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ARTICLE

ECOLOGICAL APPLICATIONS
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Species traits explain public perceptions of human–bird interactions

Riley Andrade[1] | Kelli L. Larson[2] | Janet Franklin[3] | Susannah B. Lerman[4] | Heather L. Bateman[5] | Paige S. Warren[6]

[1]Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, Florida, USA

[2]School of Geographical Sciences and Urban Planning and School of Sustainability, Arizona State University, Tempe, Arizona, USA

[3]Department of Botany and Plant Sciences, University of California-Riverside, Riverside, California, USA

[4]USDA Forest Service, Northern Research Station, Amherst, Massachusetts, USA

[5]College of Integrative Sciences and Arts, Arizona State University, Mesa, Arizona, USA

[6]Department of Environmental Conservation, University of Massachusetts Amherst, Amherst, Massachusetts, USA

Correspondence
Riley Andrade
Email: rileyandrade@ufl.edu

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Abstract

The impacts of urbanization on bird biodiversity depend on human–environment interactions that drive land management. Although a commonly studied group, less attention has been given to public perceptions of birds close to home, which can capture people's direct, everyday experiences with urban biodiversity. Here, we used ecological and social survey data collected in the metropolitan region of Phoenix, Arizona, USA, to determine how species traits are related to people's perceptions of local bird communities. We used a trait-based approach to classify birds by attributes that may influence human–bird interactions, including color, size, foraging strata, diet, song, and cultural niche space based on popularity and geographic specificity. Our classification scheme using hierarchical clustering identified four trait categories, labeled as Metropolitan (gray, loud, seedeaters foraging low to ground), Familiar (yellow/brown generalist species commonly present in suburban areas), Distinctive (species with distinguishing appearance and song), and Hummingbird (hummingbird species, small and colorful). Strongly held beliefs about positive or negative traits were also more consistent than ambivalent ones. The belief that birds were colorful and unique to the regional desert environment was particularly important in fortifying perceptions. People largely perceived hummingbird species and birds with distinctive traits positively. Similarly, urban-dwelling birds from the metropolitan trait group were related to negative perceptions, probably due to human–wildlife conflict. Differences arose across sociodemographics (including income, age, education, and Hispanic/Latinx identity), but explained a relatively low amount of variation in perceptions compared with the bird traits present in the neighborhood. Our results highlight how distinctive aesthetics, especially color and song, as well as traits related to foraging and diet drive perceptions. Increasing people's direct experiences with iconic species tied to the region and species with distinguishing attributes has the potential to improve public perceptions and strengthen support for broader conservation initiatives in and beyond urban ecosystems.

KEYWORDS

attitudes, biodiversity, conservation indicators, public perceptions, residential landscapes, urban birds, yards

INTRODUCTION

Residential yards hold particular conservation potential, partly due to their dominance as an urban land use (Destefano et al., 2005) and their capacity to harbor biodiversity (Tratalos et al., 2007). For example, residential areas are often associated with peaks in bird richness when compared with areas with higher or lower densities of development (Blair & Johnson, 2008). Management practices in privately held yards can support urban wildlife by scaling up or down to create habitat in cities (Goddard et al., 2010). Yard management practices that support urban biodiversity, such as wildlife-friendly landscaping, are often influenced by people's perceptions of nearby nature experiences (Belaire et al., 2016). As a result, bird conservation in residential landscapes depends on the perceptions and actions of individual householders as local stakeholders (Goddard et al., 2017). Accordingly, scholars have called for efforts that better integrate social science with ecological knowledge, including people's varying responses to birds, to support bird conservation globally (Dayer et al., 2020; Robinson, 2019).

Social–ecological drivers of public perceptions and human–wildlife interactions

Environmental attitudes—positive or negative judgments about some object or phenomenon (Stern, 2000; Thurstone, 1928)—are a useful social science construct to consider human–wildlife interactions (Heberlein, 2012). Cognitive attitudes in our study encompass perceptions or, in other words, beliefs about what people think to be true about the traits of birds found in their yard and neighborhood (Belaire et al., 2015). Attitudes can vary in their consistency over time and in a variety of contexts (Manfredo, 2008). Applied to this study, consistent attitudes would reflect individuals expressing uniformly positive or negative judgments across a range of perceived bird traits. Attitudinal consistency is important to consider in addition to valence (positive or negative direction), because firmly held beliefs are relatively resistant to change and more likely to elicit behavioral responses (Heberlein, 2012; Howe & Krosnick, 2017; Manfredo, 2008). Here, we focus both on the consistency (strongly versus weakly held) and valence (positive versus negative direction) of public perceptions to measure attitudes about the birds encountered close to home in residential yards and neighborhoods.

Factors such as species diversity, community composition, and functional traits have been shown to influence human–bird interactions (e.g., Ainsworth et al., 2018; Clergeau et al., 2001; Clucas et al., 2011). Biodiversity and community composition—particularly native and specialist species—have been associated with positive attitudes (Dayer et al., 2016; Lerman & Warren, 2011; Warren et al., 2019) and greater enjoyment of green space (Douglas & Evans, 2021), which may, in turn, influence management practices. In one study, citizen scientists favored the removal of House Sparrow (*Passer domesticus)* from nest boxes when they negatively perceived the species as outcompeting native songbirds for nesting sites (Larson et al., 2016). People are also interested in species that they encounter more readily or easily recognize. For example, Schuetz and Johnston (2019) found a strong, positive relationship between the encounter rate and the popularity of bird species, which they used to characterize cultural niches. However, the research used Google searches to assess people's experiences, which has limitations in measuring the potential array of public responses to birds (Robinson, 2019). People can typically only identify a few bird species and not always by name (Cox & Gaston, 2015), which may influence their use of online searches. Additionally, evidence suggests that the public does not assess biota using the same metrics as ecologists, such as species richness (Dallimer et al., 2012) or "nativeness" (Berthon et al., 2021), which can create tensions between conservation priorities with the many and diverse ways people value and experience biodiversity, especially in "disturbed" ecosystems (Pascual et al., 2021).

The traits of bird species, such as diet or physical appearance, have been linked to perceptions of cultural ecosystem services (Echeverri et al., 2020), conflict (Charles & Linklater, 2013), and general popularity (Schuetz & Johnston, 2019). For instance, bird species that forage lower to the ground may cause conflict by influencing the belief that the birds are destroying planted vegetation (Belaire et al., 2016). Additionally, urban-dwelling species with broad diets can reach large abundances in local habitat patches to amplify potential sources of conflict (Charles & Linklater, 2013). In contrast with negatively perceived traits, people tend to prefer small, colorful birds with melodic calls (Garnett et al., 2018), with particular emphasis given to preferences for colorful species (Echeverri et al., 2020; Lišková et al., 2015; Schuetz & Johnston, 2019). Bird song is another important trait and can even elicit an emotional response in people (Hedblom et al., 2017). For instance, bird songs remembered from childhood positively influence human well-being and have a restorative effect (Ratcliffe et al., 2016). Conversely, harsh or loud calls, with greater fundamental frequency of the harmonic spectrum, are often considered annoying (Björk, 1986; Clucas et al., 2011).

Broad-based values and worldviews, as well as sociodemographics and other characteristics of people can also influence perceptions (Heberlein, 2012; Tribot et al., 2018). Broader, proecological worldviews are often associated with conservation attitudes, but are also dependent on sociodemographics (Manfredo, 2008). People who identify as Hispanic and Latinx tend to view themselves as interdependent with nature, influencing their values and environmental attitudes (Chase et al., 2016; Heyd, 2004). Similarly, women may be more likely to view certain taxa as dangerous for reasons such as risk perceptions related to disease (Hanisch-Kirkbride et al., 2013). Additionally, people with higher income and education tend to hold more positive attitudes about local bird communities than people with lower incomes or less education, as do older compared with younger individuals (Belaire et al., 2015; Cox & Gaston, 2015), likely to be due to factors such as knowledge and opportunities to experience nature. However, younger generations have increasing interests in participating in nature activities, especially close to home (US Department of Interior, 2016). In general, differences associated with sociodemographics can influence perceptions of birds or other wildlife. Yet, there is also a great degree of variation in perceptions and values from person to person, as well as some differences due to external factors, such as the bird species present that people encounter, which influence experiences.

Based on existing interdisciplinary literature (e.g., Belaire et al., 2015; Cox & Gaston, 2015; Echeverri et al., 2020), we expect that bird species traits will be important variables for determining people's perceptions of birds. However, perceptions will also be based on the individual characteristics of the person, such as socioeconomic status. We addressed the following research objectives based on people's perceptions of birds they encounter in their residential yards and neighborhoods: (1) characterize species traits that may influence the interactions between people and the birds found in residential areas, (2) determine how people perceive various bird species traits based on attitudinal valence and consistency, and (3) assess how public perceptions are associated with sociodemographics, bird traits, cultural niche space, and biodiversity.

METHODS

Study area

Our study took place in the Central Arizona-Phoenix Long-term Ecological Research (CAP LTER) site, located in Phoenix, Arizona, USA (Figure 1). Metropolitan Phoenix is situated in the Sonoran Desert of the American Southwest and is characterized by a hot, dry climate. Summer temperatures can reach 49°C, and the biannual monsoon and winter rainy seasons bring only 76–400 mm of precipitation a year (Phillips & Comus, 2000). The Phoenix metropolitan area is characterized by sprawling residential development, with a prevalence of single-family homes. Although Phoenix is located in a semiarid environment, cultural legacies from the city's early stages of development have shaped the ideal of Phoenix as a "desert oasis" (Larson et al., 2009). As a result, the city has a high prevalence of mesic landscaping, with about 50% of yards sampled as part of a long-term study having some grass, which contrasts with xeric yards landscaped to reflect the native desert environment (Wheeler et al., 2020), influencing bird community composition throughout the city (Lerman & Warren, 2011). In general, desert specialist species tend to be associated with xeric landscaping in newer and higher income neighborhoods that are located at the city fringe, whereas non-native and urban associated bird species are associated with grassier yards closer to the city core (Warren et al., 2019).

Data collection: Bird diversity and interaction traits

We placed independent bird-point counts, spaced at least 200 m, in 12 neighborhoods where social data were also collected via a household survey, for a total of 36 bird sampling sites with three per neighborhood (Warren et al., 2022). Bird surveys were conducted in the winter (December–February) and spring (March–May) of 2017 and 2018. Trained observers conducted point counts within 4 h of sunrise, when they recorded all birds seen or heard within a 40 m radius for 15 min three times per season for a total of six visits per site per year and 12 visits total over the 2-year time period. We excluded species recorded in a single site from our analysis because rare species have a disproportionate influence on biodiversity metrics and are unlikely to reflect everyday engagements between people and birds (Fuller et al., 2013).

We used bird community data to derive some traditional biodiversity metrics including abundance, species richness, Shannon Diversity Index (H), and evenness (Appendix S1: Table S1). Following Lerman and Warren (2011) and Warren et al. (2019), we calculated bird abundance as the maximum number of individuals recorded for each species during any one of the multiple visits. Species richness was calculated as the number of unique species found per site. We calculated Shannon diversity and community evenness using the "vegan" package in R (Oksanen et al., 2018).

We curated data about traits related to body size, foraging strategy, diet, song, color, and cultural niches for the bird species observed during our study. We calculated the occurrence of traits for each of the bird species

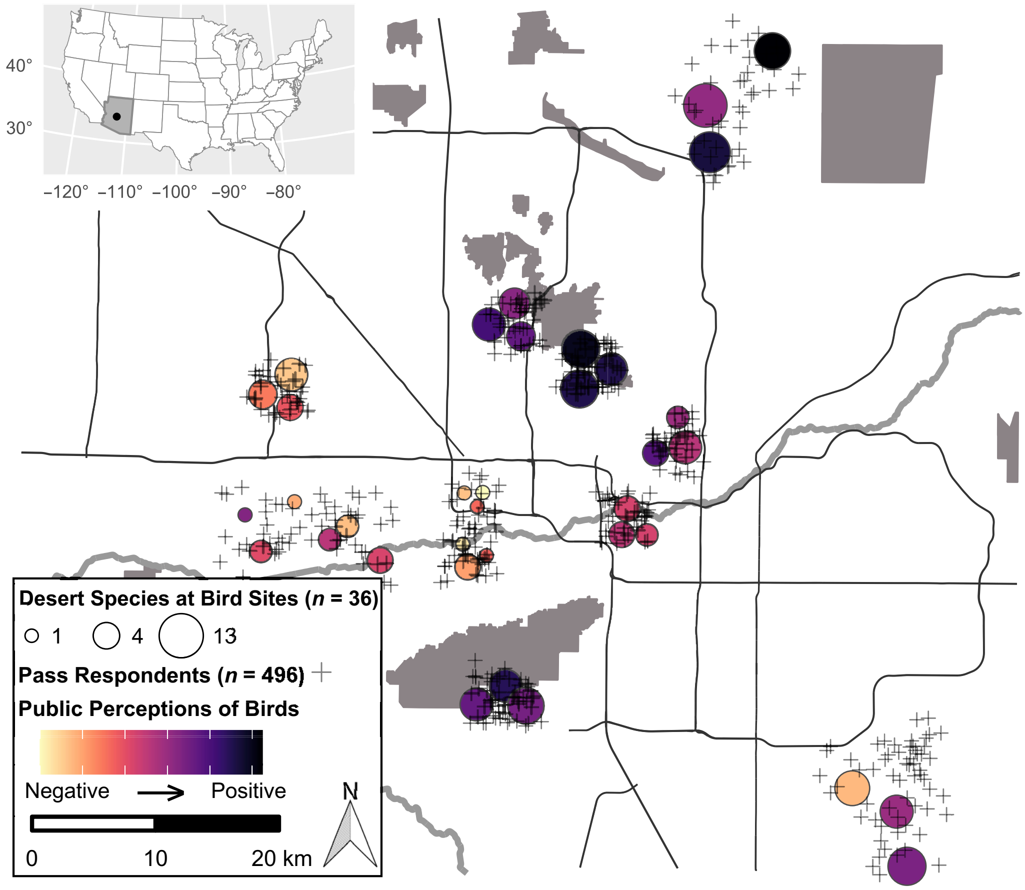

FIGURE 1 Study area map of 36 bird-point counts (bird sites) co-located with a quantitative household survey (Phoenix Area Social Survey). Public perceptions were collected from people living around the 36 bird sites ($n = 496$ respondents) and the resulting social data were matched to their closest bird site (ecological data point). Larger circles indicate greater desert species richness measured during bird surveys and darker colored circles are more positive attitudes of people living around the site based on averaged survey responses. Gray polygons represent open space in the city (desert parks and the Salt River, a riparian corridor). Survey responses are visualized as jittered cross-hairs to protect the exact location of respondents.

present at the site weighted by bird abundance per site. We derived bird size and foraging traits from the EltonTraits database (Wilman et al., 2014). Bird size was the average mass of each species in grams. Foraging strategy was determined as percentage of time each species spends foraging in a strata type: ground, understory, mid to high, canopy, and aerial. Feeding guild for each species was based on their diet percentages: plants, seeds, invertebrate (insects), fruit, and nectar.

We described the cultural niche of bird species as "Celebrity," "Friend," "Neighbor," or "Stranger," using bird species popularity and geographic congruence as described by Schuetz and Johnston (2019). The four cultural niche groups defined by species popularity and geographic congruence were calculated using the Google search popularity and geographic distribution of a species. Celebrity species had above average Google search popularity for the United States, even outside their geographic distribution. Conversely, Friend species had above average search popularity primarily within the species range. Neighbor species had below average search popularity on a national scale, but the search activity that did occur was aligned with the species distribution. Stranger species had both below average popularity that was not associated with their distribution.

Using song descriptions from the Birds of North America (BNA) database (Rodewald, 2015), we qualitatively classified bird song along three dimensions. These song classifications were categorical, but not mutually exclusive. We coded the first variable for songs or calls that were described as being "well known," the second variable for songs or calls was "loud/harsh," and the third variable for songs that were described as "musical." For example, Cactus Wren song (*Campylorhynchus* *brunneicapillus*) was described as being a "quintessential sound of the desert" but also a "loud series of harsh 'char' notes" and therefore, we categorized it into both the well known and loud/harsh song dimensions.

Finally, we used the "colordistance" package in R (Weller, 2019) to determine differences in color. We used representative photographs of breeding males obtained from the BNA database (Rodewald, 2015). We removed background colors, then randomly sampled 10,000 pixels to determine the similarity between red, green, and blue color composition between bird species. Following methodology by Weller (2019), we used the histogram method to classify the pixels into eight color bins. Using Ward's D clustering, bird species were then grouped into three clusters, which we defined as: "gray" (light gray, dark gray, black), "brown" (muted colors, brown and yellow), and "colorful" (bright/vibrant colors, orange, red, green).

Phoenix area social survey

We collected data on perceptions of birds, along with demographic characteristics, through the 2017 Phoenix Area Social Survey, from this point forwards PASS (refer to Larson et al., 2019). The survey targeted the 12 neighborhoods, where we also placed our bird-point counts. The University of Wisconsin Survey Center administered the survey from May–September of 2017. The survey was mailed to 1400 addresses selected by sampling addresses that participated in a 2011 survey ($n = 188$), with an additional 1212 addresses randomly drawn from the United States Postal Service's Delivery Sequence database provided by the Marketing Systems Group. The first mailing included the full survey, as well as a postage-paid card requesting a Spanish version. The second mailing included a reminder postcard, and the final two waves included the full survey packet. All participants received a pre-incentive of US$5 in the first packet. Participants were also assigned to post-incentive groups, which included rewards to either the participant or a charity (for details, refer to Smith et al., 2020). The final response rate was 39.4% ($n = 496$) and ranged from a low of 22 respondents to a high of 56 per neighborhood.

The survey sample was stratified to cover urban, suburban, and exurban areas of the metropolitan region while also representing race, income, and age of housing development (Larson et al., 2019). We used Census Block Group Data to determine the demographics of our study area (sampled neighborhoods) in relation to the survey respondents. The median household income was US$87,135 for the study area and US$80,000 to US$100,000 for the survey respondents. Just more than 60% of survey respondents held a Bachelor's degree or higher, compared with 35% of the population from Census data. The racial composition of the study area was 49% white, 38% Hispanic/Latinx, 7% Black/African American, 5% Asian, and 1% Native and Indigenous people. The survey respondents were comparatively 63% White, 22% Hispanic/Latinx, 3% Black/African American, 4% Asian, and 1% Native and Indigenous people. The median age of the residents was 39, but survey respondents were older with a median age of 51 years. We advise caution generalizing our survey results to the metropolitan area or regions outside of the southwest USA given the sociodemographics of our survey sample.

Measuring people's perceptions of neighborhood birds

We used 10 questions to measure people's perceptions, that is beliefs, about the birds in their neighborhood as our attitudinal scale. The first eight items were adapted from Belaire et al. (2015) based on cultural ecosystem services and disservices—here defined as the perceived benefits and negative impacts—of urban birds. Using a similar approach, our questions captured evaluative beliefs about specific attributes of the bird community. Specifically, we asked about people's perceptions regarding the following bird traits: color, ease of observation, regional association, song, disease, messiness, diet, and noise (please refer to Table 1 for verbatim questions). We also asked two additional questions about satisfaction with local birds and perceptions of risks posed by birds. We tested the reliability of the attitudinal scale using Cronbach's alpha, a measure of an internal consistency for individuals responding to multiple survey questions, with alpha values above 0.7 considered to be reliable (Santos, 1999).

Social factors

Respondents self-reported some sociodemographic variables in the survey (Appendix S1: Tables S1, S2), including income, education, age, gender, Hispanic/Latinx identity, and ecological worldviews. We coded household income on an 11-point scale starting at US $20,000 (1) and increasing in US$20,000 increments to greater than US$200,000 (11). We coded education on a binary scale to represent respondents who had a Bachelor's degree or higher. Each respondent provided their year of birth, which we used to calculate their age in 2017. Gender was coded as male (0) and female (1). Hispanic and/or Latinx identity was also coded as a binary variable by asking the respondent whether they identified as Hispanic or Latinx (including Mexican, Mexican

TABLE 1 Survey scale measuring public perceptions of urban birds in residential neighborhoods.

Survey question Prompt: The next set of questions is about the birds in your neighborhood	Mean ± SD	Frequency of responses 1	2	3	4	5
Perceptions of local birds	3.4 ± 0.4					
How colorful are the birds in your neighborhood?[a]	2.6 ± 1.1	84	127	145	70	21
How easy is it to see and watch the birds in your neighborhood?[a]	3.4 ± 1.2	37	79	114	145	95
How unique to the desert are the birds in your neighborhood?[a]	2.9 ± 1.2	69	79	134	81	42
How pleasant are the noises the birds in your neighborhood make?[a]	3.4 ± 1.2	45	61	119	145	100
How likely is it that the birds in your neighborhood carry diseases?[a]	2.5 ± 1.2	71	84	76	24	24
How likely is it that the birds in your neighborhood cause messes?[a]	3.0 ± 1.3	58	123	104	93	81
How likely is it that the birds in your neighborhood eat your plants and trees?[a]	2.5 ± 1.2	99	128	106	47	31
How unpleasant are the noises the birds in your neighborhood make?[a]	1.6 ± 1.1	308	75	52	18	16
To what extent are [birds] a problem for you at your current home?[b]	1.5 ± 1.1	355	82	31	14	12
How dissatisfied or satisfied are you with [the variety of birds in and around your neighborhood]?[c]	3.6 ± 0.9	18	55	146	138	138

[a]Response Scale: 1 = Not at all, 2 = A little, 3 = Somewhat, 4 = Very, 5 = Extremely.
[b]Response Scale: 1 = Not a problem, 2 = A small problem, 3 = A moderate problem, 4 = A big problem, 5 = A very big problem.
[c]Response Scale: 1 = Strongly Dissatisfied, 2 = Somewhat Dissatisfied, 3 = Neither dissatisfied nor satisfied, 4 = Somewhat Satisfied, 5 = Strongly Satisfied.
SD, standard deviation.

American, Chicano, Hispanic, or Latinx). Finally, we measured ecological worldviews, or value orientations, using 15 questions from the New Ecological Paradigm (NEP) scale (Dunlap et al., 2000). Orientations related to human-centered views were reverse coded (Appendix S1: Table S4), and then responses were averaged to create a single variable ranging from 1 to 5, in which higher values reflect biocentric (ecological) worldviews and lower values reflect human-centered orientations.

Statistical analysis

We integrated the social survey and ecological bird community data to address our three research objectives (Figure 2). We used bird community data to address our first research objective aimed at characterizing bird species traits that may be associated with various interactions with people in residential yards and neighborhoods (Figure 2a). We first decomposed trait data into orthogonal eigenvectors using principal components analysis (PCA) to standardize the scales and reduce redundancy among related traits, which stabilizes clustering results (Husson et al., 2010). We applied hierarchical agglomerative clustering to the unrotated principal components using Euclidean distance and Ward's linkage to cluster bird species into representative trait groups. We used the V-test (Husson et al., 2010) to calculate the cluster description by the variables. Cluster analysis was performed using the "FactoMineR" package in R (Le et al., 2008). We then used the Pearson's correlation coefficient to determine the relationship at each bird point between bird trait groups identified from our cluster analysis and the cultural niche groups (Celebrity, Friend, Neighbor, Stranger) defined in Schuetz and Johnston (2019).

Our second research objective considered people's beliefs about the local bird community, focusing on how attitudinal valence and consistency were related (Figure 2b). To do so, we used logistic regression with a quadratic expression. To measure consistency, we specified the number of times a person selected the same response value (1–5) across the 10 subjective evaluation

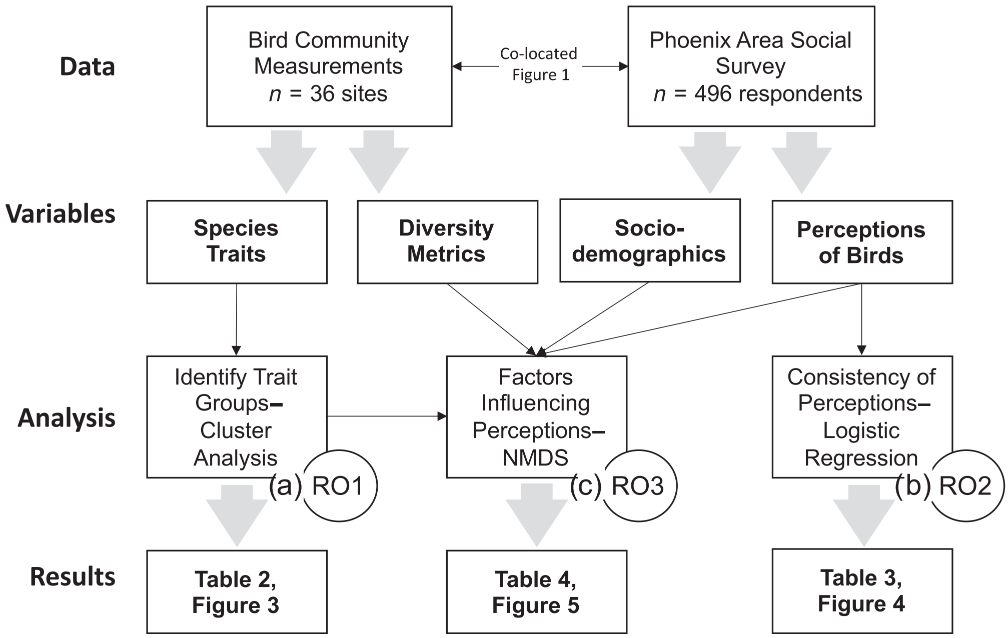

FIGURE 2 Methodological workflow describing data, derived variables, and analyses used to address the three research objectives. (a) Research Objective 1 (RO1): Characterize bird species traits related to public perceptions. (b) Research Objective 2 (RO2): Determine how people perceive various traits of the birds found in their neighborhoods. (c) Research Objective 3 (RO3): Assess how public perceptions are associated with sociodemographics, bird interaction traits and cultural niche, and ecological community diversity.

questions ("successes"). Inconsistencies ("failures") were classified as the number of times the person selected a different response. We inverted negative traits (problematic, disease, mess, eats plants, noisy) prior to counting successes and failures so all 10-question scales had the same valence. We calculated the turning point ($TP = -b/2a$) for each regression model to quantitatively interpret the shape of the quadratic relationship (Table 3). Higher TP values (>3) indicated that negative perceptions of traits were more consistent than positive ones. Conversely, lower values (<3) indicated that positive perceptions were more consistent.

For our third research objective, we used a multivariate analysis to measure the association between people's perceptions of the bird community with the actual bird species present in the respondent's neighborhood (Figure 2c). We first visualized attitudes with respect to traits, diversity metrics, and sociodemographic factors using non-metric multidimensional scaling (NMDS) based on Gower's distance (Oksanen et al., 2018). NMDS is a multivariate technique that maximizes the rank correlation between distance measures. In this instance, NMDS was used to visualize sites in attitudinal space, where sites closer on the ordination diagram represented relatively similar perceptions about the bird community. We fitted ecological (diversity metrics), social (environmental worldview and sociodemographics), and human–bird interaction (trait clusters and cultural niche) variables to the ordination plot to visualize the correlation of these factors with attitudinal patterns regarding birds (Oksanen et al., 2018). Last, we tested the overall and shared effects of ecological factors, social factors, and human–bird interaction traits on perceptions by partitioning the variance between these factors on the averaged scale that captured respondent's overall attitudes toward local birds. All statistical analyses were performed in R version 3.5.1 (R Core Team, 2018).

RESULTS

Identifying bird interaction trait clusters

We identified four distinct trait groups of species describing human–bird interactions using hierarchical cluster analysis (Figure 3 and Table 2). We defined the birds in the first cluster ($n = 9$) as "Metropolitan" based on the prevalence of urban-dwelling species within the group, such as Rock Pigeon (*Columba livia*). Species in this group were described as having a loud song, gray coloring, and were large granivores foraging low to the ground. Species in the Metropolitan group were positively related to the Celebrity cultural niche group ($r = 0.73$, $p < 0.001$), but negatively related to the Friend ($r = -0.39$, $p < 0.018$), Neighbor ($r = -0.54$, $p < 0.001$), and Stranger groups ($r = -0.53$, $p < 0.001$).

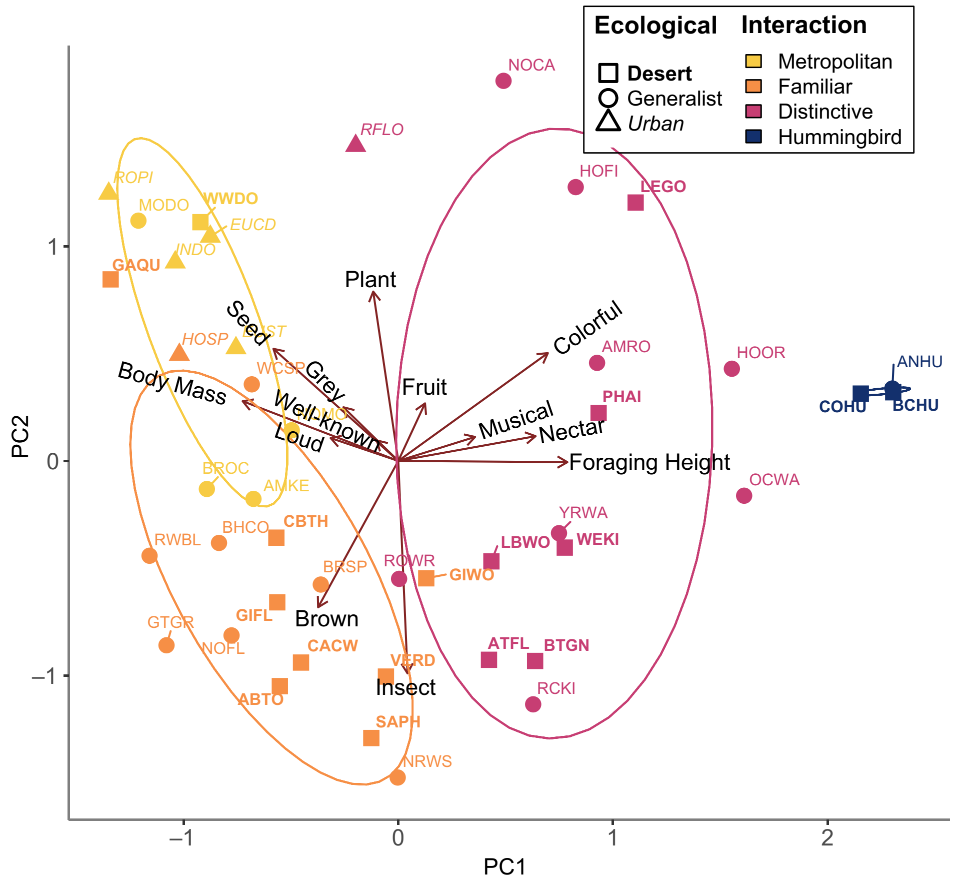

FIGURE 3 Bird species visualized in orthogonal trait space used to describe the interactions between people and birds. PC1 and PC2 explained 39.9% of the total variance. Six total components were retained based on their eigenvalue and used in the cluster analysis. The principal components were used to cluster bird species into four groups: Metropolitan, Familiar, Distinctive, and Hummingbird species. A list of bird species codes and trait interaction clusters can be found in the supplementary materials (Appendix S1: Table S3).

Cluster 2, "Familiar," birds ($n = 16$) included a mixture of generalist species, such as Great-tailed Grackle (*Quiscalus mexicanus*), urban-dwelling species such as House Sparrow, and desert species commonly present within urban or suburban areas (Lerman & Warren, 2011). Familiar desert species included Verdin (*Auriparus flaviceps*), Curve-billed Thrasher (*Toxostoma curvirostre*), and Cactus Wren. Species in the Familiar group were shades of brown and their song was described as being well known or easily recognizable. The occurrence of Familiar species was positively related to the Friend cultural niche group ($r = 0.40$, $p < 0.016$), but negatively related to the occurrence of Celebrity species ($r = -0.38$, $p < 0.020$).

Cluster 3, "Distinctive Species," consisted of bird species ($n = 15$) with a distinguishing appearance and song that people are likely to notice, such as colorful birds described as melodic or musical (e.g., Northern Cardinal [*Cardinalis cardinalis*]). The diets of bird species within this group were varied, and species tended to be smaller than Metropolitan or Familiar species. Many distinctive birds foraged in the higher vegetation strata, such as Phainopepla (*Phainopepla nitens*) and Western Kingbird (*Tyrannus verticalis*). The occurrence of Distinctive species was positively related to both the Neighbor ($r = 0.54$, $p < 0.001$) and Stranger cultural niche groups ($r = 0.48$, $p < 0.003$), but negatively related to the occurrence of Celebrity species ($r = -0.61$, $p < 0.001$).

Anna's Hummingbird (*Calypte anna*), Costa's Hummingbird (*Calypte costae*), and Black-chinned Hummingbird (*Archilochus alexandri*) observed in the study neighborhoods, were all clustered into their own group, aptly named "Hummingbirds" ($n = 3$). Species in this group shared traits related to a nectar diet, color, foraging height, and a small body size. Both the Distinctive and Hummingbird groups were composed of colorful birds that foraged in vegetation higher from the ground than species in the Metropolitan and Familiar groups. Birds classified into the Hummingbird group were positively related to classification into the Neighbor cultural niche ($r = 0.67$, $p < 0.001$), but negatively related to Celebrity species ($r = -0.59$, $p < 0.001$).

TABLE 2 V-tests of traits used to classify bird species into clusters.

Bird traits	Metropolitan Celebrity ($r = 0.73$)	Familiar Friend ($r = 0.40$)	Distinctive Neighbor ($r = 0.54$) Stranger ($r = 0.48$)	Hummingbird Neighbor ($r = 0.67$)
Number of species	9	16	15	3
Song: Musical	**−2.32***	−1.47	**4.13***	−1.23
Song: Well known	−1.47	**2.02***	−0.38	−0.78
Song: Loud	**2.21***	0.02	−1.46	−0.85
Aesthetic: Body mass	**3.25***	1.11	**−2.06***	**−3.45***
Aesthetic: Brown	**−2.83***	**5.88***	**−2.74***	−1.51
Aesthetic: Gray	**4.80***	**−3.47***	0.08	−1.23
Aesthetic: Colorful	−1.95	**−2.92***	**3.02***	**3.03***
Diet: Insect	**−2.18***	1.56	1.33	−1.97
Diet: Fruit	1.01	−1.76	1.71	−1.48
Diet: Nectar	−1.02	−1.49	−0.99	**6.30***
Diet: Seed	**2.44***	0.97	**−2.23***	−1.55
Diet: Plants	0.02	−0.66	1.13	−0.89
Foraging strata	**−2.41***	**−3.08***	**3.87***	**2.46***

Notes: Positive *v*-values indicate that the value for a trait was greater within a cluster and negative values indicate the trait was less. Bolded values with asterisk indicate significance at the $p < 0.05$ level. Cultural niche indicates a positive, significant relationship ($p < 0.05$) between bird interaction trait and cultural niche groups in Schuetz and Johnston (2019).

Attitudinal scale: Perceptions of bird community attributes

Our 10-question survey scale proved highly reliable with a Cronbach's alpha of 0.84 (Table 1). On average, people held positive attitudes toward the birds in their neighborhoods (3.4 ± 0.4). Survey respondents were more likely to disagree with statements that birds in their neighborhood exhibited negative characteristics, such as making a mess, than agree with statements that birds exhibited positive characteristics, such as being colorful. On average, people disagreed that birds in their neighborhood were problematic (1.5 ± 1.1) or made unpleasant noises (1.6 ± 1.1). The majority of respondents also disagreed that birds in their neighborhood were colorful (2.6 ± 1.1) or unique to the desert (2.9 ± 1.2), but this did not lead to dissatisfaction with the overall variety of birds (3.6 ± 0.9).

Our prediction that negative and positive attitudes would be more strongly held than neutral attitudes was supported by a logistic regression (Figure 4). Of the 10 perception variables, nine exhibited a significant quadratic relationship, demonstrating consistency for stronger positive or negative attitudes (Table 3). The exception was the belief that birds had a pleasant song, which did not have a significant quadratic relationship between valence and consistency. This means that strongly positive or negative responses were more consistent across the full suite of questions, whereas neutral responses had a lower consistency. The belief that birds were problematic (TP = 3.98) and noisy (TP = 4.04) were associated with negative attitudes across the other bird perception questions. Conversely, the belief that birds were colorful (TP = 1.95) or unique to the desert (TP = 2.02) fortified positive attitudes. Satisfaction with the variety of birds (TP = 2.98) exhibited the highest centrality, meaning that both strongly positive and negative attitudes were comparable in determining consistency.

Social–ecological drivers of attitudes

Public perceptions were related to social factors, bird species traits, and diversity metrics, as shown in the NMDS and subsequent variance partitioning (Figure 5). A two-axis solution was reached to ordinate sites in attitudinal space (NMDS stress = 0.12; non-metric fit $R^2 = 0.98$; linear fit $R^2 = 0.93$). Positive perceptions increased along the NMDS1 axis, as did the prevalence of desert specialist species associated with the distinctive trait group observed within the neighborhoods. A mixture of social factors, bird traits, and diversity metrics explained people's perceptions of birds (Table 4). Significant social

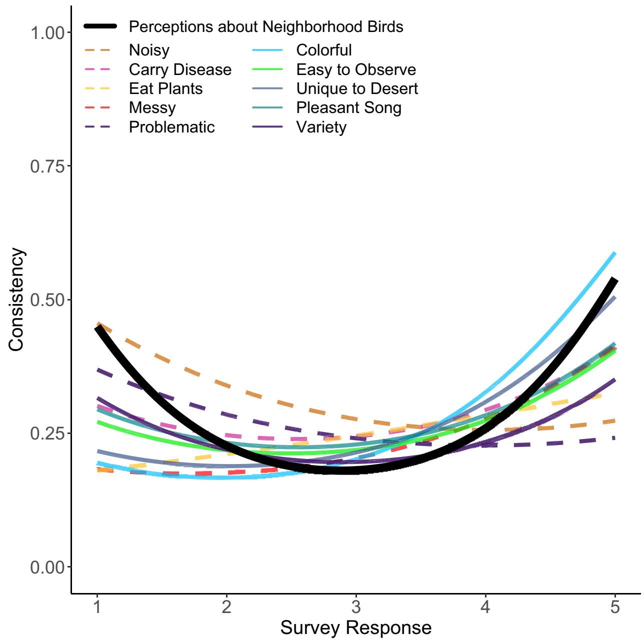

FIGURE 4 Logistic regression curves for the 10 survey questions measuring perceptions. The level of agreement for each attribute is displayed on the *x*-axis and the *y*-axis represents the consistency of responses. Smaller *x*-axis values indicate negative attitudes and positive values indicate positive attitudes. The *y*-axis represents the probability that the respondent selects the same response for all of the survey questions based on their response to each particular question. The thick black line shows respondents' average overall attitude about the birds in their neighborhood.

factors driving positive perceptions included income ($R^2 = 0.49$, $p < 0.001$), education ($R^2 = 0.53$, $p < 0.001$), and age ($R^2 = 0.43$, $p < 0.001$), whereas people identifying as Hispanic/Latinx held less positive perceptions about the birds in their neighborhood ($R^2 = 0.52$, $p < 0.001$). Gender and broad ecological orientation (NEP) were not significantly associated with attitudinal patterns.

Birds with Metropolitan traits, including being loud or foraging on seeds close to the ground, were related to negative perceptions ($R^2 = 0.19$, $p = 0.027$). Conversely, Distinctive species with traits such as a musical song and colorful plumage ($R^2 = 0.27$, $p = 0.007$), as well as Hummingbirds ($R^2 = 0.46$, $p < 0.001$) were associated with positive perceptions. Species in the Celebrity cultural niche group were related to negative attitudes ($R^2 = 0.45$, $p < 0.001$), likely to be due to the prevalence of urban-dwelling species within the group. The Friend ($R^2 = 0.29$, $p < 0.002$) and Neighbor cultural niche groups ($R^2 = 0.41$, $p < 0.001$) were related to positive attitudes. People also held more positive attitudes in neighborhoods with higher bird diversity, measured by species richness ($R^2 = 0.43$, $p < 0.001$), Shannon diversity ($R^2 = 0.42$, $p < 0.001$), and evenness ($R^2 = 0.23$, $p = 0.009$), but there was no association with bird abundance ($R^2 = 0.09$, $p = 0.206$).

Our variation partitioning determined the effects of social factors, bird species traits, and diversity metrics, which explained 77.4% of the total shared variation of

TABLE 3 Logistic regression results on binomial distribution testing consistency in public perceptions of traits related to the local bird community.

Variable	Turning point ($-\beta x/2^*\beta x^2$)	β-Estimate x, x^2	*z*-value x, x^2
Perceptions Scale[a]	2.88	−2.14, 0.37	**−25.74*, 28.41***
Problematic	3.98	−0.61, 0.08	**−2.83*, 2.49***
Variety of birds	2.89	−1.03, 0.18	**−6.01*, 7.22***
Colorful	1.95	−0.82, 0.21	**−5.44,* 7.99***
Easy to observe	2.49	−0.72, 0.15	**−4.87*, 6.40***
Unique to the desert	2.02	−0.68, 0.17	**−4.69*, 7.02***
Pleasant noises (song)	2.56	−0.78, 0.1	**−5.65*, 7.13***
Carry disease	2.54	−0.67, 0.13	**−3.74*, 4.82***
Messy	1.69	−0.37, 0.11	**−2.62*, 4.76***
Eat plants and trees[b]	0.99	−0.08, 0.04	−0.51, 1.72
Noisy	4.04	−0.77, 0.09	**−4.08*, 3.52***

Notes: Statistically significant *z*-values at the $p < 0.05$ level are shown in bold with an asterisk.
[a]Corresponds to "Peceptions about Neighborhood Birds" line on Figure 4.
[b]Linear model without quadratic term was significant ($\beta = 0.19$, $z = 6.05$, $p < 0.0001$).

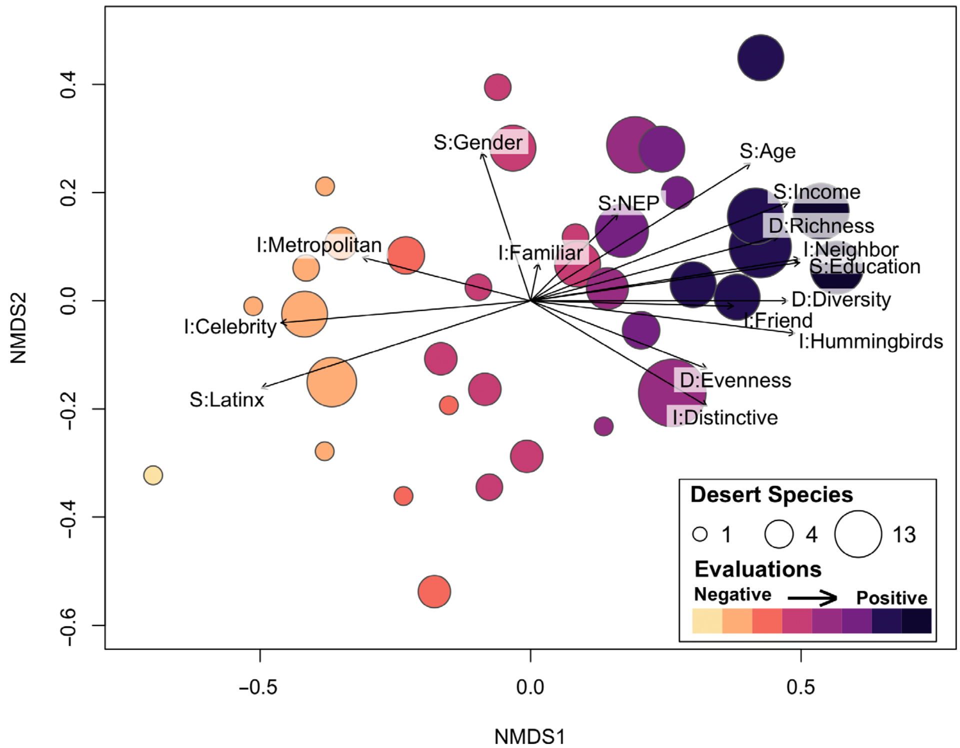

FIGURE 5 Sites arrayed in two-dimensional space based on non-metric multidimensional scaling applied to a Gower distance matrix on people's perceptions of the bird community in their neighborhood. Sites (circles) are plotted in attitudinal space based on the 10-question perceptions scale (Table 1). Larger circles indicate greater desert species richness and darker colored circles are more positive attitudes of people living around the site. Significant explanatory variables are displayed in the text boxes, and categorized into social factors (S:Income, S: Education, S:Age, and S:Latinx), bird interaction factors including trait groups (I:Metropolitan, I:Distinctive, and I:Hummingbird) and cultural niche (I:Celebrity, I:Friend, I:Neighbor), and diversity metrics (D:Richness, and D:ShannonDiversity, D:Evenness). Vector length indicates degree of correlation between explanatory variables and ordination axes.

people's perceptions of the birds they potentially encountered within their neighborhood (Table 4). Species traits that were likely to influence people's experiences with birds explained the most amount of variance in perceptions (about 15.1%), followed by social factors (5.7%). Diversity metrics explained only 0.7% of the total variance when accounting for the effects of interaction traits and sociodemographics. The effects of bird community diversity were shared with the sociodemographics of people living in the neighborhoods, which together explained 4.6% of the variance. Bird traits and sociodemographics factors shared 12.4% of the total explained variance. The shared combination of bird traits and cultural niche, sociodemographics, and community diversity was also important for perceptions, sharing 35.1% of the explained variance.

DISCUSSION

Our research identifies the importance of bird species traits in residential neighborhoods when considering public perceptions. In particular, bird traits better predicted people's perceptions than biodiversity metrics (such as abundance and richness) or sociodemographics alone. Bird traits tied to aesthetic value and local significance were especially important for positive perceptions. Conversely, widely distributed, urban-dwelling species were more likely to elicit negative reactions. The large degree of shared variation highlighted that perceptions were spatially and socially structured within the city, filtered both by the sociodemographic characteristics of people and the characteristics of the bird species present. The primary contribution of our research underscores the importance of bird traits in shaping public perceptions. In particular, the traits of the bird species that people readily encounter in their yards and neighborhoods may influence public support for conservation of birds in particular areas (Schuetz & Johnston, 2021). Overall, our study provides a valuable social–ecological framework to understand positive and negative human–wildlife interactions, as well as highlights potential conservation interventions that can encourage people's positive experiences with urban nature.

TABLE 4 Non-metric multidimensional scaling (NMDS) of people's perceptions about their local bird community, correlated with social factors, bird traits and cultural niche groups, and biodiversity metrics.

Variable	NMDS (1, 2)	R^2
Social factors (5.7% of variance)		
Income	(0.93, 0.36)	**0.49***
Gender (women)	(−0.31, 0.94)	0.16
Education	(0.99, 0.14)	**0.53***
Age	(0.84, 0.53)	**0.43***
Proecological orientation	(0.71, 0.71)	0.10
Latinx identity	(−0.95, −0.31)	**0.52***
Bird traits (15.1% of variance)		
Metropolitan[a]	(−0.97, 0.25)	**0.19***
Familiar[a]	(0.20, 0.98)	0.01
Distinctive[a]	(0.85, −0.51)	**0.27***
Hummingbird[a]	(0.99, −0.12)	**0.46***
Celebrity[b]	(−0.99, −0.09)	**0.45***
Friend[b]	(0.99, −0.03)	**0.29***
Neighbor[b]	(0.98, 0.15)	**0.41***
Stranger[b]	(0.99, −0.12)	0.00
Diversity metrics (0.7% of variance)		
Abundance	(−0.85, 0.53)	0.09
Richness	(0.97, 0.25)	**0.43***
Shannon Diversity	(−1.00, 0.00)	**0.42***
Evenness	(0.93, −0.36)	**0.23***

Notes: NMDS1 and NMDS2 are the relative position of the explanatory factors driving people's perceptions in multivariate space. We partitioned the variance independently explained by the social factors, bird interaction factors, and diversity metrics. Statistically significant R^2 values at the $p < 0.05$ level are shown in bold with an asterisk.
[a]Groups determined by trait analysis in our study (Figure 2).
[b]Groups determined by analysis from Schuetz and Johnston (2019).

Bird traits that foster positive and negative perceptions

Our study highlights the importance of considering what bird traits may shape people's perceptions, such as aesthetics, diet, and place-based connections. Additionally, many of the bird traits related to public perceptions were not clearly delineated along specialist, generalist, and urban-dwelling habitat guilds, which have often been used by ecologists to categorize bird biodiversity in cities (e.g., Lerman & Warren, 2011). For example, Rosy-faced Lovebird (*Agapornis roseicollis*)—a non-native, yet colorful species—was associated with positive perceptions in our study. The popularity of the non-native Rosy-faced Lovebird highlights that traits valued by people may not necessarily correspond to ecological roles. However, bird species with distinctive aesthetic traits are also more likely to be found in areas with greater native biodiversity, which highlights the potential overlap between social and ecological metrics for conservation (Echeverri et al., 2020).

Many common, urban-dwelling bird species shared traits that elicited negative perceptions, such as being gray, large, loud, seedeaters. One respondent even used the margins of the survey to specifically elaborate on their dislike of Rock Pigeon, a quintessential urban bird found in cities worldwide, "There should be a law that you can trap or kill pigeons—they cause physical damage to your home and surrounding areas." This sentiment has been found in other studies and is largely shared across urban-dwelling birds for species that commonly occur in large numbers (Belaire et al., 2015; Cox & Gaston, 2015). Tolerance for birds, and wildlife in general, can be easily overstepped when property is damaged (Clergeau et al., 2001; Clucas et al., 2011). However, many people living in cities globally may not dwell in the single-family households with private yards that characterized our study neighborhoods of the sprawling Phoenix metropolitan area. As a result, interactions with these uncharismatic species—such as feeding pigeons in the park—may represent important but understated ways that urbanites may directly experience nature in denser cities. Therefore, there might also be untapped potential for common urban wildlife species, such as pigeons, to act as everyday ambassadors to foster support for conservation initiatives both within and beyond urban ecosystems (Dunn et al., 2006).

Linking localized interactions to continental patterns of popularity

Our research expands the cultural niche space set forth by Schuetz and Johnston (2019) by directly measuring people's perceptions of the birds they encounter close to home (Robinson, 2019). Interestingly, Metropolitan species from our trait-based approach were related to Schuetz and Johnston's (2019) classification of Celebrity species from Google search trends (Table 2). Birds that were classified into both Metropolitan and Celebrity groups included Eurasian Collared-Dove (*Streptopelia decaocto*), European Starling (*Sturnus vulgaris*), Mourning Dove (*Zenaida macroura*), Northern Mockingbird (*Mimus polyglottos*), and Rock Pigeon. It is unsurprising that common urban species are also well known globally. However, this attention is not necessarily good (Cox & Gaston, 2015), as we found that the presence of these species elicited negative attitudes (Figure 5).

Our research also highlights how some people's experiences with birds may not accurately explain their ability to identify and search for the species online. Specifically, aesthetically distinctive species were negatively related to national-level Google search interest relative to their encounter rate (Schuetz & Johnston, 2019). Many of these bird species were unique to our study region and very important within our localized context (Ainsworth et al., 2018; Schuetz & Johnston, 2021). For example, Phainopepla are silky black birds with a prominent crest, which were classified as Distinctive species in our cluster analysis. Phainopepla garner local attention within the southwestern USA but hold less national interest due to low encounter rates outside of their distribution range.

People's experiences with biodiversity are socially and spatially configured

Human activity results in the spatial aggregation of ecological communities throughout the urban environment (Cox et al., 2018; Gámez & Harris, 2021). Similarly, in non-urban areas, birds with desirable traits are often spatially associated with certain environmental features of the landscape (Echeverri et al., 2021). As a result, human–wildlife interactions in cities are influenced by spatially and environmentally structured differences that determine which bird species are found where (Schell et al., 2020), and by extension, who interacts with particular groups of wildlife species or traits (Lopez et al., 2020). In line with past studies (Lerman & Warren, 2011; Warren et al., 2019), we found that positive perceptions of birds in local neighborhoods were stronger in areas with higher socioeconomic status and with older householders. However, birds with traits that spark positive human responses (Hedblom et al., 2017), including Distinctive and Hummingbird species, were also associated with these neighborhoods. Similarly, we found that Phoenix neighborhoods with a higher percentage of Latinx respondents also had greater abundances of Metropolitan species (e.g., Rock Pigeon and European Starling), potentially influencing the perception that birds carried disease and were a general nuisance. It follows that positive perceptions were associated with neighborhoods where the bird community was composed of species less likely to be associated with negative experiences, because localized conflict with wildlife can quickly become problematic to influence people's attitudes (Belaire et al., 2015).

Our results suggest that local variation in bird communities and associated species traits was a likely explanation for the observed relationship between attitudinal patterns and sociodemographic factors throughout the urban landscape. The local bird species present in a neighborhood have been linked to the biophysical landscape that is shaped and maintained by the yard management decisions of individual people and organizations, which are further influenced by sociocultural factors such as socioeconomic status (Lerman & Warren, 2011). As a result, xeric landscaping tends to be associated with newer and higher income neighborhoods located at the fringe of the city closer to the surrounding desert (Larsen & Harlan, 2006), and therefore also harbor diverse bird communities with greater desert specialist species than less xeric neighborhoods at the urban core (Warren et al., 2019). Following research such as that by Zoeller et al. (2021), we also found that the effects of personal characteristics and sociodemographics further influenced perceptions in light of the bird species a person observed in their neighborhood. However, any inferences from the results of our study should be constrained considering the sample demographics from our household survey, which were aggregated to the neighborhood scale to match bird-point counts in the ordination analysis. Instead, the interpretation of our results and applications of our study should focus on the relationships identified between and among social–ecological variables in the context of established interdisciplinary theory. Future research would benefit from studies that focus specifically on the values, experiences, and views of individuals from different racial and cultural groups. In particular, community-based research efforts should be inclusive of the voices currently excluded or underrepresented in biodiversity conservation (Tallis & Lubchenco, 2014) to better understand the specific factors underlying individualized, community, and societal experiences with urban nature.

Conservation implications of public perceptions

Public perceptions are insightful as conservation indicators, but can also be unreliable signals for proenvironmental behavior when stronger and more specific factors come into play (Heberlein, 2012). However, measuring attitudinal strength through valance and consistency can help to pinpoint when perceptions most likely influence behavior, and how to target public outreach about conservation topics (Rosa & Collado, 2019). Our study highlights the importance of leveraging the characteristics of attitudes to tailor place-specific conservation strategies that link locally important species to broader conservation efforts. For example, studies have shown that people with positive attitudes toward birds are more likely to take up wildlife-friendly yard practices (Belaire et al., 2016; Goddard et al., 2013). Therefore, people with positive attitudes can be targeted for implementing yard management practices that would best support local bird biodiversity. Comparably, focusing on local stewardship may be an ineffective strategy for people with weakly held or negative attitudes (Sharma & Kreye, 2021).

People whose views are relatively malleable may shift if provided with opportunities to experience the diversity of birds within their local urban ecosystem, especially birds that are positively perceived based on desirable traits. Our findings highlight that some bird species traits that are desirable to people may not necessarily support ecosystem health (e.g., the colorful but non-native Rosy-faced Lovebird). However, there does seem to be an established link with traits that are associated with specialist species, greater biodiversity, and people's positive evaluations (Echeverri et al., 2020; Warren et al., 2019). Additionally, perceptions of "ecologically undesirable" species (e.g., non-native species) may still go on to underpin urban ecological functioning when people's perceptions impact habitat creation and maintenance on private land, or through the support of open space preservation (Dunn et al., 2006). Overall, creating wildlife habitat that attracts birds with traits that people perceive positively, as well as supporting access to public open space more equitably throughout a city are both strategies that would ultimately lead to a broader support for bird conservation by fostering positive human–bird interactions.

CONCLUSION

Understanding public attitudes toward wildlife across diverse urban settings is imperative to build land stewardship in residential and urban landscapes. We found that people's perceptions were strongly related to bird traits, especially traits related to distinctive—or easily noticeable—aesthetic characteristics. Differences that emerged across various sociodemographics were similarly related to perceptions through the filter of the bird species traits present within a neighborhood. Our findings linking perceptions to people's direct experiences with their local bird community using a trait-based approach also hold broader-scale conservation implications. In particular, conservation efforts could benefit from identifying flagship species that offer important social and ecological benefits. For example, conservationists could advocate for endemic species that hold regional significance, thereby linking to both biodiversity and a person's willingness to support local wildlife. Our study is situated in a unique geographical perspective of a desert city with a substantial Latinx population, and we took a quantitative approach to integrating social (household survey) and ecological (bird community composition and traits) data. Future research should more fully explore the personal and cultural reasons underlying attitudes toward birds, including cross-regional comparisons, for a more comprehensive understanding of public experiences with neighborhood birds. Overall, a trait-based approach is a fruitful framework for integrated social–ecological analyses that reveal important insights for human–wildlife interactions and associated conservation efforts.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data used in our study are archived and available online following the LTER Network Data Access Policy. For social survey dataset (PASS) see Larson et al. (2019) at https://doi.org/10.6073/pasta/98dd5b92117e9d728b09e582fb4d1b17. For ecological bird monitoring data see Warren et al. (2022) at https://doi.org/10.6073/pasta/4fca7c8a6cd56a6abed9834aca72e764.

ORCID

Riley Andrade https://orcid.org/0000-0003-3640-6013
Kelli L. Larson https://orcid.org/0000-0001-6558-2687
Janet Franklin https://orcid.org/0000-0003-0314-4598
Susannah B. Lerman https://orcid.org/0000-0002-2331-8439
Heather L. Bateman https://orcid.org/0000-0002-3573-3824
Paige S. Warren https://orcid.org/0000-0003-0787-4635

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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