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Applying a hierarchical Bayesian framework to reveal how fear and animal ownership drive human's valuation of and interactions with coyotes

Kimberly Rivera[1] | **Carlos Garcia-Quijano**[2] | **Virginie Sonnet**[3] | **Brian D. Gerber**[4]

[1]Department of Conservation and Science, Lincoln Park Zoo, Chicago, Illinois, USA

[2]Department of Sociology and Anthropology, University of Rhode Island, Kingston, Rhode Island, USA

[3]Graduate School of Oceanography, University of Rhode Island, Kingston, Rhode Island, USA

[4]Department of Natural Resources Science, University of Rhode Island, Kingston, Rhode Island, USA

Correspondence
Kimberly Rivera, Department of Conservation and Science, Lincoln Park Zoo, 2001 N. Clark St., Chicago 60614, IL, USA.
Email: kimberly.rivera22194@gmail.com

Abstract

Human dimensions research is valuable to managing human-wildlife interactions, especially in urban environments where such interactions are common. Survey data, which commonly contain Likert scales and questions, are useful in this field; however, these data can be difficult to analyze with formal modeling approaches. We demonstrate one approach, based on hierarchical Bayesian ordinal regression, to evaluate human-coyote relationships in Rhode Island, USA. We implemented a survey to collect demographic and sociocultural characteristics of Rhode Island residents and information related to their knowledge of and experiences with coyotes. Our objectives were to assess how these characteristics affected respondents' valuation of and interactions (sightings and incidents) with coyotes. We analyzed 980 surveys from October to December 2020. We found that respondents who had fear of coyotes or experienced an incident between an owned animal and coyote, had the lowest valuation of coyotes. The same demographic of respondents also reported the highest sightings of and incidents with coyote. These results indicate that fearful residents, in addition to pet and livestock owners, are priority targets for disseminating information or programming about coyotes. Our analyses and findings demonstrate how Bayesian ordinal regression can provide clear and appropriate inference from survey data on how groups of people vary in their relationship with wildlife. These results are important in effectively and efficiently allocating resources towards mitigation, education, and management of human-wildlife interactions.

KEYWORDS

Bayesian modeling, coexistence, coyote, human dimensions, Likert, ordinal regression

1 | INTRODUCTION

Understanding how people interact with and value wildlife species is critical for building successful wildlife management programs and tools (Knopff et al., 2016). This is especially true when considering contentious issues involving wildlife species whose presence may present risks on the landscape and cause polarized attitudes from the public. People's relationships with wildlife are shaped by many factors, including their demographics, lifestyles, or interactions with wildlife (Dickman, 2010; Elliot et al., 2016; Knopff et al., 2016). For example, Knopff et al. (2016) found that tolerance for cougars (*Puma concolor*) was shaped by respondents' intrinsic value of cougars, participation in hunting, age, and perceived risk of cougars. Studies conducted on coyotes (*Canis latrans*) identified that gender, where someone lives (e.g., county), and fear were also important predictors of public attitudes towards coyotes and their management (Draheim et al., 2019; Elliot et al., 2016; Sponarski et al., 2018). Disentangling these relationships is vital as people's perceived balance of the benefits, versus risks of predators on the landscape, can affect their tolerance (or lack thereof) of such wildlife (Treves & Bruskotter, 2014).

Studies that consider human-wildlife relationships can also reveal how human behaviors shape and instigate conflict. Findings from large carnivore research, for example, wolves (*Canis lupus*), bears (*Ursus arctos*), and cougars, have identified that ranchers who do not participate in deadstock removal initiatives, attract more predators. Thus these ranchers are at higher risk for negative carnivore-human interactions, such as livestock depredation (Morehouse et al., 2020). This is especially important because livestock owners are usually among the least likely stakeholder groups to support large carnivore protection (Smith et al., 2014). Other human behaviors, such as leaving food sources or unattended pets accessible to predators, have been found to increase negative coyote-human interactions in urban environments (Gehrt et al., 2009; Mitchell, 2017). Identifying these behaviors helps shape effective mitigation efforts, such as organizing and educating the public on proper waste or food disposal and heightened care of pets outside (Elliot et al., 2016; Mitchell, 2017).

Questionnaire or survey data have been an invaluable and low cost means to studying these human-wildlife relationships. To systematically collect respondent data, survey instruments are often comprised of Likert scales with ordered responses (e.g., strongly agree, agree, disagree, strongly disagree; Casey et al., 2005; Draheim et al., 2019; Sponarski et al., 2018). However, using survey data is complex, as people's psychological interpretations of questions and available responses vary. Common methods used to analyze ordered data include descriptive statistics to hypothesis tests (Casey et al., 2005; Knopff et al., 2016; Sponarski et al., 2018). An alternative method, which is less used but equally useful, is formal modeling via ordinal regression (Liddell & Kruschke, 2018). Ordinal regression is a statistical modeling framework commonly used in psychology. It explicitly considers ordered data, such as outputs from Likert scales, which may not scale equally among values (Bürkner & Matti, 2019; Larasati et al., 2011). In addition to estimating the variation between scale items within and between individuals, ordinal regression can model hypothesized effects of continuous or categorical variables on ordered categorical response variables (Bürkner & Matti, 2019). This is particularly useful for studies, which aim to translate and compare hypotheses into statistical models to evaluate empirical support using data (Burnham & Anderson, 2002).

Here, we exemplify how hierarchical Bayesian modeling can be used to conduct ordinal regression in the field of human dimensions in wildlife management. This method accounts for the variation among Likert scale questions and the perceived rating distance among respondents, while evaluating and comparing model hypotheses (Bürkner & Matti, 2019). We do so with a case study on the coyote, a native North American carnivore.

Over the last century, coyotes have expanded their range throughout the Americas, their success likely propelled by the extirpation of apex predators and increased agricultural landcover (Hody & Kays, 2018). These drivers, in conjunction with the generalist nature of coyotes, have allowed them to adapt to human-dominated landscapes (Carter et al., 2012; Gehrt & McGraw, 2007), including agricultural, suburban, and urban areas (Hody & Kays, 2018; Jackman & Rutberg, 2015; Rivera et al., 2022). Like many carnivore species, coyotes have faced a long and contentious history in America. Since European settlement, coyotes have been persecuted as pests that compete with humans for livestock and wild game (Reynolds & Tapper, 1996). Yet, even with wide-scale government-supported culling programs, coyotes continue to persist across the landscape and generate controversy (Draheim et al., 2019; Hody & Kays, 2018). This is particularly evident in urban areas where coyotes live in proximity to people and pose threats to humans through risk of zoonotic disease transmission, destruction of property, and the attacking or harassing of livestock, pets, or people (Elliot et al., 2016; Sponarski et al., 2018). However, coyotes also serve important ecological roles as top-down regulators of primary consumers (Benson et al., 2017; Henke & Bryant, 1999). In urban regions, their diet predominantly consists of small mammals and birds, likely benefitting humans as they consume common nuisance species, such as rodents and Canada geese (Gehrt & McGraw, 2007; Morey et al., 2007). These services may be especially valuable in urban landscapes, which lack apex predators and host an abundance of small animal species. With both risks and benefits to coyotes living among people, balancing coyote management with public concerns remains a challenge for wildlife managers and conservationists in urban spaces (Sponarski et al., 2018).

Our case study employs hierarchical Bayesian modeling to disentangle relationships between people and coyotes in Rhode Island, USA, and how we can translate these statistical findings into management recommendations. Coyotes were first sighted in Rhode Island in the 1960's and quickly colonized the state due to minimal competition and abundant food resources (Riley, 2021). Currently, coyotes are widespread, but there are sparse data on population estimates statewide (Mayer et al., 2023). Importantly, coyote presence is contentious; the majority of wildlife complaints were reported to the Rhode Island Department of Environmental Management regard coyotes (personal communication, October 2020). Given this contention, managers and conservationists require interdisciplinary tools to successfully manage coyotes and their relationships with humans.

We used a survey to investigate covariation between Rhode Island resident (hereafter, 'respondent') demographics and sociocultural characteristics to their relationships with coyotes. As peoples demographics and sociocultural characters shape their experiences with and attitudes towards wildlife, we hypothesized that these characteristics would impact the valuation and interactions with coyotes (Piédallu et al., 2016; Thornton & Quinn, 2010; Wechselberger et al., 2005). Specifically, we investigated respondent's age, gender, county of residence, relationship with nature, knowledge and fear of coyotes, animal ownership, and animal incidents with coyote (see Table 1). We predicted that animal incidents and fear of coyotes would negatively affect valuation. In contrast, we predicted increased knowledge of coyotes, those close to nature (as found in Elliot et al., 2016), and those who reported lacking fear of coyotes, would report a higher valuation. Further, we predicted that valuation would vary across gender and

TABLE 1 Definitions of ordinal regression response and predictor variables.

Category	Variable	Type	Description
Coyote valuation	Benefits of coyote	4 Likert scale questions strongly disagree—strongly agree	1 = low valuation 5 = high valuation
	Risks of coyote	4 Likert scale questions strongly disagree—strongly agree	5 = low valuation 1 = high valuation
Coyote sighting	Coyote sighting	Likert frequency item never—daily	1 = low sighting frequency 6 = high sighting frequency
Coyote incident	Coyote incident	Likert frequency item never—daily	1 = low incident frequency 6 = high incident frequency
Predictors	Age	Continuous (18 to 100)	Age in years
	Gender	Nominal	Man, woman and non-binary
	County	Nominal	County of main residence
	Inclusion of Nature of Self	Discrete (1 to 5)	Measure of biospheric values (Schultz, 2001) 1 = low biospheric values 5 = high biospheric values
	Animal ownership	Dichotomous	0 = no animal owned 1 = animal owned
	Coyote knowledge	Discrete (0 to 7) from 7 True/False questions	0 = only incorrect responses or 'I don't know' responses 7 = all responses were correct
	Animal incident	Dichotomous from 5 Yes/No questions	Incident where coyote growled, stalked, or attacked livestock or pets 0 = no incident 1 = incident occurred
	Fear	Dichotomous from Likert item	0 or lacking fear = disagree — strongly disagree 1 or fear = agree — strongly agree

counties with no directional predictions, as there are many underlying mechanisms that could drive variation. In regard to respondent's interactions (sightings and incidents) with coyotes, we hypothesized these were most influenced by participant's county of residence, relationship with nature, animal ownership (pets and livestock), knowledge, and fear of coyotes. We predicted that respondents who reported being closer to nature, owned animals, had increased knowledge of coyotes, or lacked fear of coyotes would spend more time outdoors, and thus would report increased interactions with coyotes. However, we predicted that respondents who had increased knowledge of coyotes and a close relationship with nature would have significantly more sightings, but less incidents with coyotes. We also predicted that respondents who were fearful of coyotes, but felt close to nature, would have fewer coyote sightings. Lastly, we expected that incidents between coyotes and respondents would greatly decrease for animal owners who were fearful of coyotes with the assumption that this group of animal owners would spend less time near potential coyote habitat and be more vigilant of coyote presence.

2 | METHODS

2.1 | Study area

Rhode Island is a developed northeastern coastal state located between the states of Connecticut and Massachusetts, USA. Natural landcover is predominantly deciduous and softwood forest intermixed with high and low intensity human development and agriculture. Rhode Island state has the second highest human density in the United States (Rhode Island Wildlife Action Plan, 2015) with >10% of the land covered by impervious surface area (Zhou & Wang, 2007) and a population of roughly 1,060,000 (U.S. Census Bureau, 2019). Residents are largely educated with 88.8% having completed a high school degree and 34.2% completing a bachelor's degree or higher. The median household income is $67,167.00.

2.2 | Instrument and data collection

We collected data through a self-selected online survey instrument using Qualtrics Survey Software and advertised it widely through news articles and promotional social media pages across Rhode Island. We conducted the survey over 2 months (October 6, 2020–December 6, 2020). Only respondents over the age of 18 were permitted to take the survey. The survey was categorized into six sections: (1) Rhode Island residency, (2) relationship with nature, (3) valuation, knowledge, and attitudes about coyotes, (4) human-coyote interactions, (5) environmental beliefs, and (6) demographics (full survey in Appendix S1). At the start of section three, respondents were given a figure depicting an image of a coyote and some basic information about their size and distribution. This figure was included to help respondents correctly identify coyotes and their experience with coyotes.

2.3 | Variables

We define valuation, or process of assigning a value, as the strength of an individual's belief in the positive (high valuation) and negative (low valuation) role coyotes play in the landscape—which may or may not be representative of coyotes' role in Rhode Island as a whole. We use the term 'valuation' to distinguish a specific type of value (an individual's belief) from the polysemous meanings of 'value'. To quantify this response variable, we used two 5-point Likert scales, one which addressed respondent's perceived benefits (e.g., 'coyotes have an important role in Rhode Island's ecosystems') and the other, perceived risks of coyotes (e.g., 'coyotes pose a risk to pets') on the landscape (Table 1). The five-point scale was ordered: strongly disagree, disagree, neither agree or disagree, agree, and strongly agree. The risk scale was reverse-coded so both risk and benefit scales increased with respondents increasing (more positive) valuation (Table 1). To quantify our second objective, human interactions with coyotes, we considered two types of interactions separately, sightings and incidents. A sighting was defined as a visual observation of a coyote (with no specification of distance or location, e.g., sighted during a walk or from a window). An incident was specified as a direct human interaction with a coyote where a coyote exhibits the following behaviors: growling, stalking, or attacking. We note that this is distinct from the explanatory variable, animal incidents, defined as instances in which a coyote exhibits the following behaviors towards pets or livestock: growling, stalking, or attacking.

We used dichotomous, multiple-choice, and scaled questions to collect data on respondent demographics, environmental values, animal ownership, knowledge of coyotes, fear of coyotes, and incidence between owned animals and coyotes (see Table 1). Fear was measured using a likert item (strongly disagree – strongly agree) and coded as binary where strongly disagree – disagree were coded as 0 and strongly agree – agree were coded as 1. We measured respondent closeness, or 'interconnectedness', with nature using Schultz' (2001) 'Inclusion of Nature of Self' scale—adapted from Aron et al. (1992);

this scale is positively related to one's biospheric values (Schultz, 2001).

2.4 | Analysis

To evaluate our hypotheses and predictions, we constructed a small set of models for each response variable. For valuation, we considered four statistical models where hypothesized variables were strictly additive or included interacting variables (fear interacting with animal incidents, closeness to nature interacting with knowledge, or closeness to nature interacting with fear; Table S1). We considered three statistical models for each respondent's sightings of and incidents with coyotes (Tables S2 and S3). We considered an additive model and two models which considered variable interactions for each sighting (connectedness to nature interacting with fear and connectedness to nature interacting with knowledge) and incidents (fear interacting with animal ownership and connectedness to nature interacting with knowledge). Interactions allow response variables to freely vary by combinations of each variable's level, but this comes at the cost of model complexity.

We followed Bürkner and Matti (2019) by adapting a hierarchical cumulative modeling framework to assess valuation by jointly analyzing Likert scales of coyote benefits and risks and used separate cumulative models to evaluate coyote-human sightings and incidents. The cumulative model assumes that we observe the ordinal variable Y (here valuation, sightings of, and incidents with coyotes), which originates from the latent, unobserved, continuous variable $\widehat{Y}$. The model also assumes K thresholds where $K+1$ is equivalent to the number of response categories. We use a probit link function, which assumes the latent variable, $\widehat{Y}$, follows a normal distribution and that the variance between response ratings does not differ across categories and measures of predictor variables (Bürkner & Matti, 2019). In our valuation analyses, we accounted for variation between Likert items, as well as variation in respondent's perceived distance between Likert ratings in this model (e.g., Respondent A may perceive a larger difference between Agree and Strongly Agree, than Respondent B; see full survey in Appendix S1) using random intercepts, where all the thresholds in the cumulative ordinal model vary. We fitted models using the *brms* package in R (version 4.1.1) and compared their support using leave-one-out-cross-validation (Bürkner, 2017; Vehtari et al., 2017), which estimates pointwise out-of-sample prediction accuracy; lower values indicate more empirical support for a model. For each model, we used diffuse Gaussian prior distributions and 10,000 Makov chain Monte Carlo iterations using three chains to evaluate convergence. Based on the Gelman–Rubin diagnostic (Gelman & Rubin, 1992) and visually examining traceplots (sampled values per chain) of the posterior distributions, we found models converged.

We quantified support for estimated effects by reporting the proportion of posterior samples, which were >0 as an indication of the probability that the effect is positive. Proportional values >0.9 indicated strong support for a positive effect, or conversely <0.1 indicated strong support for a negative effect. Probabilities >0.7 indicated moderate support of a positive effect and <0.3 indicated moderate support for a negative effect. Further, we used the magnitude of estimated effects to compare the relative influence of predictor variables; full posterior distributions are plotted and median and 95% credible intervals (CI) are reported.

3 | RESULTS

We collected a total of 980 survey responses. Screening techniques were applied to reduce inadequate and unusable responses (https://github.com/kimberlyarivera/Coyote_RI.git), resulting in 971 valid respondent surveys. The majority of respondents, 92.1%, were Rhode Island residents and had lived an average of 35 years in the state. Participation occurred across all Rhode Island counties with higher representation (in relation to population density) in Newport (7.81% of RI's total population lived in Newport and 16.57% of surveys came from here), Washington (11.89% of RI to 33.95% of surveys), and Bristol (4.60% of RI to 7.30% of surveys). The remaining counties, which were less represented in surveys, included Kent (15.45% of RI to 10.89% of surveys) and Providence (60.25% of RI to 31.29% of surveys). Respondents were highly educated with 78.37% of them having a bachelor's degree or higher compared to the state's average of 34.2%. This may be partially due to advertisements on the University of Rhode Island's webpage, thus leading to increased university student, faculty, and staff participation. The median household income for respondents ranged from $75,000–$99,999. Most respondents who disclosed their gender were women (46.5% to 33.4% men) and <1% of the respondents identified as non-binary.

We found the most supported model by leave-one-out-cross-validation for valuation to be one with an interaction between fear and animal ownership (Table S1). Our predictions that respondent's age (0.0, 95% CI = −0.01, 0.00) and knowledge (0.04, 95% CI = −0.01, 0.09) of

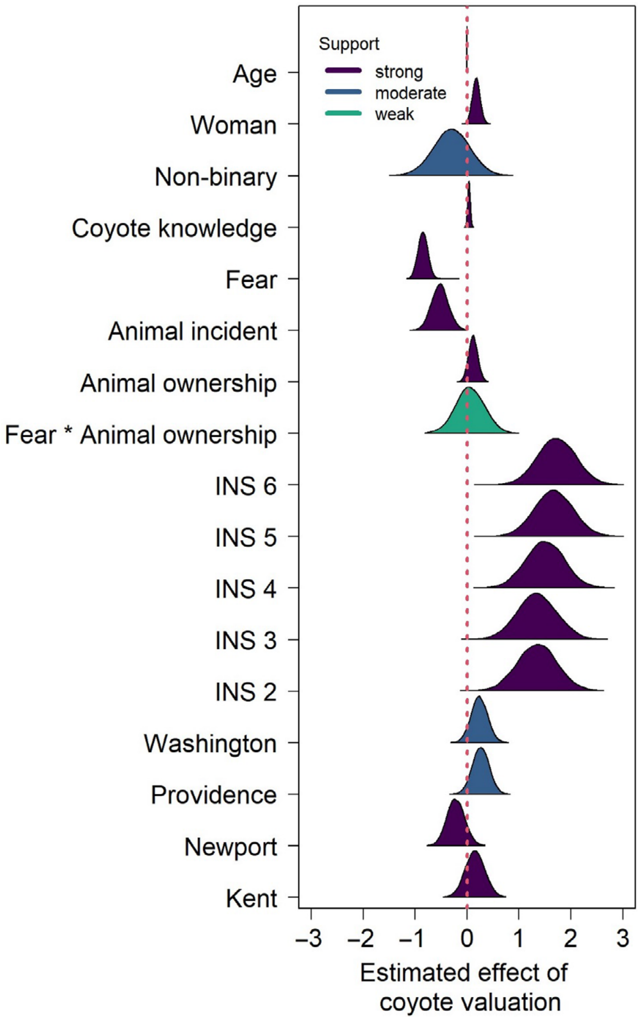

FIGURE 1 Posterior density plots for all coefficients from the most supported model (via leave-one-out-cross-validation) explaining valuation, or the strength of an individual's belief in the positive (high valuation) and negative (low valuation) role coyotes play in the landscape. Note, age is included but has a small posterior distribution with a median close to zero. The dashed red line indicates where there is a zero effect and colored posterior distributions differ by statistical support or probability of the effect, which were defined as strong support (p >.9 and <.1), moderate support (p >.7 and <.3), or weak support (p <.7 and >.3). The reference category for county was Bristol, man for gender, and 1 for the Inclusion of Nature of Self scale labeled here as 'INS'.

coyotes contribute to their valuation was unsupported with estimated medians close to zero (Figure 1). We found strong support that valuation increased with increasing connectedness to nature (Inclusion of Nature of Self >1; Figure 1). As predicted, valuation varied among genders and counties (Figure 1). Specifically, respondents who identify as a woman had a higher (e.g., more positive) valuation than those who identify as a man. Additionally, respondents from Newport and Bristol had the lowest valuation among counties (Figure 1). We found a strong conditional effect that owning an animal (owning an animal and lacking fear of coyotes) positively affected valuation (0.12, 95% CI = −0.05, 0.30; Figure 1.). However, there was strong evidence that animal owners who experienced an incident between their animals and coyotes would significantly decrease their valuation (−0.52, 95% CI = −0.84, −0.21). The strongest negative effect on valuation was the conditional effect of fear (fearing coyotes and not owning animals; −0.85, 95% = CI −1.03, −0.66). Though when respondents were fearful of coyotes and owned animals, there was no effect on valuation (0.06, 95% CI = −0.49, 0.060). This suggests that owning animals may moderate the influence fear has on valuation. Lastly, we found considerable variation in respondents Likert scores across questions (0.73; 95% CI = 0.67, 0.79) and individuals (1.06; 95% CI = 0.62, 1.98).

The most supported model by leave-one-out-cross-validation for coyote sightings considered only additive effects (Table S2). Connectedness to nature and knowledge of coyotes did not appear to have a relationship with coyote sightings (medians close to zero). The coefficients with the strongest statistical support were respondent's resident county, animal ownership and fear of coyotes. Our prediction that coyote sightings varied among counties was supported with the most sightings reported in Newport and Bristol counties. There was strong support against our prediction that fear of coyotes would decrease respondent's sightings of them, as fear had a positive effect on sightings (0.15, 95% CI = −0.05, 0.35, Figure 2). However, we did find strong evidence for our prediction that animal owners had increased coyote sightings as ownership had a strong positive effect on sightings (0.30, 95% CI = 0.10, 0.50).

The model most supported by leave-one-out-cross-validation for incidents with coyotes considered an interaction between fear and animal ownership (Table S3). We found moderate support that knowledge of coyotes had a weak effect on incidents (0.05, 95% CI = −0.04, 0.13; Figure 3). Additionally, there was no support that increasing connectedness to nature affected incidents with coyotes, though there was moderate support for a small decrease in incidents of respondents with an Inclusion of Nature of Self >1 compared to those who reported the least connection to nature (Inclusion of Nature of Self = 1). The coefficients with the strongest statistical support were respondent's county of residence, animal ownership, fear of coyotes and an interaction between respondent's fear and animal ownership (Figure 3). Our prediction that human-coyote incidents varied across counties was supported with Newport and Bristol

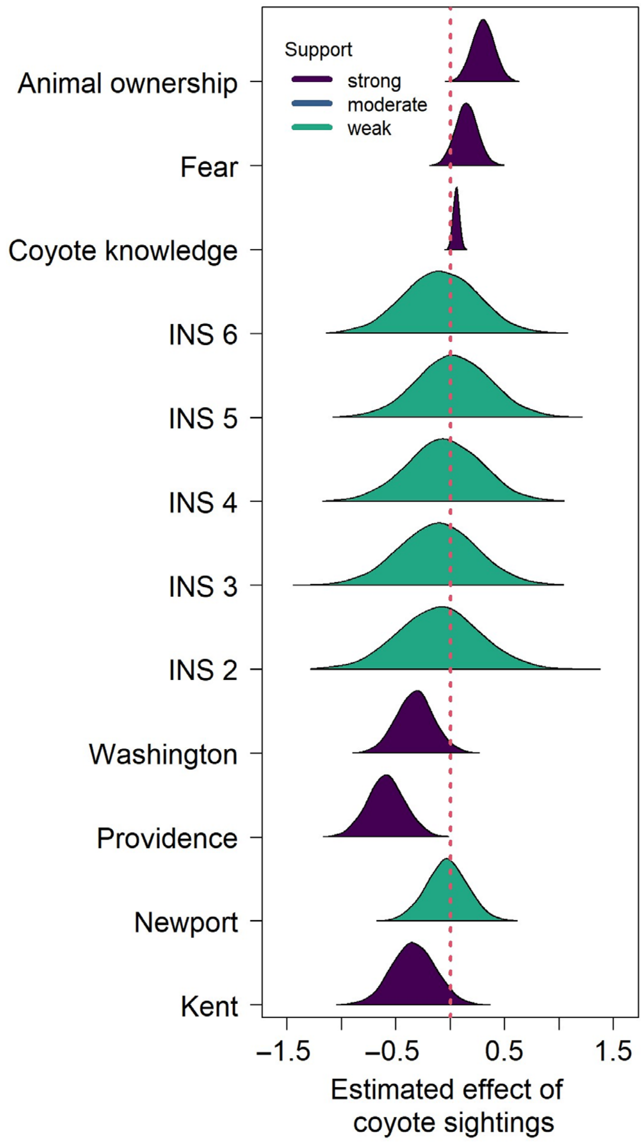

FIGURE 2 Posterior density plots for all coefficients from the most supported model (via leave-one-out-cross-validation) explaining coyote sightings. The dashed red line indicates where there is a zero effect and posterior distributions are colored by statistical support or probability of the effect, which were defined as strong support (p >.9 and <.1), moderate support (p >.7 and <.3), or weak support (p <.7 and >.3). The reference category for county was Bristol and 1 for the Inclusion of Nature of Self scale labeled here as 'INS'.

reporting the most incidents. We found strong positive support for the conditional effect of fear (fearing coyotes and not owning an animal; 1.41, 95% CI = 0.79, 2.07) and animal ownership (owning an animal and lacking fear of coyotes; 0.53, 95% CI = 0.09, 1.01) on respondent's incidents with coyotes. However, we found strong support that respondents who own animals and fear coyotes, experience decreased incidents with coyotes (−0.64, 95% CI = −1.32, 0.04).

4 | DISCUSSION

Our results highlight that both respondents' fear of coyotes and incidents between owned animals and coyotes strongly decreased (negatively affected) valuation. These results align with other studies, which have found fear to increase people's perception of risks posed by wildlife (Bruskotter & Wilson, 2013; Lambertucci et al., 2021) and generate negative attitudes towards them (Notaro & Grilli, 2021). We also found that some demographics, gender and county of residence, affected valuation differently. For example, women had a more positive valuation than men, which could lead to women being more tolerant of coyote presence than men (Draheim et al., 2019). These differences could be a driver in why men tend to support more lethal methods of coyote management (Draheim et al., 2019). Residents of Newport and Bristol counties had the most negative valuation of coyotes compared to other counties. Data gathered by the Cooperative Coyote Research Project, which aims to develop 'science-based coexistence and management strategies' for coyotes in Rhode Island (http://theconservationagency.org/narragansett-bay-coyote-study/), demonstrates that Newport, and surrounding towns on Aquidneck Island, have experienced heightened interactions with coyotes, predominantly driven by direct and indirect supplemental feeding by locals (Mitchell, 2017). These heightened negative interactions are likely driving decreased valuation in these regions. Media coverage on these incidents and project efforts may have also increased the public's awareness of coyote presence and perception of risk. Other human-wildlife coexistence campaigns, such as the New York's NeighBEARhood Watch (a human-bear conflict communication campaign) found that local media amplified risk associated with black bears despite their collaborative communication efforts with the media (Gore & Knuth, 2008).

Despite animal owners having more positive valuations than nonanimal owners, we found strong support that animal owners more frequently saw and experienced incidents with coyotes. These results could indicate that animal owners exhibit different behaviors than nonanimal owners. Of all animal owners in our study, 72.6% reported owning pets which likely require owners to spend time outside caring for their animals, such as walking or feeding them outside (e.g., livestock and dogs vs. indoor cats or reptiles). These behaviors, or additive time spent outside, could contribute to increased opportunities to interact with coyotes. The presence of these animals outside may also form as a coyote attractant, thus increasing the likelihood of an interaction with a coyote. Though there is an abundance of literature hypothesizing predictors of pet or livestock interactions with coyotes (McInturff et al., 2020; Poessel et al., 2013;

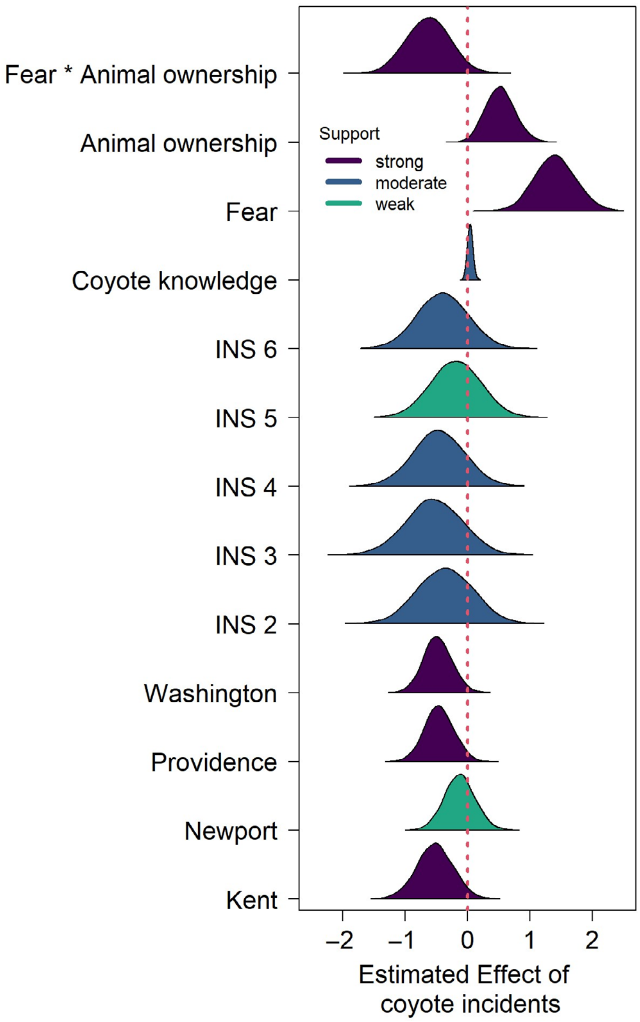

FIGURE 3 Posterior density plots for all coefficients from the most supported model (via leave-one-out-cross-validation) explaining coyote incidents. The dashed red line indicates where there is a zero effect and posterior distributions are colored by statistical support or probability of the effect, which were defined as strong support (p >.9 and <.1), moderate support (p >.7 and <.3), or weak support (p <.7 and >.3). The reference category for county was Bristol and 1 for the Inclusion of Nature of Self scale labeled here as 'INS'.

Poessel et al., 2017b), there is a lack of research specifically disentangling how the presence of owned animals impacts human-coyote interactions.

Our findings also suggest that communities, which frequently see and experience incidents with coyotes have lower valuations, as exemplified in Newport and Bristol counties. A similar result was found in communities which live among large carnivores (e.g., wolves), where people living in proximity to these species tend to possess more negative attitudes of those species (Carlson et al., 2020; Karlsson & Sjöström, 2007). These attitudes can be driven by direct interactions with carnivores or via indirect experiences shared within a community via communication with friends, media, and so forth. (Karlsson & Sjöström, 2007).

Respondents who were fearful of coyotes reported significantly higher sightings and even more incidents than nonfearful respondents. Fear of wildlife is known to increase people's perceived risks of that wildlife (Bruskotter & Wilson, 2013), thus we consider that reports of incidents may be biased for this population. Specifically, we consider that fear may affect a respondent's interpretation of a human-coyote incident, meaning fearful people may be more likely to interpret normal coyote behavior as aggressive. For example, although a coyote passing through someone's backyard may inflict fear in observers, we would not consider this experience an 'incident', as no aggressive behavior was observed (stalking, growling, attacking). However, we found that respondents who were fearful of coyotes and also owned animals, reported decreased incidents. This finding indicates that the possession or presence of an owned animal reduces real or perceived incidents with coyotes, though further study is needed to parse out the nuance of these relationships.

Large-scale coyote removal (lethal and relocation) has generally been ineffective in reducing coyote populations over short- or long-time scales (LeSher, 2020; Morin & Kelly, 2017). As such, developing effective education tools is a critical component in the path toward successful management programming (Poessel, Gese, & Young, 2017; Timm et al., 2004; van der Ploeg et al., 2011), especially as this relates to a fearful community of people (Frank et al., 2015; Røskaft et al., 2003). Our findings indicate that communicating appropriate risk assessment of coyote presence and behavior will largely benefit Rhode Island residents. Both the Rhode Island Department of Environmental Management (RIDEM) and the Cooperative Coyote Research Project have taken the lead in developing an array of educational resources including guides to mitigate human- or pet-coyote incidents (such as hazing and pet safety practices in addition to identifying coyote attractants), ecological guides, and coyote reporting tools (https://dem.ri.gov/natural-resources-bureau/fish-wildlife/learn-about-ri-wildlife; https://www.coyotesmarts.org/). Beyond fearful residents, our research indicates that pet and livestock owners are important targets for disseminating these resources. Therefore, we recommend managers and conservationists collaborate with veterinary and animal clinics in addition to pet or feed stores to disseminate synonymous information on animal safety, mitigation tools, and hazing techniques (Fox, 2006)—most of which are addressed in Rhode

Island's 'Management and Response Guide' (see first link above; Riley, 2021). Communicating via trusted and interdisciplinary networks, such as veterinarians, can be an effective communication strategy (Fox, 2006) in addition to building trust between wildlife managers and the public (Bruskotter & Wilson, 2013). Connecting with dog owners may be especially important as studies have found that the presence of dogs can reduce the effectiveness of hazing with voice, body, and/or approaching a coyote (Bonnell & Breck, 2017). Therefore, training dog owners on the appropriate use of hands-on tools such as blowhorns, citronella spray, pepper spray, and so forth. (Miller, 2001), may be an effective way to address coyote-dog interactions and dissuade pet-owner fear.

We demonstrate how hierarchical Bayesian ordinal regression modeling may incorporate and estimate known sources of variation when analyzing questionnaire data (e.g., among questions and respondents). Identifying predictors of human-wildlife interactions and valuations is critical to informing decision and policy-makers in how to best build and disseminate management practices (Knopff et al., 2016). Although our results reflect a single study system, they illustrate how we can use survey data to learn about human-wildlife relationships. Through this knowledge, we can better target conservation actions and foster positive human-wildlife relationships, not just with coyotes, but other urban wildlife.

5 | LIMITATIONS

As a self-selected, online survey, our sample of responses comes with inherent biases. Sampled demographics, such as wealth and education, were above state averages and may have biased our results relative to the total population of Rhode Island. County representation varied; therefore, we suggest future studies integrate online and in-person advertisements to be more inclusive across these demographics. However, our survey did obtain a wide distribution of respondents across age groups despite findings of decreased internet use in older age classes (65–74; Ferri-García & Rueda, 2020). Increased internet use across ages could be tied to the COVID-19 pandemic, which was largely affecting Rhode Island residents at the time of this survey. Methods to account for self-selection bias were not included in this case study, however we recommend future studies to consider methods like propensity score adjustment (PSA), which uses auxiliary information collected from an unrelated study to reduce bias from confounding factors (Ferri-García & Rueda, 2020).

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DATA AVAILABILITY STATEMENT

Custom code and data for this analysis is available on GitHub (https://github.com/kimberlyarivera/Coyote_RI.git). Data was collected under IRB permission #: 00000599.

ORCID

Kimberly Rivera https://orcid.org/0000-0001-7399-2096
Brian D. Gerber https://orcid.org/0000-0001-9285-9784

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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