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Unwanted residential wildlife: Evaluating social-ecological patterns for snake removals

Bateman HL[1*], Brown JA[2], Larson KL[2,3], Andrade R[4], and Hughes B[5]

[1]College of Integrative Science and Arts, Arizona State University, 6073 S. Backus Mall, Mesa, Arizona, USA 85212

[2]Julie Ann Wrigley Global Institute of Sustainability, Arizona State University, 800 Cady Mall, Tempe, Arizona, USA 85281

[3]School of Geographical Sciences and Urban Planning, School of Sustainability Arizona State University, 800 Cady Mall, Tempe, Arizona, USA 85281

[4]Department of Natural Resources and Environmental Sciences, University of Illinois at Urbana - Champaign, 1102 South Goodwin Ave, Urbana, Illinois, USA 61801

[5]Rattlesnake Solutions, LLC, 3620 E Nisbet Rd., Phoenix, Arizona, USA 85032

*Corresponding author: Heather.L.Bateman@asu.edu and heather.bateman@gmail.com, (480)727-1131

Abstract

Snakes are globally threatened due to anthropogenic pressures. Conflicts between snakes and people occur when residents encounter snakes in their home environments. In collaboration with a local business that provides snake removal services, we examined records from over 2,000 snake removals in Phoenix metropolitan area, Arizona, United States between 2018-2019. We examined removal locations in relation to neighborhood-level socioeconomic attributes from the American Community Survey and individual demographics from a social survey of 494 respondents. Over 68% of removals were of the venomous Western Diamond-backed Rattlesnake (*Crotalus atrox*), which is the most common species in the area observed in community-sourced data and publications. Removals occurred throughout the year except winter and peaked during summer rainy season. Snakes were frequently removed from neighborhoods with wealthier and more highly educated residents, greater proportion of Latinx residents, and recently constructed homes. Individual perceptions of snakes as problematic were not related to the number of snakes removed. This research is the first to analyze snake

removals in a social-ecological context and underscores the conservation benefits of researchers partnering with a local business to gain spatial and temporal information on an elusive taxon. Similar collaborations could lead to direct conservation action for snakes by researchers learning from community members in cities and by groups willing to use results from research partnerships to inform their practices. Understanding how to maintain biodiversity in urbanizing arid regions could protect snakes if relocating snakes away from areas of high human density translates into fewer snakes killed by people annually.

Keywords

Crotalid rattlesnake, Human-wildlife interactions, iNaturalist, Nuisance wildlife, Wildlife relocation, Risk perceptions, Snake conservation, Urban ecology

1. Introduction

Areas of high biodiversity are often conservation targets; however, many biodiverse regions also experience rapid urbanization that threatens wildlife habitat (Cincotta et al. 2000; Rebelo et al. 2011). In dryland ecosystems, such as the Sonoran Desert of North America which is home to 24 endemic species of snakes (Blair et al. 1976), urbanization is the primary force behind land use change (McDonald et al. 2011). Snakes are especially susceptible to anthropogenic pressures and are declining globally due to habitat loss, overexploitation, and direct killing (Gibbons et al. 2000). The overlap between urbanization and squamate reptiles (snakes and lizards) is of great conservation interest since squamate reptiles' responses to urbanization are among the least understood of all terrestrial vertebrates (Germaine and Wakeling 2001; Banville and Bateman 2012). Declines of reptiles in urban areas have been linked to alteration and removal of habitat (How and Dell 1994; Mitchell et al. 2008), road mortality (Shine et al. 2004), and challenges related to movement and finding food (Garden et al. 2006).

Urbanization increases human-wildlife interactions, which can have direct impacts on wildlife (Soga and Gaston 2020). For conservation in cities, managing human-wildlife

interactions requires understanding human perceptions and actions in shaping urban ecosystem outcomes (Soulsbury and White 2015). Although perceptions can influence actions, disconnects between perceived and actual risks are common (Dickman 2010). People's perceptions and interactions with wildlife can be specific to the taxon. For example, humans view birds favorably when they have a pleasant song (Cox and Gaston 2015; Andrade, Larson et al. Unpublished), and may rescue them if they are viewed as needing help (Andrade, Bateman et al. Unpublished). However, reptiles are often viewed as a threat or nuisance. Negative outcomes, such as killing, can occur when humans fear or merely dislike wildlife (Burghardt et al. 2009; Baker et al. 2016; Chippaux 2017). In contrast, positive impacts, such as removing or relocating animals from roadways may be the result of a biophilic view toward wildlife (Gilbert et al. 2017). Understanding motivations for wildlife relocation is limited because few investigations have focused on people that remove wildlife. Evaluating why individuals remove wildlife can provide insight into their capacity and willingness to engage in other actions that affect wildlife.

Human-wildlife interactions are influenced by both the geographic distribution of wildlife based on the environment and by how people are distributed in a city (Lopez and Minor 2020). The interaction between urban infrastructure and biodiversity are often stratified along socioeconomic divisions (Schell et al. 2020). For example, higher-income communities tend to support higher levels of biodiversity (Hope et al. 2003; Leong et al. 2018), including more plants (Leong et al. 2018), birds (Warren et al. 2019), and lizards (Ackley et al. 2015). This pattern is especially pronounced in arid cities (Chamberlain et al. 2020). Ultimately, whether and how humans interact with wildlife can depend upon availability of resources (e.g., time and money) and their motivations (e.g., environmental values and attitudes) to engage in nature-based activities (Clucas et al. 2015; Bennett et al. 2018). Beyond one study (Teixeira et al. 2015) that found people with higher incomes used a government service to remove snakes more so than others, little research has examined human interactions with snakes are related to the socioeconomics and public perceptions and attitudes.

Most urban wildlife species that humans interact with tend to be common species and introduced urban-exploiters (Tribe and Brown 2000; Dunn et al. 2006; Andrade, Bateman et al.

Unpublished). However, investigations of interactions between humans and wildlife are often limited to large or charismatic taxa, such as mammals and birds (Gehrt et al. 2011; Cox and Gaston 2016; Andrade, Bateman et al. Unpublished). Despite evidence for the persistence of snakes in urban environments, snakes are often understudied in these settings (Sullivan 2012; Gangloff et al. 2017). Conservationists have turned to community-based science to study urban wildlife of less studied taxa (Cooper et al. 2007). Here, we leverage a unique and extensive dataset by collaborating with a local business to better understand human interactions with snakes.

We evaluated data from individual households that paid a local business to remove snakes (hereafter, clients) and non-client households from an urban ecosystem (Figure A1) with a high diversity of Crotalid rattlesnakes, Phoenix, Arizona, in the Sonoran Desert. Our research aims were to evaluate (1) whether removals were of species common in the region, (2) whether the traits of snakes (body-size, coloration, foraging mode) related to their removal, and (3) if temporal and spatial distributions of removals were related to season and proximity to undeveloped habitat, respectively. We also investigated the spatial distribution of removals in relation to (4) the socioeconomic capacity and other demographic characteristics of residents, and (5) perceptions of snakes being problematic. We provide a novel integrative approach utilizing data sourced from a local business to evaluate biological and socioeconomic factors that influence snake removal and how they relate to urban residents that engage with problematic wildlife. Ultimately, this research contributes to the conservation of an understudied, and often misunderstood, taxon living in urban areas.

2. Materials and methods

2.1 Study area

Our study occurs in Maricopa County and the greater Phoenix Metropolitan area, in central Arizona, United States. The region has a growing population, estimated at 4.5 million (U.S. Census Bureau 2018). Maricopa County lies within the Lower Colorado River Desertscrub and Arizona Upland Desertscrub subdivisions of the Sonoran Desert (Brown and Lowe 1980). The area has a wide range of topography with low-lying areas along the Salt River (162 m) and

rocky ranges (1583 m). The Sonoran Desert is known as a biodiversity hotspot for reptiles (Dimmitt et al. 2015). It is a diverse biome and Arizona has over 50 species of native snakes (Brennan and Holycross 2006), and one of the most diverse rattlesnake (*Crotalus* spp., family Viperidae) assemblages in the United States (Crother et al. 2012). Most species of snakes in the area are non-venomous, but six species of rattlesnakes occur in Phoenix and surrounding suburbs (Pitts et al. 2017).

Rattlesnakes are diverse in habitat selection and vary from large-bodied, generalist species, such as the Western Diamond-backed Rattlesnake (*C. atrox*), to more specialized species, such as the Tiger Rattlesnake (*C. tigris*) and Southwestern Speckled Rattlesnake (*C. pyrrhus*), associated with rocky hillslopes. Other species include: Sidewinder (*C. cerastes*), Western Black-tailed Rattlesnake (*C. molossus*), and Mohave Rattlesnake (*C. scutulatus*). As a result, Phoenix residents experience different local snake communities. Moreover, the chance of encountering snakes in the city can vary dramatically depending on proximity to undeveloped desert (Pitts et al. 2017). Residential yards, such as grassy mesic yards and low water-use xeric landscaping, are influenced by sociodemographics (Wheeler et al. 2020) and provide snake habitat.

2.2 Snake data

We analyzed data on snake removals occurring in 2018 and 2019 from Rattlesnake Solutions, LLC (rattlesnakessolutions.com), a Phoenix-based company that removes snakes, conducts snake inspections, and installs rattlesnake-proof fencing. The company also works to conserve snakes and educate the community about native reptiles. For example, if a nuisance snake is determined to be a harmless non-venomous species, the company recommends avoiding removal. However, technicians will remove non-venomous reptiles if desired by the resident. The data we analyzed includes species, number of snakes removed, and location of removal. Data were collected from service calls when a snake was removed or a removal was requested.

We classified species removed based on seven functional traits derived from Brennan and Holycross (2006). Traits included whether the species was dangerously venomous or non-

venomous based on whether it posed a threat to humans and pets. Technically, some Colubrid snakes are mildly venomous or have mildly toxic saliva, but are not harmful to humans and pets. Traits included dominant coloration pattern (bright warning or cryptic), and whether the snake was bi- or tri-colored or a single color (Table A1). We also categorized snakes based on adult body size (large, medium, small), body girth (thick or thin), total length (in mm), and foraging strategy (i.e., active pursuit or passive sit-and-wait predator).

To determine if the removal rate of a species was in line with its frequency in the environment, we compared removals to published articles (Jones et al. 2011; Sullivan et al. 2017) and community science sources on snake sightings. We used the community science platform, iNaturalist.com, using the following filters: snakes, Maricopa County Arizona, observations classified as Research Grade (verified by the community), and dates from 1-1-2010 to 8-26-2020.

2.3 Neighborhood demographic data

Demographic information was aggregated at the census block level using data from the American Community Survey (U.S. Census Bureau 2018). For each census block (i.e., neighborhood), we evaluated four sociodemographic variables – income (median household), education, age (median age of residents), and ethnicity (percent of white or Caucasian, Black or African-American, and Latinx). Education was averaged among all individuals over 25 in the census block group; this variable ranged from 1-7, with 1 indicating “no formal education”, 2 less than high school education, 3 some high school with no diploma, 4 a high school diploma or equivalent, 5 some college up to an associate’s degree, 6 a bachelor’s degree, and 7 an advanced degree.

2.4 Social-survey and parcel data from non-client households

To explore how snake removals are related to people’s environmental values and risk perceptions, we used data derived from the 2017 Phoenix Area Social Survey (Larson et al. 2017). Although these survey data were not for snake removal clients, we matched snake removals within 500 m of the responder’s address to their views about snakes and the

environment broadly. We selected a 500 m buffer to represent a distance in which respondents may have interacted with a snake, as this represents the home range of common snakes in this study (RodrÍguez-Robles 2003). The area would also be a likely walking distance for city residents (Kerr et al. 2016) and representative of the type of landscaping that can influence reptiles in neighborhood (such as with lizards, Ackley et al. 2015). We included survey data that asked respondents what percent of their front and back yards consisted of turf grass. We classified yards with less than 50% grass as xeric and over 50% grass as mesic (Wheeler et al. 2020). Survey respondents were asked if they owned a cat or a dog. Tax assessor data from Maricopa County provided the year of construction, year of purchase by the respondent, and purchase price. These variables were linked to the snake removal dataset by location (i.e., unique latitude, longitude coordinates).

The social survey involved random samples drawn from 12 Phoenix neighborhoods stratified by location within the metropolitan region (i.e., central, suburban, fringe), housing age, and resident income and ethnicity. Details about the social survey mailings and response rate (39.4%) can be found in Smith et al. (2020). Although the survey yielded 497 responses, our analyses included 494 responses as some were missing locational data or were removed due to inconsistent or non-logical answers.

To measure environmental values, the survey included the commonly used New Ecological Paradigm scale (Dunlap et al. 2000). Also known as pro-ecological worldviews, the scale includes 15 statements that capture broad-based beliefs (also known as value orientations) about human relationships with natural resources and the environment (verbatim questions in Table A2). The response scale ranged from strongly disagree to strongly agree on a 5-point scale. We averaged each individual's responses to the 15 questions, wherein higher numeric values indicated pro-ecological worldviews (Table A2). To capture perceptions about snakes, the survey included a question about the extent they view snakes as problematic where they live (Table A3). This variable was measured on a five-point scale, from (1) not at all a problem to (5) a very big problem.

2.5 Pilot survey of snake-removal clients

To understand the motivations of snake-removal clients, we deployed a web-based survey from September to December 2020 using Qualtrics version 9.2020. To recruit participants, clients of Rattlesnake Solutions, LLC received an electronic message with a link to the web-based survey after they entered information for the paid snake-removal service. The link directed the clients to an external web site hosted by Arizona State University. The survey took approximately 5-10 minutes to complete and collected attitudinal data on clients' motivations for removing snakes from their property, questions to measure attitudes about snakes, and demographics of the respondents. To assess motivations for removal, clients were asked to rank five reasons for removal (Table A4). Motivations were measured on a four-point scale from (1) not a reason to (4) major reason. To understand attitudes toward snakes, individuals were asked five questions about their opinions about snakes (Table A4). Clients were asked whether it was okay to kill snakes in a variety of situations (Table A4).

2.6 Data analysis

To test how snakes' traits influenced the likelihood of removal, we used a generalized liner mixed-model. We used traits of snakes (e.g., size, color, foraging mode, etc.) as predictor variables and the number of individuals per species removed as the dependent variable drawn from a Poisson distribution. We used species identity as a random effect to help control for non-independence because multiple traits are tied to a single species, and therefore are not completely independent (Stone et al. 2011).

To test how sociodemographic factors were related to snake removal, we conducted analyses at two scales: the neighborhood and household level. The neighborhood-level analysis investigated broader patterns in how sociodemographic factors may influence snake removals, while the household-level analysis provided insight into how environmental values and perceptions of snakes were associated with snake removal. For the neighborhood-level analysis, we ran two generalized linear mixed-model with the number of venomous or non-venomous snakes removed from census blocks as the dependent variable drawn from a zero-inflated Poisson distribution. We used a zero-inflated Poisson distribution because the

underlying distribution of snakes in our study area influences whether a snake is available to be removed in the first place. A zero-inflated Poisson distribution adjusts for the underlying distribution of snakes to better account for zeros in the data set (i.e., a snake can only be removed from areas where there are snakes and thus a 0 may indicate that there are no snakes present, not that people did not remove snakes due to sociodemographic factors).

Predictor variables in our neighborhood-level models included median age, ethnicity (as three separate variables - percent white, Black, and Latinx), median income, and median education. We included interaction effects between median household income and education, median education and percent Latinx, and median income and percent Latinx. To control for the possible underlying distribution of snakes and how snake removal might depend upon the number of people in an area, we included the distance of each neighborhood (census block) from a desert preserve or desert open space (as a proxy for habitat suitability) and population density of each block (to control for increased chances of human-snake interactions in areas with more people). Prior to running this model, a Spearman's correlation analysis was run and no variables were found to be significantly colinear at a level above or below 0.7 (Hothorn and Everitt 2014). After running our models, we standardized the beta estimates to make comparisons between each predictor variable more direct (Vittinghoff 2005).

Using the social survey dataset from non-clients, we related snake removals (that occurred within 500 m) to individual household yard types and perceptions. In the analysis, we related pro-ecological worldviews and perceptions of snakes, along with demographic and yard type features, as factors associated with snake removal within the 12 survey neighborhoods. The dependent variable was the number of snakes removed within 500 m of respondents from a zero-inflated Poisson distribution. Predictor variables included gender, age, income, education, and whether an individual identified as Latinx. All analyses were done in base R version 3.5.1 and with the lme4 package (Bates et al. 2015, R Core Team 2018). To explore attitudes and motivations of people who pay for snake removals, we summarized descriptive statistics for the reasons reported from a pilot survey of individual clients (n=30).

3. Results

3.1 Snake removals by species and traits

A total of 2,322 individual snakes of 22 different species were removed between 2018-2019 (Table 1, Table A1). On a per year basis, the number of snakes removed by Rattlesnake Solutions, LLC was 3.8 times greater than snake observations from the other data sources combined (Table 1). Two generalist species, the Western Diamond-backed Rattlesnake and Sonoran Gophersnake (*Pituophis catenifer affinis*), were the most frequently removed species, making up 68% and 16% of removals, respectively (Table 1). These species were also the most common snakes recorded via community science iNaturalist observations over the past ten years (Table 1). Compared to literature sources, Western Diamond-backed Rattlesnake was the most common species in a large natural area near urbanization (Sullivan et al. 2017; Table 1), but was the fourth most common species from road-riding surveys in non-urban areas of the county (Jones et al. 2011; Table 1). Sonoran Gophersnake, the second most common species in our study, was not the most numerous species from the literature (Table 1) but it was not uncommon.

We found that removals peaked during particular times of the year and that species removed had specific traits. Common species removed, rattlesnake and gophersnake, were active during all months except for winter months (December, January, February) and removals peaked in the spring and during the summer rainy season prior to brumation (inactive season; Figures 1-2). Maps of snake removals show that non-venomous snakes occurred in the center of the metropolitan area and venomous snakes were more common near desert open space (Figure 2). Snake species with large bodies were more likely to be removed than medium or small snakes (Figure A2). Heavy-bodied, thick snakes were more likely to be removed, as were species which were longer in length. More sit-and-wait foraging type snakes were removed compared to active foragers. Species with warning coloration were more likely to be removed compared to cryptically colored (Figure A2).

3.2 Snake removals and neighborhood-scale demographics

Of the 2,322 total removals, 1,375 were venomous snakes removed from 259 census blocks (Figure 1). The neighborhood-level model results indicated four sociodemographic variables (age, income, education, and percent Black) and one interaction between sociodemographic variables (income X education) were significantly related to venomous snake removal (Figure 3, Table A5). Both income and education increased the likelihood of venomous snake removal from a census block; however, age, percent Black, and the interaction between income and education meant that venomous snake removal was less likely from neighborhoods with high income and education. Our model also showed a significant positive relationship between a census block's population density and the likelihood of venomous snake removal. Finally, fewer venomous snakes were removed from census blocks further from desert preserves.

A total of 947 non-venomous snakes were removed from 307 census blocks (Figure 2). Four sociodemographic variables (age, income, education, and percent Latinx), and two interaction effects (income X education and education X Latinx) were significantly related to non-venomous snake removal. Income, education, and percent Latinx increased the likelihood of non-venomous snake removal from a census block. However, fewer non-venomous snake removals came from neighborhoods with older residents, with high income and education, and from high income and high proportion of Latinx households (Figure 3, Table A6). The likelihood of non-venomous snake removal increased with population density and decreased with increasing distance from a desert preserve.

3.3 Snake removals and explanatory factors from non-client household survey and parcel data

Of the 494 total respondents of the neighborhood social survey, 121 households had at least one snake (and up to 7 snakes) removed within 500 m of their home between 2018 and 2019. In total, 242 venomous and 73 non-venomous snakes were removed across the 12 neighborhoods. Venomous snake removals were predicted by six variables at the household/parcel scale (Figure 3, Table A7). Snake removals occurred more often in areas with

newer housing and longer-term residents, though the age of housing was insignificant in explaining the distribution of snake removals. More snakes were removed in residential areas with xeric yards. Respondents with higher income and pro-ecological worldviews were more likely to live in areas with more venomous snake removals. Dog ownership decreased the likelihood of snake removal within the surrounding landscape. Non-venomous snake removals were predicted by income and the sale date of the house (Figure 3, Table A8). As with the venomous snake model, increasing income was associated with increased snake removal. However, unlike the venomous model, more recent home sale years were associated with increased removal, not decreased removal.

Interestingly, both analyses show nonsignificant relationships between snake removals and residents' beliefs that snakes were a problem in their neighborhood (Figure 4, Tables A6 and A7); however, there were some interesting patterns. Out of the 12 study neighborhoods, the area where the majority of residents thought snakes were a problem was adjacent to a mountain preserve and did indeed have the most snakes removed (Figure 4). However, when considering snake removals per capita, the greatest removal occurred in a southern neighborhood also near a mountain preserve (Figure 4), but the residents from these two neighborhoods perceived risks of snakes as only somewhat problematic (Figure 3A).

3.4 Motivations and attitudes of snake-removal clients

A total of 29 individuals completed the pilot survey of Rattlesnake Solutions, LLC clients. The majority of clients removed snakes because they believed them to be venomous (83%) and a threat (60%) (Table 2). Moving snakes to more suitable, desert habitat was also a major reason for the majority (60%) of survey respondents, though 17% said this was not at all a reason for their decision to have snakes removed. Generally, about half of the clients were not fearful of snakes; but instead, most clients believe that snakes should be in the desert and not at their residence (Table 2). The size and fear of snakes were less significant reasons for removal, with about half of survey respondents indicate this was a major or moderate reason (Table 2).

Snake-removal clients tended to think killing snakes was not okay (Table 2). Generally, respondents were more likely to response it was okay, or might be okay to kill a snake if it was in their yard or on private property; however, only a single individual stated it was okay to kill a snake in parks and preserves (Table 2). Regarding attitudes about snakes broadly, replies suggest that clients think snakes are interesting (70% replied that snakes were somewhat to very fascinating) and slightly more (75.9%) reported that snakes are very important to local ecosystems. Meanwhile, most clients were not disgusted by snakes (72% slightly and not disgusting) but they also didn't like snakes (24.1% somewhat to strongly like; Table 2).

4. Discussion

Our novel social-ecological research on snake removals underscores the conservation benefits of researchers partnering with the business community, such as identifying the spatial distribution and drivers of human-wildlife conflicts in urban landscapes. Snake removals related to urbanization levels have been reported on in this region (Pitts et al. 2017). Our study extends these findings to examine removals in relation to the perceptions and sociodemographic attributes of urban residents. One major conclusion is that areas with higher incomes and education levels used snake removal services, whether or not the snake was venomous. Neighborhoods with newly constructed homes and xeric landscaping had more venomous snakes removed. Non-venomous snakes were more widespread across the study area and removed from the center of the city. Proximity to desert open space and summer rainy season were good predictors of snake removal requests. Over 70% of removals were of venomous species common to the Sonoran Desert, including several endemic species that were removed. We found that large, heavy-bodied snakes were removed in greater proportion than expected. Snake with warning colors (bi- and tri-colored), although making up fewer than 5% of removals were removed more than expected. Small snakes, with lengths around 0.5 m or less, were removed less than expected.

Results indicate that sociodemographic factors influence the likelihood of actions that impact wildlife. Snake removal is related to income and education, indicating that people with access to resources can hire services to remove snakes, including snakes that pose no harm.

The pattern of more removals coming from areas with higher income was consistent across the two spatial scales in which we evaluated socio-economic variables (Census block and neighborhood scales). Affluent neighborhoods in Phoenix have more native and drought-tolerant vegetation (Wheeler et al. 2020), increasing potential snake habitat. Therefore, people living in these neighborhoods may encounter more snakes and hold the financial capacity to use wildlife removal services for animals perceived as a nuisance or threat. In Brazil, people in higher-income areas used government services to remove snakes and turtles, whether venomous or not (Teixeira et al. 2015). We also found that more snake removals came from areas with younger residents. This may likely be due to younger residents spending more time outside and utilizing outdoor spaces (Matz et al. 2014). Another possibility is that younger residents may be more likely to have younger children as two respondents from the pilot study mentioned having small children as motivation to remove snakes. Further research is needed to fully understand the relationships between snake removals or other behaviors and socio-demographics across diverse contexts.

An interesting interaction effect was that fewer snake removals occurred in affluent neighborhoods with higher levels of education. The interaction between education and income may indicate that although income allows access to removal service, education can influence whether individuals choose to use the service. Similarly, fewer snakes were removed from predominately Latinx neighborhoods with higher levels of education. Highly educated individuals may be aware of the positive benefits of snakes, or are less concerned about them and decide against removal. High rates of snake removal in neighborhoods with lower education are consistent with studies showing people with lower education levels have relatively more negative views toward snakes (Moura et al. 2010; Ceríaco 2012; Pinheiro et al. 2016). However, we recommend further research to examine how different types of residents interact with snakes in various ways.

People removing wildlife from residential yards likely have different, but perhaps related, motivations and explanations as people who rescue wildlife. Snake removals in our study and bird rescues in another study (Andrade, Bateman et al. Unpublished) both found that common species were the majority of interactions in Phoenix. Removals differ from rescuing

birds, because people tend to remove or relocate reptiles as a risk mitigation strategy (Shine and Koenig 2001; Sullivan et al. 2004; Teixeira et al. 2015), instead of acts of stewardship with birds (Andrade, Bateman et al. Unpublished). Although we did not find a relationship between the number of snake removals and perception of risks of snakes in neighborhoods, we did find that the most snakes were removed from the surveyed neighborhood where the greatest portion of respondents perceived snakes as being a problem. Based on our pilot survey of snake-removal clients, more specific perceptions such as snakes being venomous and posing a threat, are major motivations for decisions to pay for snake removal.

Neighborhoods with more venomous snakes removed were home to residents with stronger pro-ecological worldviews, which may signal that removals may be a conservation act (e.g., removing instead of killing snakes). Our pilot survey of snake-removal clients provides further evidence for this motivation, since over half reported that snakes should be removed and relocated to areas with desert habitat. Given the complex relationships among values, perceptions, and attitudes as motivations for actions, and the common disconnect between intent and outcomes, additional research is needed to unpack motivations underlying wildlife rescues and removals to better predict human-wildlife interactions.

Snake removal could be related to patterns seen from attitudes about other venomous animals that can defend themselves with painful or dangerous bites or stings. Interestingly, we found that despite the possible danger venomous snakes my pose to pets, individuals who owned dogs were less likely to have snakes removed from the area. Perhaps this is because snakes may avoid areas with dogs or it may reflect biophilia given that pet ownership has been linked to positive attitudes towards wildlife, including bees (Larson et al. 2020). We also acknowledge the challenges of conducting integrated social-ecological research and the difficulty of co-locating social surveys with biological data collection. Future work could investigate the motivations and attitudes underlying snake removals from clients of the service compared more broadly to Phoenix-area urban residents, which may vary across people's backgrounds and experiences.

4.1 Application to Conservation

Attitudes and experiences with wildlife are important to understand because they can affect human behavior and have consequences for local management and conservation efforts (Ceríaco 2012; Jarić et al. 2020). Of all animals, people dislike snakes the most (Alves et al. 2012; Liordos et al. 2018). Across the globe, people may kill snakes because both venomous and non-venomous snakes are viewed as dangerous and this can result in local extinctions (e.g., Europe - Bernis 1968; South America - Fita et al. 2010; García-López et al. 2017; North America - Langley et al. 1989; Ashley et al. 2007). We were surprised that snake removals were much more frequent than snake observations submitted to a community science platform. In just two years, 1.5 times more snakes were removed from properties than all recorded observations of snakes on iNaturalist over a 10-year period. Although there can be challenges with using community-sourced data, such as bias of who participates (Kosmala et al. 2016), scientists and conservationists have turned to these data to fill gaps in current knowledge given cost and time constraints of ecological monitoring.

Given the propensity of people to kill snakes, the removal of snakes from private property may offer an alternative that aids biological conservation. We highlight the potential benefits of working in partnership with community businesses, such as Rattlesnake Solutions LLC, to gather significantly more information than otherwise would be available through online community platforms or journal articles. Such collaborations may lead to direct conservation impacts if these groups are willing to use results from the research partnership to inform their practices and researchers are willing to learn from experienced community members (Tallis and Lubchenco 2014). Although using readily available community-collected data is broadly appealing due to ease of access, data on many popular platforms such as ebird and iNaturalist is often restricted to charismatic species (Lopez and Minor 2020). Partnerships with local businesses and organizations, especially those that remove “nuisance” or “pest” species can provide important information that may help fill gaps about urban wildlife.

Similar to other studies (Dunn et al. 2006; Wimberger and Downs 2010; Andrade, Bateman et al. Unpublished), we found that common species were subject to removal. Western

Diamond-backed Rattlesnake is the most common snake in the study area based on community-sourced data and literature (Table 1), and from other studies in Arizona Sonoran Desert (Mendelson and Jennings 1992; Rosen and Lowe 1994). The snake that people encounter most often could be a venomous species and may ultimately negatively impact the actions taken towards snakes in general. Known as the pigeon paradox, Dunn et al. (2006) postulated that people may be unlikely to take conservation actions if the only wildlife they encounter are pigeons and therefore people associate wildlife with pigeons. This association and negative consequences towards wildlife may also occur if people generally associate all snakes with danger and fear.

With the high number of snakes being removed from residential yards to reduce human-wildlife conflict, it is important to investigate the survival of relocated snakes (King et al. 2004). Despite a large body of research documenting the outcome of relocating snakes (Reinert and Rupert 1999; Shine and Koenig 2001; Nowak et al. 2002), no standard protocols are established for the conservation of snakes (Kingsbury and Attum 2009). Snakes removed in this study were not killed; the business moves snakes to non-urban habitat. Future research could use removed animals to investigate environmental factors that would benefit the survival of relocated snakes. If relocating snakes away from areas of high human density to areas of suitable habitat translates into fewer snakes being killed, removal activities could benefit many species (Walker et al. 2009).

5. Conclusion

Overall, researchers can better predict where and when human-snake conflicts might occur by partnering with a local business. Social-ecological information could be used to target urban neighborhoods adjacent to desert parks and in high-income areas, to provide conservation information on how to handle snake encounters and which snakes are harmless so as to increase positive outcomes for snakes and people. Ultimately, understanding the relationships between intentions, actions, and outcomes are central to understanding human-wildlife interactions that influence biological conservation efforts.

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Tables

Table 1. Number (and percent) of snakes observed from this study (2018-2019), community science sources, and publications from Maricopa County, Arizona, United States. Photos (from Brennan and Holycross 2006) of three most common species, left to right, in order listed. V = venomous species.

Species	This Study	iNaturalist[a]	Jones et al. 2011[b]	Sullivan et al. 2017[c]
Western Diamond-backed Rattlesnake (V)	1596 (68.7)	399 (26.5)	47 (8.2)	248 (59.0)
Sonoran Gophersnake	381 (16.4)	175 (11.6)	32 (5.6)	26 (6.2)
Desert Kingsnake	72 (3.1)	92 (6.1)	12 (2.1)	2 (0.5)
Southwestern Speckled Rattlesnake (V)	62 (2.7)	124 (8.2)	0 (0)	0 (0)
Desert Nightsnake	55 (2.4)	58 (3.8)	28 (4.9)	5 (1.2)
Coachwhip	40 (1.7)	55 (3.6)	12 (2.1)	68 (16.2)
Mohave Rattlesnake (V)	33 (1.4)	79 (5.2)	75 (13.1)	13 (3.1)
Long-nosed Snake	22 (0.9)	104 (6.9)	65 (11.4)	9 (2.1)
Western Groundsnake	15 (0.6)	49 (3.3)	1 (0.2)	17 (4.0)
Tiger Rattlesnake (V)	15 (0.6)	37 (2.5)	0 (0)	4 (1)
Western Black-tailed Rattlesnake (V)	11 (0.5)	37 (2.5)	0 (0)	0 (0)
Sidewinder (V)	7 (0.3)	123 (8.2)	201 (35.1)	0 (0)
Total observations	2322	1507	572	420

[a] data from Research Grade observations, Maricopa county, 2010-2020

[b] observations from road-riding in non-urban areas, Maricopa county, 1982-2009

[c] observations from multiple search methods in natural area close to urban, Maricopa county, 2010-2015

Table 2. Attitudes and motivations of snake-removal clients from a social survey. Responses (percent) from 27-28 individual respondents to a pilot survey. For questions about likes and dislikes of snakes, a fifth response includes neutral (ranged from 0-38%) and categories sum to 100%.

Reasons for snake removal				
	Not a Reason	Minor Reason	Moderate Reason	Major Reason
Snake is venomous	10.0%	0.0%	0.0%	83.3%
Snake is a threat	6.7%	3.3%	23.3%	60.0%
Move snake to desert habitat	16.7%	10.0%	6.7%	60.0%
Snake is too big	26.7%	10.0%	20.0%	33.3%
I'm afraid of snake(s)	33.3%	10.0%	16.7%	30.0%
When is it okay to kill snakes				
	Not Okay	Maybe Okay	Okay	Not Sure
When it is in my yard	58.6%	24.1%	13.8%	3.4%
When it is on private property	55.1%	31.0%	10.3%	3.4%
In parks and preserves	96.6%	0%	3.4%	0.0%
When it has bitten someone	34.4%	34.4%	27.6%%	3.4%
Likes and dislikes from negative to positive				
I find snakes ___.	Very Boring	Somewhat Boring	Somewhat Fascinating	Very Fascinating
	0.0%	3.4%	31.0%	37.9%
I __ snakes.	Strongly Hate	Somewhat Hate	Somewhat Like	Strongly Like
	24.1%	13.8%	10.3%	13.8%
Snakes are ___.	Extremely Disgusting	Somewhat Disgusting	Slightly Disgusting	Not Disgusting
	13.8%	3.4%	6.9%	65.5%
Snakes are ____.	Very Dangerous	Somewhat Dangerous	Slightly Dangerous	Not Dangerous
	31.0%	48.3%	|17.2%	3.4%
Snakes are a ___ part of nature.	Not Important	Slightly Important	Somewhat Important	Very Important
	3.4%	3.4%	10.3%	75.9%

Figures

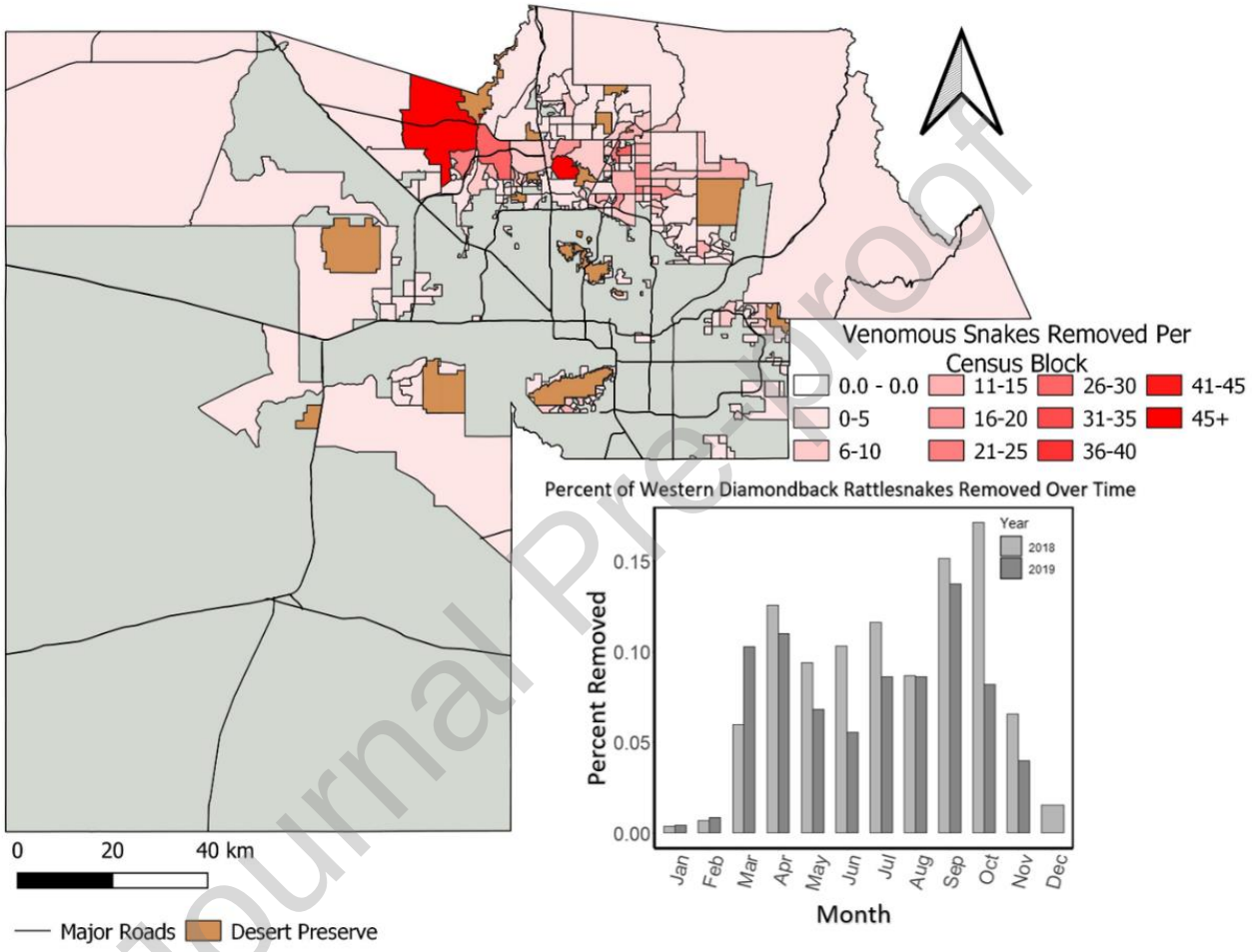


Figure 1. Frequency of venomous snakes removed by census blocks and month in Maricopa County, Arizona, United States from 2018 to 2019. Monthly removals of the most common species, Western Diamond-Backed Rattlesnake (*Crotalus atrox*), represents 68% of all snake removals.

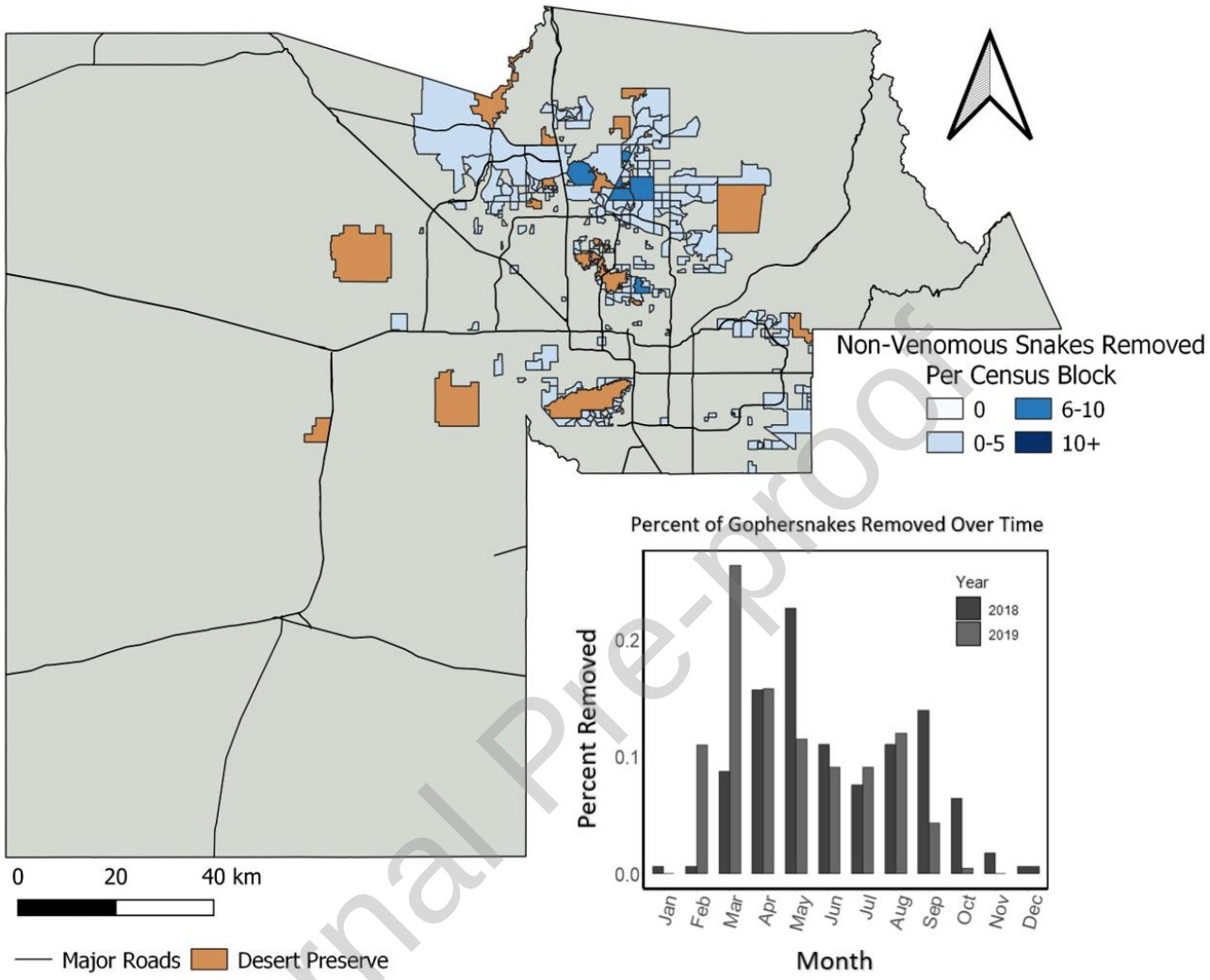
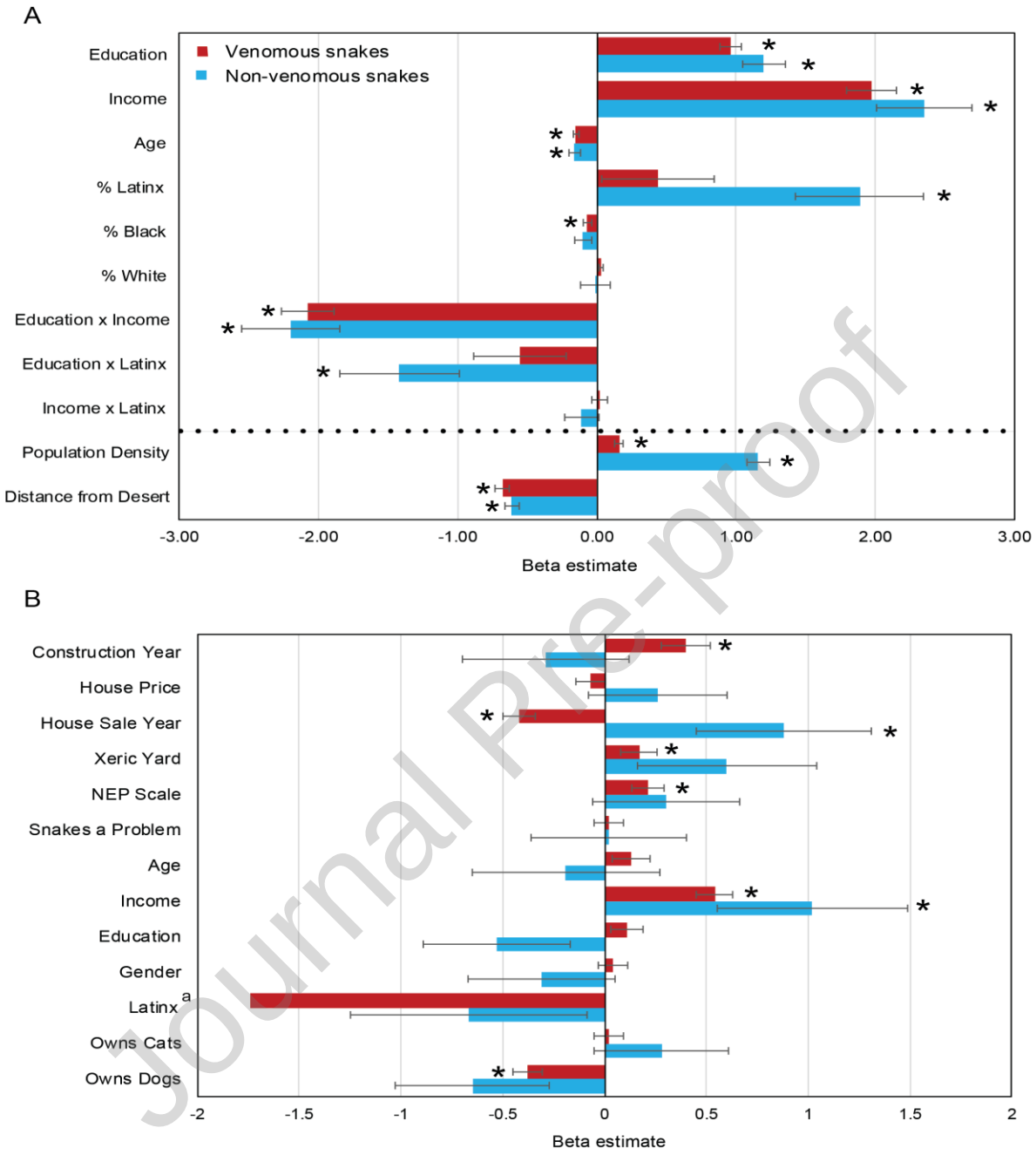


Figure 2. Frequency of non-venomous snakes removed by census blocks and month in Maricopa County, Arizona, United States from 2018 to 2019. Monthly removals of the second most common species, Sonoran Gophersnake (*Pituophis catenifer*) represents 16% of all snake removals.



[a] Error bars removed on venomous snakes for readability (values reported in Table A4).

Figure 3. Standardized beta estimates of predictor variables explaining the relationship between number of venomous and non-venomous snakes removed from metropolitan Phoenix, Maricopa County, Arizona, United States from 2018-2019. Snake removals related to (A) neighborhood demographic variables from U.S. census block groups and (B) variables aggregated to household data in a social survey. Control variables shown below dotted line in A and starred values are significant at $P<0.05$.

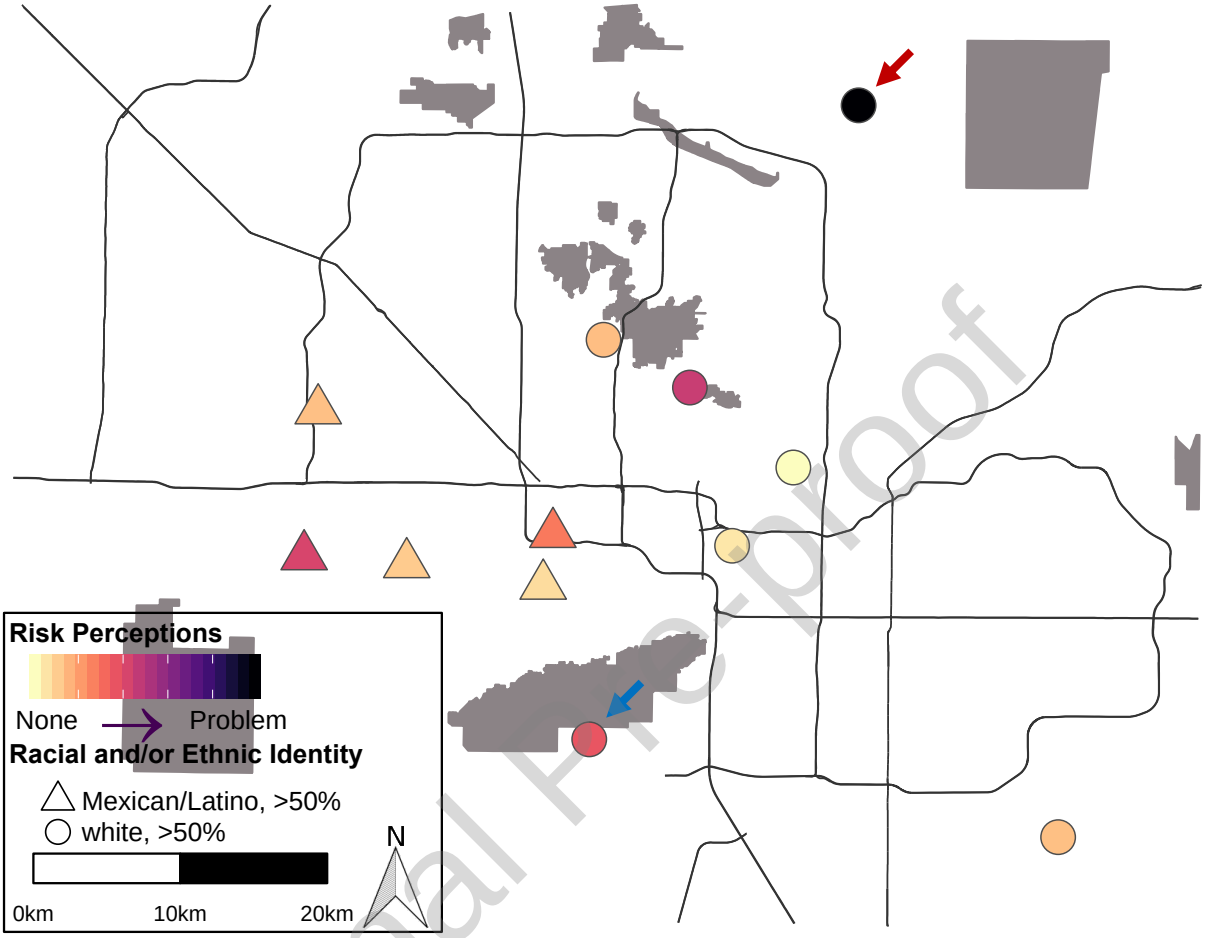


Figure 4. Twelve neighborhood-level averages of how problematic snakes are perceived to be in residential yards in Maricopa County, Arizona, United States. Two neighborhoods had the majority of snake removals. One neighborhood in the NE (red arrow) shows that the majority of residents think snakes are a problem and this neighborhood had the most snakes removed, another neighborhood in the south (blue arrow) had the most snake removals per capita, but residents perceived risks of snakes as only intermediately problematic. Desert parks shaded in gray and major interstate and highways are lines.

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: