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Paths of Coexistence: Spatially Predicting Acceptance of Grizzly Bears Along Key Movement Corridors

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Paths of coexistence: Spatially predicting acceptance of grizzly bears along key movement corridors

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ABSTRACT

Landscape connectivity is important for conserving wildlife in spaces shared with humans. Yet, differences in human attitudes and behaviors within movement corridors can lead to spatial variation in the risks humans pose to wildlife. Mapping the spatial pattern of attitudes toward wildlife provides a useful tool for measuring this variation and promoting connectivity. We surveyed ranchers ($n = 505$) in the High Divide region in eastern Idaho and western Montana (United States) about their attitudes toward grizzly bears (*Ursus arctos*) – a species that can pose risks to livestock and human safety. We assessed spatial variation in rancher acceptance of grizzly bears by combining survey and spatial predictors. Ranchers surrounded by more conservation easements and wildland-urban interface reported more positive attitudes toward grizzlies. Ranch size, experience with bears, and off-ranch income sources helped to further explain relationships between predictors and ranchers' acceptance of grizzlies. Our predictive map of acceptance provides spatially explicit information for targeted, pre-emptive conflict mitigation and a baseline for examining spatiotemporal changes in human attitudes as grizzly bear populations expand in the region. Integrating human social factors into spatial connectivity planning may better inform how organizations approach landowners and allow for a more strategic, sustainable approach to connectivity and conservation decision-making.

1. Introduction

Maintaining movement corridors – "distinct components of the landscape that provide connectivity" – is a core strategy for conserving wildlife populations that are embedded in landscapes shared with human communities (Henry et al., 1999; McRae et al., 2012; Ament et al., 2014). When human communities intersect movement corridors, human actions affect animals in both positive and negative ways (Ghoddousi et al., 2021). For large carnivore species that are prone to livestock depredation or damaging human property, such as wolves or bears, negative encounters can decrease human tolerance of these animals and even motivate some people to kill carnivores in retaliation or to prevent livestock loss in the future (Treves and Bruskotter, 2014; Lamb et al., 2020). In contrast, some human communities are willing to proactively prevent conflict with carnivores (Wilson et al., 2017) or tolerate their presence despite the risks (Manfredo, 2008; Carter et al., 2014). These differing responses, in turn, may affect the function of movement corridors, for example, by impeding or facilitating animal movement and increasing or decreasing mortality (Dolrenry et al., 2020). However, despite recognition that human dimensions may affect movement corridors, their inclusion into corridor and connectivity planning is lacking (Buchholtz et al., 2020; Carter et al., 2020; Ghoddousi et al., 2021; Goswami and Vasudev, 2017).

Here, we examine the spatial patterns of rancher acceptance for a threatened carnivore species, grizzly bears (*Ursus arctos*), in the High Divide region of Idaho and Montana, USA, and compare it with key movement corridors of grizzlies (Peck et al., 2017). Grizzly populations are highly susceptible to human-caused mortality given their slow reproduction rates (Bunnell and Tait, 1981; Mattson et al., 1992). Like many dangerous or damage-causing species, 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

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(McFarlane et al., 2007; Parker and Feldpausch-Parker, 2013). Contributing to this disagreement are concerns over the impact grizzlies can have on human communities. Ranchers are disproportionately affected by grizzly bears, including direct livestock loss from depredation. For example, in 2020, grizzly bears killed 821 farm animals and were involved in at least 141 incidents requiring management action in Idaho, Montana, and Wyoming, combined (USDA, 2020). Ranchers also spend time and money 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). Ranches are also responsible for disproportionate levels of carnivore mortality because of the wide variety of human food sources that attract carnivores (Northrup et al., 2012). Since private ranching land is one of the largest sources of open space in the western U.S. and plays an important role in preventing development and maintaining habitat connectivity for a number of species (Brunson and Huntsinger, 2008), reducing negative interactions between grizzlies and ranchers would help foster long-term coexistence.

Recent work has used the geolocations of grizzlies and landscape characteristics to predict grizzly movement corridors through our study region (Peck et al., 2017). What is lacking, however, is an understanding of rancher acceptance of grizzlies and how that acceptance varies in space and intersects with grizzly movement corridors. Acceptance of carnivores, as measured through attitude surveys, can be a useful proxy for human behaviors that may facilitate or impede carnivore recovery (Bruskotter et al., 2015; Manfredo et al., 2020). Furthermore, predicting the spatial distribution of human acceptance of carnivores can shed light on what outcomes to expect when human-carnivore encounters expand to new areas or increase in intensity. For example, in anticipation of high-conflict rates, wildlife managers can provide non-lethal carnivore deterrents (e.g., livestock guard dogs, electric fencing) and training to communities with low acceptance toward carnivores but adjacent to high-use movement corridors. Many of these practices are already in use in our study area but are often used in response to livestock depredation, rather than preemptive actions. Several local non-profits are working to move ranching communities from a reactive management style toward prevention. With information on spatial distribution of acceptance, managers can also prioritize carnivore habitat restoration in potential movement corridors where surrounding communities have high acceptance of carnivores. Thus, while behaviors toward carnivores ultimately determine human impact to these animals, acceptance is a powerful and generalizable concept that is amenable to spatial prediction and subject to change through conservation interventions (Manfredo, 2008).

Several studies have mapped spatial patterns of acceptance toward wildlife to aid recovery efforts (Morzillo et al., 2007; Bowman et al., 2009; Carter et al., 2014; Behr et al., 2017; Kuiper et al., 2018). For example, Bowman et al. (2009) modeled attitudes toward a black bear (*Ursus americanus*) reintroduction in Mississippi, USA. They found that demographic variables, number of years of landownership and proximity to public land were important predictors of attitudes. More recently, Behr et al. (2017) spatially modeled acceptance toward wolves using spatial predictors in Switzerland and coupled those predictions with measures of habitat suitability. They found that acceptance of wolves decreased with elevation and proximity to wolf presence. These studies demonstrate the utility of integrating both social and ecological factors to make spatially explicit inferences on human-wildlife interactions. Although informative, these studies did not explicitly integrate acceptance with wildlife connectivity maps; yet doing so could directly improve conservation planning and further our understanding of how acceptance affects corridor function.

To examine rancher acceptance of grizzlies, we focus on three explanatory categories – experience with grizzlies, economic dependency on ranching, and general attitudes toward conservation – because they are supported in the literature as important factors, can be spatialized to some degree and are dynamic in changing social-ecological conditions (Shumway and Otterstrom, 2001; Kansky and Knight, 2014; Lute and Gore, 2018). Personal experience, including encounters and interactions, is often a significant predictor for attitude toward carnivores (Kansky and Knight, 2014). Negative experiences with predators, such as fearing for personal safety during an animal encounter, can lower human acceptance of predators (Eriksson et al., 2015). Positive experiences, which are subjective for each person but can include the joy of seeing a wild animal in a safe manner, can lead to higher acceptance (Arbieu et al., 2020). Additionally, more negative or positive experiences typically lead to stronger, more firmly held attitudes (Heberlein, 2012). Research also indicates that the effect of negative experiences with large carnivores (e.g., livestock loss) on acceptance is influenced by financial dependence on livestock for income (Bhattarai and Fischer, 2014). Financial dependence on livestock can reflect a person's wealth and insurance against risk from carnivores, and thus shape their perceived vulnerability to impacts from living near carnivores (Naughton-Treves and Treves, 2005; Dickman, 2010). Previous studies have shown that greater dependence on livestock for livelihoods and reliance on public lands for raising livestock results in lowered acceptance for carnivores, such as African lions (*Panthera leo*; Hazzah et al., 2009) and pumas (*Puma concolor*; Palmeira et al., 2008). Lastly, based on the theory of cognitive hierarchy, we might expect that general views about wildlife and their conservation predict acceptance of specific species (Whittaker et al., 2006; Manfredo et al., 2020). An important caveat is that individuals who are supportive of conservation, may not necessarily be supportive of carnivore conservation, such as hunters who view them as competition (Treves, 2009). Thus, distinguishing those two is important.

Based on the three main explanatory categories, we hypothesize that: 1) ranchers with more positive experiences with grizzly bears have higher acceptance of bears; 2) people with a greater economic dependency on ranching have lower acceptance of bears; and 3) those who support conservation generally have higher acceptance of bears. To test these hypotheses, we surveyed ranchers on their attitudes toward grizzlies and then used a set of predictors to model rancher acceptance of grizzlies. We modeled acceptance separately with spatial and aspatial (i.e., survey items) predictors and used the spatial model to generate a predictive map. Importantly, we assume our spatial predictors characterize the three explanatory categories (Table 1). By coupling our spatial and aspatial analyses, we can better understand what is driving the spatial patterns of acceptance. That is, we can corroborate spatial predictors of acceptance via survey items, thus lending confirmatory support for our hypotheses and predicted relationships (Table 2). Examining social acceptance spatially therefore could reveal key insights into the formation and persistence of attitudes toward wildlife in shared landscapes, which prevail globally (Carter and Linnell, 2016; Locke et al., 2019). These insights will enable better decision making for addressing social challenges to promote connectivity and coexistence.

2. Methods

2.1. Study area

The High Divide (Fig. 1) spans the border of Idaho and Montana and is composed of approximately 130,000 km^2 of publicly owned, high-elevation ridgelines interspersed with private property in low-elevation valleys. It is an important region for establishing and maintaining connectivity for grizzly bears, among other species because it connects the Greater Yellowstone Ecosystem (GYE), the Northern Continental Divide Ecosystem (NCDE) and the Selway-Bitterroot Ecosystem (SBE) (Peck et al., 2017; Lukacs et al., 2020). While 60% of land is public, ranches make up much of the remaining 40% of private land (Graves et al., 2019). These ranches provide ecologically valuable open spaces and bears rely on them for movement corridors, but the risk for conflict is high (Peck et al., 2017; Wells et al., 2019; USGS, 2018).

Grizzly bears in the GYE and NCDE have increased in population and distribution in recent years (Haroldson and Frey, 2017). Minimum

Table 1
Spatial predictors for acceptance, justification for inclusion, and data sources. We chose each spatial predictor to reflect one of three broad explanatory categories, which are italicized in parentheses below the variable name.

Spatial variable	Justification for inclusion	Data source
Ranch distance to occupied bear range (*experience with carnivores*)	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 (1).	The Interagency Grizzly Bear Study Team Grizzly Distribution Greater Yellowstone Ecosystem: 2002–2016; Montana Fish, Wildlife and Parks Northern Continental Divide: 2004–2014
Area of Wildland-Urban Interface surrounding ranch (*experience with carnivores*)	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 (2, 3, 4). It might be that living closer to wild areas affects attitude toward carnivores as well.	Radeloff et al., 2005
Elevation (*experience with carnivores*)	A control variable. Ranching is more common in lower elevations; habitat corridors are more common in higher elevations (5)	USGS FRESC Digital Elevation Model
Median income per census block (*economic dependency on ranching*)	Financial costs are a top concern for managing landscapes with carnivores (6).	U.S. 2010 Census
Ranch distance to public land (*economic dependency on ranching*)	Many ranchers rely on public land for grazing their livestock. A rancher's proximity to those lands may influence their perceived vulnerability to carnivores (7, 8).	USGS PAD-US 1.4
Number of elk harvested per hunter unit (*general attitude toward conservation*)	Elk harvest rates are based on elk population so areas with higher harvest rates can support more hunters and beneficial tourism that can create positive attitudes toward the species (9). Elk can also damage crops and transmit diseases to livestock. Ranchers' attitudes toward elk may capture a more comprehensive view of their attitudes toward species conservation in general.	Montana Fish Wildlife & Parks; Idaho Department of Fish and Game
Number of conservation easements surrounding ranch (*general attitude toward conservation*)	People with more favorable attitudes toward wildlife and wildlife management are usually more willing to put their land in conservation easement (9). Communities with higher densities of conservation easements may be more likely to place a higher value on carnivores.	Graves et al., 2019

(1) Kansky and Knight, 2014 (2) Hammer et al., 2009 (3) Kertson et al., 2011 (4) Lee and Miller, 2003 (5) Noss et al., 2002 (6) Dickman, 2010
(7) Brunson and Huntsinger, 2008 (8) Fleischner, 1994 (9) Crank et al., 2010.

populations were estimated to be 709 for the GYE and 1029 in the NCDE in 2017 (USFWS, 2018). Grizzly bear range is expanding, and they are dispersing into areas grizzlies have not occupied since they were extirpated during the 19th century (Peck et al., 2017). Yet, human population growth, increased recreation, habitat fragmentation and loss of natural foods make it likely that grizzly mortality will be high in these human-dominated areas outside of grizzly recovery zones (Mattson et al., 1992; Lamb et al., 2018). While natural dispersal may be the most socially feasible method for reestablishing connectivity (Velado, 2005), the growing human population and intolerance toward their presence could prevent reconnection and hinder grizzly bear recovery in the contiguous United States (Mattson et al., 1992; Gude et al., 2006; Rasker, 2008).

Table 2
Hypotheses and predictions for spatial and aspatial model predictors.

Hypothesis	Predictor	Model	Predicted relationship with acceptance
Experience with grizzly bears increases acceptance of bears.	Experience with bears	Aspatial	(+)
	Type of experience	Aspatial	(+)
	Distance to bear range	Spatial	(−)
	Wildland-urban interface	Spatial	(+)
	Elevation	Spatial	(+)
Economic dependency on ranching decreases acceptance of bears	Economic dependency	Aspatial	(−)
	Public land dependency	Aspatial	(−)
	Income	Spatial	(+)
	Distance to public land	Spatial	(+)
Attitudes toward conservation influence acceptance of bears.	Conservation attitude	Aspatial	(+)
	Elk attitude	Aspatial	(+)
	Conservation easement use	Aspatial	(+)
	# elk harvested	Spatial	(+)
	# conservation easements	Spatial	(+)

2.2. Mail questionnaire

We developed a questionnaire to survey ranchers in the High Divide on their perspectives on land management and wildlife conservation, including their attitudes toward grizzlies (Appendix A). To cover all grizzly corridors in our study area, we sampled landowners from 13 counties in Montana and 4 counties in Idaho. We used cadastral data to select landowners of parcels containing 50 acres or more of rangeland, as determined from zoning codes. The 50 acre cutoff was used to exclude landowners whose land holdings were too small for them to engage in substantial rangeland management activities. This cutoff also increased the likelihood of excluding smaller operations that may not experience the same risks or offer the same benefits to grizzly recovery since higher numbers of livestock are correlated with increased grizzly depredations (Wells et al., 2019). From our initial list, we randomly selected 2400 landowners, stratified by county population density. We deployed the mail survey in January 2018 using a three-wave mailing design and an identical online option with a target response rate of 20% (Dillman et al., 2014). We compared respondent demographics with that of the study area and assessed nonresponse bias by comparing demographics and responses between each mailing wave using Kruskal-Wallace tests (Dillman et al., 2014).

2.3. Outcome variable: social acceptance score

We developed an acceptance score to use as the outcome variable in both models from five attitudinal survey items: 1) The grizzly population in my county should be: decreased greatly, decreased somewhat, remain the same, increased somewhat, or increased greatly; 2) I am in favor of programs that promote connected habitat for grizzly bears between public and private lands; 3) I am in favor of grizzly bear recovery to their

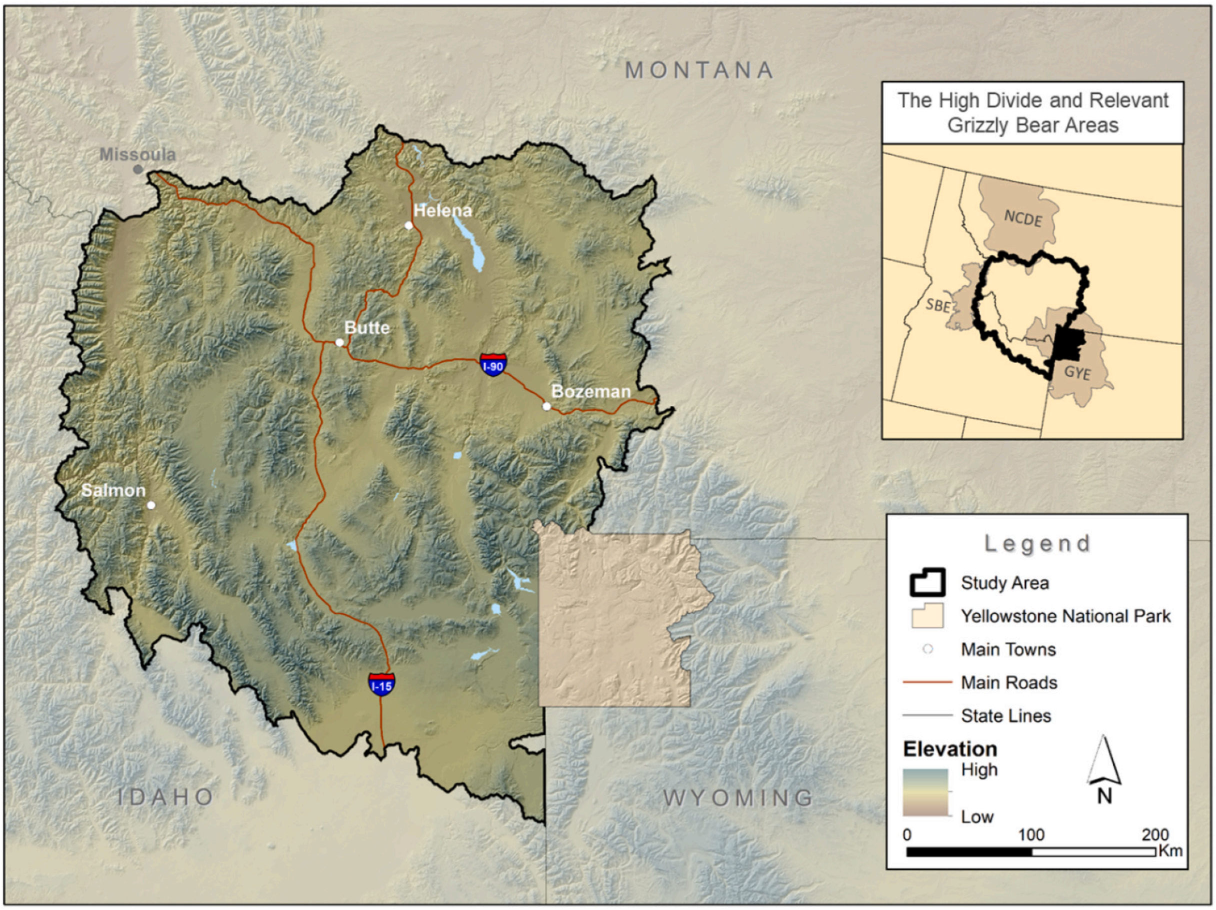

Fig. 1. The study area in Idaho and Montana is part of the High Divide region spanning from the Greater Yellowstone Ecosystem (GYE), the Northern Continental Divide Ecosystem (NCDE) and the Selway-Bitterroot Ecosystem (SBE).

former range in Idaho and Montana; 4) Grizzly bears belong only on public lands; and 5) Where I live, grizzly bears and livestock can coexist. Response options for items 2–5 were strongly disagree, disagree, agree, or strongly agree. We used an exploratory factor analysis in the *psych* package in R to develop an acceptance score (R Core Team, 2015; Revelle, 2018). Factor analysis is a data reduction technique used to characterize complex latent factors, or those not directly observed, from multiple survey items, such as acceptance toward wildlife (Costello and Osborne, 2005). We used an oblique rotation, promax, which allows items to be correlated, compared to orthogonal rotations, such as varimax, that assume item independence (Abdi, 2003). We assessed factorability with factor loadings and analyzed reliability using Cronbach's alpha (Bland and Altman, 1997). We calculated scores for individuals using the Bartlett approach (DiStefano et al., 2009). Individuals with lower acceptance of wildlife were assumed to be more likely to impede bear recovery by, for example, reporting bears for relocation or lethal removal (either legally or illegally) (Hazzah et al., 2017). We modeled acceptance in two separate models because the spatial model, utilizing only spatial layers as predictors, allowed us to predict acceptance across the study area where we did not survey. This method also allowed us to use the aspatial model to help understand the patterns in the spatial model.

2.4. Aspatial model

We selected aspatial predictors of acceptance from the questionnaire only (Table 3; Appendix A). We used two questions to characterize rancher experience with bears. Specifically, we asked whether ranchers had ever had experience with bears. If they had, we asked them to qualify their experience on a 5-point Likert scale. We used type of experience (ranging from very negative to very positive) rather than binary experience because its effect size was larger (Table 3). To characterize economic dependency on ranching, we asked respondents whether their livelihood was dependent on 1) ranching and 2) public land grazing. Lastly, we used three variables to characterize rancher support toward conservation. Specifically, we constructed two predictor variables describing ranchers' attitudes toward conservation and elk (to capture those supportive of game species conservation, but not grizzly conservation) using factor analyses on a series of Likert-scale statements. For the third variable, we asked whether ranchers enrolled their land in a conservation easement, a legal agreement that limits development on private lands (Table 3). We modeled rancher acceptance of grizzlies using multiple linear regression with a normal distribution.

2.5. Spatial model

We measured spatial autocorrelation of acceptance values by calculating the global Moran's index I (Moran, 1950) with distances ranging from 1 km to 21 km at increments of 2 km. We found that spatial autocorrelation peaked at 7 km ($p = 0.04$). To reduce this bias, we calculated the mean of each of the spatial predictors within 7 $\times$ 7 km cells that were arrayed in a grid covering the whole study area. In many cases, each cell contained only a single ranch (Fig. B1). Survey respondents were assigned to the cell in which they owned the most land. We merged all parcels for each respondent so that acceptance represented the entirety of their property.

We selected spatial predictors of acceptance using only GIS layers to represent experience with bears, economic dependency on ranching,

Table 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 nor 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 dependency	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 attitude	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 attitude	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

and attitudes toward conservation (Table 1). First, we measured experience with bears as respondent's distance to occupied bear range. This commonly used proxy for experience assumes that ranchers living within bear range would have more encounters, both positive and negative, with bears than those who lived farther away. Next, we summarized the wildland-urban interface within 7 × 7 km grid cells of each respondent (Radeloff et al., 2005). The wildland-urban interface is the "area where houses meet or intermingle with undeveloped wildland vegetation" (USDA and USDI, 2001). Since this interface reflects the spatial configuration of the human footprint amidst wildlife habitats, we expect it to relate to human experience with grizzlies (Lee and Miller, 2003; Kertson et al., 2011).

To characterize economic dependency spatially, we used median income level per census block from the 2010 census, as well as property distance from federal- or state owned-land. Income level does not directly measure economic dependency, but we expected areas with higher income to have less dependency on ranching (e.g., income from off ranch sources; Delibes-Mateos et al., 2013). We assumed that those living closer to public land rely on public grazing more to support livestock production.

We used two predictors to represent attitudes toward conservation spatially (Table B1). First, we compiled elk harvest statistics from 2017 for Idaho and Montana (total harvested by hunter unit), assuming that these numbers broadly reflect desire for game species conservation (Crank et al., 2010; IDFG, 2017; MFWP, 2017). We also summed the number of conservation easements within 7 × 7 km (Graves et al., 2019), assuming that the preponderance of easements reflects community support for land conservation. Finally, we included elevation as an additional variable. Ranching is more common in lower elevations and wildlife are more common in higher elevations, but elevation likely captures more information than just experience with bears. All spatial data were converted to rasters and resampled at a resolution of 300 m^2. We modeled rancher acceptance of grizzlies using multiple linear regression with a normal distribution.

As spatial relationships can be difficult to interpret, we also utilize insights from the aspatial model to better illuminate possible causal effects. For spatial predictors that showed relationships with acceptance, we used Kendall rank correlations and Kruskal-Wallace tests with the following survey items to infer further explanations of their importance: year ranch was acquired, number of acres owned, source of income (income from livestock and income from off-ranch sources) and socio-demographic variables (age, income, education).

2.6. *Modeling, prediction and spatial overlap*

We predicted acceptance using our spatial model and the spatial predictor GIS layers (which are continuous over the entire study area) with the predict function in the package *raster* to produce a map at a resolution of 300 m^2. We examined residuals using Moran's I and visual inspection of mapped residuals to ensure spatial autocorrelation was adequately addressed in the model. We assessed predictive ability of the spatial model using 5-fold cross validation, root mean square error (RMSE) and normalized RMSE. We also summarized acceptance from the 505 respondents and predicted acceptance from the model by county means to compare at a broad spatial scale. We clipped our maps of predicted acceptance to predicted grizzly bear paths (Peck et al., 2017).

For each model, we used the global set of predictors to test our hypotheses to determine a "best fit", rather than using model selection techniques (Mac Nally et al., 2018). In both models, we checked for multicollinearity among all 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 centering means around zero. We assessed each predictor by its effect sizes, 95% confidence intervals, and significance. We compared how much variance was explained in both the spatial and aspatial models using R^2. All data preparation and analyses were conducted in R (R Core Team, 2015).

3. Results

3.1. *Mail questionnaire*

Of the total 2400 surveys mailed out, we used responses from 505 individuals for the spatial model and 250 individuals for the aspatial model. We used different sized datasets because respondents had only to complete the section about grizzlies (5 questions) to be included in the spatial model but needed to complete more of the survey to be included in the aspatial model.

Mean age of respondents was 65 and ranged from 19 to 94. Of the 505 respondents, 80.6% were male, 19.0% were female and 0.4% did not answer. Mean and median acreage owned was 4982 and 1200, respectively. Median reported income was $70,000–$100,000, ranging from 'less than $20,000' to 'more than $150,000.' Percent of respondents who earned at least a bachelor's degree was 46%. From census data, we learned the study population was younger, (median 45 years old), had lower incomes (median $48,108), and a lower percentage of bachelor's degrees (16%) compared to the overall population in sampled counties. We did not weight data because our priority was spatial representation not demographic. Furthermore, the average resident does not represent the average rancher. We saw no difference in income (Kruskal-Wallace $H = 1.87$, $P = 0.60$) or education ($H = 3.83$, $P = 0.28$) between the 3 mailing waves and online respondents, although the latter tended to be younger ($H = 12.3$, $P < 0.001$). However, we saw no difference in acceptance toward grizzlies between mailings or online ($H = 5.60$, $P = 0.90$) negating a need to adjust for nonresponse bias.

3.2. Human attitudes and factor analyses

We found that 41.9% of respondents prefer that future bear population be smaller than it is currently, whereas 51.4% of respondents would like the same number of bears in the future and 6.5% would like an increase in the bear population. Ranchers mostly agreed (51%) that grizzlies only belong on public lands and mostly disagreed that grizzlies and livestock can coexist (69%; Fig. 2). Most were not in favor of grizzly recovery in Idaho and Montana (69%) or for programs that promote connected habitat between public and private lands (75%; Fig. 2).

The factor analysis we performed on the five attitudinal survey items indicated that a single latent factor adequately described variation among them (alpha = 0.87). We refer to this latent factor as acceptance of grizzlies, with scores ranging from −1.36 to 2.49 (Fig. B2). The factor analysis of the predictor *conservation attitude* revealed one latent factor where negative attitudes toward conservation scored positively (alpha = 0.68). As such, 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 attitudes* also revealed one latent factor, where responses supportive of elk loaded positively on this factor (−2.58 = low; 1.57 = high; alpha = 0.82). All factor loadings were 0.3 or above so no items were dropped (Table B1).

3.3. Aspatial model

We found support for hypothesis 3 where acceptance was most strongly, and positively, related to predictors associated with attitudes toward conservation (Fig. 3). Specifically, respondents with more positive grizzly acceptance scores had more positive attitudes toward elk, and a more positive attitude toward conservation in general. We found support for hypothesis 1 where respondents with more positive experiences with grizzlies reported higher acceptance (Fig. 3). We also found support for hypothesis 2 where ranchers with lower acceptance were more dependent on the productivity of their ranch (Fig. 3; Table B2). The aspatial model explained 60% of the variance in acceptance of grizzly bears.

3.4. Spatial model

We found that ranchers who lived closer to grizzly bears reported more acceptance than those who lived farther away (Fig. 3). From subsequent Kruskal-Wallace tests, we learned that ranchers living closer to bears had more experience with bears, more negative experience with bears, were younger and had a higher portion of off-ranch income sources (Table B3 and B4). We found support for hypothesis 3, where the ranchers living near more wildland-urban interface, at higher elevations and surrounded by more conservation easements, had higher acceptance. From Kruskal-Wallace tests, we learned that increasing wildland-urban interface correlated with more recently acquired ranches and income from off-ranch sources (Tables B3 and B4). However, we did not find support for hypothesis 2 that ranchers living closer to public land or in lower income areas were less accepting. The spatial model explained less variance ($R^2 = 0.15$) than the aspatial model. Residuals showed no significant spatial autocorrelation (Moran's *I*: −0.7437; *p*-value =

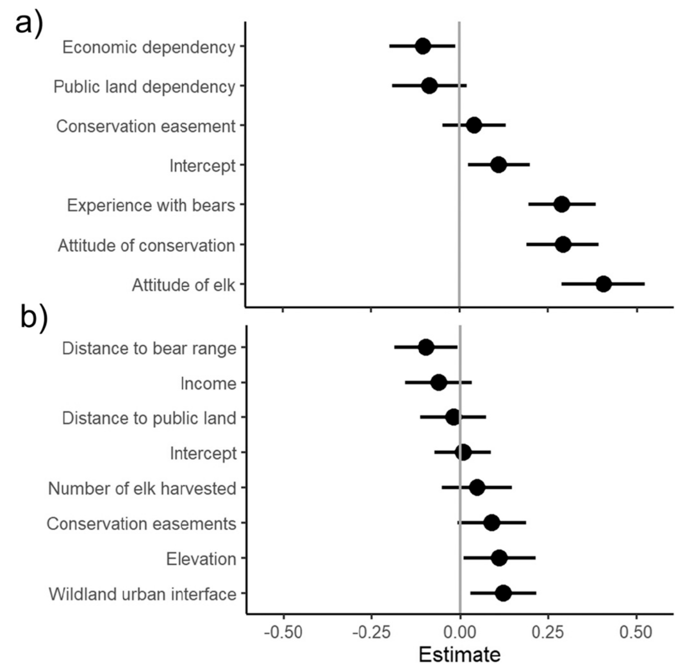

Fig. 3. Scaled coefficient estimates from (a) the aspatial model and (b) the spatial model for acceptance of grizzly bears. Dots represent the coefficient estimate and whisker lines represent 95% confidence intervals.

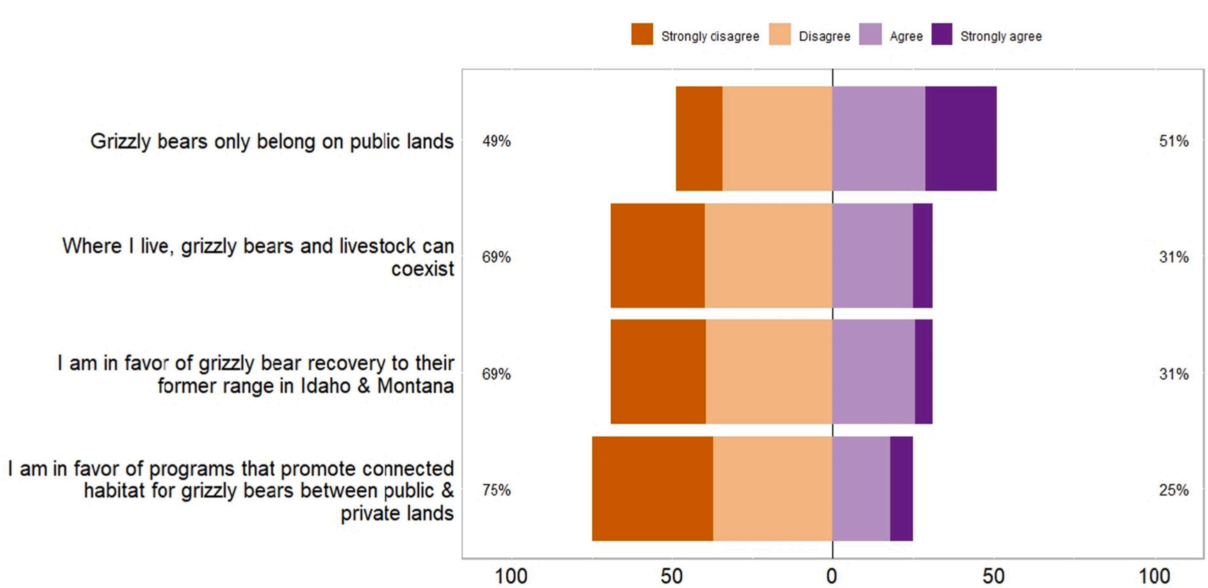

Fig. 2. Proportion of rancher responses to four survey questions related to grizzly bear recovery.

0.4571). RMSE from 5-fold cross validation was 0.92 and normalized RMSE was 0.23, or 23% of the range of the outcome variable, acceptance. By averaging actual and predicted acceptance for each county, we found that we identified the correct sign for 11 of 17 counties (Table B5; Fig. B3).

3.5. Prediction and spatial overlap

Predicted acceptance showed a strong East-West gradient, with highest areas of acceptance near the GYE and major towns in Montana (Fig. 4). There were concentrations of low acceptance spanning large sections of grizzly corridors. The areas of lowest predicted acceptance were concentrated around Salmon, Idaho, and the path moving through this southwestern region of the High Divide contained the highest densities of low acceptance values.

4. Discussion

We produced aspatial and spatial models to understand the processes underlying spatial patterning of acceptance. We found experience with bears influenced acceptance, but those relationships differ between the individual respondent level and those at a broader scale captured by spatial predictors. We also found that participation in conservation easements influenced acceptance at a broad scale, but that relationship was not evident at the individual level. In both models, we found relatively strong relationships between acceptance and experience with bears and support for conservation. Moreover, the spatial analysis allowed us to identify areas where low or high acceptance spatially overlapped key corridors for grizzlies.

Conducting the spatial and aspatial models in tandem provided us a more comprehensive understanding of factors influencing acceptance of grizzly bears. Modeling acceptance with only survey data would have missed the relationship between community level participation in conservation easements and acceptance, considering there was no relationship at the individual level for those who used a conservation easement. An individual's choice to enroll land into an easement or support grizzly conservation may be the result of outreach programs by conservation organizations such as local non-profits that promote carnivore recovery. In fact, many of these easements are established for the specific purpose of promoting carnivore connectivity (Offer, 2020; Carroll et al., 2021). Our results provide support for the utility of easements because we show that participating landowners are generally more accepting of grizzlies.

Understanding the relationship between experience with grizzlies and acceptance also benefited from a combined approach. Even though those living closer to grizzlies had more negative experiences with bears (Kruskal-Wallace p-value = 0.06; Table B4), they were more accepting of grizzlies than those who lived farther away. However, aspatial analysis revealed that increasingly positive experiences with bears were associated with acceptance. This could suggest that the benefits of living near bears outweigh the costs or that ranchers who live with bears are more confident in mitigating conflict (Zimmermann et al., 2001; Lischka et al., 2019). Alternatively, economic and social values may influence a rancher's choice to live nearer to grizzlies since these ranchers were typically younger with diversified incomes, based on our survey results. Future work could aim to identify spatial indicators of positive interactions between humans and bears to understand this relationship.

The wildlife-urban interface has a strong influence on acceptance toward grizzlies, though the specific mechanisms are equivocal. The wildland-urban interface did not capture variation related to experience as we predicted (Table B4), however we did learn that ranchers living in the interface had diversified incomes and smaller, more recently acquired ranches which could reflect the amenity-driven migration to the region (Gude et al., 2006). In the High Divide, most housing is considered low to medium density, so the wildland-urban interface correlates with population density and ranches in more densely populated areas were identified as being surrounded by more wildland-urban interface (Radeloff et al., 2005). In our model, the wildland-urban interface is likely capturing differences in the urban-rural gradient of environmental attitudes where more populated areas show greater acceptance of

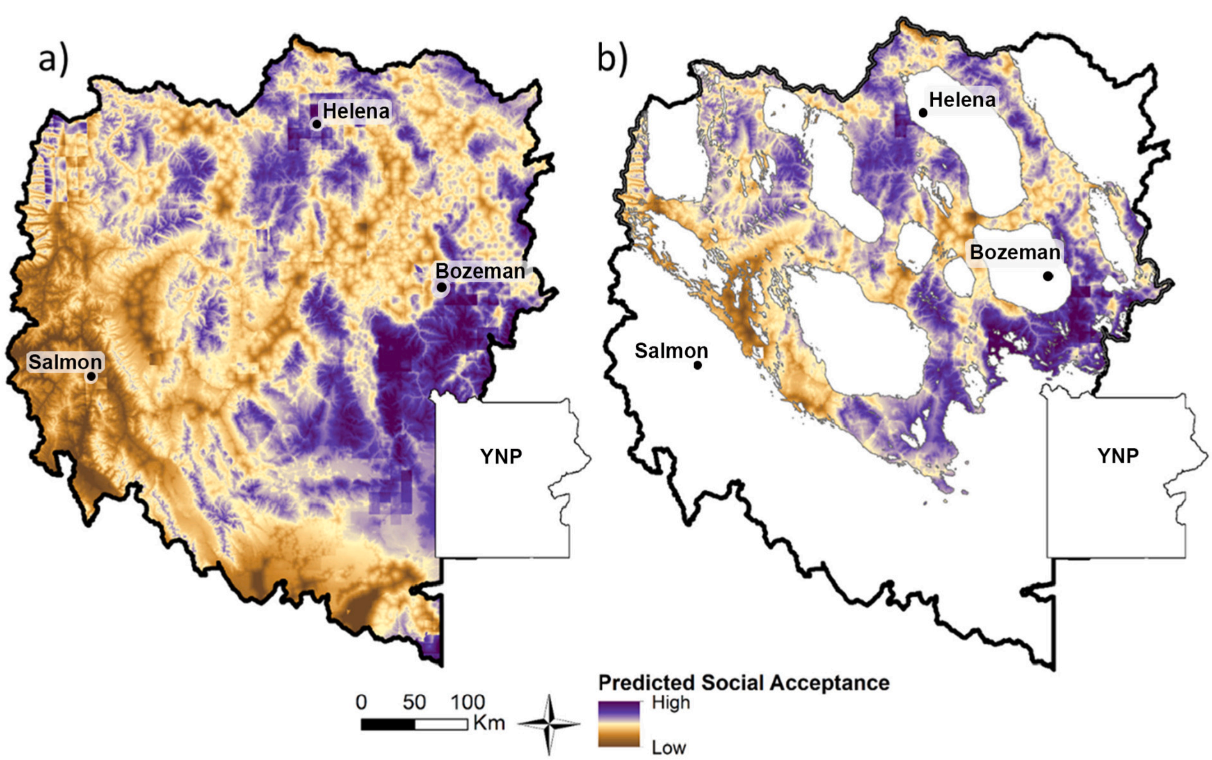

Fig. 4. Social acceptance predictions and overlay with grizzly bear predicted corridors in the High Divide of Idaho and Montana near Yellowstone National Park (YNP). a) Predicted social acceptance, and b) acceptance restricted to predicted movement corridors from Peck et al. (2017).

grizzlies (Berenguer et al., 2005). Despite increased acceptance in these areas, the risk for conflict and grizzly mortality will likely grow as the wildland-urban interface and human influence expands (Lamb et al., 2020).

Reliance on land for income appears to be important in shaping attitudes toward grizzlies. In the aspatial model, economic dependency on ranching was negatively related to acceptance (Fig. 3). This provides support for our second hypothesis and aligns with past literature that shows ranchers more reliant on the productivity of their ranch may experience more impactful financial losses from predators (Lindsey et al., 2013). Alternatively, reliance on the land may also correlate with social groups where norms help shape acceptance of grizzlies (Manfredo, 2008). But the importance of our economic predictors (income from Census data and distance to public land) was unclear at the community level in the spatial analysis, highlighting the need for fine-scale spatial variables for social and economic factors.

Our predictions provided spatially explicit information on acceptance to compare with movement corridors and allowed us to anticipate where dispersing bears might successfully establish connectivity. The northeastern most corridor (Fig. 3) was predicted to have high levels of acceptance and also high levels of bear passage, suggesting connectivity could be successful there (Peck et al., 2017). However, despite the high levels of acceptance, this corridor falls close to Helena and Bozeman, Montana, where higher densities of people create risks for negative encounters and human development and could impede successful movement. With high bear movement and high acceptance, providing ample resources and training for coexisting with bears could prepare ranchers who might be more receptive to predator-friendly ranching techniques. This area should also be prioritized for conservation easements to protect corridors from development. Acceptance was lowest across most of the southwestern corridor. This corridor was predicted to have a relatively low amount of bear movement, but Peck et al. (2017) caution against disregarding it because it contains the most contiguous, protected habitat in the region. It also connects the GYE and NCDE to the currently unoccupied SBE (Fig. 1). Here, managers might tailor educational outreach to highlight the benefits of grizzlies to increase acceptance and assess whether acceptance of grizzlies affects willingness to use nonlethal methods (Lischka et al., 2019).

Combining survey and spatial data is a new and exciting field for future work in applied conservation. Quantifying, predicting and mapping acceptance toward wildlife may be useful tool to advance foundational knowledge and the practice of coexistence in shared landscapes. We identified several challenges to overcome to help mitigate limitations. In both our aspatial and spatial analyses, a large degree of variance remained unexplained. Because of our focus on variables that could be spatialized, we suspect some of this variance was related to limited availability of appropriately scaled spatial data (Guerrero et al., 2013). Acceptance may not directly correlate to how a rancher will behave toward grizzly bears. However, spatial knowledge of acceptance could help managers know where and how to best approach each community to facilitate bear recovery. Furthermore, acceptance maps lay groundwork for understanding how attitudes affect corridor function by assessing whether successful dispersal is more likely in areas of high acceptance or not. Mapping social factors such as attitudes offers an innovative approach for understanding conservation challenges. Future work might incorporate spatial patterns of behaviors, such as use of nonlethal husbandry practices. Ranchers within these corridors play an important role in protecting and connecting habitat where development is occurring at rapid pace.

CRediT authorship contribution statement

Abigail Sage: Conceptualization, methodology, data curation, project administration, formal analysis, writing, visualization. Vicken Hillis: Conceptualization, writing – reviewing & editing, project administration. Rose Graves: Conceptualization, data curation, writing – reviewing & editing, project administration. Morey Burnham: Conceptualization, writing – reviewing & editing, project administration. Neil Carter: conceptualization, writing, project administration, supervision.

Declaration of competing interest

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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Disclaimer

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2022.109468.

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