimates (LDEs). Both groups had highest median LDEs in areas of high vegetation, riparian, or water (Figure 2.4). Tracks of individuals with greater cortisol decreases were most congregated in riparian areas (7559.735), followed by water (2926.669) and high vegetated areas (1322.333). Conversely, tracks of all other individuals (including no change and increased cortisol concentrations after recreating) had lower densities in riparian (4192.868), water (0), and high vegetated areas (1129.613). All other land cover types had a median LDE of 0.

What factors affect aesthetic perceptions?

The best model for predicting landscape aesthetic perceptions only included plant identification skills as a predictor, though this relationship was not significant ($F_{1,61}$=1.735, p=0.193).

Photo points of highly aesthetic areas were analyzed using kernel density estimates (KDE). Photo points were highly clustered in high vegetation (13.381), water (40.535), and riparian (23.981) land cover types. All other median KDEs were 0 for all other land covers. Most photographs depicted images of trees and water corresponding to riparian and waterscapes. Thus, VEP data suggests that recreationists perceived riparian and water landscapes as being the most aesthetic over other land cover types (Figure 2.5).

What variables are associated with higher rates of wildlife observation?

Total wildlife observance was best predicted by the proportion of low vegetated and riparian area, as well as the weekday/weekend recreational use metric. Wildlife observance significantly increased when recreating in greater amounts of riparian area (β=0.240, X^2=4.618, $p<0.05$), but significantly decreased in greater amounts of low vegetated habitat (β= -0.298, X^2=5.112, $p<0.05$) (Figure 2.6). Additionally, wildlife observance significantly decreased on high visitation (weekend) days (β= -0.276, X^2=6.033, $p<0.05$) (Figure 2.7).

What factors affect the perception of recreational impact on wildlife?

Increased motivation to view wildlife was correlated with positively perceived recreational impacts on wildlife (r_s= -0.2903, $p<0.05$) (Figure 2.8). There was no association between perceived recreational impact on wildlife and both familiarity with animal identification and total wildlife seen (animal ID: r_s=0.1421, p=0.2829; wildlife seen: r_s=0.2312, p=0.08362).

Discussion

This study investigated the effects of landscape aesthetics on human well-being benefits using a simplified human-environment systems approach. Based on our results, we found that high aesthetically perceived landscapes and riparian areas were associated with decreased human biological stress. We additionally found that visitor use impacted wildlife observations, though many recreationists did not perceive any negative impacts to wildlife. Overall, the results from this study provide quantitative evidence in support of our hypothesized human-environment systems diagram (Figure 1).

Human well-being, salivary cortisol, and landscape aesthetics

In accordance with our hypothesis and previous studies, we found that recreating in a higher proportion of riparian area significantly decreased hiker salivary cortisol after recreating. Riparian areas are highly biodiverse, making them a unique mixture of environmental variables that contribute to both the reduction of biological cortisol and psychological stress (Barton & Pretty, 2010; Völker & Kistemann, 2011).

Spatial LDEs of individuals with larger cortisol reductions also showed greater usage of riparian and waterscapes. Based on the density analysis, water may be a strong contributing factor to cortisol decrease and could be an important component of the efficacy of riparian areas to reduce human stress. To better model the effect of land cover types on hiker biological stress, more complex geostatistics should be used in future studies. These results, however, suggest that landscape aesthetics can be quantitatively linked to human stress relief within a human-environment systems context.

In addition to riparian area, individual perceptions of aesthetics also had a significant effect on the change in cortisol. Hikers who recreated through poor aesthetically perceived landscapes had increased cortisol after recreating. These results suggest that along with physical attributes of the landscape, individual perceptions are also an important component for recreational stress relief. Thus, stress benefits from landscape aesthetics can manifest through both environmental and sociological variables, requiring that future studies on landscape aesthetics have an interdisciplinary approach.

While we did not see any effect of recreational crowding on salivary cortisol, this is perhaps not surprising when considering the complex perceptions involved in crowding-related stress. While our use of weekday-weekend as an indicator for crowding may be valid for neutral visitor use estimates, it does not consider individual perceptions of crowding as suggested by normative theory (Manning, 1999). It is also possible that crowding has not yet reached its social carrying capacity. The continued use of, and stress release, from popular riparian trails suggest minimal to no visitor trail use displacement as a result from crowding. Though individuals cited more negative crowding-related experiences on weekends compared to weekdays, crowding complaints only comprised 31% of all surveyed hikers on weekends and 18% on weekdays (Appendix B). Thus, while crowding may still act as a potential negative feedback, visitor use in the Camel's Back – Hull's Gulch reserve may have not yet reached that threshold.

<u>Aesthetic Perceptions</u>

Contrary to our hypothesis, perceptions of landscape aesthetics were not affected by any physical environmental variables. Rather, individual perceptions of aesthetics were most associated with ecological familiarity, though this result was not significant.

While we did not find a meaningful effect, perceived aesthetics are often dependent on individual backgrounds and may be more contingent upon interpersonal variables over physical attributes of the landscape (Lyons, 1983; van den Berg, 1998; Ewert et al., 2005; Wang & Zhao, 2017).

There is some evidence to suggest that landscape aesthetics may still act as a driver of recreational movement across the landscape. Despite the lack of meaningful results on predicting landscape aesthetic perceptions, KDE analysis of photo points suggest that hikers do consider some habitat types to be more beautiful than others. Most hikers took photographs in areas that were highly vegetated, riparian, and near water. Thus, while most hikers perceived small-scale riparian areas as highly aesthetic, perceived aesthetics of the entire landscape may be separate and more deeply rooted in interpersonal differences and ecological familiarity. Knowing that hikers utilize and view riparian trails with higher aesthetic regard is useful for understanding social carrying capacity and visitor use thresholds.

Factors Affecting Wildlife Observances

As hypothesized, wildlife observances significantly increased when hikers recreated through more riparian area and less low vegetated areas. Additionally, wildlife observation significantly decreased during weekends when visitor use was higher. Unlike perceived crowding effects on stress, our use of weekday-weekend as an indicator for visitor use was effective. Though wildlife observances increased in riparian areas and lower visitor use, the most popular and highly used trails are in high aesthetically perceived riparian areas. This suggests that wildlife in the Hulls Gulch Reserve may be subject to future displacement and increased stress relating to high frequency recreation in riparian areas. The high valuation of riparian areas for both humans and wildlife makes riparian zones a hotspot for assessing possible conflicts between the human and natural systems. If wildlife indirectly effect landscape aesthetic quality and biological stress relief, any changes in wildlife stress, behavior, or distribution could reduce both environmental and experiential quality (Knight & Cole, 1995).

Perceived Recreational Impact on Wildlife

Similar to previous findings, most people did not feel that their outdoor recreation had any negative impact on wildlife: 63% perceived recreation as having a positive impact, 12% as having no effect, and only 25% of hikers perceived recreation as having a negative impact on wildlife. Consistent with part of our hypothesis, this group was largely dominated by individuals who were motivated to view wildlife. Regardless of motivation, many recreational groups view their own recreational activity as benign, choosing to blame other recreational activities for disturbances to wildlife (Taylor & Knight, 2003; Sterl et al., 2008). The perceived positive impact by wildlife viewers could also be due to a disconnect between individual values and behavior, or else a belief that valuing wildlife results in greater success of conservation and management strategies (Marzano & Dandy, 2012). Though hikers in the Lower Hulls Gulch reserve value and are motivated by wildlife, the disconnect between perceived impact and wildlife valuation may need to be addressed for future management (Opdahl, *in prep*).

Implications for Management

Riparian areas offer a multitude of ecosystem services such as wildlife habitat, wildlife viewing, and human stress benefits from outdoor recreation. The high prevalence of both wildlife sightings and visitor use in riparian areas suggest that riparian zones may be at higher risk for wildlife disturbance and displacement, as well as environmental degradation. To preserve the functionality of riparian zones for both the human and natural systems, visitor spatial use and wildlife populations should be periodically monitored (Duffus & Dearden, 1990; Leung & Marion, 2000; Taylor & Knight, 2003; Sterl et al., 2008; Marzano & Dandy, 2012). Riparian restoration efforts and strategic educational signs may also be necessary to maintain the serviceability of riparian areas and promote more mindful recreation habits.

The addition of more trails in riparian areas may also reduce the effect of visitor use by redistributing visitor flow pathways across a broader area. Introducing more trails would allow greater access to benefits and services afforded by riparian zones, as well as reduce off-trail usage and associated environmental degradation. In some cases, wildlife can habituate to recreational use along predictable trail routes (Taylor & Knight, 2003). Habituation, however, varies with species, and a biological review of the effect of recreational activity on wildlife should be done prior to establishing new trails.

<u>Limitations</u>

We were limited by the lack of investigation of landscape visual metrics that have been previously used to assess landscape aesthetic preferences, emotional bonding, and standard landscape attributes (Fourie, 2005; Cheng, 2010). Though we only used land cover types to assess landscape preferences, differentiating landscapes by land cover can be more beneficial from a managerial standpoint and was informative for our research. In addition, self-sorting confounds could have limited this study such that people seeking out restorative effects may self-select riparian areas. Despite this potential confound, however, the relationship between riparian areas and human benefits is still valid. Though the results of this study still offer important insight, future studies should incorporate network analyses and greater usage of geostatistical tools to investigate how recreationist stress response may change across broader spatial scales. Last, the results of this study has a seasonal limitation, and there may be different relationships and management strategies needed during the winter months.

Conclusion

Our data suggest that landscape aesthetics can affect human well-being via reductions in cortisol, and that perceived aesthetic value can drive human spatial movements in the outdoor recreational landscape. Though there are signs that wildlife and outdoor recreational activities are competing for shared high-quality riparian space, negative perceptions of impact on wildlife are low. This paper ties human biological stress benefits, landscape aesthetics, and wildlife into a conceptual human-environment systems framework. Based on our results, we recommend that future management should monitor visitor flow and wildlife distributions across the landscape, especially in riparian areas where both visitor and wildlife use are high. Future management and studies should incorporate greater use of spatial tools to visualize the effects of outdoor recreation across the landscape.

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Cited Chapter Two Tables and Figures

Table 2.1. GIS derived land cover variable descriptions

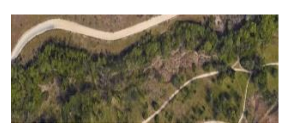
Category	Variable	Description	Depiction
Land Cover	High vegetation	Areas with high vegetation density and connectivity (trees)	
	Medium vegetation	Areas with moderate vegetation density and sporadic connectivity (dense shrubs)	
	Low vegetation	Areas with low vegetation density and no connectivity (sparse shrubs)	
	No vegetation	Areas with no vegetation, barren, dirt patches	
	Urban	Areas with human infrastructure such as roads, buildings, parking lots	
	Water	Water bodies	
	Riparian	Areas with high vegetation density, high connectivity, and proximity to water	

Table 2.2. Summary of predictor variables of hypothesized categories affecting hikers (n=88). For variables with ratings, higher ratings refer to increased importance (motivation), increased quality (aesthetics), and increased knowledge (familiarity). Recreational impact ratings span from 1 (positive impact), 3 (no effect), and 5 (negative effect).

	Variable	**Median**	**Range**	**SD**
Land Cover (proportion)	Low vegetation	0.45	0.35-0.64	0.08
	Riparian	0.08	0.00-0.19	0.05
Total Wildlife Seen	--	1	0-8	1.52
Motivation (1-5)	View Wildlife	4	1 – 5	1.00
Familiarity (1-6)	Plant ID	2	1-6	1.35
Start Time	--	12:20	9:13 – 18:31	--
Temperature (°C)	--	15.9	7.80 – 20.6	4.05
Duration	--	50	13 – 151	26.6
aPC1	--	0.020	-2.47 – 3.80	1.63
Age	--	33.5	18 – 67	13.8
Years	--	10	0 – 62	13.5
Recreational Impact (1-5)	--	4	1-5	1.20

* Recreational crowding (Mon/Tue/Wed/Thu/Fri=1; Sat/Sun=2) is a binomial variable and was not included in the table. The recreational crowding mean was 1.57, suggesting a relatively even sampling split.

Table 2.3. PC1 scores of all variables within each hypothesized category.

	Variable	PC1
Motivation (n=61)	Meet new people	-0.4149
	Enjoy nature	-0.4424
	Develop skills	-0.3648
	Enjoy solitude	-0.4543
	View wildlife	-0.4570
	Be with friends/family	-0.2893
Perceived Aesthetics (n=63)	Beautiful	-0.4770
	Peaceful	-0.5280
	Scenic	-0.5323
	Wild	-0.4591

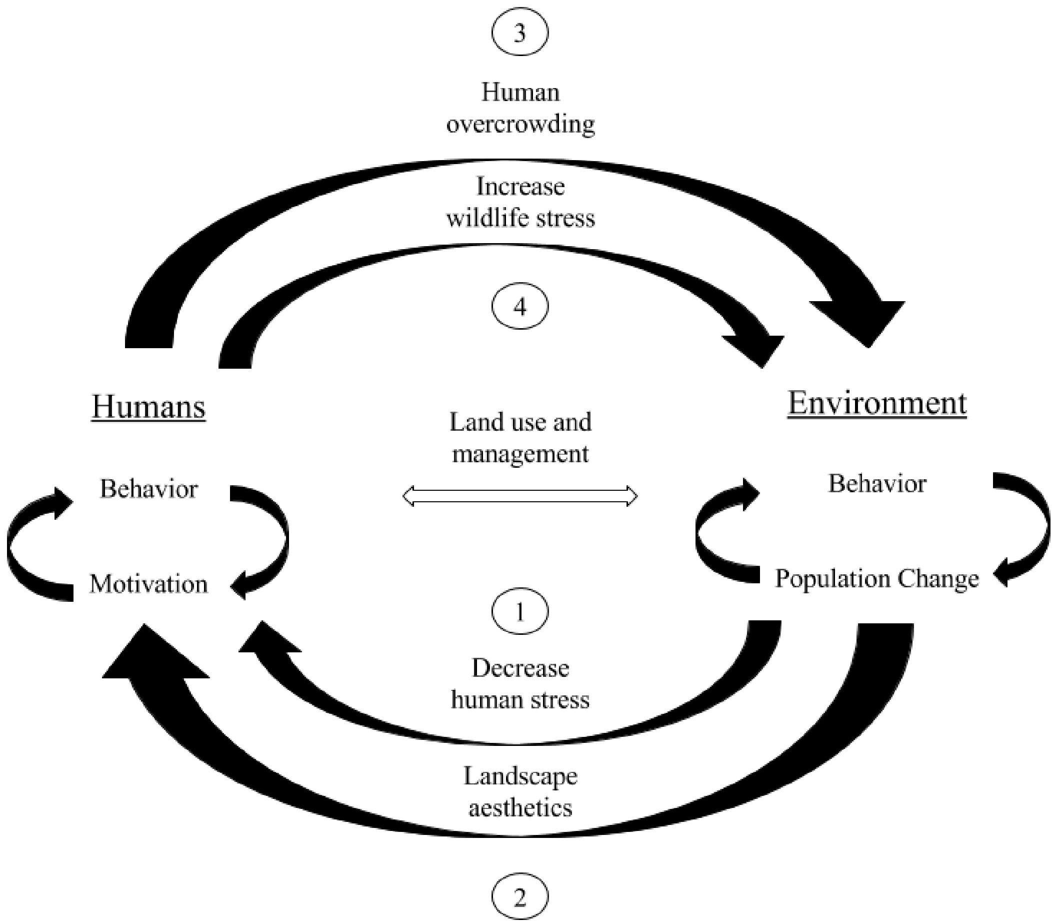


Figure 2.1. A hypothetical diagram depicting the possible relationships between the human and environment systems within the context of outdoor recreation. In this model, landscape aesthetics is considered a driver of human behavior and stress physiology. The white arrow signifies a bidirectional relationship between the two systems while black arrows refer to cyclical or unidirectional relationship within and between systems. Numbers refer to the following research questions: (1) What landscape aesthetic variables are associated with a change in hiker cortisol levels, (2) What variables are associated with higher aesthetic perceptions (3) Are wildlife observations associated with areas of high aesthetic preference and affected by visitor use and (4) How do perceptions of recreational impact on wildlife change with respect to individual motivations, landscape familiarity, and wildlife observation?

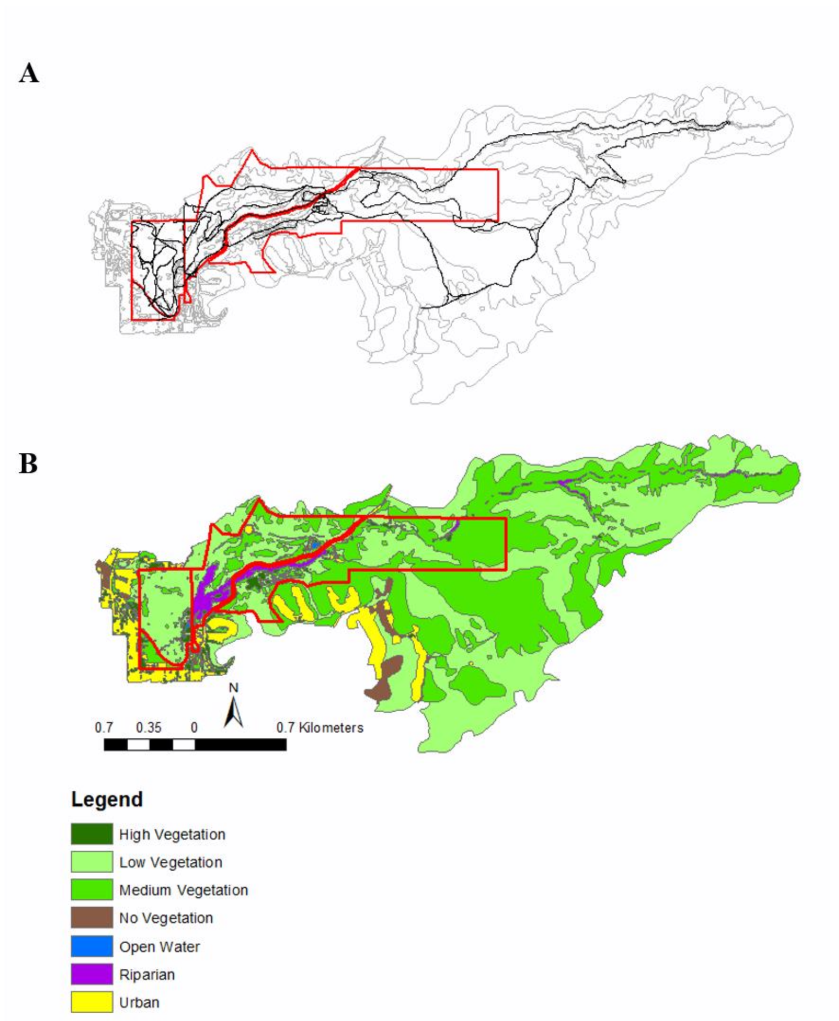


Figure 2.2. The study area including the Camel's Back – Hull's Gulch Reserve of the Ridge to Rivers management area depicted by the red boundary outline, (A) part of the Ridge to Rivers trail system depicted in black, and (B) different land cover types.

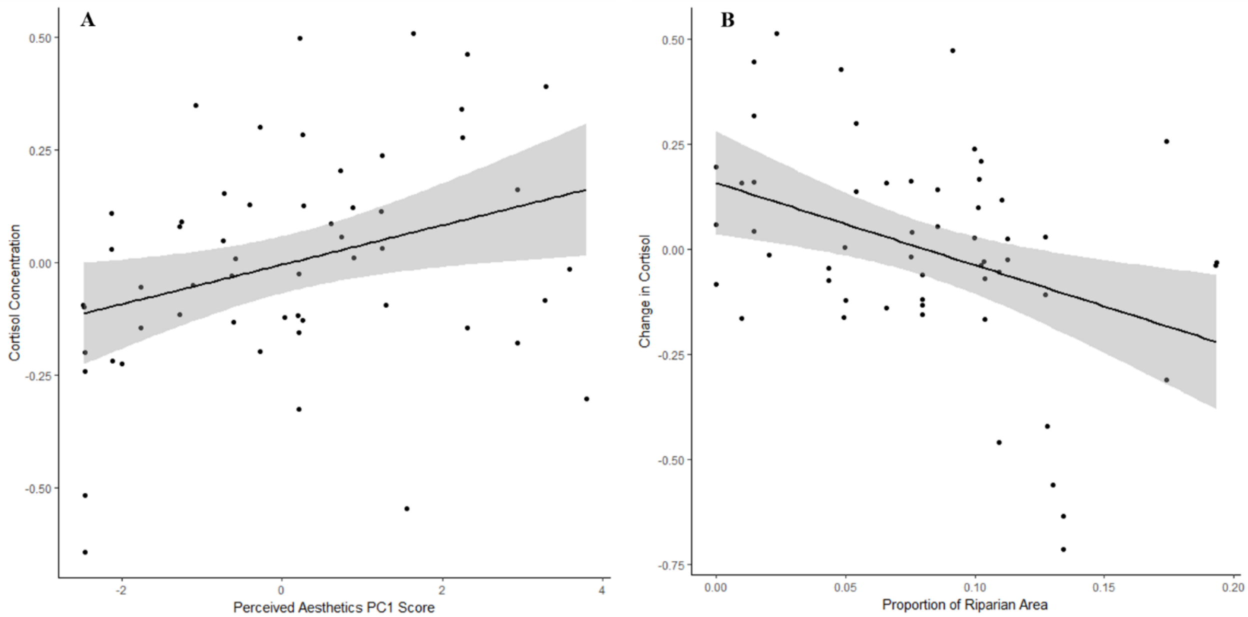


Figure 2.3. The relationship between the change in cortisol (µg/dL) and both perceived aesthetics and riparian area with best fit lines and standard error (n=55). (A) Cortisol significantly increased after recreating in low aesthetically perceived landscapes. (B) Cortisol significantly decreased after recreating in more riparian areas. Both figures are plotted against the residual change in cortisol when controlling for either aesthetic PC1 score or riparian area.

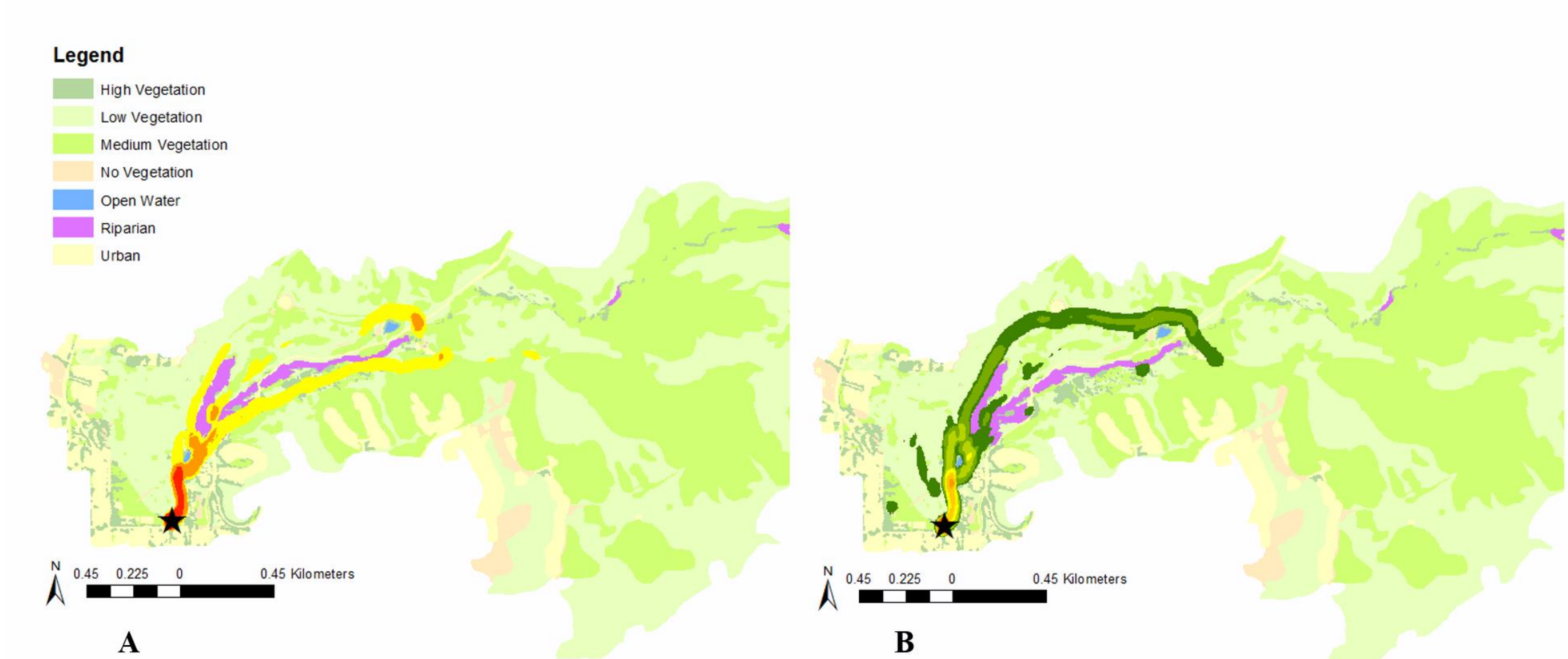


Figure 2.4. Line density results, land cover, and tracks of (A) hikers with cortisol decreases greater than average (≥0.05µg/dL, n=24) and (B) all other hikers (n=30). Density increases from green to red where highest densities are depicted in red, and lowest densities in green. The star refers to the Camel's Back trailhead where all data was collected.

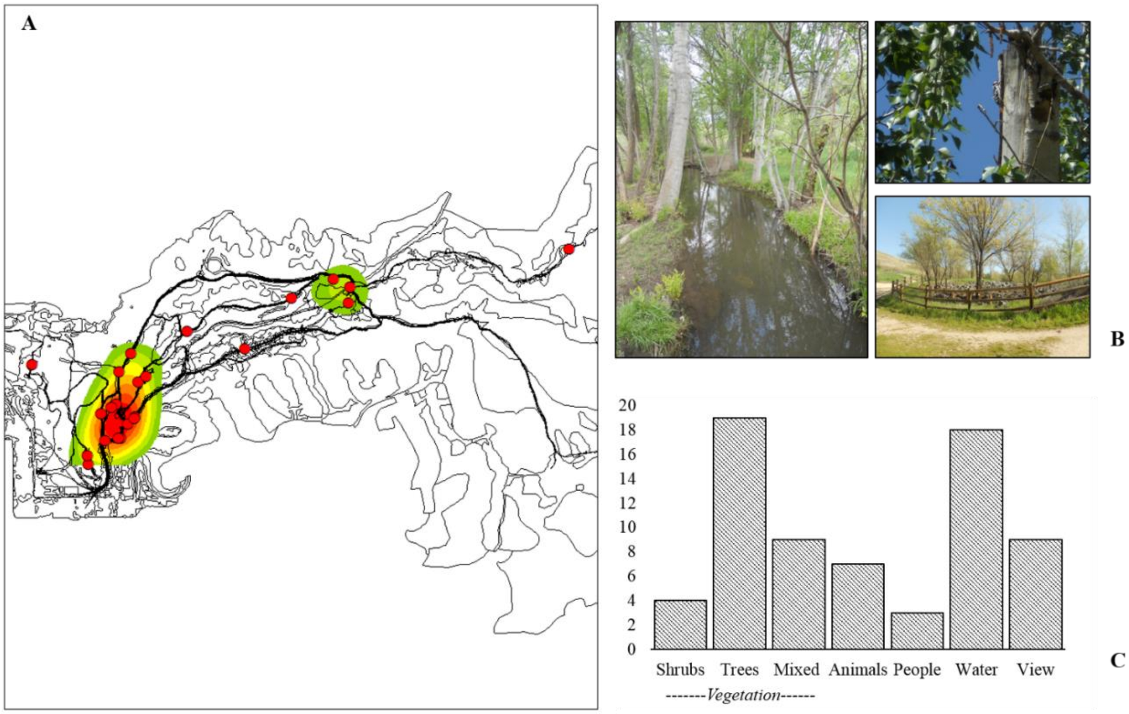


Figure 2.5. Volunteer employed photography results including (A) kernel density estimate (KDE) of photo points, (B) a sample of representative photographs from the area of highest photographic density, and (C) a bar graph depicting the various photographic elements captured by each participant (n=22). KDE estimates are shown alongside land cover type boundaries, participant tracks (black), and photo points (red). Densities are depicted from highest to lowest where red refers to high photographic density, and green as low photographic density.

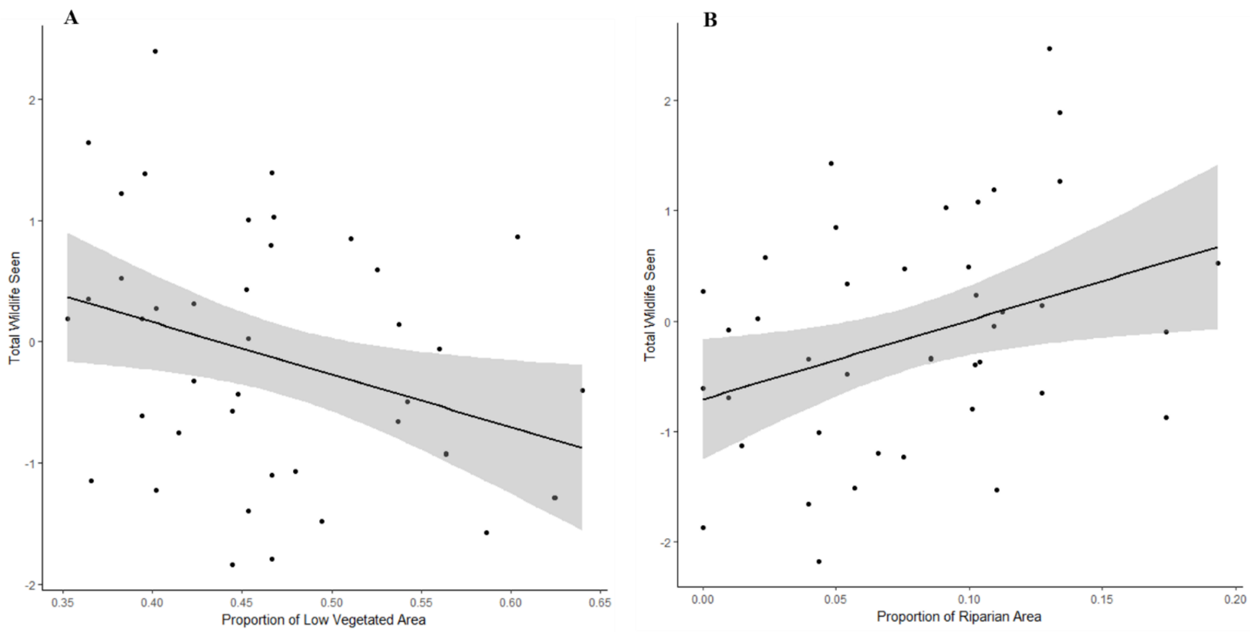


Figure 2.6. The relationships between the number of wildlife seen while recreating and both the proportion of low vegetated and riparian area travelled through with line of best fit and standard error (n=47). (A) Wildlife observances significantly decreased with increasing proportion of low vegetated area recreated through. (B) Wildlife observances also significantly increased with increasing riparian area. Both figures are plotted using the residual change in total wildlife seen when controlling for either low or riparian area, as well as recreational crowding.

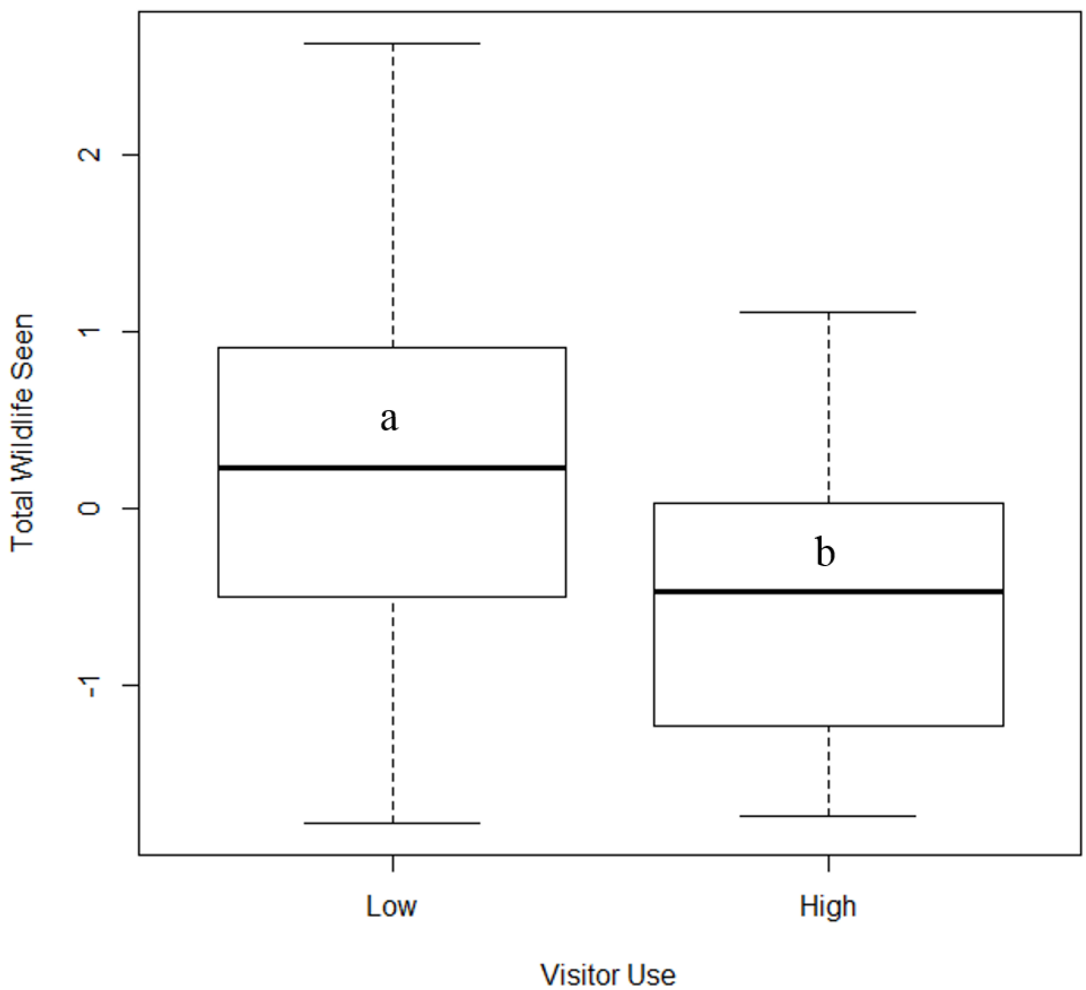


Figure 2.7. The relationship between total wildlife seen and high/low visitor use (n=47). Total wildlife seen is represented as the residual change when controlling for the effect of both low vegetated and riparian area on wildlife. Different letters denote significant differences.

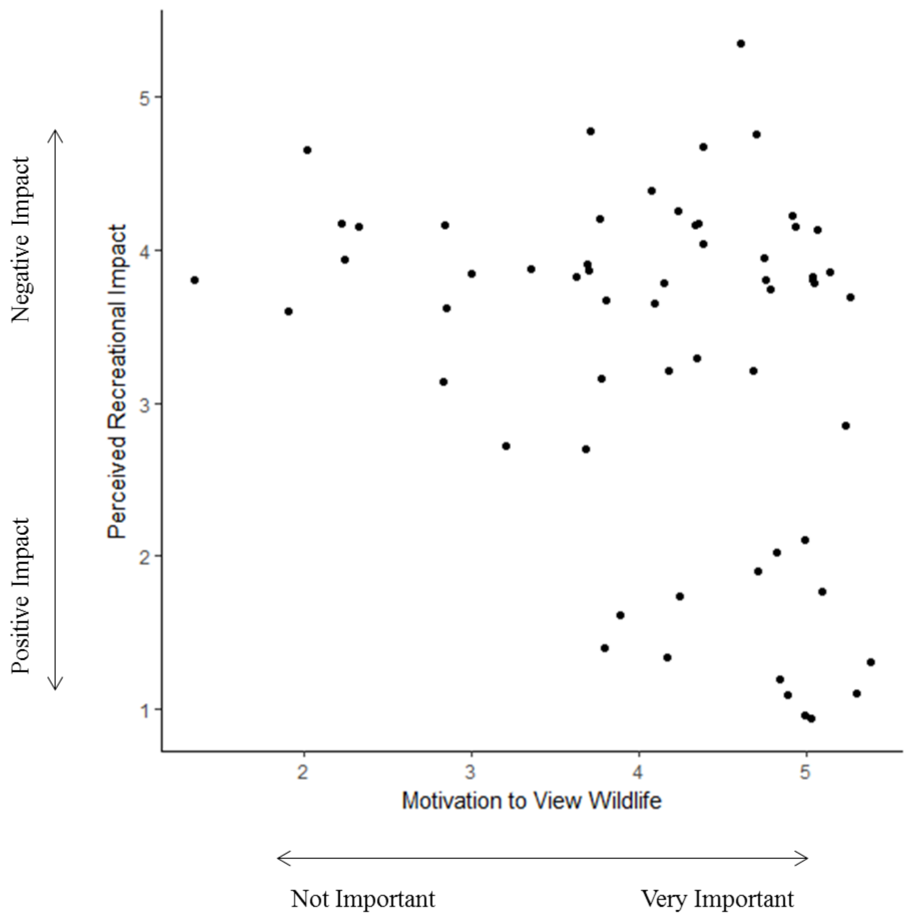


Figure 2.8. Ordinal rankings of perceived recreational impact to wildlife (1=Positive, 3=No impact, 5=Negative) compared to motivation to view wildlife (1=Not Important, 3=Neutral, 5=Very important) (n=59). There is a negative correlation between viewing wildlife and perceived recreational impacts.

CONCLUSION

Despite the complexities of the biological stress response, we found evidence for human well-being benefits via stress reduction from outdoor recreation, especially in non-strenuous activities such as hiking and OHV motoring. Though mountain bikers had elevated salivary cortisol concentrations after recreating, this was most likely due to vigorous exercise related to physical stress and does not necessarily preclude mountain biking as a beneficial stress reducing strategy. Though not tested directly, these three recreational activity types differed significantly among motivation and wildlife observance variables that could be important mechanistic pathways for stress reduction. In particular, hikers were largely influenced by environmental variables and had the largest salivary cortisol reductions. This prompted further investigation into the possible mechanisms of biological stress reduction in hikers within a simple human-environment systems framework.

Perceptions of landscape aesthetics and key land cover types were associated with reduced salivary cortisol concentrations in hikers after recreating. Though we found no meaningful predictor of landscape aesthetic perceptions, hikers seem to favor riparian areas, finding them highly aesthetic. Riparian areas were also associated with stress reduction and increased wildlife observance, highlighting the importance of such landscapes for both human and wildlife well-being. Though visitor use and crowding stress did not affect the hiker biological stress response, higher visitor use was associated with decreased wildlife observation despite many hikers perceiving their recreational activities to be benign. As visitor use continues to rise, wildlife in these high-use urban green spaces could become at risk for displacement if hikers continue to recreate in riparian areas and shared wildlife habitat space.

The results of this thesis highlight the importance of outdoor recreation on human well-being and begin to tie human stress reduction and recreational behavior back to environmental and biodiversity concerns. Though outdoor recreation and access to outdoor recreational areas can have important human well-being benefits, it is important that management strategies intervene to ensure that these shared places are correctly managed to also support wildlife populations and ecological health.

APPENDIX A

Supplemental Figures from Chapter One

BOISE STATE UNIVERSITY

Please answer the following questions on recreational activity.

	Hiking/Walking	Mountain Biking	Off-Highway Vehicle (OHV) Riding
Please select the recreational activity you did today.	☐	☐	☐
In the last 30 days, how many times have you done each of the three recreational activities listed here?			

Thinking about your recreational experience today…

How many people (other than yourself) did you recreate with today? ___________

Which trails did you use today? (A trail map of the area is available upon request if needed – just ask!)

____

Please list any wildlife you saw while out recreating below.

____

How many animal species (including birds, mammals, and reptiles) did you recognize while out recreating? ___________

How many plant species did you recognize while out recreating? ___________

How comfortable do you feel at identifying wildlife?	1 Not comfortable	2	3	4	5	6 Very comfortable
How comfortable do you feel at identifying plants?	1 Not comfortable	2	3	4	5	6 Very comfortable
How well do you know this recreational area and its trail system?	1 Not well	2	3	4	5	6 Very well
How beautiful did you find the landscape in which you recreated in today?	1 Not beautiful	2	3	4	5	6 Very beautiful
How peaceful did you find the landscape in which you recreated in today?	1 Not peaceful	2	3	4	5	6 Very peaceful
How scenic did you find the landscape in which you recreated in today?	1 Not scenic	2	3	4	5	6 Very scenic
How natural/wild did you find the landscape in which you recreated in today?	1 Not natural/wild	2	3	4	5	6 Very natural/wild

What was your most positive experience today?

____

What was your most negative experience today?

____

How do you feel after your recreational experience today? 1 Not stressed, 2, 3 No change, 4, 5 Very stressed

How important were the following things for you to experience during today's activity?

	Not important	Not very important	Neutral	Somewhat important	Very important
Meet new people who enjoy similar things	☐	☐	☐	☐	☐
Enjoy the natural environment	☐	☐	☐	☐	☐
Challenge yourself / develop skills	☐	☐	☐	☐	☐
Enjoy solitude / "get away from it all"	☐	☐	☐	☐	☐
View and appreciate wildlife	☐	☐	☐	☐	☐
Share time with friends / family	☐	☐	☐	☐	☐

How do you think recreationists and recreational activity affect wildlife? 1 Positively, 2, 3 No effect, 4, 5 Negatively

Please order the following recreational activities (from 1-5) by how much you think they impact wildlife. 1 is least impactful and 5 is most impactful to wildlife.

Hiking/Walking ____
Mountain Biking ____
Off-Highway Vehicle Riding ____
Birding/Wildlife Viewing ____
Running ____

How important is it for the Owyhee Murphy sub-region area to provide the following?

	Not important	Not very important	Neutral	Somewhat important	Very important
Place for recreational activities	☐	☐	☐	☐	☐
Opportunities to know and contact nature	☐	☐	☐	☐	☐
Cultural significance / sense of place and identity	☐	☐	☐	☐	☐
Educational opportunity and significance	☐	☐	☐	☐	☐
Aesthetic/ scenic enhancement of surrounding area	☐	☐	☐	☐	☐
Wildlife habitat	☐	☐	☐	☐	☐
Species conservation	☐	☐	☐	☐	☐

Finally, please answer some questions about you…

What type of landscape did you grow up in? Please circle your answer(s).

Desert — Grasslands
Mountains — Agricultural farm or range land
Shrublands — City/Urban
Forest (please specify what type):___________ — Other: ___________

How many years have you lived in Idaho? ___________

Age:_________

Please circle which gender you identify as: Female Male

Thank you for your time and have a great day!

Figure A.1. Written survey given to OHV motorists, mountain bikers, and hikers.

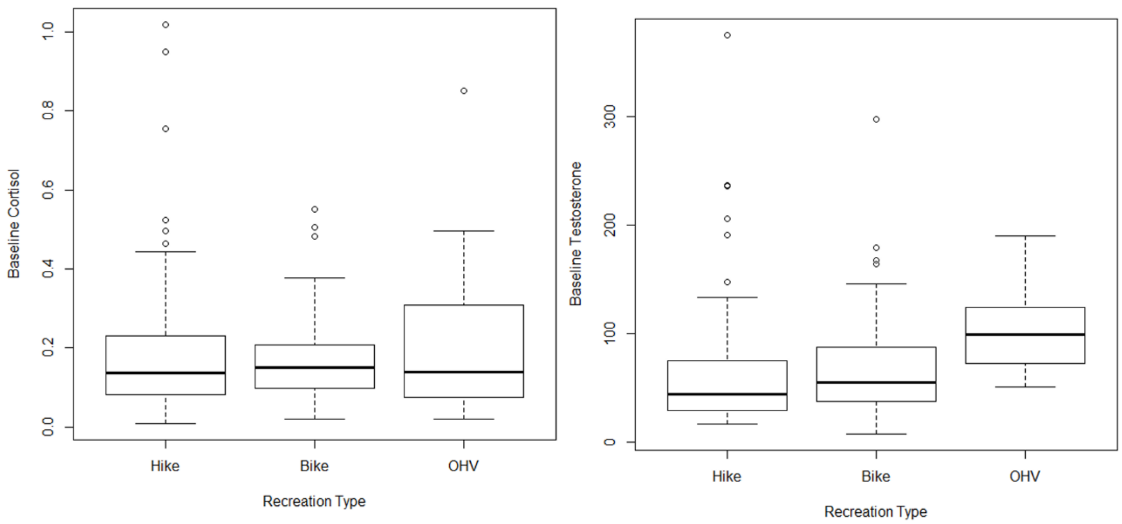


Figure A.2. Baseline cortisol and baseline testosterone by recreational activity type. Baseline cortisol was consistent across all three recreation types. Baseline testosterone was higher in OHV motorists.

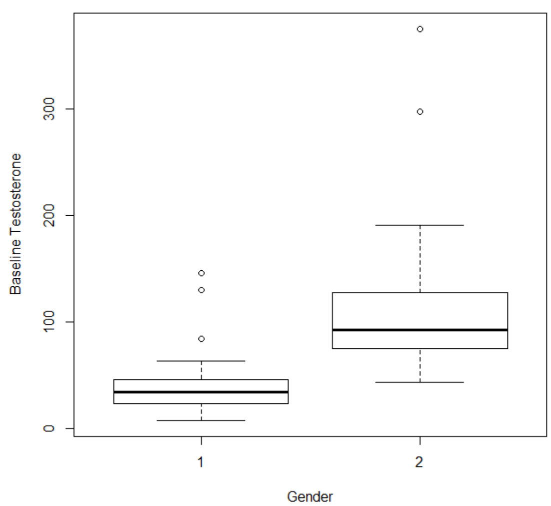


Figure A.3. Baseline testosterone by gender.

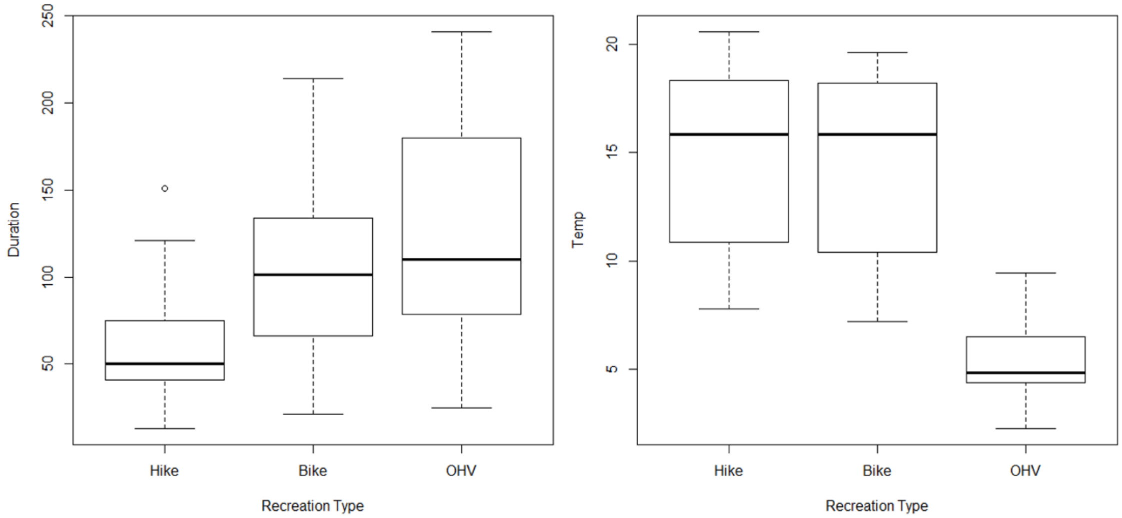


Figure A.4. Duration and average temperature by recreational activity type. Both of these variables were not included in models due to the high variation and correlation among recreation types.

Table A1. Total counts of top negative experiences perceived by all recreation types, hikers, mountain bikers, and OHV motorists. Bolded numbers refer to the top negative experience categories among recreation types.

Types of negative experiences	**All Recreation Types (n=213)**	**Hikers (n=88)**	**Bikers (n=81)**	**OHV (n=44)**
No negative experience	**48**	**16**	**16**	**16**
Falling, wrecking, tripping	6	1	1	4
Bad weather	11	1	7	3
Bad trail conditions/closed trails	10	4	2	4
Popped tires	4	0	1	3
Negative social encounters	11	5	6	0
Crowded trails	13	4	**8**	1
Sharing trails	**16**	**12**	4	0
Dogs	13	**10**	3	0
Physical discomfort	9	5	2	2
Trash	8	6	2	0
Wildlife interactions	3	3	0	0
Other	**18**	3	**11**	4

APPENDIX B

Supplemental Statistical Figures from Chapter Two

BOISE STATE UNIVERSITY

Please answer the following questions on recreational activity.

	Hiking/Walking	Mountain Biking	Off-Highway Vehicle (OHV) Riding
Please select the recreational activity you did today.	☐	☐	☐
In the last 30 days, how many times have you done each of the three recreational activities listed here?			

Thinking about your recreational experience today…

How many people (other than yourself) did you recreate with today? __________

Which trails did you use today? (A trail map of the area is available upon request if needed – just ask!)

Please list any wildlife you saw while out recreating below.

How many animal species (including birds, mammals, and reptiles) did you recognize while out recreating? __________

How many plant species did you recognize while out recreating? __________

How comfortable do you feel at identifying wildlife? 1 2 3 4 5 6 (Not comfortable – Very comfortable)

How comfortable do you feel at identifying plants? 1 2 3 4 5 6 (Not comfortable – Very comfortable)

How well do you know this recreational area and its trail system? 1 2 3 4 5 6 (Not well – Very well)

How beautiful did you find the landscape in which you recreated in today? 1 2 3 4 5 6 (Not beautiful – Very beautiful)

How peaceful did you find the landscape in which you recreated in today? 1 2 3 4 5 6 (Not peaceful – Very peaceful)

How scenic did you find the landscape in which you recreated in today? 1 2 3 4 5 6 (Not scenic – Very scenic)

How natural/wild did you find the landscape in which you recreated in today? 1 2 3 4 5 6 (Not natural/wild – Very natural/wild)

What was your most positive experience during your recreational activity?

What was your most negative experience during your recreational activity?

How do you feel after your recreational experience today? 1 2 3 4 5 (Not stressed – No change – Very stressed)

A B

A B

A B

A B

How important were the following things for you to experience during today''s activity?

	Not important	Not very important	Neutral	Somewhat important	Very important
Meet new people who enjoy similar things	☐	☐	☐	☐	☐
Enjoy the natural environment	☐	☐	☐	☐	☐
Challenge yourself / develop skills	☐	☐	☐	☐	☐
Enjoy solitude / "get away from it all"	☐	☐	☐	☐	☐
View and appreciate wildlife	☐	☐	☐	☐	☐
Share time with friends / family	☐	☐	☐	☐	☐

How do you think recreationists and recreational activity affect wildlife? 1 2 3 4 5 (Positively – No effect – Negatively)

Please order the following recreational activities (from 1-5) by how much you think they impact wildlife. 1 is least impactful and 5 is most impactful to wildlife.

Hiking/Walking ____
Mountain Biking ____
Off-Highway Vehicle Riding ____
Birding ____
Running ____

How important is it for the Ridge to Rivers area to provide the following?

	Not important	Not very important	Neutral	Somewhat important	Very important
Place for recreational activities	☐	☐	☐	☐	☐
Opportunities to know and contact nature	☐	☐	☐	☐	☐
Cultural significance / sense of place and identity	☐	☐	☐	☐	☐
Educational opportunity and significance	☐	☐	☐	☐	☐
Aesthetic/ scenic enhancement of surrounding area	☐	☐	☐	☐	☐
Wildlife habitat	☐	☐	☐	☐	☐
Species conservation	☐	☐	☐	☐	☐

For each pair of photographs, please circle which landscape you would prefer to see while out recreating.

A B

For the following characteristics, please write the letter of the picture you think is the best match.

Most scenic ______ Most inspiring ______
Most peaceful ______ Most wilderness ______
Most beautiful ______ Most calming ______
Most comfortable ______ Most natural ______

A B C

D E F

Finally, please answer some questions about you…

What type of landscape did you grow up in? Please circle your answer(s).
Desert — Grasslands
Mountains — Agricultural farm or range land
Shrublands — City/Urban
Forest (please specify what type):__________ — Other: __________

How many years have you lived in Boise? __________

Age:__________

Please circle which gender you identify as: Female Male

Thank you for your time and have a great day!

Figure B.1. Written survey given to hikers

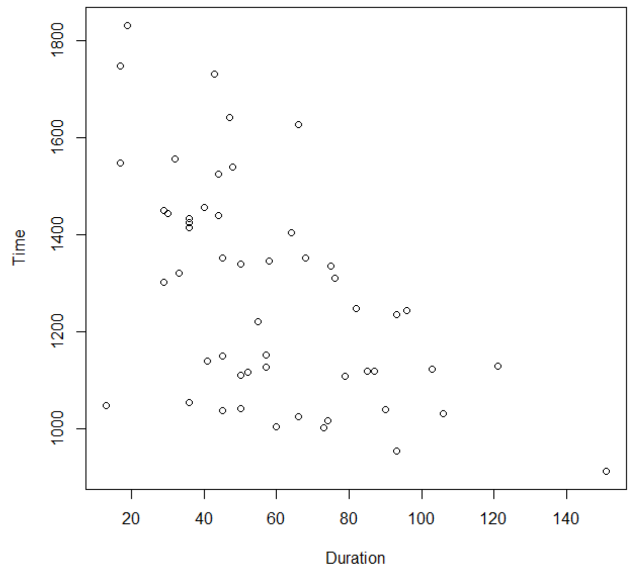


Figure B.2. Temperature and duration are correlated with one another and were excluded from the same model.

Table B1. Total counts of top negative experiences perceived by hikers while recreating. Bolded numbers refer to the top three negative experiences.

Types of negative experiences	**Hikers (n=88)**
No negative experience	**16**
Falling, wrecking, tripping	1
Bad weather	1
Bad trail conditions/closed trails	4
Negative social encounters	5
Crowded trails	4
Sharing trails	**12**
Dogs	**10**
Physical discomfort	5
Trash	6
Wildlife interactions	3
Other	3