INTEGRATING SOCIAL DIMENSIONS INTO SPATIAL CONNECTIVITY PLANNING FOR GRIZZLY BEARS

by

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ABSTRACT

In anthropogenic landscapes, which prevail globally, preserving key habitat corridors or routes between wildlife populations is vital for long-term species persistence. Animals moving through these corridors can encounter a number of barriers, including roads, fences, or other human land-uses. Additionally, people unwilling to cohabitate with wildlife can also kill animals considered nuisances or disturb animals in ways that reduce their fitness. The spatial patterns of human tolerance therefore play an important role in the efficacy of habitat corridors. Although there are large bodies of research on habitat corridors and human attitudes toward wildlife, studies that examine the spatial interaction of the two are nonexistent. In this thesis, I examined spatial patterns of two social dimensions, attitudes and behaviors, of ranchers along key dispersal corridors for grizzly bears (*Ursus arctos*) between North American source populations: the Greater Yellowstone Ecosystem and the Northern Continental Divide Ecosystem. I focused on this system because risks from grizzlies on rancher safety and livelihoods exacerbate disagreements among different stakeholder groups on where grizzlies should be allowed to expand and how to manage their populations.

First, I measured acceptance of ranchers toward grizzly bears through a mail questionnaire of 505 respondents. I found that social acceptance was positively related to the area of wildland-urban interface and number of conservation easements in the surrounding landscape, and was negatively related to distance to occupied bear range. Spatial predictions revealed several areas where low acceptance was aggregated within

critical bear habitat corridors, which could potentially act as significant barriers to bear movement (Chapter 1). Next, I investigated spatial patterns of rancher use of four techniques that are meant to prevent conflict with grizzly bears and other predators. Three were methods that prevent mortality - carcass removal, fencing around livestock, and nonlethal techniques (such as fladry or noisemakers) – in addition to use of lethal removal. I found distinct spatial clusters of respondents that used different techniques for living with wildlife. I also found that the use of carcass and lethal removal were negatively related to acceptance for grizzly bears and elk, while use of wildlife-safe fencing was positively related to acceptance (Chapter 2). Combined, these findings provide evidence that examining the spatial patterns of social factors can help to prioritize conservation planning, understand drivers of attitudes and behaviors and move towards coexistence with wildlife.

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Abstract

Maintaining wildlife habitat connectivity is a major conservation challenge. People living within ecological corridors vary in their tolerance and willingness to share landscapes with wildlife, which could have serious implications for animal movement. However, social factors and their spatial patterns are rarely considered when planning for connectivity. To address this knowledge gap, we surveyed 505 ranchers in the High Divide region of Idaho and Montana on their attitudes towards grizzly bears (*Ursus arctos*) – a threatened species heavily dependent on corridors as they expand their geographic range in the Intermountain West. By integrating survey responses with various spatial predictors, we modeled and spatially predicted human acceptance of grizzlies. Acceptance was found to be positively related to the area of the wildland-urban interface and number of conservation easements surrounding respondents' ranches, and negatively associated with increasing distance from current grizzly extent. Our map provides spatially-explicit information for targeted, pre-emptive conflict mitigation and a baseline for examining spatio-temporal changes in attitude as grizzly bear populations expand in the region. Integrating social factors into spatial connectivity planning may alter how organizations approach landowners and allow for a more informed, sustainable approach to connectivity and conservation decision-making.

Introduction

Human land-use development continues to expand into natural areas worldwide to accommodate the growing demands of human populations (Theobald et al. 2016; Venter et al. 2016). To help mitigate human degradation of wildlife habitats, managers and practitioners strive to maintain habitat connectivity by preserving key corridors or routes between wildlife populations to prevent genetic isolation and ensure species survival (Heller & Zavaleta 2009; Krosby, Tewksbury, Haddad, & Hoekstra 2010; Hanski 1998). However, animals moving through land-use mosaics can encounter a number of barriers, including roads, fences, or other human disturbances (Corlatti, Häcklander, & Frey-Roos 2009; Seidler et al. 2015). Animals also alter their behaviors to avoid negative interactions with people, such as shifting their temporal activity patterns to avoid human disturbance (Gaynor, Hojnowski, Carter, & Brashares 2018). For unpopular wildlife or those that can pose risks to human livelihood or safety, encounters with humans can be lethal. For example, illegal killing of carnivores often happens in response to livestock depredation (Creel & Rotella 2010) and even in protected areas, humans cause the largest source of mortality for many species of carnivores (Woodroffe and Ginsberg 1998).

Human intolerance to live with wildlife can therefore significantly affect the function of habitat corridors, for example, by increasing human-caused mortality or decreasing animal fitness by altering their movements. Likewise, people willing to cohabit might be more likely to support conservation policy, allow some level of conflict, or take actions to facilitate animal connectivity, such as enrolling land into a conservation easement that limits human activity on private property (Knegtering, Hendrickx, Van Der Windt, & Uiterkamp. 2002; Miller et al. 2010; Karanth, Naughton-Treves, DeFries, &

Gopalaswamy 2013). Human tolerance (ranging from intolerant behaviors to stewardship) toward wildlife can vary widely between different groups of people, different locations, and even through time (Manfredo 2008; Kansky & Knight 2014; Dietsch, Teel & Manfredo 2016; George et al. 2016). For example, some people are more likely to use conflict prevention techniques while others will lethally remove animals before they cause damage (Marker 2003; Maclennan, Groom, Macdonald, & Frank 2009). The spatial patterns of those variations could significantly influence animal survival and dispersal if intolerant people lie in the path of key ecological corridors. Therefore, determining these spatial patterns is critical for coexistence and connectivity for wildlife in numerous ecosystems (Treves & Bruckotter 2014).

Researchers often use surveys to measure human attitudes toward wildlife, which is considered a reasonably good proxy for acceptance or behavioral intentions (Manfredo, Vaske & Decker 1998; Bruskotter, Vaske, & Schmidt 2015). Several recent efforts have examined the spatial patterns of human attitudes toward conservation or wildlife. For example, Behr, Ozgul & Cozzi (2017) modeled and mapped acceptance towards wolves (*Canis lupus*) to combine with habitat suitability models. Williamson, Schwartz & Lubell (2018) designed a framework for modeling spatially explicit conservation action, demonstrated through adoption of conservation easements in the US west. However, to our knowledge, no studies have incorporated spatial patterns of attitudes toward wildlife into connectivity planning. Yet, a spatial representation allows managers to target specific areas of low acceptance for preemptive conflict prevention, educational outreach and identify areas of high acceptance for habitat improvement programs that facilitate connectivity. Furthermore, examining social acceptance spatially could reveal key insights into the formation and persistence of attitudes towards wildlife in shared landscapes, which prevail globally.

We address this knowledge gap by examining the spatial distribution of rancher acceptance for grizzly bears (*Ursus arctos*) in the High Divide region and comparing it with key predicted dispersal corridors (Peck et al. 2017). The High Divide, along the border of Idaho and Montana, is a mix of grassland and upland forests where public land is interspersed with working ranches; it is also experiencing rapid low-density 'ex-urban' development of the wildland-urban interface (Gude, Hansen, Rasker, & Maxwell 2006; Theobald & Romme 2007). We focus on grizzly bears for three main reasons. First, their protection status has fluctuated recently: the Greater Yellowstone Ecosystem (GYE) distinct population segment, for example, was delisted and relisted as threatened on the Endangered Species List twice from 2005 to 2018 (USFWS 2005; USFWS 2018). Second, their populations are highly susceptible to human-caused mortality given their slow reproduction rates (Bunnell & Tait 1981; Mattson, Blanchard, & Knight 1992). Third, their recovery has been rife with disagreement on where they should be allowed to expand, and how to manage their populations, amidst industry interests and habitat loss (McFarlane, Stumpf-Allen & Watson 2007; Parker & Feldpausch-Parker 2013). We focus on ranchers for two main reasons. First, they are disproportionately affected by grizzly bears, including direct livestock loss from depredation as well as time and money in implementing conflict prevention techniques, such as carcass removal, use of fladry on fences, electric fencing, grizzly-proof storage of livestock feed and range riding (Gunther et al. 2004). Second, private ranching land is one of the largest sources of open space in the US west and plays an important role in preventing development and maintaining habitat connectivity for a number of species (Brunson & Huntsinger 2008).

We sought to answer the questions: what are the spatial patterns of social acceptance toward grizzly bears, and what are their implications on connectivity planning? To address these questions, we 1) modeled social acceptance using aspatial and spatial predictors; 2) mapped social acceptance using spatial predictors; and 3) compared spatial predictions with key grizzly bear corridors. We focus on three explanatory categories of predictors in our model –experience with grizzlies, economic dependency on ranching, and social identity (in relation to conservation) – since they are supported in the literature as important predictors (see Methods for more details), can be spatialized to some degree and are dynamic in changing social-ecological conditions (Shumway & Otterstrom 2001; Kansky & Knight 2014; Lute & Gore 2018). We hypothesized that: 1) negative experiences with grizzly bears are negatively related to acceptance for bears; 2) greater economic dependency on ranching is negatively related to acceptance for bears; and 3) support for conservation in general is positively related to acceptance of bears. Testing these hypotheses allows us to better understand what factors drive the spatial pattern of human acceptance toward grizzlies, and make recommendations for addressing social challenges to promote coexistence between ranchers and grizzly bears. Furthermore, by mapping acceptance, we provide baseline information with which to compare future predictions over time as human populations grow, the wildland-urban interface expands, and grizzly bear distribution and protections change. We found that social acceptance of bears has strong spatial patterning across our study area, highlighting important areas to target interventions. Incorporating social factors into habitat connectivity assessments opens up new opportunities to develop spatial conservation plans that are both biologically critical and socially feasible (Dickman 2010).

Methods

Study Area

The region between the GYE and the Northern Continental Divide Ecosystem (NCDE) in Idaho and Montana, called the High Divide (Fig. 1.1), is comprised of approximately 130,000 km^2 publicly-owned, high-elevation ridgelines interspersed with private property in low-elevation valleys. It is an important region for establishing and maintaining connectivity for many wildlife species, including grizzly bears (Gude et al. 2006). Both ridgelines (forests) and valleys (sagebrush steppe and riparian areas) are ecologically suitable for grizzly bears; however, the risk for conflict with livestock is higher in low-elevations where ranching is common.

Grizzly bear populations in the GYE and NCDE have increased in population and distribution in recent years (Haroldson & Frey 2017). Minimum populations were estimated to be 650 for the GYE and 765 in the NCDE (IGBST 2018). These estimates achieved recovery targets, which prompted the U.S. Fish and Wildlife Service (USFWS) to propose delisting. The most recent delisting of the GYE population in 2017 was remanded by a Montana court responding to lawsuits in 2018, citing unclear impacts of the GYE's delisting on other bear recovery areas (Crow Indian Tribe et al. v. United States of America and State of Wyoming). The order elaborated that USFWS incorrectly cited studies whose conclusions show that genetic exchange is necessary to ensure the GYE population's long-term survival.

Genetic exchange can be achieved for the GYE population through artificial means (relocating bears from other populations) or natural means (reestablishing genetic connectivity). Establishing genetic connectivity will rely on a number of factors, including population density effects, which can trigger male dispersal, and unimpeded movement between the GYE and NCDE. Highways, development, individual bear behavior and the attitudes and behaviors of people living within bear corridors will all play a role in establishing connectivity. Bears are expanding back into portions of their historic range and dispersing individuals are increasingly found between the GYE and NCDE populations (Peck et al. 2017). Yet, 2018 was a record-breaking year for human-caused mortality at 65 bears in the GYE, compared to an average of 48 bears per year from 2010-2017 (USGS 2010-2018). Causes of increased conflict could be a combination of more dispersing bears, a decline of natural food sources, growing human population and infrastructure in the area and increasing intolerance to their presence (Mattson et al. 1992; Gude et al. 2006; Rasker 2008).

Survey Instrument

As part of an inter-disciplinary, multi-investigation research plan, we developed a questionnaire to survey ranchers in the High Divide on their perspectives on land management and conservation (Appendix A). This research was reviewed and approved by the Idaho State University's Institutional Review Board (IRB#280). Our questionnaire consisted of four sections: 'Land management practices', 'Rancher Attitudes and Perspectives', 'Wildlife' and 'You, Your Land Resources and Your Ranching Operation'. Each team member reviewed all survey questions for clarity, double-barreled meanings and language. We used common pretesting techniques to review the final survey instrument including cognitive interviewing (n=5), pilot testing (n= 50) and informal expert review (n=3; Czaja 1998; McColl 2005).

Based on Idaho and Montana cadastral spatial datasets, we created a list of ranches with more than 50 grazing acres to increase the likelihood of selecting only livestock producers. Next, we selected 2400 stratified random ranchers from this list for our sample based on population density of 18 counties. Each person on this list received a unique survey identification number. We deployed the mail survey in January 2018 to the 2400 ranchers. We used a standard three-wave mailing design (Duncan 1979). If returned, respondents were entered into a raffle to win one of two $500 gift cards to Cabela's. We also gave the option of filling the survey out online, which was identical to the mail survey and created in Qualtrics. Two months after the 3rd wave of surveys were mailed, University of Idaho colleagues entered, coded and cleaned the data.

Spatializing Data

To spatialize the data, we linked each respondent to their privately owned parcels. We used partial string matching or 'fuzzy matching' to match patterns between respondent names from the survey and cadastral data names (Dubois, Prade, & Testemale 1988). Fuzzy matching allows the user to define the Levenschtein distance, or how much the pattern can vary to accept a match (Vanallemeersch & Vandeghinste 2014). The remaining respondents that were unable to be matched using this automated method were manually matched using Microsoft Excel. The final spreadsheet contained the list of parcels each survey respondent owned with the survey ID number attached for linking each parcel back to survey responses. We merged this spreadsheet with the Montana and Idaho cadastral shapefiles in ArcGIS to create two spatial datasets with unique ID numbers: one with all 2400 ranchers we sent surveys to and one with only those who responded with complete or partial complete surveys. Names and addresses were removed for confidentiality before sharing the spatial data with the research group.

Developing a Social Acceptance Score

We developed an acceptance score, based on the assumption that individuals with low acceptance could be more likely to behave in a way that impedes bear recovery, such as reporting for relocation, lethally removing (either legally or illegally) or altering their property to deter bears. We used five attitude items (Table 1.1) to develop a social acceptance score (hereafter, acceptance) through an exploratory factor analysis in the *psych* package in the software R (R Core Team 2015; Revelle, 2018). Factor analysis is a data reduction technique often used to characterize a complex latent factor, such as acceptance toward wildlife. It uses multiple survey items (Costello & Osborne 2005) that capture different aspects of the same latent factor (e.g., Carter et al., 2013; Graves, Pearson & Turner 2014). We used the Cattel's scree test to determine number of factors present (Cattell 1966). Each question can load onto the factor positively or negatively and each individual receives a score for how their responses placed along that factor. We used an oblique rotation, promax, which allows items to be correlated to one another, compared to orthogonal rotations, such as varimax, that assume independence among items (Abdi 2003). We calculated scores for each individual using the Bartlett approach, which is most likely to represent "true" scores (DiStefano, Zhu, & D. Mîndrilă 2009). We merged each score with the parcels the respondent owned in the spatial dataset. This acceptance score was used as the dependent variable in our models.

<u>Selection of Predictors</u>

Attitudes and behaviors are formed through feedbacks between behavioral (e.g., actions), cognitive (e.g., beliefs and emotions), and environmental (e.g., social norms) factors (Bandura 1977). Therefore, based on these factors, our knowledge of rancher relationships with predators, and our goal to spatialize acceptance we selected three explanatory categories from which to draw predictors of attitude formation: experience with bears, economic dependency on ranching and social identity in relation to conservation.

Behavioral factors are important in forming and strengthening attitudes (Ajzen 1991). We expect ranchers who have more negative experiences with bears to have lower acceptance due to more exposure and repeated actions regarding bears and conflict. Direct experience, including encounters and interactions, is typically a significant predictor for attitude towards large mammals, although it is rarely applied in attitude studies (Kansky and Knight 2014). Eriksson, Sandström & Ericsson (2015) found that direct experience with bears and wolves was correlated with a lower level of support for their conservation. The type and intensity of experience with wildlife is also important as more negative or positive experiences typically lead to stronger attitudes (Glasman and Albarrac'in 2006; Heberlein 2012). Therefore, we asked ranchers two questions about their experiences with bears using binary and categorical responses (Table 1.3). The categorical question asked ranchers whether their experience was positive or negative (along a 5-point Likert scale). We coded respondents who had no experience with bears as zero in this predictor. Spatially, we measured experience through distance to current occupied bear range, a common proxy for experience (Table 1.4; Kansky & Knight

2014). This predictor assumed that ranchers living within bear range would have a greater frequency of negative encounters with bears than those who live farther away. Last, we extracted mean elevation values for each respondent. Grizzly bears sometimes move longer distances and seek lower elevations when natural food sources, such as whitebark pine seeds, are scarce (Mattson & Knight 1989). Because of this and possibly unexplained factors, conflict between grizzly bears and livestock is common at lower elevations (Wilson et al. 2005; Northrup, Stenhouse & Boyce 2012). Ranchers living at different elevations might have varying levels of experience with bears and conflict that influence their levels of acceptance.

Cognitive factors related to emotions, knowledge and beliefs play a role in forming attitudes (Bruskotter, Vaske, & Schmidt 2009). While emotions like fear and reverence likely influence ranchers' attitudes towards grizzly bears, these concepts are difficult to measure spatially. We expect that ranchers with more to lose financially will have stronger emotional responses and therefore lower levels of acceptance towards bears. Acceptance towards wildlife is usually lower when people have an economic dependency on the industry involved in conflict with those animals (Vaclavikova, Vaclavik, & Kostkan 2011; Hazzah, Borgerhoff, & Frank 2009; Delibes-Mateos, Díaz-Fernández, Ferreras, Viñuela, & Arroyo 2013). We also expect ranchers who rely on grazing their livestock on public land to perceive greater risks from bears, since public lands are more likely to support predators. Therefore, we asked ranchers about their economic dependency on ranching and their dependency on public land. Spatially, we used median income level per census block from the 2010 census and distance from federal or state publicly owned land. We expect acceptance to be higher farther away from public land. Income at the census level does not allow us to differentiate the source of income. However, given the high rate of amenity-driven immigration to the High Divide (Gude et al. 2006), we expect that much of the higher levels of income are from non-ranching sources and predict a positive relationship with acceptance (Nelson 1999). While not perfect metrics for dependency on ranching and public land, we expect that both will capture some of this variance related to economic dependency and risk perception toward grizzly bears.

Environmental factors such as social norms, conditioning or community engagement, influence attitudes and behaviors (Zinn, Manfredo, Vaske, & Wittmann 1998; Treves & Bruskotter 2014). Predator conservation and management is a polarizing topic and differences between rancher social groups likely influence an individual opinion through varying group norms (Dickman, Marchini & Manfredo 2013). Wildlife value orientation is probably similar within social groups, therefore it could provide clues to ranchers' social identity (Fulton, Manfredo, & Lipscomb, 1996; Kellert 1994). Furthermore, attitude towards other species or concepts like conservation are likely driven by values towards wildlife in general and have been important predictors for attitudes towards large mammals in the past (Kansky & Knight 2014). We asked ranchers several questions related to elk and to conservation in general and conducted two exploratory factor analyses to measure acceptance towards both. We also asked whether ranchers enrolled their land in a conservation easement agreement.

To capture these factors spatially, we compiled elk harvest statistics from 2017 for Idaho and Montana (summarized by hunter unit and harvest using any weapon), the number of conservation easements for the study area and the area of wildland-urban interface (WUI; IDFG 2017; MFWP 2017; Graves, Williamson, Belote, & Brandt 2019; Radeloff et al. 2005). These spatial predictors capture the actions of individuals who live near the ranch and assume that there is some spatial clustering of various social groups. WUI is the area where low to medium density housing meets wild, undeveloped land (Theobald & Romme 2007). In the High Divide, most housing is considered low to medium density, so there are greater amounts of WUI where population density is higher (Radeloff et al. 2005). More isolated, or rural areas, tend to have higher proportions of residents with utilitarian or "traditional" values towards wildlife (Manfredo, Teel and Bright 2003; Kleiven, Bjerke, & Kaltenborn 2004). Therefore, we expect to see higher levels of acceptance in areas with higher amounts of WUI because more densely populated areas could be socially different from sparsely populated areas (Glenn & Hill 1977; Scala & Johnson 2017). See Tables 1.3 and 1.4 for full survey questions and further justification for spatial predictors. Appendix A contains the entire questionnaire.

Modeling and Spatial Prediction

We measured spatial autocorrelation with the global Moran's index *I* of acceptance and used this information to inform the resolution at which we extracted spatial predictor values (Moran 1950). Moran's *I* requires the user to define neighborhoods at which individuals influence one another. Without a-priori knowledge of neighborhoods in our survey area, we measured Moran's *I* with distances ranging from 1 km to 21 km at increments of 2 km. Each spatial predictor was clipped to the study region, converted to rasters, projected to USA Contiguous Albers Equal Area Conic projection, and resampled at a resolution of 300 m^2 - the most common resolution among the predictors that retained details for fine scale layers, such as elevation.

We calculated the mean of each predictor within 7 x 7 km cells that were arrayed in a grid covering the whole study area. We chose this cell size because Morans *I* effects peaked at 7 km (p-value = 0.04), allowing us to address spatial autocorrelation effects. It also allowed each cell to contain a single ranch for many ranchers in the study area (Table 1.2). Many of the ranchers in our survey owned more than one parcel of land, but most owned fewer than 5 parcels (68%). We assigned ranchers to the 7 x 7 km cell where they owned the most land. We checked for multicollinearity among predictors using variance inflation factors (VIF) and correlation matrices, where values over 5 and 0.6, respectively, resulted in dropping a predictor.

All predictors were scaled by dividing inputs by two standard deviations using common techniques (Gelman 2008). We modeled each set of aspatial and spatial predictors separately in multiple linear regressions assuming Gaussian distributions. Modeling spatial predictors separately allowed us to spatially predict acceptance (Obj. 2) and evaluate the utility of this approach for future applications. We assessed each predictor by its effect sizes, 95% confidence intervals and significance and compared spatial and aspatial models using R^2.

We predicted acceptance spatially by mapping model predictions using the package *raster* at a resolution of 300 m^2. This function generates a continuous prediction using spatial predictor layers as inputs for new data in areas where we have no data on the response variable. We examined residuals using Moran's *I* and visual inspection of mapped residuals to ensure that spatial autocorrelation was adequately addressed in the model. We assessed predictive ability of the spatial model using 5-fold cross validation and assessing root mean square error (RMSE) and normalized RMSE (RMSE / (Y_{max} –

Y_{min}). We also summarized raw acceptance and predicted acceptance by means per county. To simplify visually, we provided dichotomous maps of mean positive and mean negative acceptance and created a final map highlighting counties that predicted the wrong sign.

We compared acceptance to predicted grizzly bear paths (Peck et al. 2017) by restricting acceptance to the paths for visual inspection and by summarizing acceptance as high, medium and low within and outside each path. We binned acceptance by multiplying the standard deviation by 0.25, then subtracted this value from the mean to obtain the threshold for setting 'low' scores and added it to obtain the threshold for setting 'high' scores and scores between high and low were coded as 'medium'. All data preparation and analyses were conducted in R (R Core Team 2015).

Results

<u>Survey Responses</u>

We received responses from 724 ranchers for a response rate of 30%. Some participants did not fill out the survey completely, and of those, 505 ranchers fully completed the section asking questions about grizzly bears. For the aspatial analysis, 371 ranchers completed the 5 grizzly-related questions and the questions we used as predictors. Based on factor loadings, we identified a single latent factor representing acceptance towards grizzlies. The score ranged between -1.36 and 2.49, with lower scores indicating lower acceptance and higher scores indicating higher acceptance (Fig. 1.2). The factor analysis of the predictor conservation acceptance revealed one latent factor where negative attitudes towards conservation scored positively so we reversed the sign on each score for ease of interpreting this factor as a conservation acceptance score (-2.55

= low; 2.60 = high). Elk acceptance also revealed one latent factor, although responses supportive of elk loaded positively on this factor (-2.58 = low; 1.57 = high).

Aspatial and Spatial Models

For the aspatial model, predictors related to social group had the top two largest effect sizes, both positive relationships (elk acceptance = 0.39, SE=0.06, and conservation acceptance = 0.25, SE = 0.05; Table 1.6 and Fig. 1.3). The next largest effect size was economic dependency, which had a negative relationship with acceptance (-0.20, SE=0.04). We modeled acceptance aspatially with the binary experience predictor and the type of experience predictor separately because they were highly correlated. We chose the model that included type of experience because it was more significant and had a larger effect size (0.10, SE = 0.02). Dependency on public land had a negative relationship at -0.06, SE = 0.02. Use of a conservation easement had a positive relationship but low significance (0.11, SE=0.09).

For the spatial model, we found that distance from bear range was negatively related to social acceptance (-0.10, SE=0.05) (Karlsson and Sjöström 2007; Table 1.6 & Fig. 1.4). In other words, as the distance that ranchers lived from current occupied grizzly range increased, the lower their acceptance towards bears. Income at the census block level was negatively related to acceptance. Area of WUI (0.11, SE=0.09), number of conservation easements (0.10, SE=0.05), number of elk harvested (0.03, SE=0.05) and elevation (0.10, SE=0.03) had a positive relationship with acceptance. Distance to public land (-0.02, SE=0.05) and income had negative relationships (-0.07, SE=0.05). We found that high values of predicted acceptance tended to be within predicted paths (56%) more so than medium (30%) and low values of acceptance (14%; Table 1.8). Outside of paths, medium levels of acceptance were highest (40%).

The aspatial model explained more variance than the spatial model (Multiple R^2 = 0.60 and 0.15, respectively). Spatial distribution of model residuals was random which suggests that either we accounted for the weak autocorrelation by selecting an appropriate grid size or autocorrelation was too weak to affect residuals (Moran's *I*: -0.7437; p-value =0.4571). RMSE from 5-fold cross validation was 0.92 and normalized RMSE was 0.23, or 23% of the range 3.85. By averaging actual and predicted acceptance for each county, we found that we identified the correct sign for 11 of 15 counties (Table 1.7). The three highest differences in average acceptance per county were 0.99, 0.49, and 0.34, with only one of those (0.34) predicting the wrong sign (Fig. 1.6).

<u>Prediction and Spatial Overlap</u>

Predicted acceptance showed a strong East-West gradient, with highest areas of acceptance near the GYE and major towns (Figure 1.4). The areas of lowest predicted acceptance were concentrated around Salmon, Idaho. There were concentrations of low acceptance spanning large sections of grizzly corridors. The path moving through the southwestern region of the study area (near Salmon, Idaho) contained the highest densities of low acceptance values. Visually, the spatial model predicted acceptance to be high in counties with high average acceptance, and low in counties with low acceptance.

Discussion

Spatial information of human acceptance towards wildlife is often lacking but is critical for coexistence and connectivity in many ecosystems. Our spatial model revealed relatively strong relationships between acceptance and the amount of WUI, distance to occupied bear range, and number of conservation easements surrounding ranches. These relationships suggest that attitudes towards wildlife interact with space in compelling and relatively unexplored ways. The spatial location of a ranch might influence a rancher's attitude through differences in exposure to grizzly bears, social group membership or risk perception related to economic vulnerability. For example, ranchers who have many neighbors who choose to enlist land into a conservation easement might influence an individual's acceptance towards wildlife. Brain, Hostetler & Irani (2014) found that ranchers were significantly more likely to enroll their land into a conservation easement if their neighbors, family members, or other influential members of their ranching group viewed conservation easements positively. Social groups tend to vary spatially and our results indicate that WUI could be one metric for measuring those differences spatially (Glenn & Hill 1977). Furthermore, attitudes towards wildlife might also influence location choice when a rancher chooses to buy property (Gosnell & Abrams 2011). Possibly, ranchers living near the GYE and NCDE are more willing to accept wildlife-associated costs as a trade-off for enjoying the natural amenities of these ecosystems. Both situations are probably true in various situations or at the same time. Although our analysis is unable to elaborate further on the mechanisms at work, these novel relationships would have been missed in aspatial-only models.

Spatial patterns of acceptance provide vital information to compare with ecological corridors. Acceptance was lowest across most of the southwestern path. This path was predicted to have a relatively low amount of bear movement, but Peck et al. (2017) caution against disregarding it. This path contains the most contiguous, protected habitat in the region. It also connects the GYE and NCDE to the currently unoccupied SBE (Fig. 1.1). It is likely to be an important route towards bear recovery for connectivity and reestablishing a population in this important recovery area.

The middle of each path had mixed low and high acceptance (Fig 1.5). Ranches in the center of the study area are farther from bear range and ranchers likely have less experience on their ranch with bears. Direct experience, especially positive or negative experiences, help to strengthen attitudes. A community of mixed and indefinite attitudes towards bears might be driven by a lack of direct experience. These are important ranches to target for acceptance improvement toward bears because more loosely held attitudes are much easier to influence than stronger attitudes (Fazio & Zanna 1981). Moreover, ranchers inexperienced with bears in this region could benefit from positive personal experience with conflict prevention techniques to prepare for future dispersing animals.

In the aspatial model, type of experience with bears was positively related to acceptance. Particularly, very negative and very positive experiences with bears led to low and high scores, respectively. Distance to occupied grizzly range, a common proxy for experience, was negatively related to acceptance. We would expect ranchers living near grizzly bears to experience both costs and benefits related to their presence (i.e., damage to property risks, and economic benefits related to tourism). We predicted a negative relationship because of these costs and the risk related to conflict. However, these conflicts are rare and when they do occur, human injury or property loss is rarer still and can be compensated with sufficient evidence. One possible explanation is that those with more experience with conflicts, either directly or indirectly through social learning, have less fear of bears. Psychologists hypothesize that fear of the unknown is the strongest fundamental fear, as opposed to fear of death or pain (Carleton 2016). Zimmermann, Wabakken & Dötterer (2001) found that fear towards re-establishing brown bears and wolves were highest before carnivore arrival, and dissipated over time as experience with them increased. Distance from bear range could be capturing an emotional response if this relationship draws from fear of the unknown.

If this predictor does not accurately represent experience with bears, there are two other possible explanations. First, this variable could be compensating for a missing variable in the model, such as tourism. Tourism is concentrated near GYE and NCDE, where acceptance was higher. A spatial metric for ecotourism would have been beneficial in our analysis since this could represent a key economic benefit towards living with grizzly bears. A second possibility is that some respondents feared their responses would be used as evidence to support a grizzly reintroduction if they were accepting of bears. The location farthest from bear range in our study area is near the Bitterroot Ecosystem Recovery Area. In 2000, USFWS released a plan to reintroduce grizzly bears to the ecosystem by relocating 5 bears each year for 5 years to begin the goal of reaching 200-300 bears in this ecosystem (USFWS 2000). The plan was controversial and led to an Idaho State lawsuit (Smith 2003). Interviews with locals revealed that though the reintroduction had widespread public support, local groups with land-based income, particularly ranching interest groups, strongly opposed the plan (Velado 2005). For some respondents, the grizzly reintroduction plan, and likely the backlash to the gray wolf reintroduction, is likely not far from memory. Some groups that may be accepting toward the species are much less accepting toward reintroduction which can be seen as the urban populous or federal government forcing their decisions on rural communities (Clark et al. 2002). If grizzly bears are to recolonize the Bitterroot Ecosystem, the most socially feasible method might be through natural dispersal. Future efforts that examine social factors spatially should be explicit in their questions on acceptance towards reintroduced versus naturally occurring organisms to prevent such ambiguity.

Most ranchers in our survey lived in an area with some amount of WUI and higher acreage of WUI was present in more populated areas of our study region since most housing was categorized as low density (Radeloff et al. 2005). Place of residence, especially in terms of urban-rural differences, seems to have implications for attitudes towards environmental variables (Corral-Verdugo 2003; Berenguer, Corraliza, & Martin 2006), though this is not always the case (Arcury & Christianson 1993). Areas of higher WUI could be associated with a different sense of community, lower perceived risk from predator damage or differing information sources (Pahl 1966; Corbett 1992; Miller and Crader1979; Thornton & Quinn 2009). Alternatively, an ecological explanation for this relationship might be that ranchers living in more isolated areas, or lower acreage of WUI in our study area, could have more direct, negative experiences with predators. Isolated ranches surrounded by wilderness are likely to have more interactions with wildlife (Nielsen, Boyce & Stenhouse 2004), but given the other finding that experience tends to be associated with higher levels of acceptance this explanation seems less likely. Development, and in particular, low-density exurban housing in the High Divide is growing rapidly. Explanations for social differences along the gradient of WUI and population density are of interest not just for wildlife managers, but those interested in wild fire management and prevention.

Acceptance towards another species (elk) and conservation in general were the strongest predictors for grizzly acceptance in our aspatial model. Use of a conservation easement was also positively related to acceptance. Furthermore, we found a positive relationship between number of conservation easements surrounding the ranch and acceptance. This suggests that even if ranchers do not enroll their own property into an easement, having many neighbors with easements influences their attitude. These results are not unexpected but do provide support for the utility of conservation easements. Since conservation easements agreements typically minimize human development on private land, they could be important for reestablishing connectivity, especially if landowners with easements are more tolerant towards bear presence.

An economic dependency on ranching was negatively related to acceptance. This aligns with literature in that those who rely on their ranch for income have more to lose from costly interactions with predators (Table 1.6; Vedeld et al. 2004). Likewise, we found a negative relationship between public land dependency and acceptance consistent with predictions. However, spatial relationships for both income at the census block level and distance to public land were weak. This suggests that income at the census level block and distance to public land might not be accurate proxies for the relationship between acceptance and economic dependency on ranching.

A region predicted to have high levels of acceptance does not necessarily mean it will be void of individuals with strongly negative intentions towards bears. Rather this map captures the general trend of acceptance throughout the High Divide. Furthermore, attitude does not necessarily predict behavior (Heberlein 2012). To understand how individuals will behave towards bears, even those who feel strongly in support or opposition of predator recovery, other situational factors should be considered. In both aspatial and spatial analyses, a large degree of variance remains unexplained. Because of our focus on variables that could be spatialized, we suspect that a portion of the unexplained variance is related to factors that we did not currently have spatial data for. Development of spatial datasets that capture a wider range of human responses to wildlife would be an exciting, and important, area of future work. For example, spatializing emotional responses through use of social media, spending behavior or social networks.

Management Recommendations

The northeastern most path (Fig. 1.5) was predicted to have high levels of acceptance and also high levels of bear passage (Peck et al. 2017). However, this also means bears have to contend with higher densities of people since this route falls closely to Helena and Bozeman, Montana. Effort for habitat improvement and particularly mitigating effects of human impact will be important for facilitating bear movement along paths where social and ecological suitability is high. While lack of acceptance in the western part of the region is prevalent, changing attitudes towards wildlife, especially strong negative attitudes, is complex and unlikely (Bright et al 1993). Efforts should instead focus on preparing ranchers in this region with conflict prevention resources to prevent eroding minimal support even further from future bear damage. Improving acceptance towards grizzly bears is probably more feasible in the center of the study area where attitudes were mixed (Fig. 1.5). Because of the importance of the messenger in relaying information meant to change attitudes, we recommend workshops and information sessions led by ranchers who live with grizzly bears in regions that do not yet experience large amount of bear travel. Acceptance of a species may not directly correlate to how a rancher will behave towards grizzly bears, but it can have significant implications in how and where managers approach communities of ranchers in grizzly bear recovery efforts.

Social acceptance plays an important but underexplored role in grizzly bear conservation and recovery. Understanding the drivers of attitude towards wildlife, while essential for building theory, is only the first step towards operationalizing social factors for management. Quantifying, predicting and mapping acceptance towards wildlife will advance the theory and practice of coexistence in shared landscapes.

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TABLES

Table 1.1. Attitude items used in a factor analysis to develop the "Social Acceptance Score" for grizzly bears for each of the 524 ranchers that completed the mail questionnaire.

Survey Question
The grizzly population in my county should be decreased greatly, decreased somewhat, remain the same, increased somewhat, increased greatly
I am in favor of programs that promote connected habitat for grizzly bears between public & private lands.
I am in favor of grizzly bear recovery to their former range in Idaho and Montana.
Grizzly bears belong only on public lands.
Where I live, grizzly bears and livestock can coexist.

Table 1.2. Numbers and percentages of ranchers within grid cells.

Number of Ranchers per Cell	Percentage of Cells
1	20%
<4	51%
>5	17%

Table 1.3. Aspatial predictors for rancher acceptance of grizzly bears, with corresponding survey question, response options. Likert 5-point scale refers to one question, type of experience: very negative, somewhat negative, neither negative or positive, somewhat positive, very positive. Likert 4-point refers to several questions: strongly disagree, disagree, agree, strongly agree.

Survey Variable	Survey Question	Response Options
Experience	Have you had experience with grizzly bears?	Yes/no
Type of experience	If yes, please indicate whether that experience was positive or negative.	Likert 5-point
Economic depedency	My family's livelihood depends on the productivity of my ranch.	Likert 4-point
Public land dependency	If grazing on public land was not allowed, my ranching operation would be significantly impacted.	Likert 4-point
Conservation acceptance	I am responsible for conserving nature.	Likert 4-point
	How land is used should be determined only by the person who owns it.	Likert 4-point
	I think my land should be used to provide environmental benefits to the region.	Likert 4-point
	I think my land should only be used to benefit myself or my family.	Likert 4-point
	The actions I take on my land have little impact on regional environmental problems.	Likert 4-point
Elk acceptance	Elk only belong on public lands.	Likert 4-point
	Where I live, elk and livestock can coexist.	Likert 4-point
	I think my privately owned land should be used to connect elk habitat between public lands.	Likert 4-point
	I am in favor of programs that promote connected habitat for elk between public & private lands.	Likert 4-point
Conservation easement	Indicate whether you voluntarily use a conservation easement.	Use/do not use

Table 1.4. Spatial predictors for acceptance, justification for inclusion and sources.

Spatial Variable	Justification for Inclusion	Source
Area of Wildland-Urban Interface (WUI)	People living within the Wildland-Urban Interface are the closest land cover type to undeveloped wilderness. They are more affected by wildfire and are most likely to affect wildlife (1, 2, 3). It might be that living closer to wild areas affects attitude toward wildlife as well.	Radeloff et al. 2005
Distance to occupied bear range	Distance to a species current range is often used in attitude studies as people living with or near the animals are likely to have a different perception of them due to either experience, knowledge or values (4).	The Interagency Grizzly Bear Study Team Grizzly Distribution Greater Yellowstone Ecosystem: 2002-2016; Montana Fish, Wildlife and Parks Northern Continental Divide: 2004-2014
Distance to public land	Many ranchers rely on public land for grazing their livestock. Livestock living near public land is likely to experience more interactions with wildlife (5, 6).	USGS PAD-US 1.4
Elevation	A control variable. Ranching is more common in lower elevations; wildlife corridors are more common in higher elevations (7)	USGS FRESC Digital Elevation Model
Number of conservation easements	People with more favorable attitudes towards wildlife and wildlife management are usually more willing to put their land in conservation easement (8). It could be that communities with higher densities of conservation easements are likely to place a higher value on wildlife.	Graves et al. 2019
Number of elk harvested	Elk harvest rates are set based on elk population so areas with higher harvest rates and differing values towards elk. Elk hunting can support a variety of hunters and possibly different wildlife values.	Montana Fish Wildlife & Parks and Idaho Department of Fish and Game
Median household income	Financial costs are a top concern for managing landscapes with carnivores (9).	U.S. 2010 Census

(1) Hammer, Stewart & Radeloff 2009 (2) Kertson, Spencer, Marzluff, Hepinstall-Cymerman & Grue 2011 (3) Lee & Miller 2003 (4) Kansky & Knight 2014 (5) Brunson & Huntsinger 2008 (6) Fleischner 1994 (7) Noss, Carroll, Vance-Borland, & Wuerthner 2002 (8) Willcox, Guiliano, & Monroe 2012 (9) Dickman 2010

Table 1.5. Hypotheses and predictions for spatial and aspatial model predictors.

Hypothesis	Predictor	Model	Predicted Relationship
Negative experience with grizzly bears decreases acceptance for bears.	Experience with bears	Aspatial	(-)
	Type of experience: negative to positive	Aspatial	(+)
	Distance to bear range	Spatial	(+)
	Elevation	Spatial	(+)
Economic dependency on ranching decreases acceptance for bears	Economic dependency	Aspatial	(-)
	Public land dependency	Aspatial	(-)
	Income	Spatial	(+)
	Distance to public land	Spatial	(+)
Social group influences acceptance for bears.	Conservation acceptance	Aspatial	(+)
	Elk acceptance	Aspatial	(+)
	Conservation easement use	Aspatial	(+)
	WUI	Spatial	(+)
	Elk harvest	Spatial	(+)
	# conservation easements	Spatial	(+)

Table 1.6. Parameter estimates for modeling social acceptance of grizzly bears aspatially (n= 371) and spatially (n= 505) using scaled predictors.

Model	Predictors	Estimate	SE	P-value
Aspatial	*Elk acceptance*	0.39	0.06	<0.001
	Conservation acceptance	0.25	0.05	<0.001
	Economic dependency	-0.20	0.04	<0.001
	Experience type	0.10	0.02	<0.001
	Public land dependency	-0.06	0.05	0.01
	Easement use	0.11	0.09	0.23
Spatial	*WUI area*	0.11	0.05	0.01
	Distance to bear range	-0.10	0.05	0.03
	Elevation	0.10	0.05	0.05
	# Easements	0.10	0.05	0.06
	Income	-0.07	0.05	0.12
	Elk harvest	0.03	0.05	0.48
	Distance to public land	-0.02	0.05	0.48

Table 1.7. Averaged actual and predicted acceptance per county in the High Divide. Difference is the absolute value between predicted and actual. Sign change indicates whether the model predicted the wrong sign at the averaged county level.

County	State	Mean Acceptance	Predicted Acceptance	Difference	Sign Change
Clark	ID	0.00	-0.30	0.30	Yes
Fremont	ID	-1.00	-0.01	0.99	No
Lemhi	ID	-0.60	-0.31	0.29	No
Teton	ID	-0.10	-0.02	0.08	No
Beaverhead	MT	-0.17	-0.04	0.13	No
Broadwater	MT	0.02	-0.10	0.12	Yes
Deer Lodge	MT	-0.11	0.01	0.12	Yes
Gallatin	MT	0.25	0.28	0.03	No
Granite	MT	-0.01	-0.02	0.01	No
Jefferson	MT	0.14	-0.01	0.15	Yes
Lewis & Clark	MT	0.64	0.15	0.49	No
Madison	MT	0.13	0.05	0.08	No
Meagher	MT	-0.10	-0.06	0.04	No
Park	MT	0.10	0.27	0.17	No
Powell	MT	-0.24	0.10	0.34	Yes
Ravalli	MT	0.04	-0.05	0.09	Yes
Silver Bow	MT	-0.25	-0.07	0.18	No

Table 1.8. Percentages of low, medium and high predicted acceptance divided by location (within grizzly bear predicted paths or outside of them). Acceptance categories were binned by subtracting and adding 0.25*standard deviation (0.940) from mean acceptance (-0.001). Low values ranged from -1.36 to -0.235, medium ranged from -0.235 to 0.235 and high ranged from 0.235 to 2.49. Mean predicted acceptance within paths was 0.125 and outside of paths was -0.065.

Location	Acceptance Level	Percent
Within Paths	Low	13.9%
	Medium	30.3%
	High	55.8%
Outside of Paths	Low	23.7%
	Medium	39.6%
	High	36.7%

FIGURES

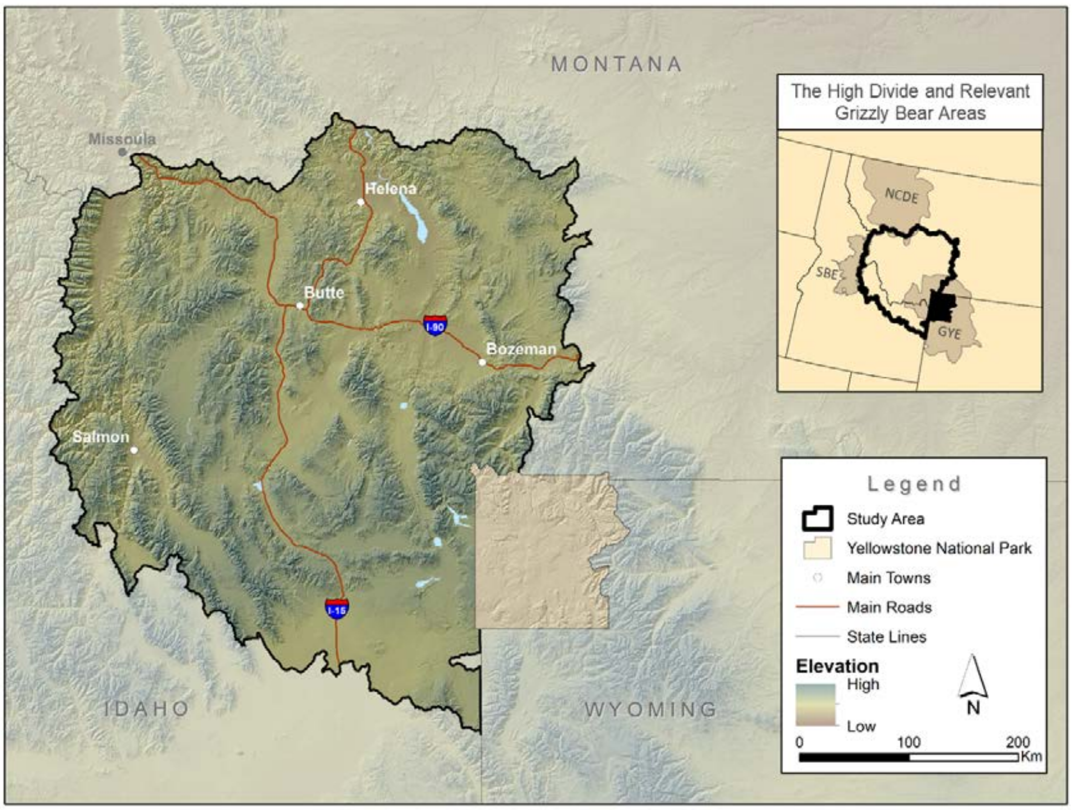

Figure 1.1. The study area in Idaho and Montana is part of the High Divide region spanning from the Greater Yellowstone Ecosystem (GYE), the Northern Continental Divide Ecosystem (NCDE) and the Selway-Bitterroot Ecosystem (SBE).

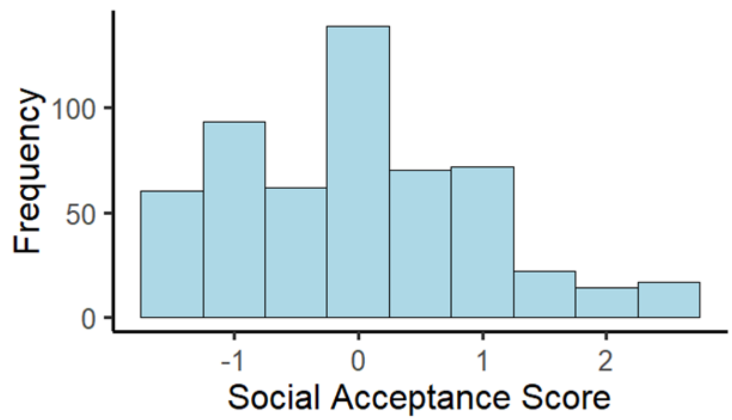

Figure 1.2. Distribution of social acceptance for grizzly bears among ranchers. Scores were calculated through a five item exploratory factor analysis.

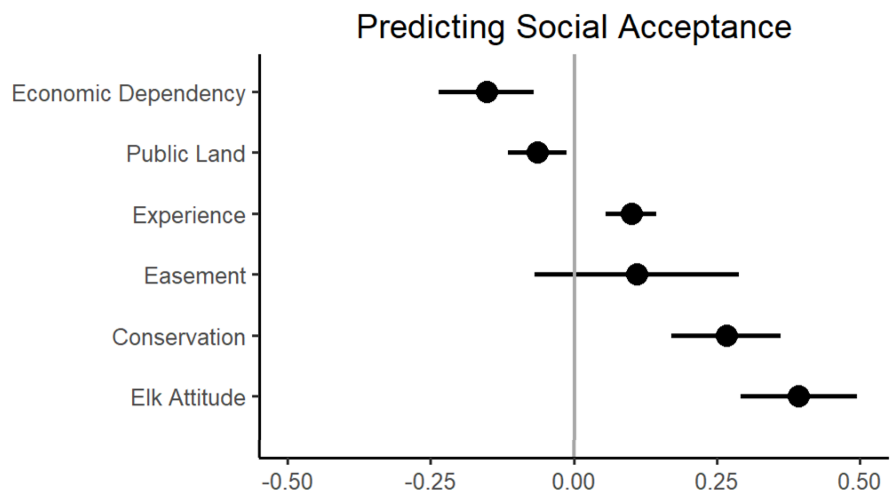

Figure 1.3. Scaled coefficient estimates from the aspatial model for acceptance for grizzly bears. Dots represent the coefficient estimate and whisker lines represent the standard error of that estimate.

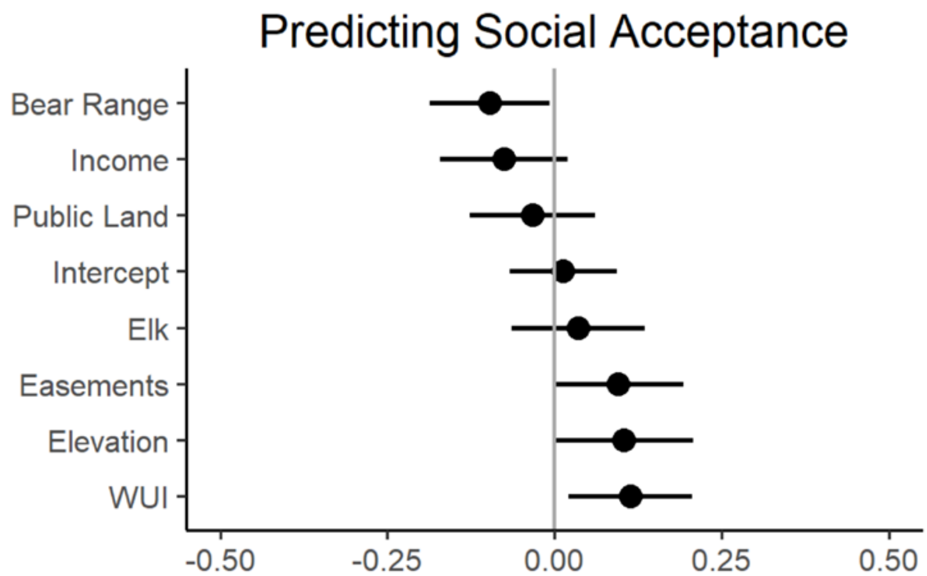

Figure 1.4. Scaled coefficient estimates from the spatial model for acceptance for grizzly bears. Dots represent the coefficient estimate and whisker lines represent the standard error of that estimate.

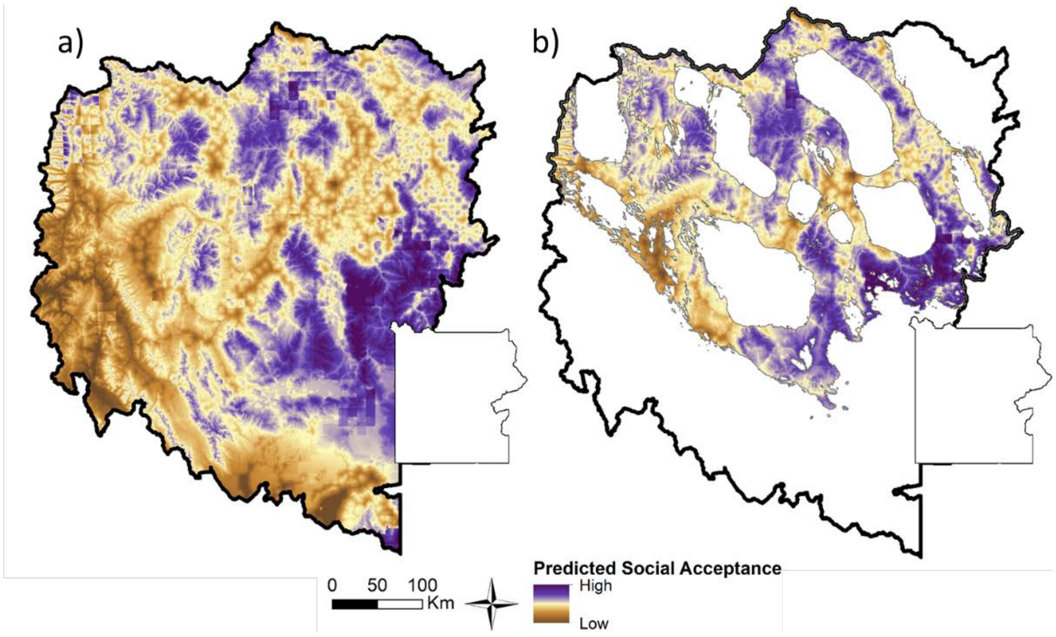

Figure 1.5. Social acceptance predictions and overlay with grizzly bear predicted corridors. a) Predicted social acceptance, and b) acceptance restricted to predicted male-mediated bear dispersal paths (Peck et al. 2017).

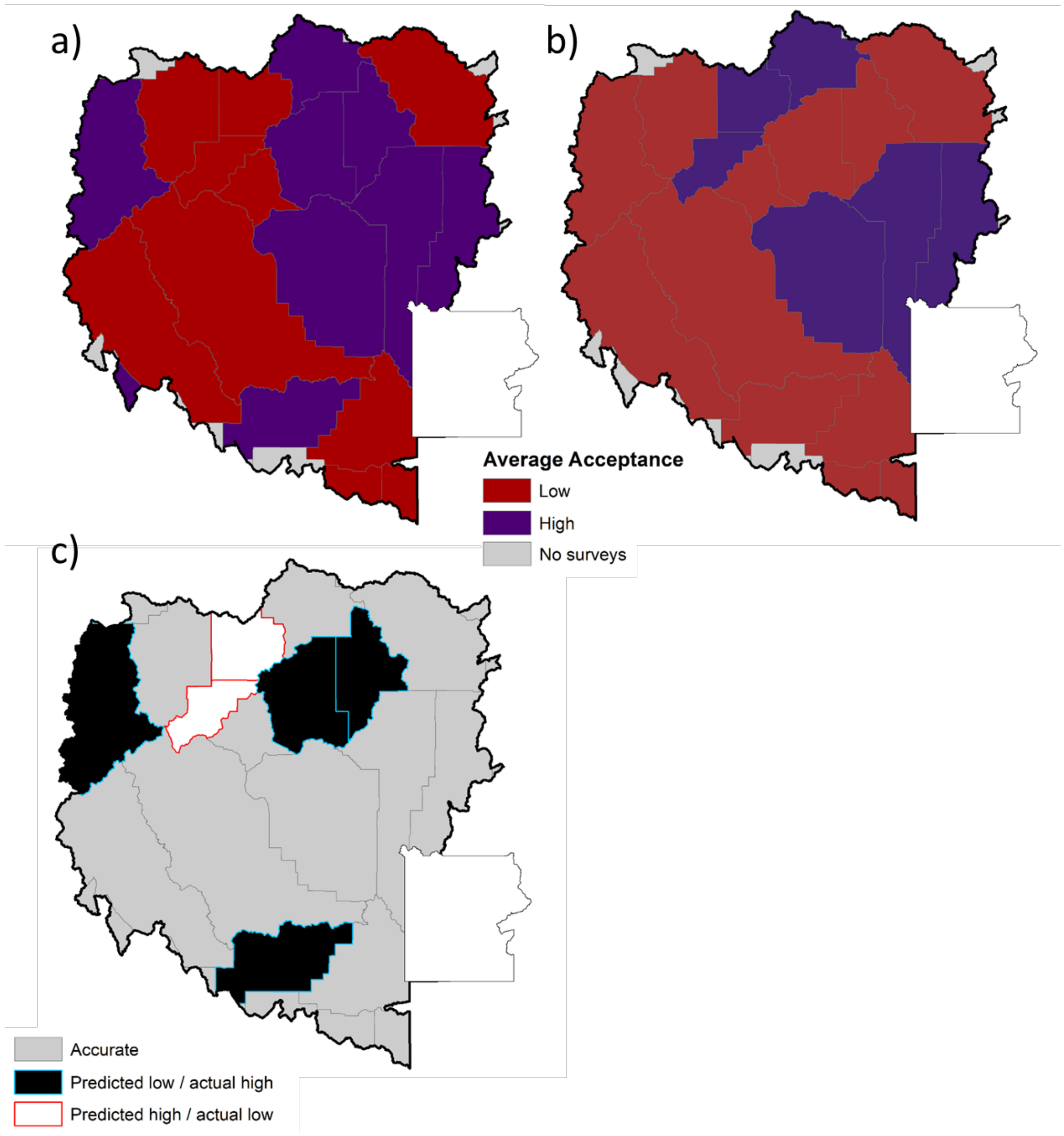

Figure 1.6. Averaged acceptance per county in the high divide. A) is surveyed acceptance, b) is predicted acceptance and c) shows where the model predicted accurately, predicted positive (high) when acceptance was actually low (negative) and predicted low when it was actually high.

CHAPTER TWO: SPATIAL PATTERNS OF WILDLIFE-FRIENDLY HUSBANDRY PRACTICES ON RANCHLANDS IN IDAHO AND MONTANA

Abstract

Human willingness to use nonlethal versus lethal methods for addressing negative consequences of sharing landscapes with wildlife vary spatially. Therefore, the spatial patterns of human behaviors play an important role in the efficacy of habitat corridors. Although there are large bodies of research on habitat corridors and human behaviors toward wildlife, studies that examine the spatial interaction of the two are nonexistent. Our study combined geospatial statistical methods with a geographic information system to assess the patterns of three wildlife-friendly techniques in addition to lethal removal use in the High Divide region of Idaho and Montana. We compared this cluster analysis with predicted corridor paths of a recovering, generalist carnivore, the grizzly bear (*Ursus arctos*) to make inferences on how those behaviors might interface with grizzly bear movement. Data on rancher use of these four techniques were obtained through a mail questionnaire completed by 486 individuals. We assessed spatial clusters of each practice to reveal several hot spots (57 lethal, 29 nonlethal, 29 wildlife-friendly fencing, 31 carcass removal) and cold spots (23 lethal, 12 nonlethal, 8 wildlife-friendly fencing, 32 carcass removal). Lethal removal and nonlethal removal tended to overlap grizzly bear paths, while carcass removal use and wildlife friendly fencing did not. These patterns revealed several important areas for grizzly conservation. Lethal removal hot spots were most common in the center area of the study region, creating a barrier directly between

the Greater Yellowstone Ecosystem and Northern Continental Divide Ecosystem. However, nonlethal techniques and carcass removal were also common in these areas. More ranchers used carcass removal and lethal removal in combination than other techniques (28.1%) suggesting that carcass removal may be a socially feasible method even among groups who oppose carnivore recovery. We found that acceptance of grizzly bears and elk were significantly lower for those using lethal and carcass removal, but higher for those using wildlife-friendly fencing. We found that those who used wildlife-friendly fencing had on average higher levels of income and were closer to an NGO that provided resources. We recommend that managers increase carcass removal use in the northeastern area of the study region and continue to promote non-lethal practices in the center of the study region.

Introduction

Interactions between humans and wildlife are increasing due to changes in habitat, climate, and population dynamics (Sanderson et al. 2002; Parmesan & Yohe 2003; Theobald & Romme 2007). While some of these interactions are positive for humans, such as viewing iconic species, many end in dangerous or costly scenarios for both people and wildlife. For sustainable coexistence to occur, both groups must adapt to increasing interaction to sustain healthy wildlife populations and enhance human wellbeing (Carter & Linnell 2016). Some species of wildlife are able to adapt to living alongside humans by shifting food sources (Mattson, Blanchard, & Knight1992), temporal activity (Gaynor, Hojnowski, Carter, & Brashares 2018), or habitat use (Dickson, Jenness & Beier2005). However, other species, especially large carnivores, adapt toward living with humans and declines of natural food sources by targeting human attractants, such as livestock, crops, or garbage (Morehouse & Boyce 2017). These risks, along with the dangers large carnivores present to human safety, have been the main reason for their decline or, in some cases, near eradication across the globe (Ripple et al. 2014; Penteriani et al. 2016). These declines prompted urgent conservation intervention to prevent extinction for many species of carnivores. By limiting human-caused mortality, some of these species are now reestablishing in population and distribution (Chapron et al. 2014; Gompper, Belant, & Kays2015). Yet, much of the habitat they once occupied has been converted for human use. Livestock and crop production are especially dangerous landscapes for native predators because they frequently provide the space requirements but with a multitude of attractive human food sources (Northrup, Stenhouse & Boyce 2012). Their presence can present risks and costs that degrade landowner acceptance towards their conservation or prompt actions to remove or deter predators (Treves & Karanth 2003).

Presence of predators on livestock range can result in onerous cost increases for producers (e.g., Oli, Taylor & Rogers 1994; Yom-Tov, Ashkenazi & Viner 1995; Butler 2000). These increased costs are often claimed as the number one reason for decline of the sheep industry (Johnson and Gartner 1975; Gee, Magelby, Nielson, & Stevens1977; Dunlap 1988). Berger (2006) disputes that claim, however, and states that the perception of increased financial burden from predators, compounded by decreasing livestock prices and increasing land value, is an important consideration for persistence of small-scale livestock producers (Muhly and Musiani 2009). The most direct cost associated with predators is through depredation. These costs can be calculated since managers attempt to verify and compensate producers for these losses in the US west. For example, wolf kills accumulated approximately $11,076 in Idaho, Montana and Wyoming from 1987 to 2003 (Muhly and Musiani 2009). However, there are many other, indirect costs associated with predator-livestock co-occurrence. Due to changes in stress and foraging, cow calves in herds that experienced confirmed depredations by wolves weighed approximately 22 pounds less than the average calf on 18 ranches in Montana (Ramler, Hebblewhite, Kellenberg, & Sime2014). For producers living in grizzly bear range, the risk to human safety is another time-costly consideration (Morehouse & Boyce 2017). It is often unsafe to work alone on the range when grizzlies are present, leading to additional costs of protecting employees.

These costs and risks can cause people to lethally remove wildlife or advocate for policy that allows for greater levels of lethal removal (Treves and Karanth 2003). Since human-caused mortality is one of the main contributors to the global decline of large carnivore species, recovery remains uncertain for many species, despite population growth (Ripple et al. 2014). This is apparent in the Greater Yellowstone Ecosystem (GYE), where 88% of grizzly bear mortalities in 2016 were from lethal human removal (Haroldson and Frey 2017). In 2018, human-caused grizzly bear mortality was especially high with 65 bears killed in the GYE (USGS 2018). Though this amount does not exceed conservation thresholds (7.6% for females), if mortality continues to increase bear population growth will decline below targeted goals (Haroldson and Frey 2017). Population density and growth is an important component in dispersal and genetic connectivity between metapopulations (Kareiva 1990). Grizzly bear conservation in the lower 48 of the US is under evaluation and scrutiny as USFWS proposes delisting. The question of reconnecting populations naturally is at the center of the debate regarding recovery success.

Solutions exist that protect both human and carnivore interests by preventing conflict nonlethally (Carter & Linnell 2016; Treves, Wallace, Naughton-Treves, & Morales2006). Livestock producers have a number of nonlethal conflict prevention techniques at their disposal. Conflict can be reduced by using electric fences for livestock, livestock carcass removal (to prevent attracting predators), fladry on fences, noisemakers, livestock guard dogs, grizzly-proof grain and feed storage, and various husbandry methods (Bangs et al. 2006). Conservation non-profits, state or federal agencies and industry groups will sometimes offer services or information on preventing conflict with predators nonlethally free or for low charge. For example, the Montana Stockgrowers Association and Montana Livestock Loss Board put out a guide toward preventing losses from grizzly bears (Edwards & Bodner 2017). Most recently, the Western Landowners Alliance put out a collaborative guide, “Reducing Conflict with Grizzly Bears, Wolves and Elk: A Western Landowner’s Guide,” for managers and producers that outlines predator behaviors, techniques and resources for preventing conflict in 11 western states (WLA 2018). Many carnivores are intelligent and can sometimes learn that human food sources are easily accessible from conspecifics (Bangs et al. 2006; Morehouse, Graves, Mikle, & Boyce2016), so teaching them to avoid human-food sources before they learn (and teach) these habits could be an important coadaptation strategy.

Some of these techniques require drastic alterations to ranch management that are costly, time-intensive and controversial. For example, one study indicated that fladry installation on a 150 ha ranch in the Upper Peninsula of Michigan cost approximately $4,392 in 2010 (Davidson-Nelson & Gehring 2010). Carcass removal, which is a legal obligation in many states, requires availability of a program in place that picks carcasses up, or falls to the landowner to bury livestock according to methods that prevent the spread of disease (IDAPA 02.04.17, MDOL 32.4.1002).However, when livestock are grazing in remote locations retrieval of carcasses can be difficult or impossible. Electric fencing, which can be portable or permanent, is also labor and cost intensive (Hayward & Kerley 2009). Whether or not ranchers use these options depends on a number of factors related to financial expenses, attitude towards the method, availability of resources, perceived risk from carnivore presence, and motivation to contribute to conservation.

Husbandry practices could greatly influence conflict with bears because agricultural land can easily become ecological traps for grizzly bears (Northrup, Stenhouse & Boyce 2012). At the finer scale, Wilson et al. (2005) showed that unprotected human attractants, such as beehives, calving pastures and boneyards, were associated with likelihood of human-grizzly bear conflicts in Montana. At the landscape level, grizzly mortalities were positively associated with human access, water and edge features and negatively associated with greenness and ruggedness in Alberta (Nielsen, Boyce & Stenhouse 2004). With many historical food sources, such as whitebark pine seeds and cutthroat trout, in decline from anthropogenic impacts, grizzly bears are more likely to seek out human food sources (Mattson et al. 1992; Gunther et al. 2004). The management and protection of these attractants at the individual level to prevent conflict with bears will be essential in minimizing human-caused bear mortality and ensuring their continued survival in the lower 48 states.

Husbandry practices are a top driver for conflict, and while most managers use predation risk maps to prioritize where conflict prevention measures should be implemented (Wilson et al. 2005; Rigg et al. 2011; Miller 2015), spatial information of where conflict prevention measures are already in place or not are rare. A sole focus on ecological metrics such as depredation risk, carnivore movement and population densities alone will miss the vast social differences related to husbandry that also contribute to conflict. An integrated social-ecological approach has been proposed to address the complex problem of human-wildlife conflict (Baruch-Mordo, Breck, Wilson & Broderick 2009; Dickman 2010; Carter et al. 2014; Lischka et al. 2018). Combined with ecological information of wildlife corridors, evaluating the spatial patterns of husbandry practices can reveal possible hot spots of conflict, helping target locations for conservation interventions. However, to our knowledge, such integrated spatial analyses have not yet been conducted.

Here, we used mail questionnaires and spatial statistics to identify clusters of four behaviors (lethal removal, wildlife-friendly fencing, carcass removal, and nonlethal techniques) in the High Divide of Idaho and Montana. We then overlaid these cluster analyses onto predicted movement corridors for grizzly bears (Peck et al. 2017). We focus on grizzlies because of their uncertain recovery and connectivity status. Our final analysis, while not a complete catalog of use in the region, provides managers with a starting point to determine where nonlethal and lethal techniques are common and uncommon. The ranchers living within grizzly movement corridors are likely to be more susceptible to conflict and the behaviors of individuals living in corridors will play a key role in connectivity and the future of bear recovery. Finally, this spatial analysis provides baseline knowledge for developing hypotheses on the underlying drivers of wildlife-friendly behavior that can be very useful in shared landscapes around the world.

Methods

Study Area and Grizzly Bear Conflict

The region between the Greater Yellowstone Ecosystem (GYE) and the Northern Continental Divide Ecosystem (NCDE) in Idaho and Montana, called the High Divide (Fig. 2.1), is comprised of approximately 130,000 km^2 publicly-owned, high-elevation ridgelines interspersed with private property in low-elevation valleys. It is an important region for establishing and maintaining connectivity for many wildlife species, including grizzly bears (Gude, Hansen, Rasker, & Maxwell 2006). Both ridgelines (forests) and valleys (sagebrush steppe and riparian areas) are ecologically suitable for grizzly bears; however, the risk of conflict with livestock is high in low-elevations where ranching is common.

Survey Instrument

We developed a questionnaire to survey ranchers in the High Divide on their perspectives on land management and conservation (Appendix A). This research was reviewed and approved by the Idaho State University's Institutional Review Board (IRB#280). Our questionnaire consisted of four sections: 'Land management practices', 'Rancher Attitudes and Perspectives', 'Wildlife' and 'You, Your Land Resources and Your Ranching Operation'. Each team member reviewed all survey questions for clarity, double-barreled meanings and language. We used common pretesting techniques to review the final survey instrument including cognitive interviewing (n=5), pilot testing (n= 50) and informal expert review (n=3; Czaja 1998; McColl 2005).

Based on Idaho and Montana cadastral spatial datasets, we created a list of ranches with more than 50 grazing acres to increase the likelihood of selecting only livestock producers. Next, we selected 2400 stratified random ranchers from this list for our sample based on population density of 18 counties. Each person on this list received a unique survey identification number. We deployed the mail survey in January 2018 to the 2400 ranchers. We used a standard three-wave mailing design (Duncan 1979). If returned, respondents were entered into a raffle to win one of two $500 gift cards to Cabela's. We also gave the option of filling the survey out online, which was identical to the mail survey and created in Qualtrics. Two months after the 3rd wave of surveys were mailed, University of Idaho colleagues entered, coded and cleaned the data.

We selected four behavioral items in our survey relevant to grizzly bear connectivity and conservation (Appendix A: Question 2). We asked ranchers, "Indicate whether or not you *voluntarily* use each practice on your *privately owned* grazing land." The four focal practices for this study were "use lethal predator control," "compost or buy carcasses," "use nonlethal predator control (e.g., fladry, lights, noise deterrents)," and "use wildlife-friendly fencing." These questions allowed for four response options: "never used and don't plan to use", "tried but no longer use", "currently use" and "plan to use in the future". For this analysis, we were more interested in learning the current state of use across the landscape relevant to corridors than examining behavioral intentions. Therefore, we collapsed the responses into binary categories: "use" (1) and "does not use" (0). "Plan to use in the future" and "tried but no longer use" were included in the "does not use" category. Some respondents selected both "currently use" and "plan to use in the future," and we categorized these individuals as "use."

Descriptive Statistics

We summarized the number and percentages of ranchers who used each of the four techniques and the percentages of overlap of use between each technique. Next, because we wanted to learn about some of the differences that might drive use or non-use of each behavior, we categorized use and non-use by five potential drivers: income level, percentage of income from ranching, acceptance towards grizzly bears, acceptance towards elk, and distance from a nongovernmental organization (NGO) that offers resources for preventing predator conflict. Income categories included in the survey ranged from 1 to 6, with 1 for 'less than $20,000', 2 for '$20,001-$50,000', 3 for '$50,001-$70,000', 4 for '$70,001-100,000', 5 for '$100,001-150,000' and 6 for 'more than $150,000' (Appendix A). As another metric for economic productivity we also asked "On average, what percentage of your household's annual income comes from the following sources?" Write in answer options included '% livestock production (e.g., cattle, sheep, horses)', '% Other on ranch activities (e.g., hay/crop production, dairy/poultry production, leasing land, recreation, conservation program)', and '% Off-ranch sources (e.g., other jobs, investments, retirement plans)', which is a common method used as a proxy for quantifying economic dependence (Vedeld et al. 2004; Mamo, Sjaastad & Vedeld 2007). We combined percentages from livestock and other ranch activities, because grizzly bears are also attracted to crops and other non-livestock related ranch products. We measured acceptance for grizzly bears and elk through two exploratory factor analyses where the former contained 5 attitude items and the latter contained 4 attitude items (see Chapter 1). Finally, we created a list of NGOs in the study region that offer resources for preventative conflict (Appendix B). We calculated

Euclidean distance to NGOs and extracted mean distance for each rancher. Since distributions of these variables were not normally distributed, we used the nonparametric Mann-Whitney U test to detect differences in these five potential drivers for those who used and did not use each technique.

<u>Cluster Analysis</u>

The geostatistical methods in our study (Global Moran's *I* and Getis-Ord Gi*) require variation in the input variable, so we aggregated binary responses into a fishnet grid at the 100 km^2 size. This size serves several functions: 1) one side of the square cell, 10 km, is equal to 2 times the mean distance between ranches (5.02 km) which is recommended as a best practice for choosing resolution when the study area is not densely populated; 2) this size is coarse enough to protect identities of survey individuals; yet 3) it is also fine enough to reveal some of the finer scale spatial relationships at neighborhood levels.

We first calculated Global Moran's *I* for each behavior at 20 incremental distances to detect peak spatial autocorrelation for defining neighborhoods (Bivand, Müller, & Reder 2009; Figure 2.2). Increments were 8.7 km which was the maximum distance threshold (110 km) minus the beginning distance (28 km) divided by number of distance bands (10). The beginning distance band was the distance at which every cell had at least one neighbor. This formula ensured that the largest distance bands will not have all or nearly all neighbors (Rosenshein & Scott 2011).

Moran's *I* measures the amount of correlation of a variable between one location and the surrounding values. Discovering the peak distance at which spatial autocorrelation is highest allows us to inform and fine-tune local Getis-Ord Gi* analyses.

For the Getis-Ord Gi* analyses (hereafter local G), we used a fixed distance band with a zone of indifference. The latter allows for a specified fixed distance and a gradual decline of influence outside of that zone, rather than a steep drop. We focus on the local G to detect hot spots of use and cold spots of non-use for each behavior. Local G is given as:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \bar{\boldsymbol{X}} \sum_{j=1}^{n} w_{i,j}}{S\sqrt{\frac{\left[n \sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}}$$

where x_i is the number of people who use the focal behavior for each 100 km^2 cell, j, w_{ij} is the spatial weight between i and j, and n is the total number of 100 km^2 cells. □ is the mean number of people who use the focal behavior across the sample, and S is the standard deviation of counts between grid cells. A Gi* z-score and p-value are given for each cell and z-scores above 1.65 or below -1.65 are identified as hot or cold clusters, respectively, at the 90% confidence interval.

<u>Mapping Along Grizzly Bear Corridors</u>

To operationalize these clusters for applied conflict mitigation, we overlaid the map of each practice onto onto a connectivity predictive model for male-mediated grizzly bear dispersal (Peck et al. 2017). Peck et al. (2017) generated step selection functions based on biophysical and anthropogenic features combined with movement data from 124 GPS-collared male grizzly bears. Step selection functions compile decisions made by individual bears when they move through a landscape that varies in biophysical and anthropogenic traits into predicted paths. It uses turning angles from each GPS fixed point to measure a bear's willingness to move across a spatial unit. Next, they used randomized shortest path algorithms to assign values based on the number of paths present in each cell. We chose to overlay the randomized path which moved from NCDE to GYE because most bears found in between these two occupied ranges typically fell in cells which had high NCDE net passage rates (0.87 for the model with sigma = 0.0001). We also chose to use the greatest level of variation (sigma = 0.0001) which represents the amount bears will "wander" as this is likely the most biologically realistic for bears dispersing into new landscapes. Finally, we identified whether clusters of use overlapped or did not overlap with the predicted bear paths, made management recommendations based on use or non-use clusters, and hypothesized potential drivers of behaviors for future research on conflict prevention.

Results

Descriptive Statistics

Of 2400 mailed surveys, 724 ranchers mailed the survey back full or partially completed and 486 filled out the four behavior questions. Of these ranchers, 62.3% used lethal removal, 54.1% used carcass removal, 50.2% used wildlife-friendly fencing and 14.6% used nonlethal techniques (Table 2.1). We found that respondents tended to select carcass removal and lethal removal in conjunction more so than other practices (28%; Table 2.2). We found the lowest overlap between wildlife friendly fencing and nonlethal techniques (8.1%) and carcass removal and nonlethal techniques (8.1%). Use of nonlethal techniques with lethal removal was also low (9.1%). We found 26 ranchers used all four practices (5.1%) and only 6 who used the three prevention techniques and said they did not use lethal removal (1.2%).

The most significant differences from Mann-Whitney tests were observed for lethal removal, where those who used lethal removal had lower acceptance towards bears on average ($p<0.0001$) and a higher percentage of income from ranching ($p<0.0001$; Table 2.4). Acceptance was also significantly low for elk among this group. Likewise, we found significantly lower acceptance for grizzly bears among those who used carcass removal techniques. Wildlife-friendly fencing practices were associated with higher levels of acceptance. Overall, attitudes towards grizzly bears and elk were close to neutral (factor analysis score of 0.00 and 0.00) for the sample population. We also observed significant differences for income source across three of the practices (lethal removal, carcass removal and nonlethal methods). However, we found little difference between income levels and the various groupings where each group had a mean income that fell into the '$70,001 - $100,000' category. The only significant difference was between use and non-use of wildlife-friendly fencing, with the latter characterized with a higher level of income (Table 2.4). Use of all techniques tended to be somewhat closer to conservation NGO's (average 3-5 km) than non-use of the same technique (Table 2.3), although this difference was only significant for use of wildlife friendly fencing (Table 2.4).

Cluster Analyses & Mapping

Most ranchers (n = 308) lived outside of the predicted grizzly corridors and 217 ranchers had some amount of their property that fell within the paths. Of those within the path, 112 (51.6%) used lethal removal, 96 (44.2%) used carcass removal, 89 (41.0%)

used wildlife-friendly fencing and 30 (13.8%) used nonlethal techniques. Aggregating ranches into counts in 100 km^2 cells resulted in 299 cells. Spatial clustering was present in each behavior. Morans *I* incremental analyses revealed that spatial autocorrelation peaked at 65 km for lethal removal, 38 km for carcass removal, 25 km for wildlife-friendly fencing and 41 km for nonlethal techniques.

Out of 299 cells, local G analysis revealed 57 lethal removal hot spots, 31 carcass removal hot spots, 29 wildlife friendly fencing hot spots, and 29 nonlethal techniques hot spots. It also revealed 23 lethal removal cold spots, 32 carcass removal cold spots, 8 wildlife-friendly fencing cold spots, and 12 nonlethal technique cold spots (Fig. 2.2). When categorizing clusters as overlapping or misaligning with grizzly bear paths (Table 2.5), we found that lethal removal hot spots tended to overlap paths more often (62.1%) while cold spots of non-use tended to fall outside of paths (54.5%). Similarly, more nonlethal technique hot spots overlapped paths (65.5%), yet non-use cold spots also tended to overlap (83.3%). Carcass removal hot spots tended to fall outside (71.0%) while cold spots tended to overlap (66.7%). Wildlife-friendly fencing hot spots also tended to fall outside (60.7%) while cold spots tended to overlap (62.5%). Cluster analyses identified specific locations along grizzly paths and highlight areas of non-use, such as lack of carcass removal in the northeastern region, and areas of high use, such as the center of the study region (Fig. 2.3).

Discussion

Spatial patterns of conflict mitigation practices were pervasive throughout our study and provided spatially explicit information for managers seeking to prevent conflict (Fig. 2.2). Compared to grizzly bear paths, we found low overlap of carcass removal, wildlife-friendly fencing, and high overlap with nonlethal techniques and lethal removal (Fig. 2.3). The lack of carcass removal and wildlife-friendly fencing and high use of lethal removal along these routes could increase conflict with dispersing bears.

In particular, the region surrounding Helena, MT had a high amount of ranchers not using carcass removal techniques. Considering this area is close to the NCDE border and predicted to have high bear passage, we highlight the need to address the lack of use here. One region with several clusters of carcass removal use was near Salmon, Idaho. This region is predicted to have low levels of acceptance towards grizzly bears (see Chapter 1), but is also the gateway to the Selway-Bitterroot Ecosystem (SBE; Figure 2.1). Despite having a low number of predicted connectivity paths, this region of the High Divide is key for recolonizing the currently unoccupied SBE grizzly recovery zone (Peck et al. 2017).

Overall, ranchers who used lethal removal and carcass removal had lower acceptance towards both grizzly bears and elk (Table 2.3 and 2.4). Furthermore, carcass removal and lethal removal were the most common combination between use of two or more of these practices at 28%. Given that livestock carcasses are a major source of conflict for grizzly bears (Wilson et al. 2005), this result gives some promising evidence that carcass removal may be a socially feasible method for preventing conflict nonlethally, even among those who would prefer to remove predators. Whether this is because ranchers perceive the method as more effective than alternative nonlethal techniques, or resources for this method are more prevalent in areas that also have low acceptance towards wildlife, remains unclear. This practice is not without social pitfalls, however, since some people might be hesitant to declare deceased animals publicly and many carcass removal programs require displaying animals in accessible places for pickup. Likewise, there was high amount of overlap between hot spots for use of lethal removal and nonlethal techniques.

Lethal removal was the most common hot spot in all our analyses (57 cells) and the most frequently used technique (252 ranchers). This is not unexpected considering many perceive lethal removal to be the most effective and cheapest method of preventing conflict (Conover 2001). Moreover, many producers perceive nonlethal options as less effective than lethal methods (Scasta, Stam, & Windh 2017), despite evidence that the opposite is true in many cases (Treves, Krofel, & McManus 2016; Stone et al. 2017). While it is likely that the main targets for this removal are mesopredators or other wildlife, it is also possible that many ranchers who are accustomed to autonomy when it comes to removing damaging wildlife from their property could be less likely to accept recovery for protected carnivores, such as grizzly bears (Chapter 1). It is possible that ranchers living within predicted grizzly movement paths experience more damage from wildlife, which could drive both lower acceptance for wildlife and use of lethal removal. Indeed, many of the spatial parameters used to define movement for grizzly bears in the predicted path study are important predictors for other carnivores as well (e.g., home density, distance to roads, ruggedness, greenness; Peck et al. 2017). Thus, there might be more need for conflict mitigation practices within paths.

Together, spatial patterns and descriptive statistics provide clues into the drivers behind willingness to try wildlfie-friendly methods. Given that acceptance for bears and elk was lower among those who used lethal removal than those who did not, and that acceptance for these species was higher among those who used wildlife-friendly fencing than those who did not (Table 2.3 and 2.4), we think attitude plays an important role in translating to behavior for wildlife management on ranches. The finding that acceptance was lower for those who used carcass removal was unexpected and highlights the importance of considering situational factors, such as availability of resources or perceived efficacy of the technique at preventing conflict. Social theories suggest that in addition to attitude, perceived control over the behavior and social norms dictate how a person behaves (Ajzen 1991). We suspected that income might be a limiting factor for use of some of the more costly methods. We only found support for that hypothesis for wildlife-friendly fencing ($p<0.01$). Some NGOs or government organizations offer these resources at low cost or for free, which might negate the effects of cost (Bangs 2005). Income source was more important across the other three practices. This suggests that respondents who relied on ranching for a larger portion of their income might be more likely to use lethal removal, nonlethal techniques or carcass removal. We also thought that perceived control might be influenced by availability of resources, yet only use of wildlife-friendly fencing showed a significant difference in this distance (Table 2.3). Possibly, distance to an NGO is not an appropriate metric for resource availability.

We did not ask respondents to specify which predators for which they used the techniques to prevent conflict nor did we make explicit explanations for each technique. Thus, there was room for individual rancher interpretation of each technique. A respondent might interpret wildlife friendly-fencing to mean electric or wire fencing to keep predators out, or they might select it if they have installed fencing that allows for pronghorn (*Antilocapra americana)* passage. One rancher might interpret grizzly bear proof grain storage as a nonlethal technique while another might disregard that technique as applying to that category. Many ranchers lethally remove mesopredators, such as coyotes, but may also support lethal removal by management for larger predators such as wolves and bears. Despite this imprecision, the responses give us a general sense of where ranchers are using more wildlife-friendly practices for addressing conflict with predators. We linked each ranchers' response to his or her privately owned parcels.

Other unmeasured factors could be contributing to the differences in use and non-use of each practice. Ranchers who are more opposing to carnivore recovery might be less likely to adopt practices that are promoted by a social group they are not a part of (e.g., environmental groups). Perceived control of each behavior could also influence and interact with other driving factors. While resource ability and feasibility of implementing conflict prevention practices are probably the main considerations for control, it is also possible that the perceived efficacy among different groups plays an important role in social norms. For example, if many individuals in a rancher's social network have strong opinions that using fladry to prevent wolf depredations does not work, he or she might be less likely to start using fladry. Finally, perceived risk from predators probably plays an important role in adoption of these techniques. Some ranchers who have not lived with carnivores at all or in many years are beginning to see more large predators in their region or could begin to soon.

Management Recommendations

Sustainable coexistence with recovering predators will require producers to adopt new strategies, preferably before conflict occurs, to achieve conservation and economic goals. Depredations are often unevenly distributed and influenced by local conditions, such as husbandry methods (Rigg et al. 2011). Clashes with grizzly bears are especially unpredictable because they are generalists and individual bears can vary greatly in behavior. Despite these factors, we have demonstrated that by combining social and ecological methods, we can refine our ability to identify vulnerable ranches. These maps could aid managers or practitioners making decisions about resource allocation.

The northwest region of the study area exhibited several cold spots of non-use of carcass removal. Two of the predicted grizzly bear paths move through this region and some of the cold spots are close to the NCDE bear population boundary. These cold spots could serve as a starting point for practitioners looking to increase use of carcass removal by either allocating resources and funding to that region for education, carcass removal programs or investigating why there is a lack of use here. Further, while carcass removal is likely an effective strategy for preventing unwanted interactions with grizzly bears, there is some debate about its efficacy for preventing wolf depredations (Mech et al. 2000; Bradley & Pletscher 2005). For regions such as the western part of the High Divide, near Salmon, ID, where carcass removal hot spots are common, depredations by wolves might be better mitigated by offering resources for other techniques, such as livestock guard dogs (Fritts, Stephenson, Hayes & Boitani2003).

Use of all four techniques was prevalent in the communities in the center of the study area, between Butte and Bozeman, MT. This result suggests social feasibility of techniques that protect carnivore recovery among communities who also use lethal removal. Given the high number of predicted bear paths that move through this area, continued work should be done in this area to promote nonlethal methods and facilitate coexistence proactively. Social change is usually more likely to occur when credible, known individuals convey the message (Hovland & Weiss 1951; McGuire 1985);

therefore, widespread adoption of nonlethal methods might be better facilitated by engaging with ranchers who use techniques in hot spots and creating opportunities for knowledge transfer to regions where they are used less frequently.

By examining spatial patterns and potential drivers of rancher reported use of several conflict mitigation practices, we have shown the importance of human dimensions in conservation planning for large carnivores. Spatial analyses of social factors present a relatively unexplored and exciting new branch of research in promoting coexistence with wildlife.

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TABLES

Table 2.1. Percentages of ranchers who use lethal removal, carcass removal, wildlife-friendly fencing and non-lethal techniques (n= 486).

Behavior	n	Percent
Lethal Removal	303	62.3%
Carcass Removal	263	54.1%
Wildlife-Friendly Fencing	244	50.2%
Non-Lethal Techniques	71	14.6%

Table 2.2. Numbers and percentages of ranchers who used two techniques in conjunction.

Behavior	Lethal Removal	Carcass Removal	Wildlife Fencing
Lethal Removal			
Carcass Removal	142 (28.1%)		
Wildlife-Friendly Fencing	127 (25.1%)	122 (24.2%)	
Nonlethal Techniques	46 (9.1%)	41 (8.1%)	41 (8.1%)

Table 2.3. Mean and standard deviation for each practice grouped by use and non-use.

Potential Driver	All	Lethal Removal		Carcass Removal		Wildlife Fencing		Nonlethal Techniques	
		Use	Non-use	Use	Non-use	Use	Non-use	Use	Non-use
Income	4.3 (1.6)	4.3 (1.5)	4.4 (1.6)	4.2 (1.5)	4.4 (1.5)	4.5 (1.4)	4.1 (1.6)	4.2 (1.8)	4.3 (1.5)
Ranch income	50.5 (38.1)	56.8 (38.5)	37.0 (37.5)	57.3 (38.3)	40.3 (38.5)	49.5 (38.7)	49.4 (40.0)	67.6 (36.9)	46.4 (38.9)
Attitude: bears	0.00 (0.92)	-0.24 (0.85)	0.41 (0.99)	-0.11 (0.92)	0.13 (0.97)	0.13 (0.98)	-0.14 (0.91)	0.02 (0.87)	-0.01 (0.97)
Attitude: elk	0.00 (0.86)	-0.15 (0.84)	0.17 (0.84)	-0.11 (0.87)	0.07 (0.83)	0.16 (0.82)	-0.20 (0.86)	0.01 (0.73)	-0.04 (0.88)
NGO	39.6 (22.7)	40.6 (22.5)	43.0 (26.6)	40.4 (24.7)	42.8 (23.4)	39.0 (23.1)	44.0 (25.0)	38.1 (22.0)	42.1 (24.5)

Table 2.4. P-value results from Mann-Whitney *U* tests used to detect differences in distributions between groups who use or do not use each technique.

Potential Driver	Lethal Removal	Carcass Removal	Wildlife Fencing	Nonlethal Methods
Acceptance of bears	<0.0001	<0.05	<0.01	
Acceptance of elk	<0.01	<0.05	<0.01	
Income			<0.01	
Income source	<0.0001	<0.01		<0.01
Distance to NGO			<0.05	

Table 2.5. Percentages that clusters of use and non-use of four conflict prevention behaviors overlap and misalign with predicted grizzly bear corridors. Cluster analyses were calculated at a 100 km^2 resolution and overlap with paths were defined as any amount of intersection with the paths or current grizzly occupied range.

Behavior	Overlap of Use	Non-overlap of Use	Overlap of Non-use	Non-overlap of Non-use
Lethal Removal	62.1%	37.9%	45.5%	54.5%
Carcass Removal	29.0%	71.0%	66.7%	33.3%
Wildlife-Friendly Fencing	39.3%	60.7%	62.5%	37.5%
Non-Lethal Techniques	65.5%	34.5%	83.3%	16.7%

FIGURES

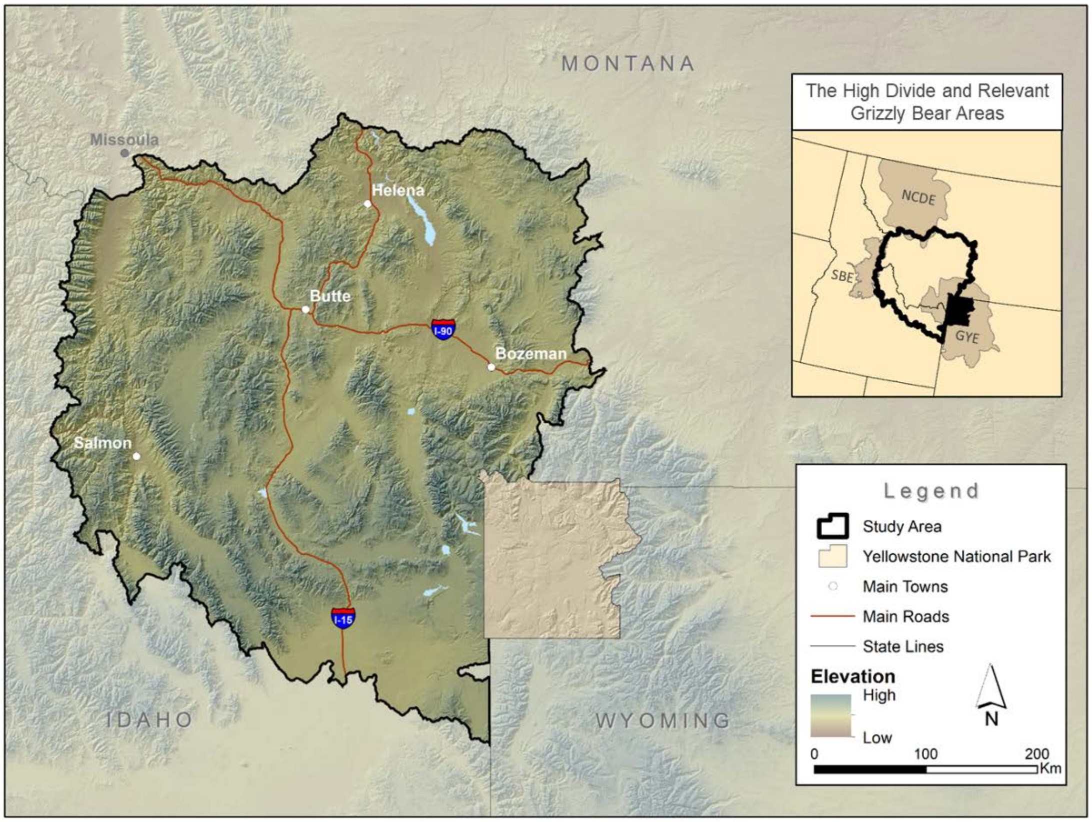

Figure 2.1. The study area in Idaho and Montana is part of the High Divide region spanning from the Greater Yellowstone Ecosystem (GYE), the Northern Continental Divide Ecosystem (NCDE) and the Selway-Bitterroot Ecosystem (SBE).

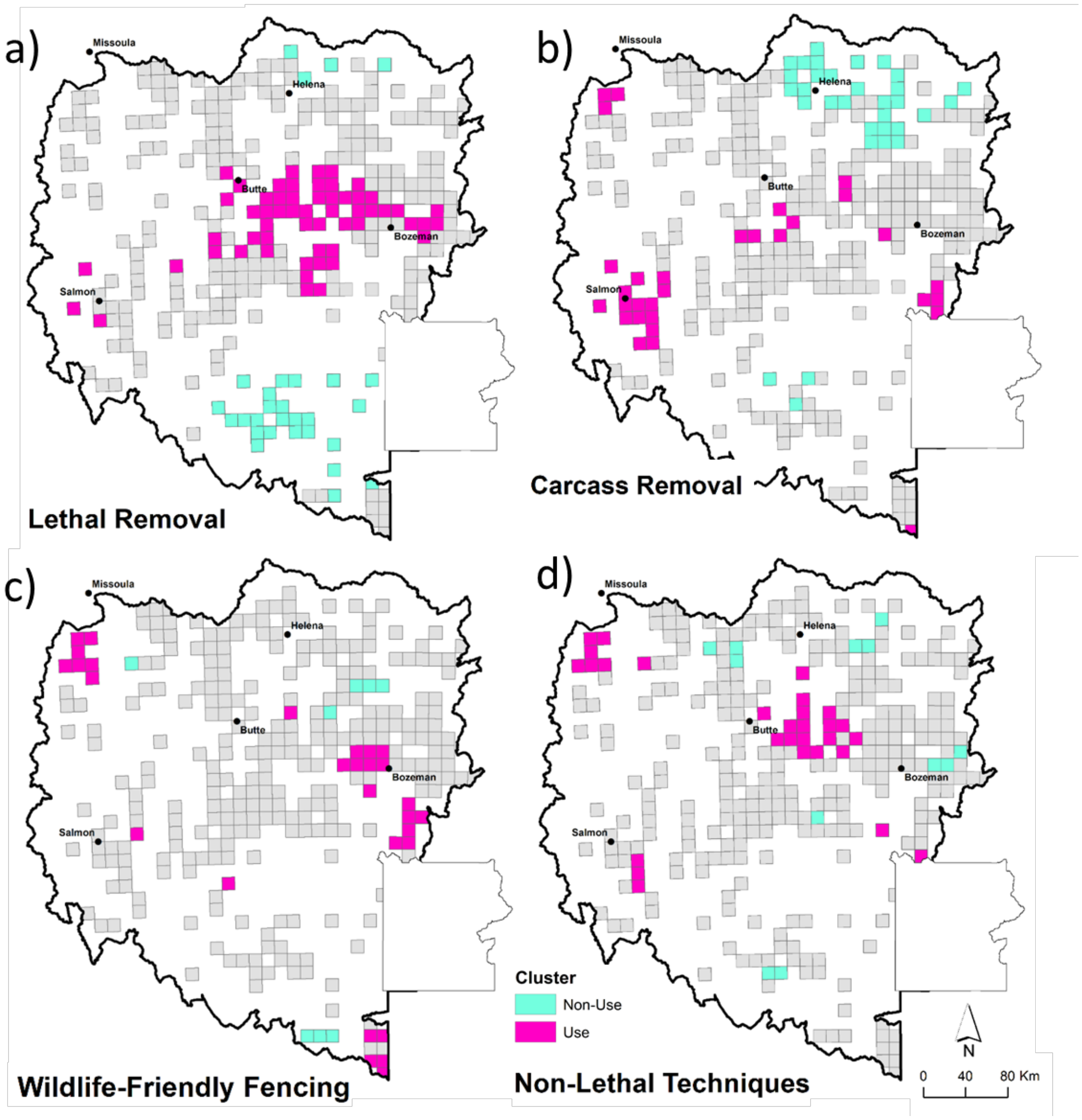

Figure 2.2. Results from cluster analyses of four techniques ranchers use to prevent conflict with predators. Counts of use and non-use were aggregated for each 100 km^2 cell. Spatial relationship was defined as a zone of indifference, which started at the following distances for each behavior: a) Lethal removal, 65 km; b) carcass removal, 38 km; c) wildlife-friendly fencing, 25 km; and d) non-lethal techniques, 41 km.

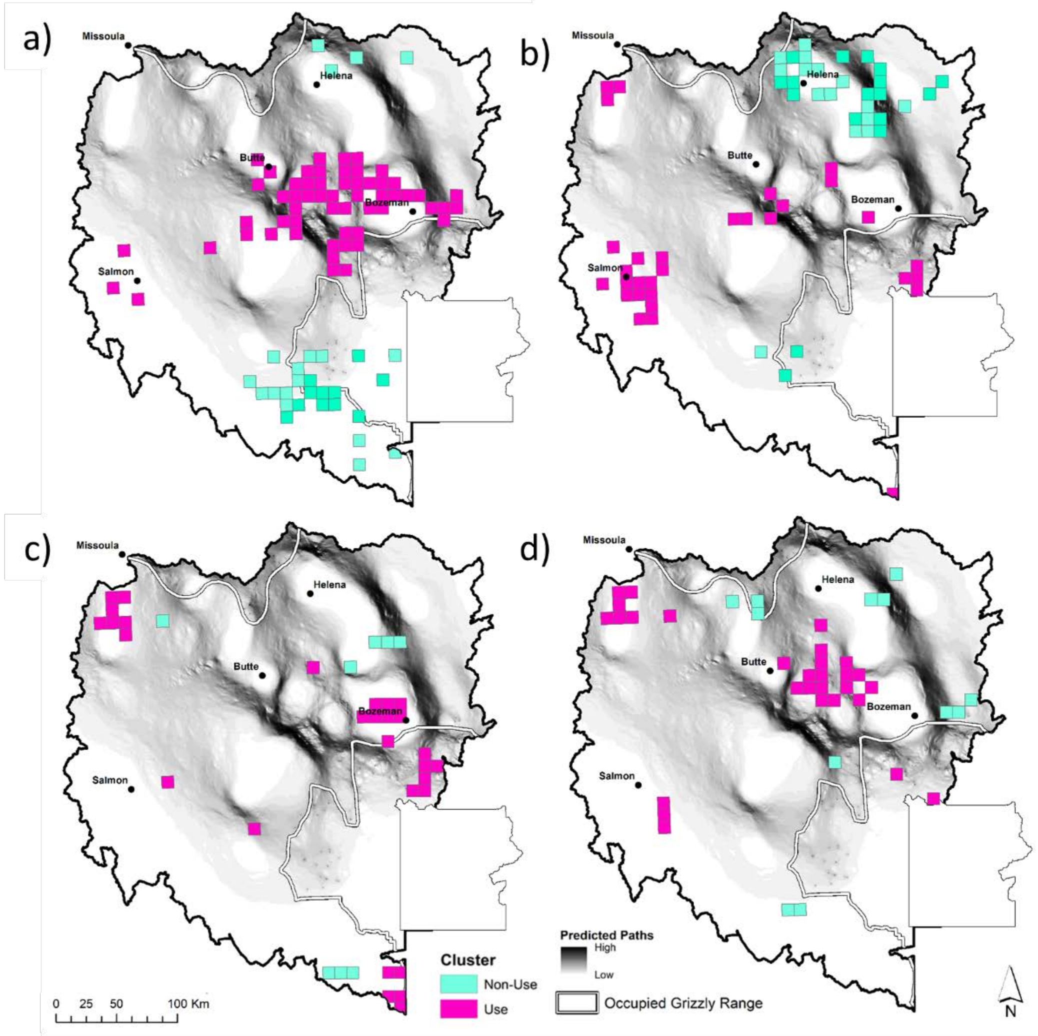

Figure 2.3. Getis Ord Gi* cluster analyses laid onto the predicted grizzly bear corridors in black and white (Peck et al. 2017). Clusters of use are in pink and non-use in teal for lethal removal (a), carcass removal (b), wildlife-friendly fencing (c) and nonlethal techniques (d).

APPENDIX A

Mail Questionnaire: "Ranchers' Perspectives on Land Management and Conservation"

Ranchers' Perspectives on Land Management and Conservation

Ranching is an important part of the economy and culture of the rural West. This survey will help us learn about ranchers' perspectives and better understand the challenges facing this vital sector.

Do you own or manage a ranching operation within the counties listed?

In Idaho: Clark, Fremont, Lemhi, Madison, and Teton Counties
In Montana: Beaverhead, Broadwater, Deer Lodge, Gallatin, Granite, Jefferson, Lewis and Clark, Madison, Meagher, Park, Powell, Ravalli and Silver Bow Counties

___ Yes → Continue to the next page

___ No → Thank you for your time.

This study has been reviewed and approved by Idaho State University's Institutional Review Board (IRB# 280), and if you have any questions about your rights as a participant you may contact them by telephone at 208-282-2179. By completing this survey, you acknowledge that you are at least 18 years old and consent to participate in the study.

SECTION 1: LAND MANAGEMENT PRACTICES

1. What year did you or your family begin ranching in the region?

____

2. Below are some management practices that you may use on your grazing lands. Indicate whether or not you *voluntarily* use each practice on your *privately owned* grazing lands.

	Currently use	**Tried but no longer use**	**Plan to use in the future**	**Never used and don't plan to use**
Remove invasive plant species				
Remove conifer species (like juniper)				
Use fences to exclude livestock from riparian areas				
Create riparian buffers				
Manage vegetation to reduce wildfire risk				
Use a conservation easement				
Compost or bury carcasses				
Participate in cost-sharing programs to create or improve wildlife habitat				
Use lethal predator control				
Use non-lethal predator control (e.g., fladry, lights, noise deterrents)				
Use wildlife-friendly fencing				

3. Are there any other important ranch/land management practices that you regularly use on your land (*please write your answer in the box*)?

4. Do you monitor vegetation on your grazing lands?

☐ Yes, I monitor vegetation on at least some of the land I graze. ☐No, I do not

5. If you answered **YES** to question 4, which of the following methods do you use to monitor vegetation (*check all that apply*):

☐Stubble height measurements ☐ Vegetation cover measurements
☐Photo monitoring ☐ Invasive plant surveys
☐Other: ____

6. Please indicate how important public grazing access is to your ranching operation by rating its contribution to your operation.

No contribution to our ranching operation	Minor contribution to our ranching operation	Moderate contribution to our ranching operation	Major contribution to our ranching operation	Our ranching operation depends on it
☐	☐	☐	☐	☐

SECTION 2: RANCHER ATTITUDES AND PERSPECTIVES

7. Indicate your level of agreement with the following statements:

	Strongly Disagree	Disagree	Agree	Strongly Agree
The ranching lifestyle is more important to me than economic returns				
My family's livelihood depends on the economic productivity of my ranch				
My future livelihood depends on having flexible land use options				
My financial well-being conflicts with conservation				
Government involvement in conservation has helped ranchers				
If grazing on public land was not allowed, I would no longer ranch				
If grazing on public land was not allowed, my ranching operation would be significantly impacted				
In situations where there are conflicts between economic viability and				

environmental protection, it is more important to protect economic viability				
I am responsible for conserving nature				
How land is used should be determined only by the person who owns it				
I think my land should be used to provide environmental benefits to the region				
I think my land should only be used to benefit myself or my family				
The actions I take on my land have little impact on regional environmental problems				

8. If you have one or more grazing permits for public land, please rate your level of agreement with the following statements:

	Strongly Disagree	**Disagree**	**Agree**	**Strongly Agree**
Stewardship of public grazing land is solely the responsibility of public agencies				
Stewardship of public grazing land is a shared responsibility between public land management agencies and grazing permittees				
I have no obligation to take public interest into account when making management decisions on my grazing permit land				
Grazing should be prioritized on public land over other uses (such as recreation and hunting)				

SECTION 3: WILDLIFE

9. Indicate your level of agreement with the following statements about wildlife.

	Strongly Disagree	Disagree	Agree	Strongly Agree
Elk only belong on public lands				
Grizzly bears only belong on public lands				
Where I live, elk and livestock can coexist				
Where I live, grizzly bears and livestock can coexist				
I think my privately owned land should be used to connect elk habitat between public lands				
I think my privately owned land should be used to connect grizzly bear habitat between public lands				
I am in favor of programs that promote connected habitat for elk between public & private lands				
I am in favor of programs that promote connected habitat for grizzly bears between public & private lands				

10. a. Have you ever had direct experience with a grizzly bear, including just seeing one?

☐ Yes ☐ No

b. If **yes**, please indicate whether this experience was positive or negative:

Very negative	**Somewhat negative**	**Neither positive or negative**	**Somewhat positive**	**Very positive**
☐	☐	☐	☐	☐

11. Are there grizzly bears in your county? ☐ Yes ☐ No

12. The grizzly population in my county should be:

Decreased greatly	Decreased somewhat	Remain the same	Increased somewhat	Increased greatly
☐	☐	☐	☐	☐

13. Indicate your level of agreement with the following statements about grizzly bears.

	Strongly Disagree	Disagree	Agree	Strongly Agree
I am in favor of grizzly bear recovery to their former range in Idaho and Montana				
My privately owned property is important for grizzly bear conservation				
I would use any means within my control to ensure grizzlies do not use my privately owned property				
I would voluntarily participate in livestock protection programs in order to prevent grizzly bears depredating my animals				
Ranchers should be compensated for livestock losses caused by grizzly bears				
Livestock losses caused by grizzly bears should only be compensated if livestock protection measures were in place				
Recreational hunting of grizzlies should be allowed once recovery goals are met				
I trust wildlife managers to provide me with the means to cope with grizzly bears on my property				

SECTION 4: YOU, YOUR LAND RESOURCES AND YOUR RANCHING OPERATION

In this section, we will ask you some questions about you and your household. Your responses will never be associated with your name and will only be used for statistical purposes and to determine if the ranchers who respond to the survey are a good representation of the ranching population.

14. Are you? ☐Male ☐Female

15. Do you live full time in the region? ☐Yes ☐No

16. What year were you born? ____________

17. How many acres do you own or manage in the region?

____

18. Which of the following best describes your role in relation to the private land used in the ranching operation?

☐ I own the land but do not make day-to-day management decisions (owner/non-operator)
☐ I own the land and make day-to-day management decisions (owner/operator)
☐ I lease/rent the land and make day-to-day management decisions (non-owner/operator)
☐ I am hired to make day-to-day management decisions (hired operator)
☐ Other, please explain:____

19. In a typical year, how many head of livestock do you graze on any land (your own, another private landowner's, or public land) in the region?

_____________ cow-calf ___________stockers __________sheep ___________other

20. Of your privately owned land, how many total acres are managed for grazing?

____

21. Do you have a grazing permit for public land?

☐Yes, approximately how many AUMs:__________________________

☐No

22. a. How many total acres of ***public land*** do you use for grazing?

____

b. How many acres of that land is owned by:

US Forest Service (USFS)?

____

Bureau of Land Management (BLM)?

____

Other public land management agency?

____

23. What is the highest level of formal education you have completed?

☐Some high school ☐High school graduate

☐Vocational/technical school/some college ☐Associate's Degree

☐4-year college degree ☐Post-graduate degree

24. Please specify your ethnicity.

☐White or Caucasian ☐Hispanic or Latino

☐Black or African American ☐Native American or American Indian

☐Asian ☐Native Hawaii or Pacific Islander

☐Other

25. Over the last five years, what is your average total annual household income before taxes (include ranch and non-ranch income sources)?

☐ Less than $20,000 ☐ $20,001 – $50,000 ☐ $50,001 – $70,000

☐ $70,001 – $100,000 ☐ $100,000 – $150,000 ☐ More than $150,000

26. On average, what percentage of your household's annual income comes from the following sources?

________% Livestock production (e.g., cattle, sheep, horses)

________% Other on ranch activities (e.g., hay/crop production, dairy/poultry production, leasing land, recreation, conservation program)

________% Off-ranch sources (e.g., other jobs, investments, retirement plans)

Thank you for your help! Please use the space below to provide us with comments or any other information you think we should know:

Thank you for taking this survey!

Please return your booklet using the postage paid envelope provided.

If you have questions, feel free to contact us at:

Local telephone: 208-426-1622
Email: rosegraves@boisestate.edu

Survey conducted in partnership by:

University of Idaho
College of Agricultural and Life Sciences

BOISE STATE UNIVERSITY

Idaho State University

APPENDIX B

List of locations with NGO's that supply resources for conflict prevention with predators

Table B1. List of locations with NGO's that supply resources for conflict prevention with predators. Euclidean distance was calculated and mean value of distance extracted for each ranch.

Name	Location
Defenders of Wildlife	Missoula, MT
Montana Watershed Coordination Council	Helena, MT
Blackfoot Challenge	Ovando, MT
Heart of the Rockies Initiative	Missoula, MT
Future West	Bozeman, MT
Centennial Valley Association	Dell, MT
People & Carnivores	Bozeman, MT
Big Hole Watershed Committee	Southwest of Butte, MT