INFLUENCES ON OFF-HIGHWAY VEHICLE (OHV) RECREATION USE PATTERNS WITHIN A COMPLEX TRAIL SYSTEM IN SOUTHWEST IDAHO

by

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DEDICATION

To my beautiful wife Emily. I love having adventures with you.

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ABSTRACT

Off-highway vehicle (OHV) recreation on public lands provides participants with the opportunity to experience positive connections with nature; however, like all outdoor recreation activity, OHV use can have impacts on the environment. In order to maintain the health of the landscape and wildlife while also providing recreational opportunities, managers must make decisions based on sound biological and social science data. We hope this research provides knowledge that may aid in the implementation of sound management strategies that are successful in fulfilling these goals.

In the first chapter, in order to gain knowledge on OHV recreationists and their distributions across a landscape, we used a combination of a pre-trip written survey and visitor-employed GPS survey to determine characteristics that influence their travel within a complex trail system on federally managed land in southwest Idaho. The pre-trip written survey supplied us with characteristics of the recreationists that were put into one of four categories, group constraints, site experience, site knowledge, or motivations. The GPS survey provided spatial and temporal data in order to describe the participant's distributions. Using principal components analysis, we found that distributions can be summarized by two distinct dimensions. The most informative dimension was a measure of overall extensiveness of the trip while the second dimension can be described as the dichotomy between "purpose driven" and "aimless" travel. Using a theoretical information approach, overall extensiveness was influenced by group constraints, site knowledge, and motivations while the second dimension ("purpose driven" or "aimless"

travel) was influenced by group constraints and site experience. We found that all four variable categories influenced at least one of the distribution dimensions, supporting our conceptual model. These findings can aid land managers in meeting management objectives by giving them the necessary information to identify uneven use patterns, better direct educational and informational programs, and to allow indirect management strategies to be affectively used.

In the second chapter, we concentrated on how the landscape may influence OHV use patterns and behavior, specifically stopping behavior. All outdoor recreation has an impact on the environment and on wildlife; however, heterogeneous or transitional behaviors such as stopping often increases disturbance to wildlife. It has been observed that OHV recreationists, when riding in golden eagle habitat in southwest Idaho, disturb eagles more often when they stop their vehicle(s) as opposed to continuing to ride until they are outside of the sensitive area. Using a visitor-employed GPS survey and a presence-only modeling method, our objective was to identify where OHV recreationists stopped and to describe what natural and infrastructure landscape characteristics are more suitable for this transitional human behavior to occur. We then wanted to determine if there was a significant difference in stopping suitability between areas of varying habitat utilization by the local golden eagle population. We successfully identified stopping locations and developed two distinct models. One model described the suitability for all stopping events five seconds or greater while the second model described the suitability where an accumulation of five minutes of stopping occurs. We determined what landscape characteristics contributed to stopping suitability across the study site for both models. In the "All" model, we found that the stopping suitability index was greater in

unoccupied territories when compared to occupied territories. In the “Five Minute” model, we determined that stopping suitability was lower in non-territory areas than in both unoccupied and occupied golden eagle territories. When examining used and available habitats based on perch locations away from nest sites, we found no significant difference. This research exhibits how transitional human behaviors can be identified and modeled across a landscape as well as how the results can be used to aid in land management strategies in order to accomplish management objectives.

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Abstract

Off-highway vehicle (OHV) recreation on public lands provides participants with the opportunity to experience positive connections with nature; however, like all outdoor recreation activity, OHV use can have impacts on the environment. In order to maintain the health of the landscape and wildlife while also providing recreational opportunities, managers must make decisions based on sound biological and social science data. To gain knowledge on OHV recreationists and their distributions across a landscape, we used a combination of a pre-trip written survey and visitor-employed GPS survey to determine characteristics that influence their travel within a complex trail system on federally managed land in southwest Idaho. The pre-trip written survey supplied us with characteristics of the recreationists that were put into one of four categories, group constraints, site experience, site knowledge, or motivations. The GPS survey provided spatial and temporal data in order to describe the participant's distributions. Using principal components analysis, we found that distributions can be summarized by two distinct dimensions. The most informative dimension was a measure of overall extensiveness of the trip while the second dimension can be described as the dichotomy between "purpose driven" and "aimless" travel. Using a theoretical information approach, overall extensiveness was influenced by group constraints, site knowledge, and

motivations while the second dimension (“purpose driven” or “aimless” travel) was influenced by group constraints and site experience. We found that all four variable categories influenced at least one of the distribution dimensions, supporting our conceptual model. These findings can aid land managers in meeting management objectives by giving them the necessary information to identify uneven use patterns, better direct educational and informational programs, and to allow indirect management strategies to be affectively used.

Background

Off-highway vehicle (OHV) use is a highly valued recreational activity on public lands across the United States (Hallo et al. 2009), providing participants with a way to experience positive connections with nature, themselves, and others (Lord et al. 2004, Mann and Leahy 2009). Due to national population increases, it has been predicted that total OHV use could further increase by as much as 58%, from 48 million participants in 2008 to 76 million by 2060 (Bowker et al. 2012). In the early 2000s, OHV use in the U.S saw an increase in total participation days of 56% (Cordell 2008). Also, technological advances in OHVs allow a greater number of individuals to participate as well as allowing these vehicles to consume greater areas of a landscape (Adams and McCool 2009). With increases in the amount of recreational use across landscapes, the probability of ecological impacts and human-wildlife conflicts occurring also increase (Duffus and Dearden 1990, Leung et al. 2000, Monz et al. 2010), placing greater pressures on land managers to not only continue to provide OHV recreationists with opportunities for positive experiences, but also to ensure protection of natural resources.

OHV use, like other outdoor recreational activities, has been shown to produce negative ecological impacts, including damage to native vegetation and disturbance of wildlife (for extensive reviews on ecological impacts, see Ouren et al. 2007 and Boyle and Sampson 1985). However, OHV use also provides positive experiences for participants (Hallo et al. 2009, Mann and Leahy 2009, Manning 2010) and has become an accepted outdoor recreational activity within many public lands under the management of various state and federal agencies. Therefore, balancing ecological impacts and OHV recreation opportunities has placed a dual mandate on managers of public lands (Exec. Order 11644 1972).

For land managers to balance use and protection, monitoring and knowledge is needed not only on the natural environment and its processes, but also on how people are using the landscape. Spatial and temporal distributions of outdoor recreationists are varied and can directly influence ecological impacts (Hadwen et al. 2007, Hallo et al. 2012). Ecological impacts, in turn, can then affect the recreationist's experience due to degradation of the natural landscape as well as the trail/infrastructure systems. One method of obtaining use distributions is a visitor-employed GPS survey. Visitor-employed GPS surveys have been used previously to identify distributions of recreationists (Lyon and Burcham 1988, Arrowsmith and Chhetri 2003, Stedman et al. 2004, Hallo et al. 2012). In 2014, however, Beeco and Hallo (2014) stated that little research has been done on the factors that may cause differences in these use patterns. In this research, we examined recreationist characteristics and factors that contribute to the variation in motorized recreationist travel patterns by using a visitor-employed GPS survey.

Introduction

OHV Management

In 1972, Executive Order (E.O.) No. 11644 was issued that required all federal agencies to designate areas and trails under their jurisdiction as open or restricted to OHV use. The purpose of this Order was to “establish policies and provide for procedures that will ensure that the use of off-road vehicles on public lands will be controlled and directed so as to protect the resources of those lands, to promote the safety of all users of those lands, and to minimize conflicts among the various uses of those lands.” Since 1972, agencies and the distinct areas they manage have been developing regulations to comply with E.O. No. 11644 and its amendment E.O. No. 11989[1] (U.S. Department of the Interior Bureau of Land Management 2001, USDA Forest Service 2005, USDOI National Park Service 2006) without a guiding universal procedure in place. In 1979, seven years after E.O. 11644, federal land management agencies continued to struggle with compliance, resulting in OHV impacts on federal lands being described as “out of control” (Sheridan 1979). In 2004, Chief of the U.S. Forest Service Dale Bosworth listed unmanaged outdoor recreation as one of the four biggest threats to national forests and grasslands, specifically citing the creation of “hundreds of miles of unauthorized roads and trails due to cross-country [OHV] use”. These federal agencies and their individual units continue to try and comply with E.O. No. 11644, E.O. No. 11989, and additional federal regulations though they are often vague (Adams and McCool 2009). The lack of

[1] E.O. 11989 added the provision that dictates the immediate closing of areas to OHV use whenever it is determined that continuing use will cause “considerable adverse effects on the soil, vegetation, wildlife, wildlife habitat or cultural or historic resources of particular areas or trails of the public lands…”. This order also authorizes agencies to close all areas of public lands that are not specifically designated as open to OHV use.

specific OHV management guidelines as well as the lack of scientific research on OHV planning has made sucessful compliance to these federal policies a challenge, placing a great onus on land managers to create local OHV travel management plans (TMP) within the broad context of agency policies, legal precedencies, local conditions, and more often than not, political contention (Issa 2003).

The challenge of managing public lands for OHV use is often compounded with the absence of data on the OHV recreationists and their current use patterns within the area. An integrated approach including social science research is vital in understanding ecological landscapes as a whole (Roggenbuck and Lucas 1987, Hadwen et al. 2007). This leads to better satisfying the wants of the recreationists and providing adequate ecosystem services, while also gaining a better understanding of factors that lead to ecological impacts. Many times, however, management decisions are based solely on data from the environmental and biological realms, limiting the knowledge of how human and ecological systems interact and the feedback mechanisms that are involved (Grimm et al. 2000). To make sound decisions, it has been suggested that social science data such as research on recreationists' characteristics and use patterns must also be available and considered to inform accurate environmental decision-making and problem solving (Watson 1990, Kessler et al. 1992, Wing and Shelby 1999, Albritton and Stein 2011, D'Antonio et al. 2013).

As land managers try to maintain this balance between use and protection, they must develop and implement management strategies. Management strategies can be categorized as indirect or direct. Indirect management actions emphasize influencing or modifying behavior while direct actions focus on the regulation of recreation behaviors

(Manning 2010). Indirect management is generally favored by the public (Lucas 1983, Kuehn et al. 2011) and tends to cost less to implement, which increases its appeal to land managers and agencies as well (Manning 2010). Without information on current human use, the influence of use patterns and behaviors with indirect management strategies is difficult and inefficient (Roggenbuck and Lucas 1987). To implement effective indirect strategies, an understanding of the recreational spatial and temporal patterns that currently exist as well as information on what factors contribute to variation in these distributions are helpful if not necessary (Hendee et al. 1978). This information may allow managers to better provide recreational opportunities more focused to each recreationist group's desires or needs while simultaneously influencing distributions to minimize human-wildlife interactions (Lucas 1981).

Recreationist Characteristics and Behavior

It is important for managers to understand that recreationists can vary greatly, even within activity groups, and the preferences of one group should not dictate management practices (Manning 2010). Recreationists, even within activity type, vary in their past experience (Bryan 1977), knowledge of the setting in which they are recreating (Hammitt et al. 2006), desired benefits from participating (Manfredo et al. 1996), and the groups in which they choose to recreate (Dottavio et al. 1980). These differences have also been shown to affect how they utilize the landscape spatially and temporally. For example, canoe route choices in a Canadian wilderness area were shown to be influenced by past experience and knowledge of the setting, with more experienced or knowledgeable canoeists choosing routes that were more remote and with the least amount of management intervention (McFarlane et al. 1998). Also, the desired benefits or motivations of OHV recreationists have been shown to vary, leading to possible behavioral choices and setting preferences (Smith and Burr 2011). Additionally, some characteristics of the recreating group have been shown to influence spatial distributions across a landscape. Distributions of non-motorized recreationists in a forest setting in South Carolina were affected by the number of individuals within the group (Beeco 2013). Hikers in Australia were shown to travel more extensively if their planned trip duration was longer (Arrowsmith and Chhetri 2003). Social dynamics of groups has also been theorized to have greater influence on site choice than past experience or setting preferences (Kuentzel and Heberlein 1992). Skill level has been shown to affect site preferences of mountain bikers in North Carolina, with higher skilled riders preferring greater technical and challenging trails more than lower skilled riders (Hopkin and Moore 1995). This suggests that trails available or desired by lower skilled riders may be limited, causing groups with a lower skilled individual to exhibit a different use pattern than a group of all highly skilled individuals.

Utilizing this past research and theory on recreationists and behavior, we developed a conceptual model (Figure 1.1) similar to a model put forth by Shoval and Isaacson (2007). While their model conceptualized the distributions of tourists in a more structured and urban environment, it has been modified previously to examine outdoor recreation distributions of hikers, runners, mountain bikers, and horseback riders within a moderately complex trail system (Beeco and Hallo 2014). With the paucity of research investigating personal factors of outdoor recreationist distributions, we were not surprised to find no previous research that specifically explored factors of OHV recreation distributions.

Tracking Human Distributions and Visitor-employed GPS Surveys

Capturing accurate and complete data on recreationist distributions can be a challenge, especially within a complex trail system (Yang et al. 2014). A complex system has been used to describe landscapes with multiple trails, routes, and attractions (Hallo et al. 2012). Within complex trail systems, there are many possible use patterns that can result from an individual's decisions and behavior making many data collection methods insufficient. Written survey methods have shown a lack of accuracy due to incomplete recollection as well as poor spatial awareness (Hallo et al. 2005, Isaacson and Shoval 2006). Counting equipment, including motion sensor cameras, may provide accurate counts of use at a set point or location, but is limited in their ability to collect data on movement patterns over an extensive trail system or area (Arrowsmith and Chhetri 2003, Cessford and Muhar 2003, Yang et al. 2014).

An additional method to collect spatial distributions is by providing global positioning system (GPS) receivers to recreationists, often referred to as a visitor-employed GPS survey. This method does not rely on people's recollection or lack of spatial awareness, and provides a complete picture of an individual's movements throughout their entire experience, rather than at set points along a trail as in motion sensor cameras. Spatial and temporal data collected by visitor-employed GPS surveys can be combined with written survey data on participant characteristics to determine if certain variables (i.e. group constraints, experience, knowledge, and motivations) affect the travel patterns of the recreating individual or group.

Since the mid-1990s, visitor-employed GPS surveys have been used to collect spatial and temporal distributions of humans. One of the earliest studies tracked the movements of elk hunters in Montana (Lyon and Burcham 1988). Subsequent research using visitor-employed GPS surveys have tracked the movements of hikers (D'Antonio et al. 2010), boaters (Beeco et al., in press), mountain bikers, and horseback riders (Beeco and Hallo 2014). The methodology also has been used in urban settings to analyze transportation patterns (Quiroga and Bullock 1998, Murakami and Wagner 1999) as well as tourists' movements in urban settings or at public events (Isaacson and Shoval 2006, Nielsen and Stilling Blichfeldt 2009, Pettersson and Zillinger 2011). Utilizing GPS receivers to track human movement patterns and distributions continues to grow in popularity and functionality due to the availability of more precise and less expensive GPS receivers (Hallo et al. 2012). Although the use of visitor-employed GPS surveys continues to be a popular method of examining spatial and temporal distributions of recreationists, there is minimal literature available that discusses utilizing these methods to map and analyze OHV distributions (Dr. Jeffrey Hallo, personal communication, January 23, 2015). In addition, the majority of visitor-employed GPS surveys utilize constrained, limited systems due to the difficulty in retrieval of GPS receivers (Hallo et al. 2012). This research will demonstrate collection methods of OHV distributions and offer insight into best methods for using visitor-employed GPS surveys within complex trail systems.

Objectives

The first objective of this research is to characterize OHV recreationist movement in the study area and to describe distance, depth, dispersion, and duration of trips. The second objective is to determine if the constraints, experience, knowledge, and motivations of group members affect the pattern of the group's recreation. In addition to these objectives, we will also use the project to evaluate visitor-employed GPS survey employed in the context of OHV recreationists within a complex trail system. Our goal is to provide accurate social science data on OHV recreation that can be integrated with existing ecological and biological data for the purpose of more comprehensive management decisions pertaining to OHV recreation.

Methods

Study Area

We collected data from OHV recreationists in the Murphy Subregion of the Owyhee Front Management Area (OFMA), located in southwest Idaho (USA) (Figure 1.2). Managed by the Bureau of Land Management (BLM), the Subregion is an estimated 94,290 hectares (ha) primarily composed of sagebrush-steppe habitat. A complex network of trails totaling approximately 1350 km is available for OHV use. Different trail designations exist, permitting certain vehicle types on certain trail sections. Eight official trailheads with parking areas are available to recreationists for staging and accessing the trail network. A multitude of pull-offs and unofficial parking areas are also used by recreationists to access trails (personal observation). A “play area” is adjacent to two of the trailheads where riders are not restricted to designated routes and can participate in hill climbing, providing for a more unstructured recreation opportunity if desired. The trail system is marked by an alphanumeric system, with signs present at most major intersections. An effort is also made by the BLM to maintain signs designating trails as closed, either permanently or seasonally. Most permanently closed trails were accessible prior to the adoption of the Murphy Subregion Travel Management Plan in 2009. In addition, approximately 65 miles of trails are closed seasonally to protect areas deemed as sensitive habitat. Compliance with trail restrictions and closures is not heavily enforced and is primarily left to the discretion of the recreationists. In addition to OHV recreation, the area provides opportunities for other activities including non-motorized recreation, camping, and recreational shooting.

Data Collection

Data collection occurred from March 13 to May 25, 2015. The majority of sample days were on weekends (Fri – Sun) from late morning to early evening, which coincided with peak use. Participant recruitment by researchers occurred at six of the eight official trailheads. The other two trailheads were not included due to lack of regular use (personal observation). Typically, we sampled one trailhead each field day; if multiple researchers were available, multiple trailheads were simultaneously sampled. Efforts were made to approach 100% of observed OHV users; however, some limitations were experienced due to the concurrent arrival of multiple users at the trailhead.

Recreating groups who chose to participate were given a paper survey (Appendix 1). Only one individual from each recreating group was requested to physically complete the survey, but group participation and conversation were encouraged to formulate answers. The survey requested information pertaining to the individuals of each group as well as the group as a whole. We attempted to recruit the individual with the most experience and knowledge of the study site from each group to fill out the survey.

Each group which completed the written survey was given the option of participating in the collection of spatial and temporal data. Researchers offered an incentive to participate. The incentive was in the form of a file of their trip and data sent to them by email in which they could see their track using GoogleEarth or GoogleMaps.

If willing, a GPS receiver (Globalsat dg-100) was attached to the individual's vehicle. The Globalsat dg-100 receiver model was previously field tested and found to be an effective unit for tracking recreational use distributions, with a mean precision of 6.7 meters (Hallo et al. 2012). The receiver was turned on several minutes prior to the group leaving the trailhead area to ensure the acquisition of satellite signals. Receivers recorded position, time, date, speed, and altitude on a five-second interval. After the participant returned to the trailhead, the receiver was collected in person by the researcher.

All data collection methods were approved by the Boise State University Institutional Review Board under protocol #028-SB15-043.

Cleaning and Operationalization of Spatial and Temporal Data

Each set of points was cleaned and operationalized using ArcMap 10.2 (ESRI, Redlands, CA, USA). Boundary polygons for each of the six trailhead parking areas were defined to maintain consistency for the beginning and end of each trip. To prevent oversampling of locations before and after the trip, all points except for the final point recorded prior to exiting the trailhead area for the first time were deleted. Likewise, only the first point recorded upon entering the trailhead area for the final time was retained. Each point set was then visually inspected for any position anomalies based on the adjacent points, as well as recorded speeds and time. Any anomalies found were deleted.

For each filtered set of points, three spatial variables (distance, depth, and dispersion) and one temporal variable (duration) were calculated. Distance was defined as the total distance traveled by the participant. Because the receivers continued to record points even while participants were stationary, GPS error during stopping events could artificially inflate distance estimates. Therefore, any point with an associated speed < 0.7

km/h was removed. Points were then converted to a line using the points to line tool in ArcMap and total length of the line was then calculated. Depth was defined as the maximum Euclidean distance between the trailhead centroid of the participant's origin and the points within each participant point set. Maximum Euclidean distance was calculated using the point distance analysis tool in ArcMap. Dispersion was defined as the area of the minimum convex polygon (MCP) of all points for each track. MCPs were calculated using the minimum bounding geometry tool for a convex hull in ArcMap. Finally, duration was defined as the elapsed time from the first to the last retained point for each participant.

Group Characteristics

A pre-trip written survey was used to collect demographics and characteristics of each participant and all members in their recreational group. We also asked about travel constraints, experience, knowledge of the local trail system, and motivations for their trip.

Vehicle Type

Survey takers recorded the vehicle type for each participant in their group. The choices were limited to dirt bike, all-terrain vehicle (ATV), and utility-terrain vehicle (UTV). A visual check by the researcher was also made once the survey was returned. Trails are varied in use designation within the study site, with some trails open to all vehicle types while other trails only open to a specific vehicle type (i.e. single track for dirt bikes). To account for the differences in trail accessibility and this constraining effect, riding groups were reclassified as a binomial variable (0 = dirt bikes, 1 = at least one quad vehicle) and treated as a blocking fixed effect.

Group Constraints

Three distinct group constraints were considered for analysis; lowest skill level in group, group size, and estimated trip duration. The survey taker was asked to assess each group member's skill level pertaining to riding their vehicle. An integer number scale was used with "1" defined as "Beginner" and "5" defined as "Expert". Group size was defined as the number of vehicles in each group. Finally, survey takers were asked to answer the question, "How long do you expect to be out today riding?" Answers were converted to minutes.

Survey Taker Characteristics

Experience

The past experience of the survey taker was measured using both a length and frequency variable. Length of experience was measured by the number of years riding OHVs within the study site and frequency was measured by the number of days riding OHVs within the study site in the previous calendar year.

Knowledge

Knowledge was self-assessed by the survey taker's answer to the question, "How much knowledge do you have of the Owyhee Front area and trail system?" An integer number scale from 1 to 5 was used to record their answer, with an answer of "1" defined as "none" and "5" defined as "a lot". We attempted to recruit the most knowledgeable participant from each group to fill out the survey. A second binary variable was also recorded that asked the survey taker "Do you have a plan about where you are going?" to further assess knowledge of the trail system and area.

Motivations

Three broad motivations were examined that previously had been identified as being important to OHV recreationists (Mann and Leahy 2009). These motivations were a connection with self, a connection with others, and a connection with the natural environment. Two measures were used to assess the motivations of the survey taker (Table 1.1). Scores were indicated using a 5-point scale, with 1 = not important and 5 = very important. The measures were either taken directly from the Recreation Experience Preference scale (REP) (Manfredo et al. 1996), or were an amalgam of two similar measures from the REP scale.

Statistical Analyses

We used principal component analysis to represent the four distribution variables (distance, depth, dispersion, duration) as multiple orthogonal variables and identify unique dimensions of OHV trips. Analysis was done using a correlation matrix due to the different measurement scales of the spatial variables (distance, depth, dispersion) and time variable (duration). Components were retained for analysis based on eigenvalue, percent of variance explained, and examination of the scree plot to identify the dimensions that are most informative in describing OHV distributions.

We assigned predictor variables to one of four categories (group constraints, experience, knowledge, or motivations) which represented the factors of interest (Table 1.1). Within each category, we analyzed predictor variables for any significant correlations ($r \geq |0.7|$). We created linear mixed models (LMM) for each predictor variable category to determine the influence of constraints, knowledge, experience, and motivations on OHV recreationist distributions. Models were created using the R-package “lme4” (Bates et al. 2014). The trailhead sampled, or “location”, was considered a random effect variable and was included in all models. The binomial variable “vehicle type” was considered a blocking fixed effect to account for the difference in trail availability between vehicle types. This variable was also included in all models. We used a two-step model selection method to analyze the influence of each fixed effect variable category on the distribution components. Models with the lowest ΔAICc were considered as the most parsimonious models within each category. We then analyzed best models across categories to determine a final model with the best fit. Parameter estimates for each fixed effect in the final model were reported along with parametric bootstrapped 85% confidence intervals (Arnold 2010). Variables with confidence intervals not crossing zero were considered to have significant influence on model fit.

Results

A total of 153 OHV recreation groups were asked to participate with 102 (66.7%) fully participating in both the pre-trip written survey and the visitor-employed GPS survey. Due to malfunction of GPS receivers, seven tracks (6.9%) were returned with incomplete data and removed from analysis. The most common malfunction of receivers was turning off at some time during the participant’s trip. An additional three tracks were not retained for analysis due to predictor variable data missing from the written survey. Finally, one track was determined to be an outlier using a graphical display of the data and was removed from analysis. The resulting effective sample size after all data exclusions was 91 tracks and their corresponding written surveys. A total of 191,054 GPS data points were included in the 91 tracks and were used for analysis. During cleaning of the data, a total of eight points from three tracks needed to be deleted due to position anomalies. These deleted points did not compromise the accuracy of the distribution data for the three tracks.

Summary of OHV Recreationists

The individual and group data collected from the pre-trip written surveys were analyzed and descriptive statistics were calculated (Table 1.2). We collected information on a total of 265 people in 91 groups.

Groups had a mode of 2 people ($\bar{x}$ = 2.91, SD = 1.64) and 2 vehicles ($\bar{x}$ = 2.64, SD = 1.57). Of the 91 groups, 13 (14.3%) were individuals who recreated alone.

OHV recreationists in the sampled groups were overwhelmingly male (84.2%) with a mean age of 40, ranging from 3 to 82. Of the 41 groups who had more than one rider and complete age information, 22 groups had an age range of 25 years or greater (53.7%), indicating these groups were comprised of multiple generations.

A majority of participants rode dirt bikes (65.8%), while 22.9% utilized ATVs and 11.3% rode UTVs. Most groups were homogenous being comprised of only one vehicle type, with only 17 of the 91 groups (18.7%) having two or more different types of vehicle represented. For those individuals who reported their age and were not indicated as passengers, the mean age of dirt bike, UTV, and ATV operators were 37.06 ($n = 96$), 47.77 ($n = 22$), and 47.85 ($n = 39$) years, respectively. Six people indicated they would be riding more than one type of vehicle during their trip and were also excluded in these means. Using a Kruskal-Wallis test and Dunn's multiple comparison post-hoc test, the age of riders was found to significantly affect the vehicle type ridden ($H(2) = 15.82$, $p < 0.001$), with dirt bike riders being significantly younger than both UTV ($p = 0.013$) and ATV operators ($p = 0.002$).

An overwhelming majority (84 of 91) of survey takers identified their residence as being in the adjacent counties of Ada or Canyon County, Idaho. Of the remaining 7 individuals, four indicated their home zip code as out of state (3 in Oregon and 1 in Colorado).

The mean number of years riding at the study site for the survey respondent was 11.24 (SD = 10.74) while the mean number of days riding at the study site in the previous calendar year was 13.87 (SD = 21.55). Self-assessed site knowledge scores for the survey taker had a mean of 2.99 (SD = 1.27). A total of 48 groups (52.75%) indicated they had a plan about their trip route or destination.

The mean start time for trips was ~1230 hours. Estimated trip times had a mean of 236 minutes (SD = 99.0). Actual trip durations ranged from 20 to 359 minutes, with a mean of 163 minutes (SD = 76.2). On average, groups overestimated how long they would ride by 73 minutes (SD = 83.1). Five groups explained that they ended their trip early due to mechanical issues with one or more vehicles in the group. One group also stated that they ended their trip earlier than expected due to inclement weather. The difference in estimated and actual time was still found to be an overestimation of recreation time by 68 minutes (SD = 81.9) when these six groups were excluded.

All motivation factors examined were rated at least “important” to the survey takers (Table 1.2). The motivation with the lowest overall mean, “meet new people”, still registered as important (3.2 out of 5). The most important motivation recorded for the total sample was “enjoy the natural environment” (4.8 out of 5).

Distribution Variables and PCA

Descriptive statistics for the distribution of participant groups across the trail system are reported in Table 3. Distance, depth, dispersion, and duration were analyzed for correlation using Spearman's Rank Correlation. All correlation coefficients were greater than 0.4 (Table 4), making principal component analysis (PCA) appropriate. Sampling adequacy was found to be "meritorious" (Kaiser 1974) for the analysis using the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO = 0.8), and all KMO values for individual variables were greater than the suggested minimum acceptable limit of 0.5 (Kaiser 1974). PCA was used to reduce the distribution variables into orthogonal components (Table 5). The first component (PC1) explained 79% of the variance and had an eigenvalue of 3.16 while the second component explained 13% of the variance and had an eigenvalue of 0.54. Although the eigenvalue for PC2 was less than 1, it was retained for analysis due to the steepness of the scree plot and the amount of variance the component explained. The third and fourth components were disregarded, with each only explaining 4% of the variance and each having an eigenvalue of 0.15. Factor loadings on PC1 for all four distribution variables were negative and assumed to be relevant due to all values being greater than |0.4|. For PC2, depth had a relevant positive loading, duration had a relevant negative loading, and distance and dispersion were determined not to hold significant relevance due to having a loading less than |0.4|. To help in the interpretation of each component, example trips representing the extremes of each component are illustrated in Figure 1.3.

Model Selection

No variable correlated significantly with another, allowing us to consider all variables in the model building process. In the assessment of PC1, the top model for group constraints contained the variables estimated time, lowest skill, and number of vehicles. In assessing the effect of knowledge on PC1, having a plan was the only important variable. The null model was found to be the best model when considering experience variables. Finally, two motivation variables, meet new people and enjoy nature, were included in the model that best predicted PC1. Using an exploratory approach, the combination of all three model categories was determined to have the best model fit (Table 6). The constraint variables of estimated time (β = -0.0088, 85% CI = -0.0113, -0.0064) and lowest skill level (β = -0.3184, 85% CI = -0.5064, 0.1306) influenced PC1 negatively while number of vehicles (β = 0.2313, 85% CI = 0.0686, 0.3949) had a positive effect. The only knowledge variable, plan (β = -0.8408, 85% CI = -1.3048, -0.3764), had a negative effect. Finally, the motivation to enjoy nature (β = -0.2840, 85% CI = -0.7345, 0.1777) also had a negative effect while the motivation to meet new people (β = 0.4161, 85% CI = 0.1977, 0.5941) influenced PC1 positively.

For PC2, estimated time and number of vehicles per group were included in the best model for constraints. The best model for assessing the effects of knowledge on the component contained only the site knowledge variable. Both experience in years and experience in days were present in the best model for the experience category of variables. The null model was determined to be the best performing model for motivation variables. When top models were combined, only constraints and experience contributed to the best final model for PC2 (Table 7). The constraint variables estimated time (β = -

0.0020, 85% CI = -0.0030, -0.0011) and number of vehicles (β = -0.1693, 85% CI = -0.2406, -0.1142) each had a negative effect on PC2. The experience variable experience in days (β = -0.0020, 85% CI = -0.0065, 0.0028) also had a negative influence while the variable experience in years (β = 0.0175, 85% CI = 0.0095, 0.0266) positively influenced PC2.

Discussion

Our research shows that OHV recreationists can vary in their social groups, site experience, site knowledge, and motivations for participating in their trip. We also validated our conceptual model that these factors can influence different dimensions of OHV distributions across a complex trail system. While previous studies have found similar results with other recreation activities, we believe our work to be one of the first to explore these influences on distributions for OHV recreation. A pre-trip written survey paired with a visitor-employed GPS survey was used successfully to collect data on both rider characteristics and their movements across the landscape.

OHV Recreationists and Their Distributions

Distributions of OHV recreationists were sufficiently described by two uncorrelated dimensions. The first dimension, as described by PC1, accounted for the majority of variance (79%) in trip distributions with all four distribution variables having a strong affect. This dimension can be interpreted as overall extensiveness of the trip, with low values representing trips that were long in both distance and duration, extended far from the trailhead, and dispersed more across the landscape. Group constraints, knowledge, and motivations best predicted this type of trip.

An increase in estimated time or lowest skill level in the group positively influences the extensiveness of the participant's trip, resulting in longer trips in duration and distance, traveling further from the trailhead, and dispersing more across the landscape. As the perceived length of time available for recreating increases, it can be assumed that the group's spatial and actual temporal distributions will also increase. In regards to skill level, a novice rider may influence the entire group's riding style, "holding them back" and inhibiting their ability to have extensive trips. It may be necessary for beginners to travel at slower speeds, take more frequent rests, or to remain close to the trailhead for the purpose of feeling safe. These results are similar to those found in hikers in Australia (Arrowsmith and Chhetri 2003). Hikers that planned to spend more time recreating with an overnight stay showed an increase in trip distributions. Also, if we consider the presence of children in a group as a surrogate for lowest skill level, these groups were found to travel less extensively. In our analysis of group size as a constraint, we discovered that as the number of off-highway vehicles in a group increases, their trip extent decreases. An increase in the number of vehicles and/or participants would assumingly also increase the chance of a mechanical issue or physical injury occurring, forcing the group to return from their trip prematurely, and thus limiting their spatial and temporal distributions. Our results for these three variables show support for our conceptual model in considering these factors as constraints on the distribution of the recreating group.

Having a plan about their route or destination prior to departing the trailhead has a significant positive affect on group distribution, resulting in longer and more extensive trips. The want and/or need for having a plan may possibly increase for many groups as a trip becomes longer in duration and more extensive due to greater logistics and uncertainties. Conversely, the absence of a plan and its negative effects on extensiveness may be exacerbated within a complex trail system such as our study site. The existence of hundreds of different trail segments and intersections may influence where participants of an unplanned trip feel comfortable riding, confining this area around the trailhead or easily accessed areas. The existence of a pre-trip plan is not a proxy for site experience, as a first time visitor who researched the trail system and site on the internet or who had access to interpretive maps has the ability to formulate a trip plan. Because of this fact, as well as no experience factor was found to have influence on this extensiveness dimension, land managers may be able to influence route choice, even with experienced OHV recreationists, by providing more informational and interpretive materials online or on site. Distributing information to hikers highlighting underused trail routes in Yellowstone National Park was found to significantly increase their use (Krumpe and Brown 1982). Specific to our study site, the distribution of extensive, underused trails could be used as an indirect management strategy to influence route choice of both experienced and first time visitors, resulting in more evenly distributed use or the decrease of trail use densities in sensitive habitats.

Two motivation factors, the importance of experiencing the natural environment and the importance of meeting new people, were also significant predictors of trip dimensions. Groups who had a strong desire to experience the natural environment had more extensive distributions while groups who had a greater desire to meet new people had more condensed distributions. This suggests that these two motivations affect the distribution of OHV recreationists in opposing ways. Those with a desire to enjoy the natural environment traveled more extensively, reaching areas of the trail system that are less frequented by other recreationists. These areas, because of less use, may exhibit less aesthetic impacts and may be more sought after by those that prefer experiencing a connection with nature over experiencing a connection with other individuals. Support for this idea is provided by a previous study of wilderness hikers that identified "naturalness" as the highest contributor to overall trip satisfaction. It was shown that human impacts including the widening and extension of trails, litter, and erosion all negatively impacted their trip (Lynn and Brown 2003). On the other hand, those groups which had a strong desire to meet new people traveled less extensively and remained in areas closer to the trailhead where use densities are greatest, increasing the chance in meeting others with similar interests. This idea is supported by a study of recreationists in Arkansas, which found that individuals seeking a connection with others, or wanting "to be a part of the group", were less sensitive to higher use levels (Ditton et al. 1983).

The second dimension of OHV distribution, as described by PC2, was characterized by a negative relationship between depth and duration. One way to interpret this dimension is to characterize those trips with high depth and low duration as "purpose driven" and trips with low depth and high duration as "aimless". Those exhibiting a "purpose driven" trip dimension may have one destination in which they want to visit, or may be traveling far and fast to achieve one goal. OHV users exhibiting an "aimless" dimension may be viewed as having no set destination or goal, and simply is recreating for the sake of the activity. Two constraint variables and two experience variables influence these trip patterns. An increase in the estimated time or the number of vehicles in the group increases the trip duration and decreases trip depth, making these trips more “aimless”. This result is somewhat intuitive for the effects of estimated time since duration is the most influential variable in this component. A greater number of vehicles in the group, similar to the first dimension, can be assumed to increased chance of vehicle troubles or malfunction which could increase stopping events, thereby increasing duration and decreasing how far into the system the group can travel. Also, personal needs (i.e. physical rests, different points of interest) may increase stopping events in groups with a greater number of vehicles and individuals. Regarding site experience, survey takers who had a greater number of years riding at the site ended up traveling farther into the system in a less amount of time than riders with limited or no years of experience. A possible interpretation for this result could be that riders with greater experience know the trail system and landscape better, can travel at faster speeds, and stop less frequently at trail junctions in order to become oriented or choose a travel route, consequently exhibiting characteristics of a more “purpose driven” trip. However, survey takers who indicated a greater number of days riding at the site in the previous year exhibited a more “aimless” trip pattern. As frequency of participation increased, the trip became longer in duration and condensed around the trailhead of origin. A possible explanation for this influence is the presence of a “play area” concentrated near two of the most popular trailheads surveyed. These “play areas” provide a place for unstructured, more aimless riding experiences as opposed to traveling a set trail or visiting a destination. Groups or individuals with a higher frequency in participation at the site may concentrate their use at these play areas, preferring a trip they can customize more than set routes or trails that they have already experienced.

All variable categories of interest had an influence on OHV distributions to some degree, adding validity to our conceptual model (Figure 1.1). Group constraints seem to have the greatest influence on motorized spatial and temporal distributions since they influence both trip dimensions. By using the recreation group as our sample as opposed to the individual, we were able to analyze these group dynamics and their effects on OHV distributions. While knowledge and motivations of the group member(s) influenced the overall extensiveness of the trip, experience influenced the negative relationship between a trip's depth and duration. We found that different sets of factors best describe the two uncorrelated trip types, indicating that OHV recreationists are not homogenous, that sub-groups within OHV participants may exist, and that these differences can affect how OHV users consume the landscape.

An understanding of how each of these factors influence OHV distributions allows land managers to better provide desired recreational opportunities for subsets of OHV users. This could be accomplished by a number of methods, including selective dissemination of information to certain rider types or highlighting trails or areas that are being underused but highly suitable for a subset of riders. As an example, since the number of vehicles per group can affect the overall extensiveness of a trip, information tailored toward group size could be disseminated at trailheads, highlighting longer routes for individuals or small groups and shorter routes for larger groups. Another example may be to highlight underused routes that go deep into the trail system for individuals wanting to experience the natural environment while adding facilities closer to trailheads that might encourage those individuals who have a desire to socialize with and meet other like-minded individuals. Routes and facilities can not only be tailored for the recreating group, but also for the health of sensitive species and habitats. This research, when integrated with biological and ecological knowledge, may help in applying indirect management strategies, thereby making it possible to mitigate resource impacts from recreation activities without regulating OHV access. Compliance with federal regulations may then become more efficient and feasible due to management strategies not just taking into account the ecological impacts of OHV recreation, but also the recreationist themselves and their use of the landscape.

Visitor-Employed GPS Survey

Although the employed methods have previously been used with success for examining other recreation activities, this research is one of the first examples to examine OHV recreationist behaviors and their influencing factors. We have demonstrated that a written survey paired with a visitor-employed GPS survey is a viable method to analyze social factors that affect spatial and temporal distributions of OHV recreationists. First, the methods for GPS collection and the unit's functionality were shown to be successful. Return rate for GPS receivers was 100%, despite the study being done within a complex trail system with multiple entry and exit points. In-person collection by researchers as well as securing the units to the vehicles instead of having individuals carry them on their person are assumed to contribute to the 100% return rate. Receivers were deployed 102 times, resulting in 96 (94.1%) complete sets of data. Incomplete data sets were due to the receivers turning off at some point during the trip. These instances were attributed to the nature of the recreation activity as well as attachment methods and not GPS receiver malfunction or their operability in the landscape.

Second, using a 5 second time-interval to record data was found to be sufficient in providing an accurate and complete description of distributions and behavior without an overburden of data. Collection intervals should be determined by the scale and purpose of the research, providing sufficient data to identify the behaviors of interest (Beeco and Hallo 2014). Longer intervals would have provided inaccurate totals of distance traveled due to the speed of OHV travel and the non-linear nature of the trails.

Third, by spatially standardizing the method of start and stop points for each participant, it was possible to eliminate the difficulties of calculating distance traveled and duration of each trip. In order to record accurate positions in the beginning of the participant's trip, GPS units needed to be turned on and recording data prior to distributing them to the individual. Setting the start and stop location spatially by defining boundaries to the trailheads allowed the systematic cleaning of data. The main drawback of this method is the loss of data that describes the behaviors of groups at the trailheads prior to departure and after returning, but this was not of interest in our research.

Limitations

While the application of pairing a pre-trip written survey and a visitor-employed GPS survey was successful in analyzing factors of influence on OHV recreation distributions, several limitations were realized. Due to small volume of OHV recreationists at many of the sampled trailheads, a convenience sampling technique was used primarily on weekend days to ensure an adequate sample size. Another sampling size limitation was our method of defining the sampling unit as the recreating group instead of the individual. Although 265 individuals fully participated in the study, our sampling size was 91 groups. This method, however, allowed us to better integrate GPS data with group dynamics of interest such as number of vehicles, lowest skill level, and whether the group had a plan for their trip. Another limitation was the use of self-assessments for certain rider characteristics such as site knowledge and skill level. A broader set of questions may have produced more informative values for these variables, but would have increased the amount of time needed to complete the survey and possibly reduce our participation rate. Finally, due to ethics and protocols of human studies, participant's awareness that their movements were being recorded may have biased riding behavior or participation.

Conclusion

We have shown that OHV trip distributions can be described using two dimensions which are best predicted by a unique set of participant characteristics. The addition of this social science data provides the necessary information to better mitigate ecological impacts caused by OHV recreational demands through indirect management strategies.

Land managers are expected to balance resource protection and the provision of desired recreational opportunities. In landscapes rich with established recreational activities and sensitive wildlife, the knowledge of all species and interactions present in the system, including humans, is required. This research, through the integration of user characteristics and their distributions, has attempted to better understand OHV recreationists within the study site. We have provided a case study that exhibits the functionality of a written survey and visitor-employed GPS survey to analyze factors of OHV use distributions. Distribution data, even standing alone, has the ability to identify uneven use distributions, informing managers how to best mitigate resource impacts and perceptions of crowding, as well as promoting areas that are underutilized by OHV recreationists. When integrated with user characteristics, managers can understand the underlying causes of distribution differences and implement indirect strategies that influence human behavior and patterns as opposed to regulating them.

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Tables and Figures

Table 1.1. Group constraints, experience, knowledge, and motivation variables evaluated as potential factors of OHV recreationist distributions. A random effect (Location) and a blocked effect (Vehicle Type) were included in all models.

Model Category	Variable	Description
Group Constraints	Estimated time	Estimated duration of the participant's trip
	Number of vehicles	Number of vehicles in participant group
	Lowest skill level	Lowest self-assessed skill level of any OHV operator in group
Experience	Experience in years	Number of years OHV recreating at study site by survey taker
	Experience in days	Number of days OHV recreating at study site in previous year by survey taker
Knowledge	Site knowledge	1 – 5 self-assessed score of the survey taker's knowledge of site and trail system
	Plan	0 = No plan about their trip/destination; 1 = Have a plan about their trip/destination
Motivations	Meet new people	1 – 5 self-assessed score about importance of meeting new people who enjoy similar things
	Share time with others	1 – 5 self-assessed score about importance of sharing time with friends and/or family
	Experience solitude	1 – 5 self-assessed score about importance of experiencing solitude or "getting away from it all"
	Challenge	1 – 5 self-assessed score about importance of challenging oneself or developing their skills
	Enjoy nature	1 – 5 self-assessed score about importance of enjoying the natural environment
	View wildlife	1 – 5 self-assessed score about importance of enjoying/viewing wildlife
Random Effect	Location	Trailhead where participant's trip began and ended
Blocked Effect	Vehicle type	0 = Only dirt bikes in group; 1 = One or more quad vehicle in group

Table 1.2. Summary of recreationist variables of interest (n = 91). Lowest skill level and knowledge variables based on a 1 to 5 integer scale (1 = none 5 = a lot). Motivation category variables based on a 1 to 5 integer scale (1 = not important 5 = very important).

	Variable	**Range**	**Mean**	**SD**
Group Constraints	Estimated time (min)	90 - 480	236.2	99.02
	Number of vehicles	1 - 9	2.64	1.57
	Lowest skill level	1 - 5	2.71	1.23
Experience	Experience in years	0 - 40	11.24	10.74
	Experience in days	0 - 150	13.87	21.55
Knowledge	Site knowledge	1 - 5	2.99	1.27
	Plan[1]	-	-	-
Motivations	Meet new people	1 - 5	3.20	1.17
	Share time with others	1 - 5	4.63	0.81
	Challenge	2 - 5	4.23	0.79
	Experience solitude	3 - 5	4.52	0.72
	Enjoy nature	3 - 5	4.76	0.50
	View wildlife	2 - 5	4.54	0.76

[1] The knowledge variable indicating a plan for the group's trip was a binomial variable and is omitted from this table. A total of 48 groups (52.75%) indicated they had a pre-trip plan.

Table 1.3. Summary of distribution variables (n = 91).

Variable	**Unit**	**Range**	**Mean**	**SD**
Distance	km	7.34 – 106.89	43.60	20.62
Depth	km	1.78 – 32.28	10.92	6.56
Dispersion	km^2	0.98 – 205.02	39.64	39.21
Duration	min	20 - 359	163	76.21

Table 1.4. Correlations (Spearman's ρ) between response variables.

	Distance	Depth	Dispersion	Duration
Distance	1.00	-	-	-
Depth	0.79	1.00	-	-
Dispersion	0.88	0.86	1.00	-
Duration	0.66	0.48	0.54	1.00

Table 1.5. Summary of principal component analysis results of distribution variables (n = 91). Loadings > 0.4 are in bold.

	PC1	PC2
Distance	**−0.531**	0.013
Depth	**−0.511**	**0.402**
Dispersion	**−0.519**	0.310
Duration	**−0.433**	**−0.861**
Eigenvalue	3.163	0.535
% variance	79.08	13.38

Table 1.6. AICc table of candidate models assessing the influence of individual and group characteristics on PC1 of OHV distributions. Models represent the best combination of variables within each model category. The AICc for the top model was 344.04.

Model[1]	***K***	**ΔAICc**	w_i
Constraints[2] + Knowledge[3] + Motivations[4]	10	0.00	0.79
Constraints + Knowledge	8	3.69	0.12
Constraints + Motivations	9	4.65	0.08
Constraints	7	9.04	0.01
Knowledge + Motivations	7	20.89	0.00
Knowledge	6	23.86	0.00
Motivations	6	24.46	0.00
Intercept	4	26.46	0.00

[1] All models included the random effect variable Location and the blocked effect variable Vehicle Type
[2] Constraints = Estimated Time + Lowest Skill Level + Number of Vehicles
[3] Knowledge = Plan
[4] Motivations = Meet New People + Enjoy Nature

Table 1.7. AICc table of candidate models assessing the influence of individual and group characteristics on PC2 of OHV distributions. Models represent the best combination of variables within each model category. The AICc for top model was 176.33.

Model[1]	***K***	**ΔAICc**	w_i
Constraints[2] + Experience[3]	8	0.00	0.50
Constraints + Experience + Knowledge[4]	9	1.17	0.28
Constraints + Knowledge	7	1.64	0.22
Experience + Knowledge	7	23.80	0.00
Intercept	4	26.31	0.00

[1] All models included the random effect variable Location and block variable Vehicle Type
[2] Constraints = Estimated Time + Number of Vehicles
[3] Experience = Experience in Years + Experience in Days
[4] Knowledge = Site Knowledge

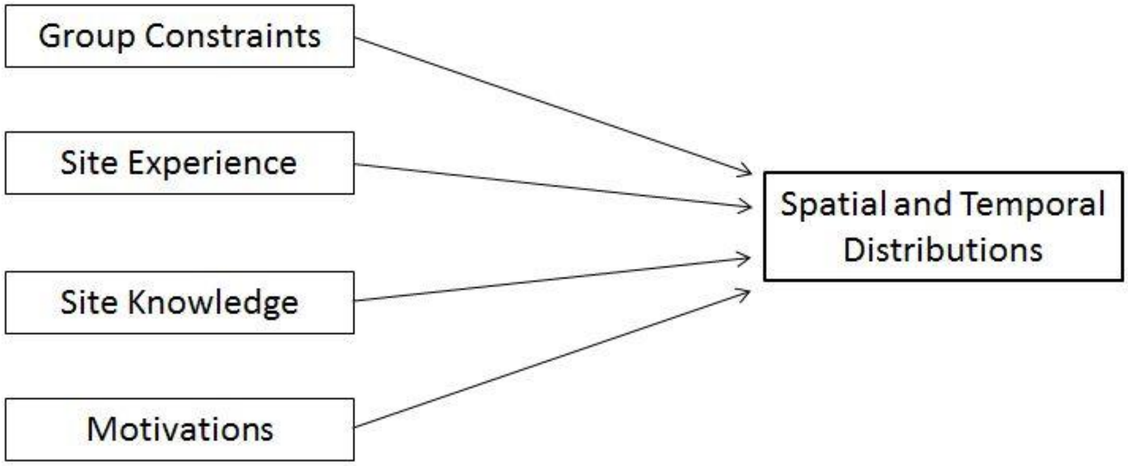

Figure 1.1. Conceptual model of variable categories of interest and their effect on OHV recreation distributions

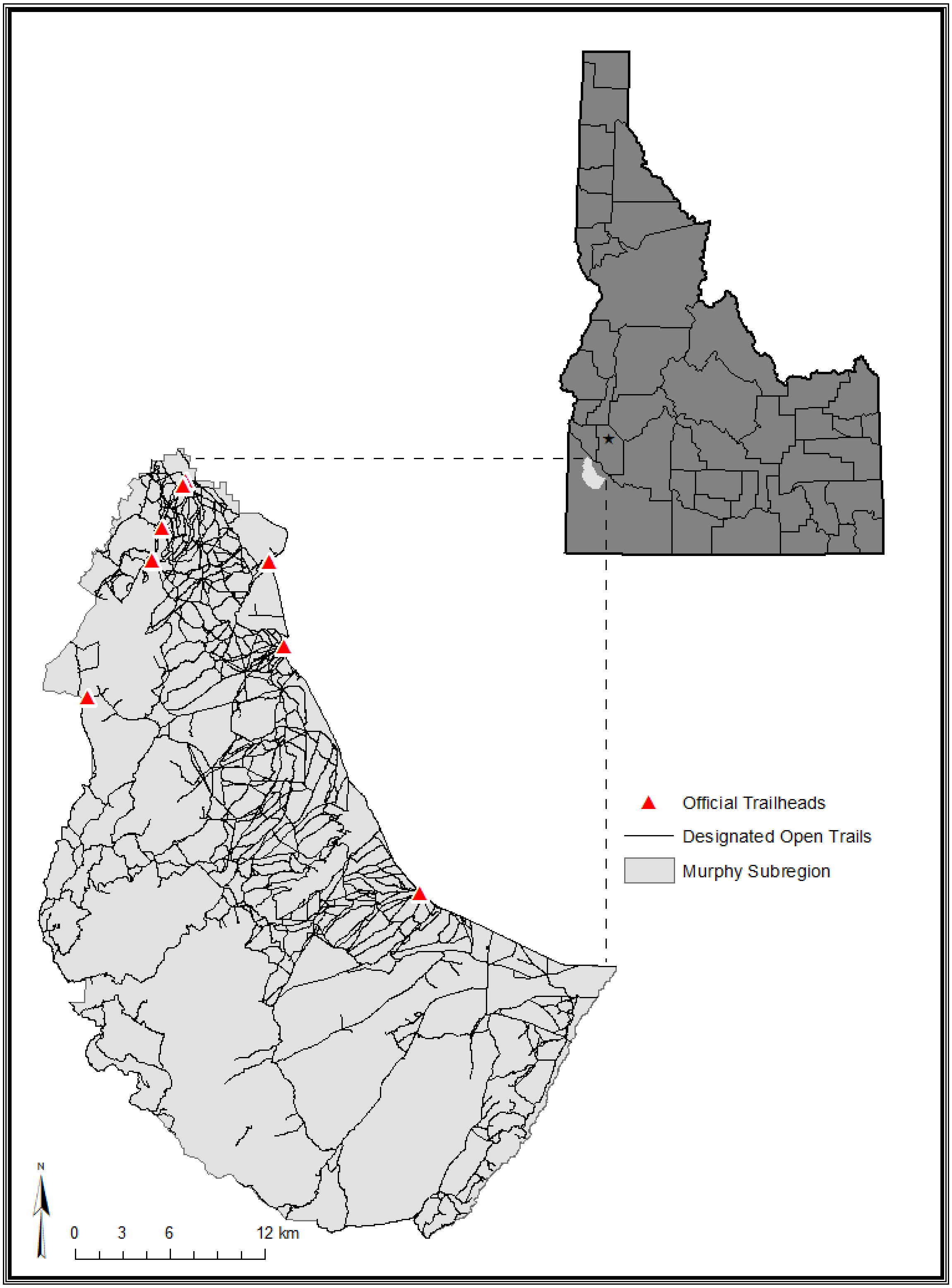

Figure 1.2. The Murphy Subregion of the Owyhee Front Management Area (BLM) and complex trail system open for OHV recreation.

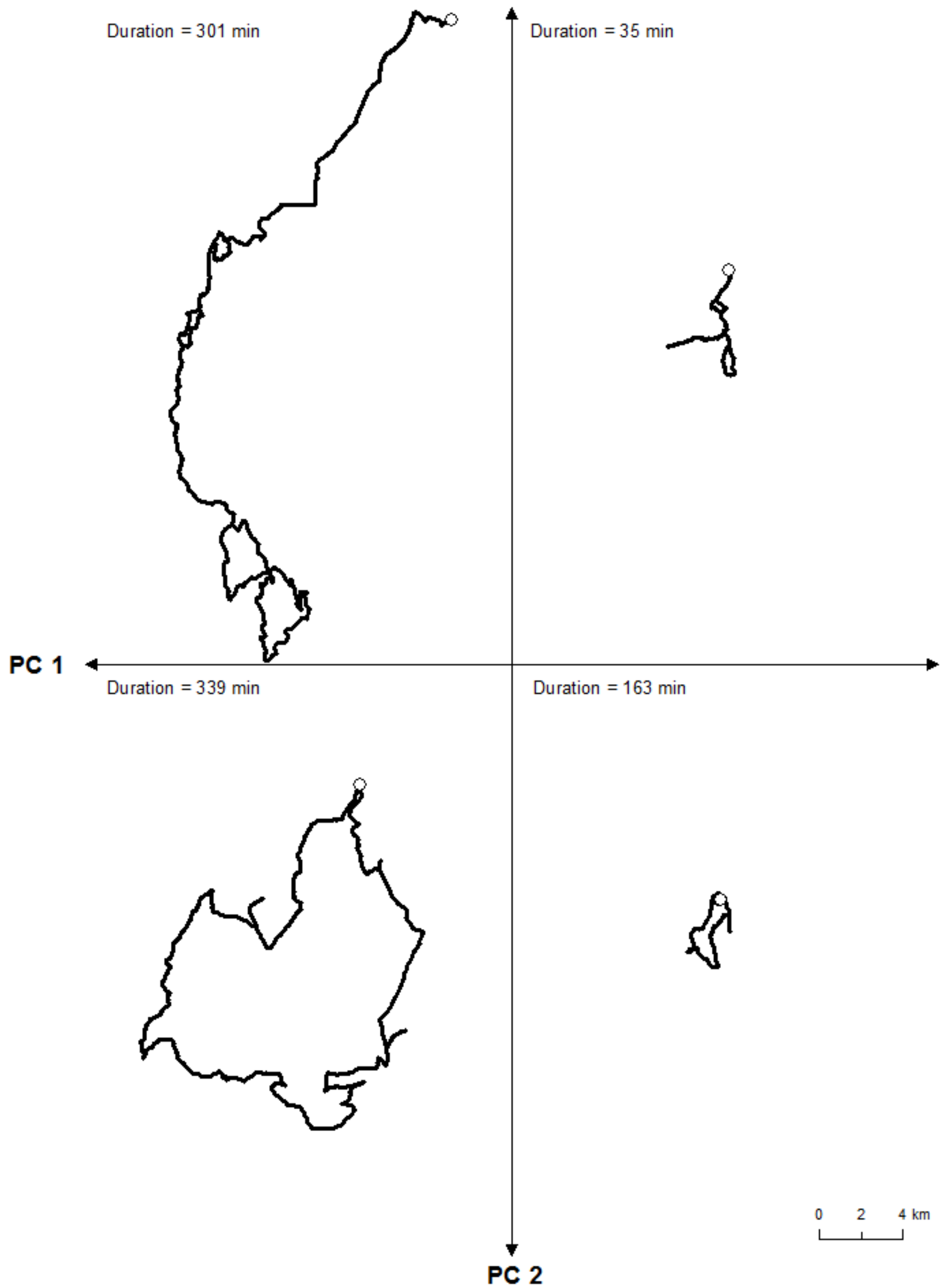

Figure 1.3. Recorded trip examples representing the distribution principal components. Trailhead used is indicated by circle. As PC1 increases, overall trip distributions decrease. As PC2 increases, duration decreases and depth increases. Durations of each trip example are located in upper left corners.

CHAPTER TWO: PREDICTING THE UNPREDICTABLE: IDENTIFYING AND MODELING LANDSCAPE SUITABILITY OF STOPPING BEHAVIOR FOR OFF-HIGHWAY VEHICLE RECREATIONISTS

Abstract

Outdoor recreationists have an impact on the environment and on wildlife. Heterogeneous or transitional behaviors exhibited by these recreationists often increase disturbance to wildlife. It has been observed that OHV recreationists, when riding in golden eagle habitat in southwest Idaho, disturb eagles more often when they stop their vehicle(s) as opposed to continuing to ride until they are outside of the sensitive area. Using a visitor-employed GPS survey and a presence-only modeling method, our objective was to identify where OHV recreationists stopped and to describe what natural and infrastructure landscape characteristics are more suitable for this transitional human behavior to occur. We then wanted to determine if there was a significant difference in stopping suitability between areas of varying habitat utilization by the local golden eagle population. We successfully identified stopping locations and developed two distinct models. One model described the suitability for all stopping events five seconds or greater while the second model described the suitability where an accumulation of five minutes of stopping occurs. We determined what landscape characteristics contributed to stopping suitability across the study site for both models. In the “All” model, we found that the stopping suitability index was greater in unoccupied territories when compared to occupied territories. In the “Five Minute” model, we determined that stopping suitability

was lower in non-territory areas than in both unoccupied and occupied golden eagle territories. When examining used and available habitats based on perch locations away from nest sites, we found no significant difference. This research exhibits how transitional human behaviors can be identified and modeled across a landscape as well as how the results can be used to aid in land management strategies in order to accomplish management objectives.

Introduction

Outdoor recreation disturbs and causes impacts to the natural surroundings (Leung et al. 2000, Adams and McCool 2009) and the wildlife within. Wildlife disturbance can cause short term impacts on individuals including increased vigilance or flushing from foraging or nest sites, leading to increased energy expenditure (Frid and Dill 2002). Long-term impacts of sustained disturbance on wildlife can include decreased reproductive output and increased mortality which can cumulatively cause population declines or even extirpation (Knight and Cole 1995, Blanc et al. 2006).

The predictability of recreationist behavior influences the disturbance effect on wildlife. When activities are constant and constrained to particular areas, animals may become habituated to the disturbance, thereby decreasing the negative impacts experienced (Whittaker and Knight 1998, Miller et al. 2001, Papouchis et al. 2001). Consistent behavior such as traveling on defined trails and homogenous movement has been shown to invoke a reduced reaction by wildlife as compared to unpredictable or transitional behaviors including off-trail use and heterogeneous movement (MacArthur et al. 1982, Mainini et al. 1993, Taylor and Knight 2003). In particular, stopping behavior by recreationists has been shown to cause a range of wildlife species to flee at greater distances. White-tailed deer, for instance, were observed to flush more often when a snowmobile in proximity to the animal stopped along a trail as opposed to a vehicle that continued moving (Richens and Lavigne 1978). Similarly, ten of the eleven waterfowl species studied by Klein (1993) showed a greater response toward stopped vehicles than vehicles that continued to drive by. More recently, it was observed that golden eagles flushed from their nest or perch site at a higher rate when off-highway vehicle (OHV) recreationists exhibited heterogeneous movements, such as stopping (Spaul 2015). When stopped, recreationists exhibit more unpredictable behavior as perceived by wildlife. Thus, mitigating the effects of recreational disturbance on wildlife will require the assessment of transitional behaviors such as stopping.

Difficulty arises when trying to identify and describe why or where such transitional human behavior may occur. Many methods of collecting spatial and temporal distributions of recreationists, such as post-trip surveys, automated counters, or observational techniques, offer incomplete and sometimes inaccurate data (D'Antonio et al. 2010), making the identification of certain behaviors such as stopping events difficult or impossible.

One method that has proven to be successful at providing extensive data on spatial and temporal distributions of individuals across large areas while placing minimal burden on both the participant and the researcher is visitor-employed GPS surveys. This method has been used in a variety of settings to determine distributions of individuals, including road vehicles across several counties (Hallo et al. 2012), non-motorized recreationists in protected areas (Arrowsmith and Chhetri 2003, Beeco and Hallo 2014), and tourists at events or attractions (Pettersson and Zillinger 2011). By using position and speed data collected by the receivers, it is possible to identify certain transitional behaviors such as stopping.

Once the transitional behaviors are identified, landscape variables at these locations can be analyzed to determine if qualities of the physical area contribute to the occurrence of the behavior. OHV riders consider specific natural and infrastructure landscape characteristics as conditions of greater interest when recreating, including scenic vista points, forested lands, and loop trails (Snyder et al. 2008). OHV use distributions have also been found to correlate with both natural landscape features such as washes, as well as corresponding to pre-existing infrastructure features (Matchett et al. 2004). These examples indicate that both natural and infrastructure landscape variables can influence OHV distributions and behavior.

Presence-only models are one set of methods for examining how a landscape may predict where heterogeneous behaviors occur. Maxent is a presence-only modeling platform that uses machine learning to determine habitat suitability and environmental predictors for a focal species (Phillips et al. 2006, Merow et al. 2013). Maxent uses a set of environmental variables across a defined geographic area and a set of species observation points to determine habitat suitability (Phillips et al. 2006). Presence-only models have been used to determine the habitat suitability in a wide range of species, including plants (Kumar and Stohlgren 2009), fish (Huang and Frimpong 2015, Radinger and Wolter 2015), birds (Bécares et al. 2015), amphibians (Ficetola et al. 2007), and mammals (Waltari and Guralnick 2009, Rodríguez-Soto et al. 2011). Recently, presence-only models have also been used to examine human distributions in the form of outdoor recreationists (Braunisch et al. 2011, Coppes and Braunisch 2013, Pauli et al. in review) and to identify areas of human-wildlife conflict (Vanausdall et al. in review, Santos et al. 2013).

To demonstrate how transitional human behavior can be modeled in natural landscapes and the benefit of this knowledge to land managers, we examined OHV recreationists within a complex trail system in southwestern Idaho and their relationship with a sensitive wildlife species, the golden eagle (*Aquila chrysaetos*). Golden eagles are a federally protected raptor species that are year round residents within southwestern Idaho, and have a substantial breeding population in the spring. Spaul (2015) documented recreation disturbance to eagles both at the nest and perching sites within the study area. In a survey of resource managers, human disturbance was identified as one of the primary threats to raptor populations (LeFranc and Millsap 1984).

Our first objective was to identify locations within the study site that stopping behavior occurred by OHV recreationists. Our second objective was to use the stopping locations in a presence-only modeling framework to model suitability for stopping behavior across the entire study area using a set of landscape variables. We also wanted to further examine only those stopping locations where a greater aggregate of stopping time was observed to determine if those landscape variables that contribute to these stopping locations differed from those landscape qualities where any amount of stopping behavior occurred. Our final objective was to examine if there was a significant difference in stopping suitability between areas of varying habitat utilization by the local golden eagle population. Overall, the aim of this research is to determine if transitional behavior by recreationists could ultimately be modeled using presence locations of stopping behavior and landscape variables, and if so, to illustrate how these methods could be utilized by land managers to better understand and mitigate human-wildlife conflicts.

Methods

Study Area

The Murphy subregion of the Owyhee Front Management Area comprises an area of approximately 94,290 hectares (ha) in southeastern Idaho (Figure 2.1) consisting mainly of salt desert shrub and sagebrush-steppe habitats (Bureau of Land Management 2009). In 2009, the Murphy Subregion Travel Management Plan (TMP) designated roughly 1350 km of roads and trails as open to OHV use, either year round or seasonally. Additional trails that exist within the subregion were closed to all OHV use. The trail network is a complex system due to its extensiveness and many intersections (Hallo et al. 2012). There are eight official trailheads with many additional unofficial pull-off spots used to gain access to the trail system. Types of OHV use include dirt bikes, all-terrain vehicles (ATVs), and utility terrain vehicles (UTVs; personal observation). Road vehicles (SUVs, trucks, etc.) and modified vehicles such as rock crawlers are also utilized on portions of the trail system but were not included in this research due to their limited use and limited trail availability for these vehicle types (unpublished data). The majority of trails are open year round to OHV recreation, with peak use occurring on weekends between March and May (Spaul 2015, personal observation). Multiple golden eagle nesting territories are also located within the study area, with estimated egg laying dates occurring within the first week of March (Spaul 2015), making much of the incubation period coincide with peak OHV use.

Spatial Data Collection

Spatial data on OHV trail use was collected from March 13 to May 25, 2015. A GPS receiver (Globalsat dg-100) was attached to the vehicle of consenting individuals, or if requested, placed in a pouch or backpack. This GPS receiver model is an effective unit for tracking recreational use distributions, with a mean precision of 6.7 meters (Hallo et al. 2012). The receiver was turned on several minutes prior to the group leaving the trailhead area to ensure the acquisition of satellite signals. Receivers recorded position, time, date, speed, and altitude at a five-second interval during the duration of the recreationist's trip. After the participant returned to the trailhead, the receiver was collected in person by the researcher. Data were downloaded from the unit using DG Manager.NET software. All methods were approved by the Boise State University Institutional Review Board under protocol #028-SB15-043.

The majority of sample days (27 of 31) were on weekends from late morning to early evening, which coincided with peak use. Participant recruitment by researchers occurred at six of the eight official trailheads. The remaining two trailheads were not sampled due to lack of regular use by OHV riders (personal observation). The number of trailheads surveyed in a given day (1-2) was determined by the number of researchers available. Efforts were made to approach all observed OHV users. In some instances, however, the concurrent arrival of multiple users at the trailhead prevented complete sampling.

Stopping Locations

All GPS locations for all OHV routes were standardized and cleaned using ArcGIS 10.2 ESRI software. Standardization was accomplished by defining boundaries to each of the six trailhead parking areas. All points except for the final point recorded prior to exiting the trailhead area for the first time were deleted to prevent oversampling of trailheads. Likewise, at the end of the trip all points recorded except for the first point recorded upon entering the trailhead area for the final time throughout the participant's trip, were deleted. Each point set was then visually inspected for any position anomalies based on the adjacent points, as well as recorded speeds and time. Any anomalies observed were deleted from the data set.

To identify stopping locations that occurred during each route or trip, points with a recorded speed of 0.1 km/h or less were selected and retained for analysis. Although GPS error could produce speeds greater than 0.1 km/h for a stationary receiver, a threshold of 0.1 km/h was chosen to prevent false positives. Points within 5 m of each other were combined to reduce these points to a single stopping location.

A second set of stopping locations was produced to include only those locations where 5 minutes or more total stopping time were recorded. This was done using the same process as the previous set of stopping locations, selecting those points with a speed of 0.1 km/h or less and integrating these points with a 5 m threshold. Only those locations with 60 or more integrated points, equaling a total time of 5 minutes, were retained for analysis.

To minimize overfitting caused by autocorrelation (Veloz 2009, Elith et al. 2011, Boria et al. 2014), both sets of stopping points were spatially filtered by iteratively removing one of the closest two points until no two points were closer than 1 km to one another. A 1 km buffer was chosen to ensure the retention of a sufficient number of presence locations while minimizing potential similarity of environmental conditions. We used R 3.2.0 software (R Core Team 2015) and the “rangeBuilder” package (Title 2016) to complete spatial filtering.

Environmental Variables

Variables were chosen to examine the influence of both natural environmental variables as well as infrastructure characteristics on stopping locations. Environmental variables can influence recreationists’ behaviors due to visual perception (Dorwart et al. 2009) and setting preferences (Baker 2008). Predictors of stopping events in this study included elevation, slope, topographic position index (TPI), visibility index, and land cover. Elevation data were derived from a 30 meter digital elevation model (DEM) of the area (US Shuttle Radar Topography Mission). Slope was derived from a 10 meter DEM and the resulting raster was then aggregated to a 30x30 meter raster using the minimum slope within that area. Minimum slope was chosen due to the assumption that a lower slope would be more conducive to stopping. The TPI was calculated by subtracting the mean elevation within a radius of 1 km from the elevation of the center cell (Weiss 2001). A scale of 1 km was used to represent an individual’s influential surroundings. This scale was chosen in the attempt to include the objects and landscape structures of interest in the surrounding area that could be clearly seen in the absence of any obstacles. In a previous study, Hull and Stewart (1995) found that 80% of the objects and landscape viewed by hikers were within a distance of 1 km, with only 20% of views at a distance of greater than 1 km. Visibility Index was calculated using Whitebox Geospatial Analysis Tools software (Lindsay 2009). The visibility index is the viewshed for each cell in the raster. A viewing height of 1.5 m was used to approximate the height of a recreationist on an off-highway vehicle. Finally, land cover data was acquired from the 2011 National Land Cover Database (Homer et al. 2015).

Trail and infrastructure preferences can be varied among OHV recreationists (Fly et al. 2002, Lord et al. 2004, Baker et al. 2008, Snyder et al. 2008). These differences can affect recreationist behavior when utilizing a landscape (Coppes and Braunisch 2013). Infrastructure variables considered as predictors of stopping locations were distance to nearest designated open trail, distance to nearest trailhead, distance to nearest trail intersection, distance to nearest trail dead end or terminus, and trail density (1 km). All variables were calculated using the most up to date trail system shapefiles (BLM) in ArcGIS 10.2.2 (ESRI, Redlands, CA). All distance variable rasters were calculated using the euclidean distance tool and the trail density (1 km) raster was calculated using the line density tool. Maps for both infrastructure and environmental variables were projected using the WGS 1984 UTM Zone 11N coordinate system with a 30 meter resolution.

Modeling Stopping Suitability

Maxent was used to determine the environmental and infrastructural variables that best described stopping locations. We formulated two distinct models. The first model used all stopping locations while the second model used only those locations with an accumulated 5 min or more stopping time to determine stopping suitability across the study area in reference to landscape variables. Hereafter, these models will be referred to as the “All” model and the “Five Minute” model.

Maxent is sensitive to sampling biases (Anderson and Gonzalez 2011, Merow et al. 2013), so pseudo-absence points were restricted to the area considered available to OHV riders in the area. Background data was limited to any area within the minimal convex polygon created using all presence points (including both stopping and non-stopping locations) collected during all participant trips. A total of 10,000 pseudo-absence locations were chosen randomly using Maxent.

In Maxent, the user can adjust a regularization parameter in order to constrain model complexity by minimizing the overfitting of input data (Phillips et al. 2006, Warren and Seifert 2011) by incorporating a weighting penalty for adding extra parameters (Anderson and Gonzalez 2011, Warren and Seifert 2011). To determine the optimal regularization parameter value for each model it is necessary to conduct model selection of alternative models where the regularization value is changed while keeping all other settings constant. For both models, we used regularization values of 1, 2, 3, 4, 5, 6, 7, 9, and 11 to create nine candidate models. Candidate models were then compared using ENMTools 1.4.4 (Warren et al. 2010) under an information theoretic framework. The model exhibiting the lowest AICc value was considered the “best” model and its corresponding regularization value was used for subsequent model runs.

The “All” model and “Five Minute” models were set to use 70% of presence records for model training and 30% for model evaluation. The number of presence locations for the “All” model (206) was greater than the minimum of 80 recommended (Phillips and Dudík 2008), which allowed for a sufficient sample size for all five possible feature types to be potentially used for generating variable response curves (hinge, linear, product, quadratic, and threshold). The “Five Minute” model had only 66 presence locations, so variable response curves were restricted to only hinge, linear, and quadratic feature types.

We used two measures to assess model fit. Area under the curve (AUC) for the receiver operating characteristic measures how well a model discriminates between presence locations (stopping locations) and pseudo-absence locations (random locations). AUC values of 1 indicate perfect discrimination while an AUC value of 0.5 indicates differentiation at a random level (Fielding and Bell 1997). While the use of AUC is advocated and widely used in determining model fit (Veloz 2009), it should not be utilized as a stand-alone method since an AUC value of 1 is impossible in many presence-only models (Raes and ter Steege 2007). In addition, models should also test for significance when compared to null distribution models (Raes and ter Steege 2007). Therefore, performance of each empirical model was compared to 500 generated null models to determine if the empirical model significantly contributed to predicting stopping locations. Each null model consisted of random locations generated in ENMTools, matching the sample size of presence locations. All generated random locations were constrained by the minimal convex polygon of all OHV points observed. Each set of random points was then modeled in Maxent, keeping all settings and parameters constant with those used for each empirical model. The AUC values for the empirical models were then compared to the AUC values of all 500 null models, allowing us to determine if the performance of the empirical models were significantly greater than random.

To assess individual variable importance to each model, Maxent provides variable contributions to the model in the form of percent contribution and permutation importance. Percent contribution of each variable depends on the path that Maxent takes in order to find the optimal model. For each iteration of the training algorithm, the change in regularized gain is either added or subtracted from the contribution of the corresponding variable. Permutation importance relies only on the final model and is determined by randomly permuting each variable and calculating the decrease in model performance to represent the variable's importance. A higher percent contribution or permutation importance indicates that the variable is of greater importance to the suitability of the habitat for the target species than other variables. Both of these variable contribution measures are reported.

Stopping Suitability and Golden Eagle Habitat Analyses

After producing maps of stopping suitability for each model using Maxent, we wanted to determine if golden eagles selected nesting territories relative to OHV stopping suitability. Golden eagle nesting territories within the subregion were defined by a 3-km buffer around the most recently used nest. A 3-km buffer around the nest has been suggested as an appropriate representation of golden eagle territories in southwestern Idaho (Marzluff et al. 1997). Buffer areas were clipped if they extended outside of the Murphy subregion. Territories were then classified as "occupied" or "unoccupied" using observations from the 2015 breeding season (unpublished data). All areas within the Murphy subregion but outside of any golden eagle territory were classified as "non-territory" (Figure 2.1). A total of 5,000 random points within the study site were generated in ArcGIS and the stopping suitability score of each point for both models was determined. We analyzed the data with R 3.2.0 software (R Core Team 2015) using Kruskal-Wallis H tests to determine if stopping suitability significantly differed between non-territory, unoccupied, and occupied areas for both models. If necessary, a Dunn's multiple comparison post-hoc tests was performed using the R statistical package "PMCMR" (Pohlert 2014).

We also compared the used and available perching habitat of golden eagles in relation to stopping suitability. Golden eagles were observed during the 2012-2014 breeding seasons and perching locations away from occupied nest sites were recorded within the Murphy Subregion (Spaul 2015). Only perch locations away from the nest site were analyzed because these locations are "chosen" whereas nest locations are "fixed". Binary maps of stopping suitability were created in Maxent using the threshold that maximized the sum for sensitivity and specificity (Liu et al. 2013) to create maps of suitable and unsuitable areas for OHV stopping. Threshold values were calculated for both models. We then used the Euclidean Distance tool in ArcGIS to generate raster files for the Euclidean distance of each cell in the study area from the closest suitable stopping location. The mean distance and standard deviation for all cells within each used eagle territory (3 km) was then calculated using the Zonal Statistics tool in ArcGIS. Distances were also measured between each perch location and the closest suitable stopping location, then standardized based on the mean and standard deviation distance for the entire corresponding territory. A one-sample t-test was used to determine if standardized perch locations were significantly greater than 0. Both stopping suitability models were again analyzed using R 3.2.0 software.

Results

During visual inspection of spatial data, seven points from three different participant trips were deleted due to position anomalies. A total of 2,101 unique stopping locations were identified after integrating all points with a recorded speed of 0.1 km/h or less.

<u>"All" Model</u>

The "All" model considered all stopping locations observed. After filtering to reduce spatial autocorrelation, 206 stopping locations were retained for analysis. The number of presence locations was of sufficient size that, all five possible feature types (hinge, linear, product, quadratic, and threshold) were available to generate variable response curves for the model (Phillips and Dudík 2008). In model testing, a regularization multiplier value of 2 resulted in the lowest AICc. A total of 145 points (70 %) were used for model training while the remaining 61 points (30%) were used for model evaluation. The training AUC was 0.942 while the test AUC was 0.893 (SD = 0.025). Both training and testing AUC values were higher than the AUC values of all 500 null models tested ($p < 0.002$). Percent contribution and permutation importance were both used to determine the relative contribution of each parameter to the model (Table 2.1).

Proximity to open designated trails had the highest percent contribution as well as permutation importance. While distance to trail junction had the second highest percent contribution (10.0%), its permutation importance showed relatively little contribution (2.3%). This large discrepancy can be attributed to the high correlation between this variable and the distance to trails variable. Stopping suitability was maximized when the distance to open, designated trails and trail intersections was low (Figure 2.2). The parameter with the second highest permutation importance was trail density (9.2%). Areas with greater trail density resulted in low stopping suitability (Figure 2.2c). The most powerful non-infrastructure variable was slope, with a percent contribution of only 0.7% and a permutation importance of 4%. Maximum suitability correlated with a slope ranging from 2.8 to 4.5 degrees (Figure 2.2d). The top four variables had total percent contributions and permutation importance greater than 95%. A map of relative suitability was created for the study area (Figure 2.3). Areas of highest suitability were almost exclusively located directly at or very near trail intersections.

“Five Minute” Model

Of the 2,101 stopping locations, a total of 129 locations were found to have at least 5 minutes of aggregated stopping time. After spatial filtering, 66 locations were retained for analysis. Due to a lower number of presence locations, only hinge, linear, and quadratic feature types were used to generate the model’s variable response curves. Model testing of regularization values resulted in a regularization multiplier of 3 having the lowest AICc. A total of 47 presence locations (70%) were used for model training and 19 locations (30%) used for model testing. Training AUC of the Maxent model was 0.954 and test AUC was 0.905 (SD = 0.050). Both AUC values were higher than all of the AUC values of the 500 generated null models ($p < 0.002$). Distance to open designated trails and proximity to trail junctions had the highest percent contributions (Table 2.1).

Suitability for locations with at least five minutes of stopping time was greatest directly on trails and junctions and decreased as the distance from these features increased (Figure 2.4). In analyzing permutation importance, however, TPI and land cover contributed greater predicting power than distance to trail junction. Extreme low and high values for TPI were found to be most suitable for stopping locations in the model (Figure 2.4c). The most suitable land cover was barren land, including rock, sand

and clay (Figure 2.4d). Total percent contribution of the top two variables was greater than 95% while total permutation importance of the top three variables contributed more than 95% to the predictive power of the model (Table 2.1). Again, a map was created for relative stopping suitability for long-term stopping across the study area (Figure 2.5).

Eagle Habitat Analysis

A total of 14 golden eagle nests and their surrounding territories (3km) were used to compare stopping suitability between non-territory, unoccupied, and occupied areas of the study area. Six territories were documented as unoccupied and 8 were observed to be occupied during the 2015 breeding season (unpublished data). To determine if stopping suitability varied between areas, 5000 random points were generated within the Murphy subregion border in ArcMap 10.2. Of the 5000 points, 3552 (71%) were in non-territory areas, 578 (12%) were in unoccupied areas, and 870 (17%) were in occupied areas.

For the “All” model, the data was not normally distributed and was rank-transformed. Mean stopping suitability index was 74.72 (SD = 251.77) for non-territory, 80.81 (SD = 260.94) for unoccupied, and 63.32 (SD = 228.85) for occupied areas. A Kruskal-Wallis test determined there was a significant difference in stopping suitability between the three areas ($\chi^2 = 10.556$, $p = 0.005$). Due to unequal sample sizes within groups, Dunn’s multiple comparison post-hoc tests with a Bonferroni correction was performed to determine which areas significantly differed from one another. The stopping suitability of unoccupied territories was found to be significantly greater than occupied territories ($p = 0.0036$) (Figure 2.6). Stopping suitability for non-territory areas was not significantly different than occupied ($p = 0.1239$) or unoccupied areas ($p = 0.0936$).

We also analyzed the stopping suitability values for the “Five Minute” model. Mean stopping suitability index was 95.00 (SD = 372.17) for non-territory, 104.43 (SD = 325.86) for unoccupied, and 93.59 (SD = 348.02) for occupied areas. Using the same non-parametric methods, stopping suitability was significantly different between the three areas ($\chi^2 = 22.75$, $p = 1.146e-05$). Stopping suitability in non-territory areas was significantly lower than unoccupied territories ($p = 0.00024$) and occupied territories ($p = 0.00289$) (Figure 2.7). Stopping suitability values did not differ between occupied and unoccupied territories ($p = 0.99774$).

We also examined differences between used and available habitat within nine eagle territories in which we had known perch locations. Using the stopping suitability threshold maps, we calculated the distance of each cell in all territories to the closest suitable stopping location. Mean distances and standard deviations were calculated for each territory (Table 2.2). Distances of perch locations to suitable stopping sites were standardized by territory and analyzed to determine if they differed from zero (average standardized distance for territory). We found no significant difference between standardized perch location distances and zero for either the “All” model ($t_{39} = 1.62$, $p = 0.114$) or the “Five Minute” model ($t_{39} = 0.26$, $p = 0.797$).

Discussion

<u>Capturing Recreation Behavior Using Visitor-Employed GPS Survey</u>

As human populations grow and recreation demands increase or shift in popularity, an understanding of recreation behavior characteristics becomes more vital in wildlife management. Predictability of recreation behavior is one of the most influential factors in disturbance to wildlife (Knight et al. 1995). We demonstrated that stopping locations by OHV recreating groups can be successfully identified by the use of a visitor-employed GPS survey. Using speed and position data collected by the GPS receivers allowed us to identify distinct stopping locations and provide necessary presence data for further analysis. Compared to alternative methods used to collect use distributions such as map or trip diaries, GPS tracking produces a more accurate data set since it does not rely on participant recollection or spatial knowledge of the area (Shoval and Isaacson 2007, D'Antonio et al. 2010). Visitor-employed GPS methods also provide a more complete data set of spatial distributions because it can consistently record data throughout the entire trip, as opposed to trip diaries or trail cameras/counters that provide information only at certain isolated locations (Cessford and Muhar 2003).

Stopping Suitability

Trail and infrastructure variables contributed more than natural environmental variables when modeling stopping locations of OHV recreationists. The variable that most contributed to the suitability of stopping locations was proximity to open, designated trails. This was true for both stopping suitability models. Locations on or closer to trails exhibited a higher suitability for stopping behavior than locations farther away from trails (Figure 2.2a, Figure 2.4a). Although expected, this provides evidence that trails and trail network design can strongly influence travel patterns, even within an expansive landscape and a complex trail system where off-trail travel was observed and has been known to occur previous to our study.

Proximity to trail junctions was found to be the variable with the second highest percent contribution to stopping suitability for both models. As distance to a juncture approached zero, stopping suitability increased (Figure 2.2b, Figure 2.4b). However, the contribution of this variable to stopping suitability decreased when permutation importance was examined, probably due to the variable's high correlation with distance to open trail. Trail intersections can be viewed as locations where decisions are made about which direction or trail to ride, possibly resulting in greater incidences of stopping behavior. Trail density had the second highest permutation importance in the "All" model, with the response curve indicating higher stopping suitability for areas with very low trail density (Figure 2.2c). Therefore, in analyzing the "All" model, a location on a trail will have a higher stopping suitability if there are fewer other trails in close proximity, as compared to if there is an abundance of other trails in the area.

In the "Five Minute" model, trail/infrastructure variables again contributed the most to the model's predicting power of stopping suitability. However, when permutation importance was considered, two natural landscape variables, TPI and land cover, contributed substantially to the predicting power of the model. In the "All" model, these variables had a small total permutation. This indicates that natural landscape characteristics may be more important to stopping suitability when people stop for a longer period of time or an area experiences stopping events more frequently. The TPI response curve indicates extreme TPI values, such as those found in canyons and on summits or cliffs, maximizes stopping suitability (Figure 2.4c). This result corresponds with previous research that has shown landscape and dynamic environmental features are valued by OHV recreationists (Snyder et al. 2008, Westcott and Andrew 2015). Preference for linear features such as canyons have been shown in past research of OHV recreationists as well (Matchett et al. 2004). Land cover also contributed more to the

"Five minute" model than the "All" model, with stopping behavior more suitable on barren land (Figure 2.4d).

One possible interpretation for these different variable contributions between our models can be classifying locations with shorter stopping behavior as "utility" locations and locations with longer accumulated stopping behavior as "quality" locations. Utility locations can be defined as areas where individuals stopped for short durations in order to wait for other riders in their group, to orient themselves with a map, or to maintain or adjust equipment. These areas would include trail junctures and areas of minimal slope adjacent to trails. Quality locations would indicate areas that riders may possibly dismount their vehicle to enjoy the natural surroundings or for a physical rest. These locations would be areas providing extreme topographic position with barren land cover, and adjacent to an open trail. Although beyond the scope of this research, further efforts should be considered to identify reasons for stopping at certain locations to better understand the mechanisms of the behavior.

Some limitations to our model were due to the inaccessibility of additional, potentially important variables. All infrastructure variables examined were based on the designated, official trail system. We considered additional infrastructure variables for inclusion, but were found to be impracticable due to the lack of complete data. Considered variables included proximity to unofficial camping and recreational shooting areas. Future identification of these recreational areas throughout the landscape would be beneficial to determine if other recreational activities also influence stopping locations in addition to OHV trail riding.

Golden Eagle Habitat Analysis

Minimizing transitional, heterogeneous behaviors by OHV recreationists within golden eagle habitat could potentially decrease flushing events by 77% (Spaul 2015). By modeling the suitability for stopping locations across the entire landscape, we were able to identify potential hotspots where high stopping suitability and eagle habitat coexisted. We also were able to identify landscape features that contributed to locations being highly suitable for stopping behavior.

Our resulting "All" model showed that golden eagle territories that were unoccupied during the 2015 breeding season contained areas of significantly higher stopping suitability than those areas within occupied golden eagle territories. These results may indicate that transitional behavior at these suitable stopping locations by OHV recreationists may impact golden eagle territory selection. Although certain mechanisms were not examined, Steenhof et al. (2014) found lower young production of golden eagles in OHV impacted areas partially due to territory abandonment. Previous studies have also shown that OHV recreation can decrease the use of suitable habitat by a variety of fauna, including songbirds (Barton and Holmes 2007), grizzly bears (Graves et al. 2003), and reptiles (Bury and Luckenbach 2002). It was also previously shown within our study area that unoccupied territories had higher trail densities and greater OHV use than occupied territories (Spaul 2015). It is reasonable to assume that these factors would increase the occurrence of stopping due to more individuals being present to exhibit the behavior as well as providing more suitable stopping areas due to more trails and presumably more trail intersections. While our results are statistically significant, interpretation of their meaning should be done cautiously because of the limited time frame of the project (one season) as well as the artificiality of our sample size. Although evidence is present that stopping suitability is higher in unoccupied territories than occupied territories, its effect cannot be translated directly to its biological relevance. Also, analysis of additional breeding seasons should be considered in an attempt to support our findings.

Analysis of our “Five minute” model showed that non-territory areas had significantly lower stopping suitability than both unoccupied and occupied breeding territories. One explanation for this finding is the presence of a human-wildlife conflict due to similar natural landscape preferences. Topographic position index had the second highest permutation importance of all variables in the model and the highest permutation importance of all the natural landscape variables. Extreme values of TPI showed a higher probability for greater accumulation of stopping behavior, with extreme positive values having the highest probability (Figure 2.4). These values are indicative of summits, cliffs, or large rock outcrops. While we found these areas to be highly suitable for stopping by OHV recreationists, these same features are also preferred nesting areas for golden eagles in southwest Idaho (Kochert et al. 2002). Keystone landscape features such as these may be causing an increase in human interactions with the golden eagle breeding population. Again, these results should be interpreted with caution due to our inflated sample size. Given more data, golden eagle nests and perch locations could be modeled in a similar fashion by using the same environmental variables as stopping locations. The importance of variables could then be compared to determine if certain variables drive the potential for eagle disturbance by OHV recreationists. Additional research should also attempt to model a variety of recreation activities that take place within the study area, as all types of recreation display transitional behaviors and can ultimately disturb wildlife.

Considering that distance to an open designated trail and distance to trail junction were the two highest contributing variables in this model, another explanation for the difference in stopping suitability between non-territory and territory areas may simply be that there are more trails and trail intersections within golden eagle breeding territories compared to non-territory areas. The majority of trails within our study area currently available to OHV recreation were not planned or purposefully located across the landscape, but rather were created by OHV riders before any official trail system was present (Homan 2016). Thus, these trails and their location can be interpreted as representative of where OHV recreationists chose or preferred to travel prior to being constrained by an existing trail system. This interpretation provides support for the existence of a keystone landscape conflict between OHV riders and golden eagles.

The distances of each perch location and all corresponding territory locations to the closest suitable stopping location were compared and we found no significant difference in either model. This suggests that golden eagles, when selecting a perch, are not behaviorally responding to the proximity of a suitable stopping location. This may be because they cannot assess on a microhabitat level the difference between areas with low and high stopping suitability. This may also result because they do in fact have the ability to assess this difference in perch proximity to an area with the potential for increased disturbance, but find it to be inconsequential due to limited alternative perch locations, higher quality of the occupied location compared with other available perch sites farther from suitable stopping areas, or simply that infrequent flushing does not significantly impact the individual’s overall survival and fecundity (Ydenberg and Dill 1986, Gill et al. 2001). The lack of evidence that golden eagles disproportionately use areas farther from stopping locations may suggest that efforts to mitigate stopping behavior and its effects on eagles should not be focused on a small microhabitat level, but should take into account stopping behavior across entire territories.

Management Implications

An understanding of transitional human behaviors could allow a greater variety of management strategies to be considered in mitigating human-wildlife conflicts while maintaining or even enhancing the quality of the recreation experience. Direct management strategies that regulate recreationist behavior, such as closing trails or prohibiting entry to certain areas, are primarily used to reduce disturbance in protected natural lands (Manning 2010). However, indirect management strategies, which influence recreationist behavior, are generally preferred by recreationists, cost less to implement, and have been shown to be able to produce the same outcomes as direct management (Manning 2010). One reason why indirect strategies are less frequently used is their reliance on social science data relating to recreational behavior and preferences, which is often incomplete or nonexistent. By identifying anthropogenic disturbance behaviors and where they occur, it may be possible for land managers to redirect where this behavior is exhibited.

For our study area, one example of indirect management that could reduce human-wildlife conflict within the study area would be to designate rest areas with minimal facilities situated in areas outside of known golden eagle territories. These designated stopping locations could still incorporate preferred natural settings such as canyons or summits, but be established outside of historically used golden eagle nesting areas. Recreationists' knowledge of these locations could decrease human interactions with sensitive golden eagle habitat while simultaneously enhancing the recreation experience. Having a set destination might also reduce uncertainty about route choice and in turn reduce stopping behavior at trail intersections. Another alternative action would be to minimize trail junctures within sensitive areas while still maintaining or expanding loop trails, which are typically preferred by OHV riders (Snyder et al. 2008).

Conclusion

Our research illustrates how recreation behavior patterns can be modeled using the combination of identified locations of particular behaviors and a presence-only species distribution modeling approach. Using a presence-only modeling method is an innovative way to examine human spatial and temporal patterns, and provides a transferrable technique for examination of other human behaviors and distributions. The use of a visitor employed GPS survey also eliminates many subjectivities and limitations that are encountered with other methods such as trip diaries and post trip interviews.

The methods and results presented broaden the understanding of how landscape qualities can influence OHV recreation patterns. Compared with natural environmental variables, trail variables contributed more to the suitability of stopping locations for OHV recreationists within the study area. This knowledge can aid land managers in minimizing wildlife disturbance by employing indirect management strategies and/or manipulations of the trail system infrastructure. This research also helps us to understand where OHV recreationists are more likely to impact wildlife by providing information on possible hotspots where high stopping suitability and sensitive habitats coexist. Furthermore, we concluded that the qualities that best predicted all stopping locations varied from those that best predicted locations where a greater total of stopping time occurred, providing support to the idea that stopping behaviors may differ in their functionality. With this study, we demonstrated how a presence-only modeling approach can be affectively used to model transitional recreation behavior and how these results can be applied to better manage for human-wildlife interactions across a landscape.

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Tables and Figures

Table 2.1. Relative contributions of natural and infrastructure landscape variables on the stopping suitability of OHV recreationists. Variable values constituting 95% total contribution in bold.

Variable	All Stopping Locations		Locations ≥ 5 min	
	Percent Contribution	Permutation Importance	Percent Contribution	Permutation Importance
Distance to open, designated trail	**86.5**	**82.0**	**74.3**	**78.0**
Distance to trail junction	**10.0**	2.3	**23.9**	2.6
Trail density (1 km)	1.6	**9.2**	0	0
Slope	0.7	**4.0**	0	0
Distance to trailhead	0.4	1.2	0	0
Visibility index	0.3	0.6	0.2	0
Topographic position index (TPI)	0.2	0.2	1.2	**12.1**
Elevation	0.2	0.3	0	0
Land cover	0.1	0.2	0.4	**7.3**
Distance to trail dead end	0	0	0	0

Table 2.2. Mean distances (m) and standard deviations to closest suitable stopping location for territories and corresponding perch locations.

Territory ID	Territory		Perch Locations	
	Mean Distance	SD	Mean Distance	SD
BRC	730.44	777.21	701.93	556.21
CHB	63.19	84.50	49.32	39.87
GRR	474.53	383.35	406.23	228.47
HAC	606.56	539.42	608.60	215.37
RYL	203.53	199.25	196.09	95.11
MOC	332.14	288.47	344.54	294.92
ROC	116.62	117.23	233.08	72.91
RYE	495.72	503.64	447.67	135.00
RYU	543.81	432.86	317.90	244.59

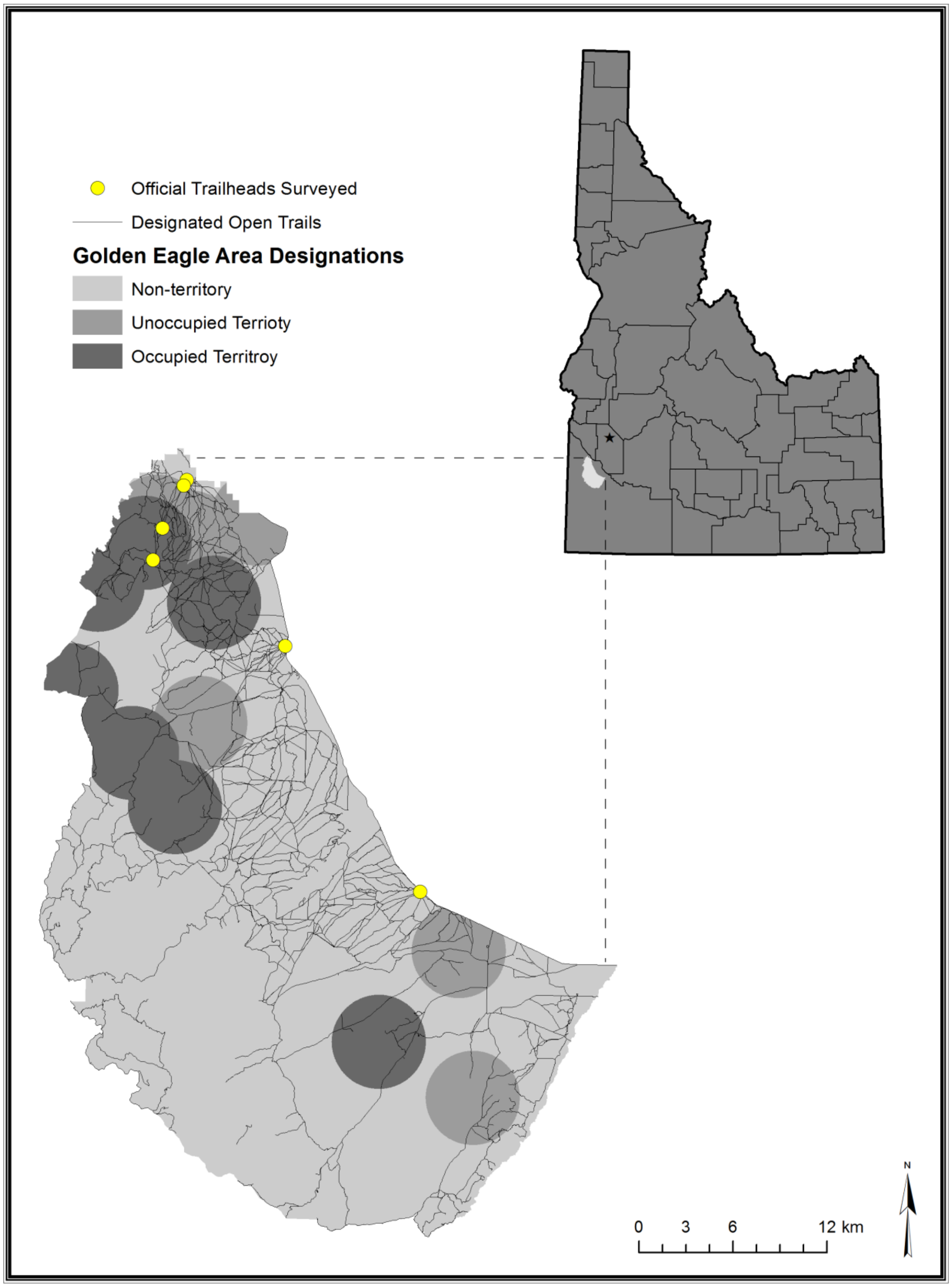

Figure 2.1. The Murphy Subregion of the Owyhee Front Management Area (BLM) located in southwest Idaho, USA. The complex trail system with roughly 1350 km trails open for OHV recreation is shown along with the trailheads surveyed. Area designations for eagle habitat analysis are also shown.

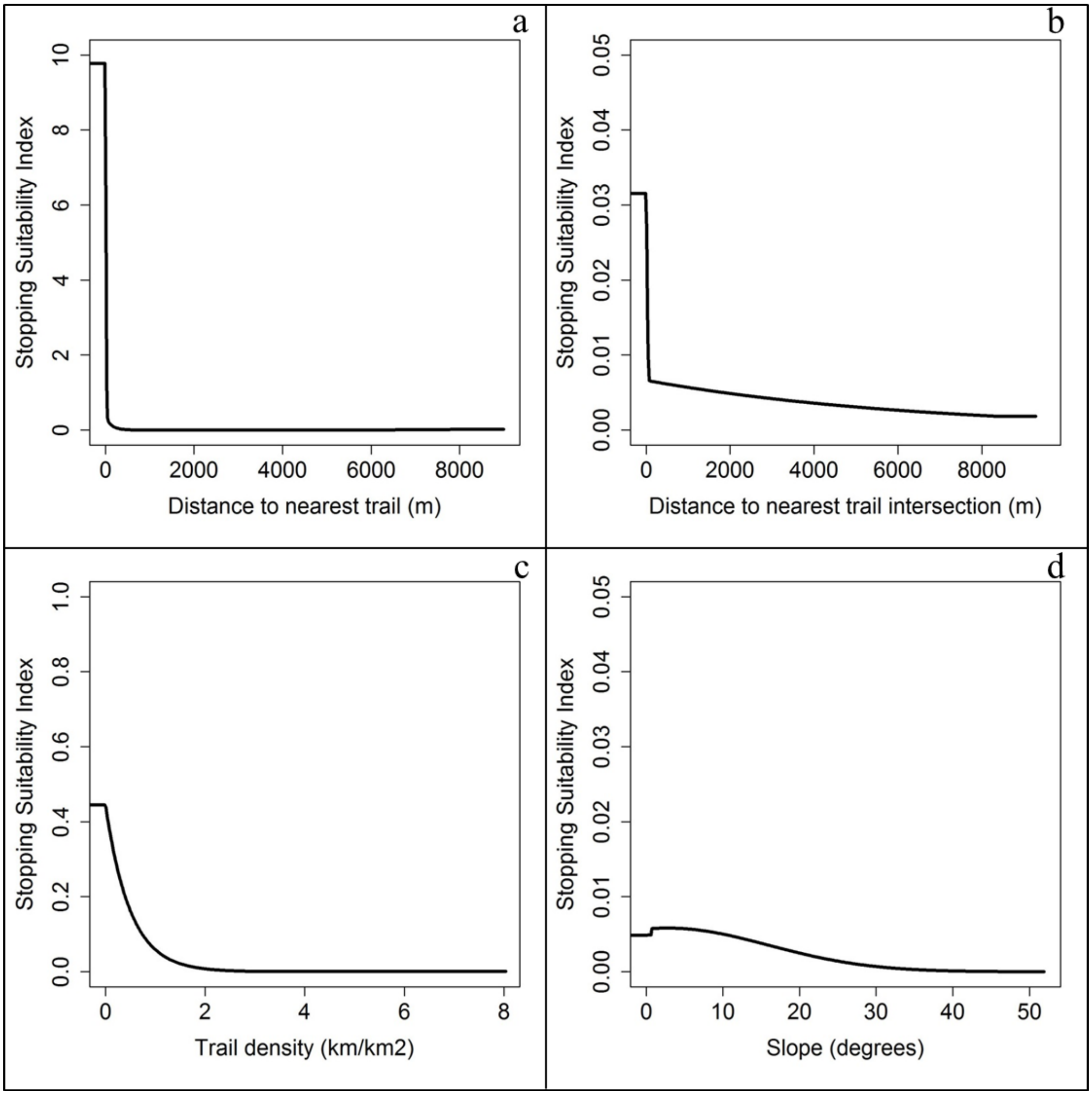

Figure 2.2. Response curves of the four most influential variables when all stopping locations were considered. Graphs show how stopping suitability changes with each variable of interest while all other variables are held constant at their mean values. Stopping suitability values raised by 10^4.

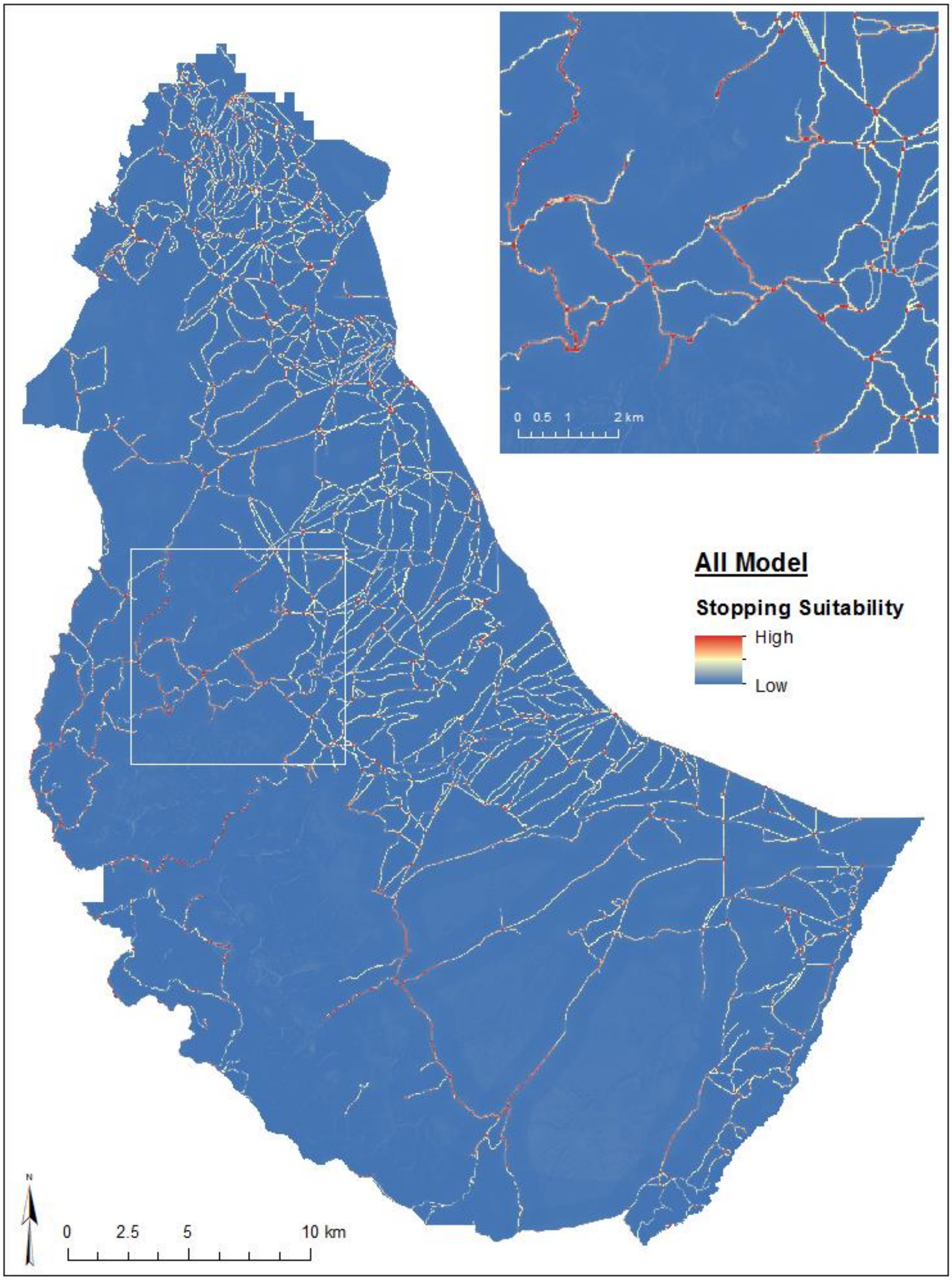

Figure 2.3. OHV stopping suitability map for "All" model in the Murphy Subregion (Owyhee Front Management Area, BLM). Blue represents low suitability areas while red represents high suitability. Inset provided to show detail.

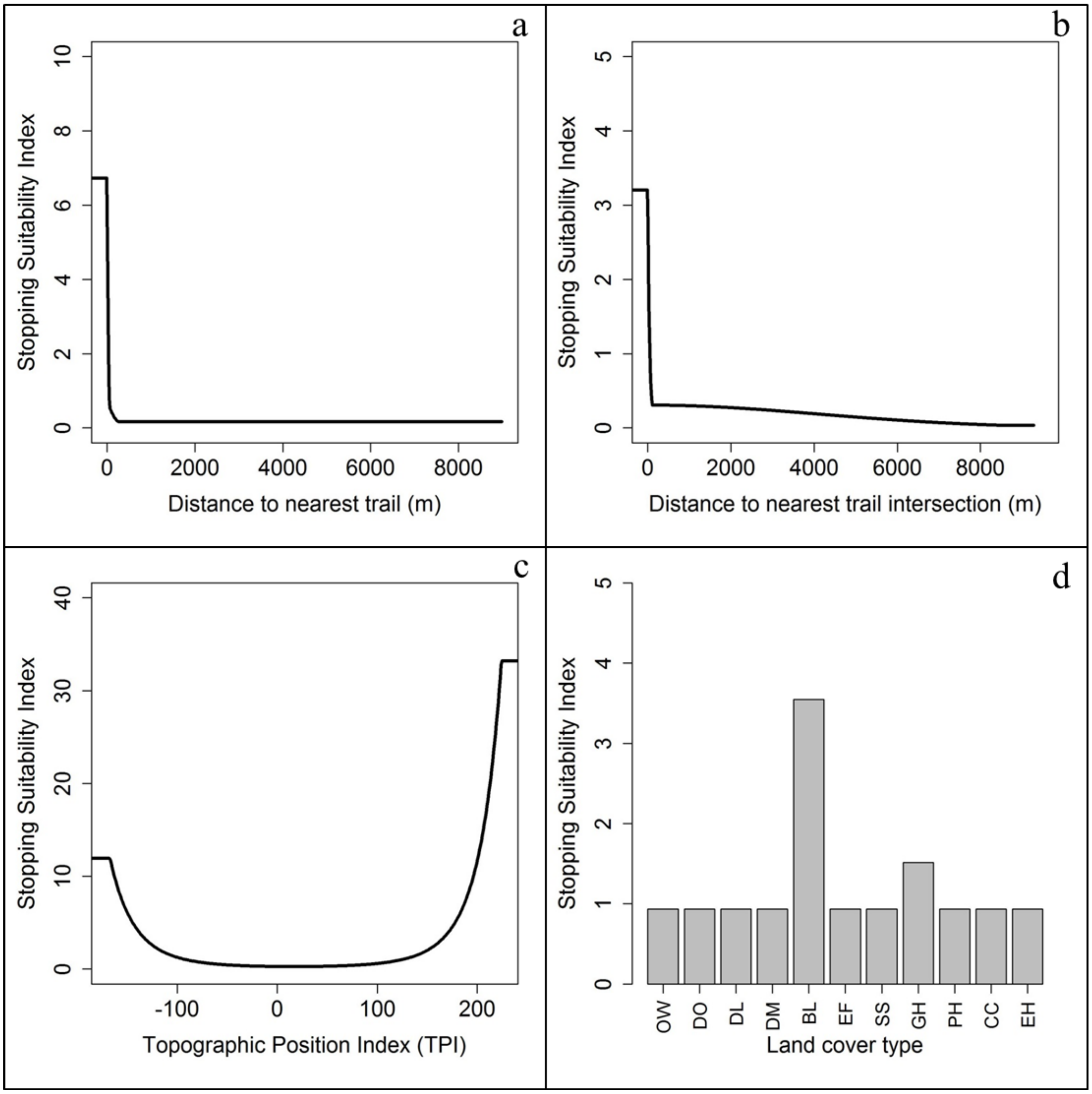

Figure 2.4. Response curves of the four most influential variables when locations with at least five minutes of accumulated stopping time were considered. Graphs show how stopping suitability changes with each variable of interest while all other variables are held constant at their mean values. Land cover types are : overwash (OW), developed open space (DO), developed low intensity (DL), developed medium intensity (DM), barren land (BL), evergreen forest (EF), shrub/scrub (SS), grassland/herbaceous (GH), pasture/hay (PH), cultivated crops (CC), and emergent herbaceous wetlands (EH). Stopping suitability values raised by 10^4.

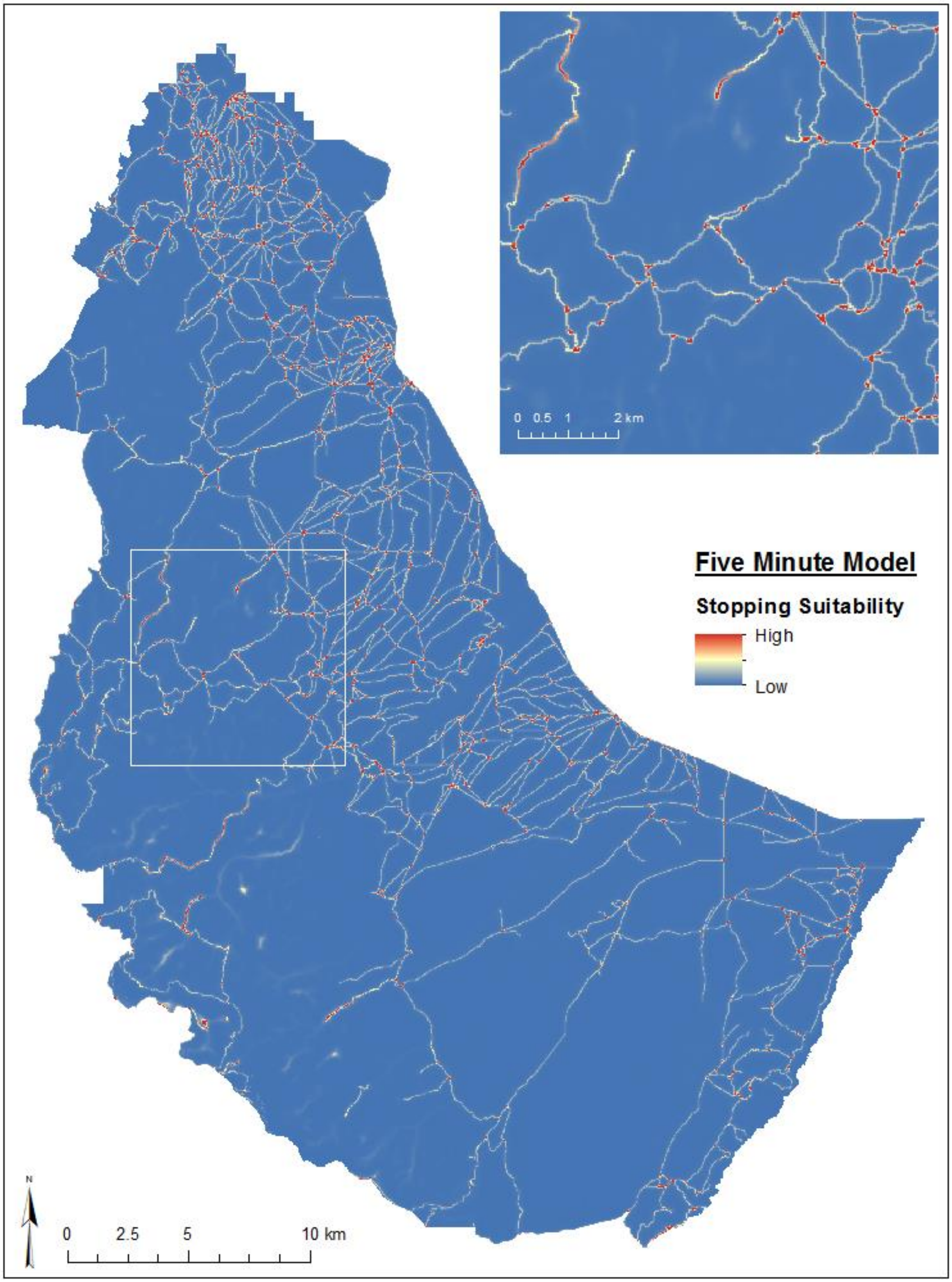

Figure 2.5. OHV stopping suitability map for "Five Minute" model in the Murphy Subregion (Owyhee Front Management Area, BLM). Blue represents low suitability areas while red represents high suitability. Inset provided to show detail.

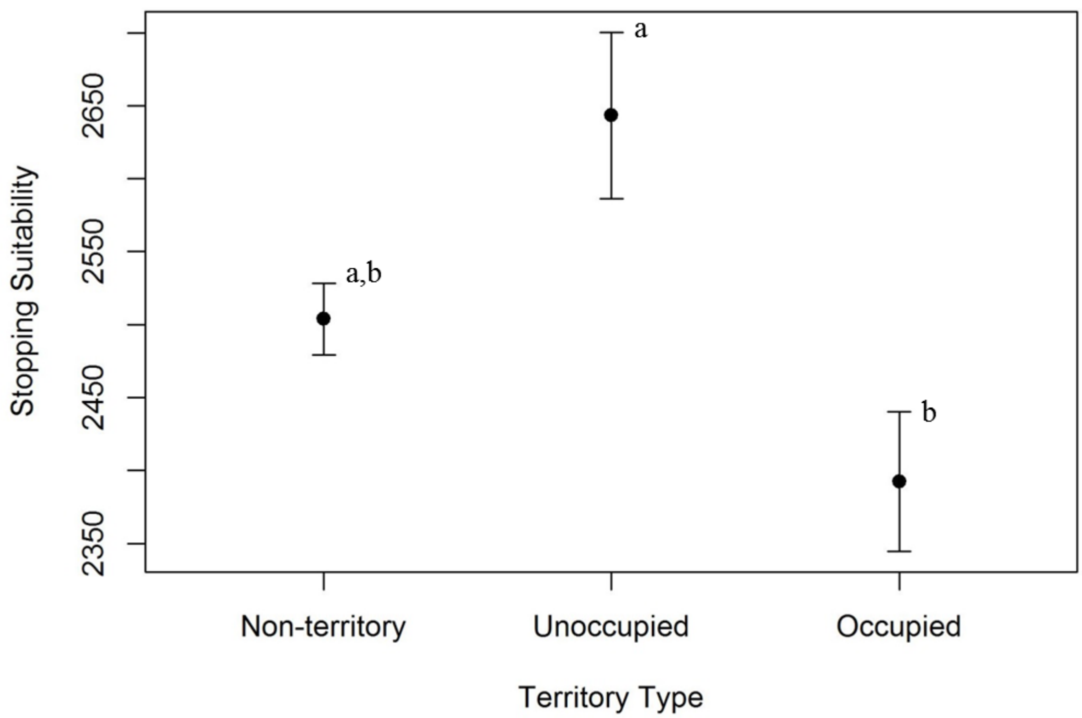

Figure 2.6. Mean ranks and standard error bars for stopping suitability of territory types calculated with the All model. Stopping suitability in unoccupied golden eagle territories was found to be significantly higher than suitability in occupied golden eagle territories (p = 0.0036).

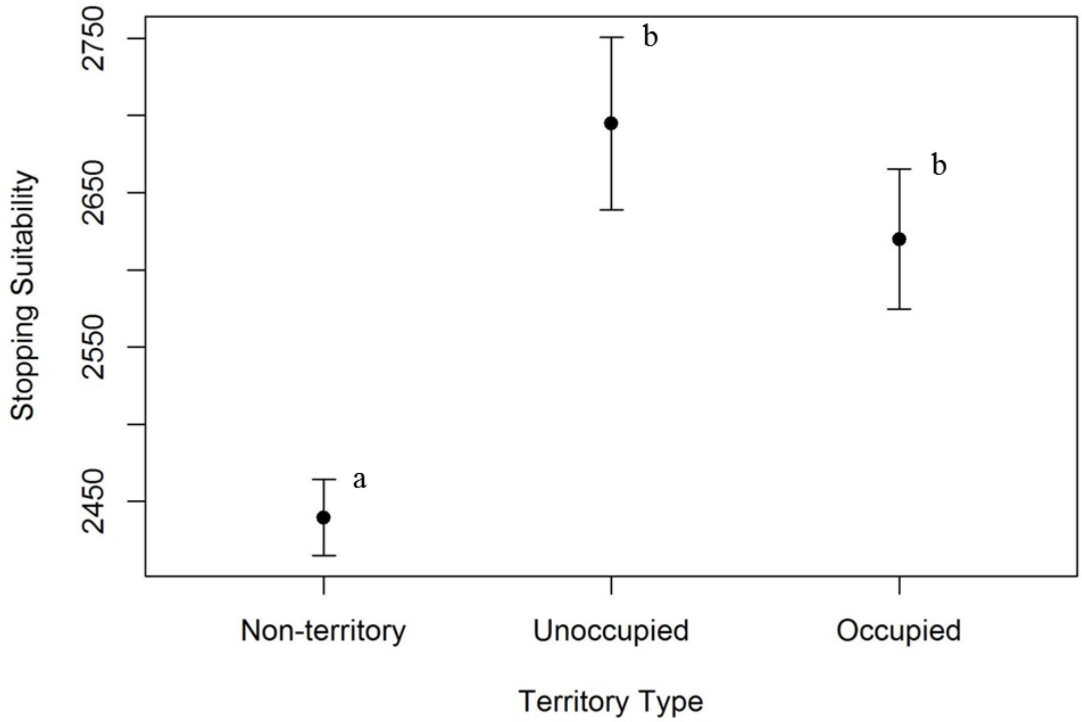

Figure 2.7. Figure 2.6. Mean ranks and standard error bars for stopping suitability of territory types calculated with the 5 Minute model. Stopping suitability in non-territory areas was found to be significantly lower than suitability in both unoccupied ($p = 0.00024$) and occupied golden eagle territories ($p = 0.00289$).

APPENDIX A

Pre-Trip Written Survey

BOISE STATE UNIVERSITY

DEPARTMENT OF BIOLOGICAL SCIENCES

The Recreation Experience in the Owyhees (OHVs)

First, some information about you...

Gender: M F Birth Year: ___________ Zip Code of Residence: ___________

Vehicle Type: ATV UTV (side-by-side) Dirt Bike

How much knowledge do you have of the Owyhee Front area and trail system? 1 none 2 3 average 4 5 a lot

What is your skill level on the vehicle you are riding today? 1 beginner 2 3 average 4 5 expert

How many years have you been riding OHVs in the Owyhees? _________years

Last year (2014), how many days did you ride OHVs in the Owyhees? _________days

Have you previously taken this survey in the past 3 months? Yes No

How important are the following things for you and your group to experience on today's trip?

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

Figure A.1. Pre-trip written survey (front)

Please describe the other people in your group today…

	Gender		Age	Skill Level					Vehicle Type			
1	M	F		1 Beginner	2	3 Average	4	5 Expert	ATV	UTV (side-by-side)	Dirt Bike	None (passenger)
2	M	F		1 Beginner	2	3 Average	4	5 Expert	ATV	UTV (side-by-side)	Dirt Bike	None (passenger)
3	M	F		1 Beginner	2	3 Average	4	5 Expert	ATV	UTV (side-by-side)	Dirt Bike	None (passenger)
4	M	F		1 Beginner	2	3 Average	4	5 Expert	ATV	UTV (side-by-side)	Dirt Bike	None (passenger)
5	M	F		1 Beginner	2	3 Average	4	5 Expert	ATV	UTV (side-by-side)	Dirt Bike	None (passenger)
6	M	F		1 Beginner	2	3 Average	4	5 Expert	ATV	UTV (side-by-side)	Dirt Bike	None (passenger)
7	M	F		1 Beginner	2	3 Average	4	5 Expert	ATV	UTV (side-by-side)	Dirt Bike	None (passenger)
8*	M	F		1 Beginner	2	3 Average	4	5 Expert	ATV	UTV (side-by-side)	Dirt Bike	None (passenger)

*if more than 8 people, please ask for additional sheet

Finally, some general questions about today's trip…

How long do you expect to be out today riding? _________hours ________minutes

Do you have a plan about where you are going? Y N

Thanks for your participation. Have a safe and fun trip today!

Figure A.2. Pre-trip written survey (back)

APPENDIX B

IRB Approval Letter

BOISE STATE UNIVERSITY
RESEARCH AND ECONOMIC DEVELOPMENT

Date: March 07, 2016

To: Eric Frey cc: Kathryn Demps

From: Office of Research Compliance (ORC)

Subject: SB-IRB Notification of Approval for Modification - 028-SB15-043

Factors Affecting Spatial and Temporal Distribution of Off-Highway Vehicle (OHV) Recreation Within a Complex, Open Trail System in Southwest Idaho

The Boise State University ORC has reviewed and approved the proposed modifications to your exempt protocol application.

Protocol Number: 028-SB15-043

Approved: 3/4/2016 Submission Received: 3/2/2016

Review: Exempt

Your research is still exempt from further IRB review and supervision under 45 CFR 46.101(b). This exemption covers any research and data collected under your protocol as of the date of approval indicated above, unless terminated in writing by you, the Principal Investigator, or the Boise State University IRB. All amendments or changes (including personnel changes) to your approved protocol **must** be brought to the attention of the Office of Research Compliance for review and approval before they occur, as these modifications may change your exempt status. Complete and submit a Modification Form indicating any changes to your project.

All forms are available on the ORC website at http://goo.gl/D2FYTV

Please direct any questions or concerns to ORC at 426-5401 or humansubjects@boisestate.edu.

Thank you and good luck with your research.

Office of Research Compliance

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Phone (208) 426-5401 orc@boisestate.edu

This letter is an electronic communication from Boise State University