Characterizing the cultural niches of North American birds

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Efforts to mitigate the current biodiversity crisis require a better understanding of how and why humans value other species. We use Internet query data and citizen science data to characterize public interest in 621 bird species across the United States. We estimate the relative popularity of different birds by quantifying how frequently people use Google to search for species, relative to the rates at which they are encountered in the environment. In intraspecific analyses, we also quantify the degree to which Google searches are limited to, or extend beyond, the places in which people encounter each species. The resulting metrics of popularity and geographic specificity of interest allow us to define aspects of relationships between people and birds within a cultural niche space. We then estimate the influence of species traits and socially constructed labels on niche positions to assess the importance of observations and ideas in shaping public interest in birds. Our analyses show clear effects of migratory strategy, color, degree of association with bird feeders, and, especially, body size on niche position. They also indicate that cultural labels, including "endangered," "introduced," and, especially, "team mascot," are strongly associated with the magnitude and geographic specificity of public interest in birds. Our results provide a framework for exploring complex relationships between humans and other species and enable more informed decision-making across diverse bird conservation strategies and goals.

birds | citizen science | culture | eBird | Google

Human values and the actions that they inform increasingly dictate the fates of other species (1). Advances that have enabled exponential growth of human populations have also led to the extinction and redistribution of taxa at rates unprecedented in recent geological history (2, 3). Because human values are implicated in the current biodiversity crisis and any potential solutions, conservationists are becoming more focused on understanding how and why humans value other species (4–6). With a better understanding of valuation processes, efforts to reshape human priorities for the benefit of other taxa should become more feasible (7).

Assessing the value of other species is a significant challenge. An array of economic, aesthetic, and cultural values can be reasonably ascribed to species using a diversity of methods (8, 9). In addition, human perceptions of value are sensitive to the provision of information about the species under consideration, even when researchers agree on valuation currencies and methodologies (10, 11). Given our incomplete knowledge of the natural world and poor grasp of the ways in which we depend on other species, it is difficult to anticipate how much information—or what kind of information—is required to meaningfully assess their value.

Here, we describe an unobtrusive approach to understanding how species are positioned within contemporary culture that circumvents some of these complications. Using Internet query data and citizen science data, we analyze patterns of public interest in North American birds while controlling for variation in potential public exposure to species. In contrast to studies with broadly similar goals (i.e., those aimed at describing the value of species), we do not specify a traditional valuation currency nor do we determine a priori which information about species is likely to shape assessments of their value. Rather, we assume that Internet searches for information about birds—calibrated with data describing the rates at which people encounter different species—can be used to gain broad perspective on the ways in which species are situated in contemporary culture and may be driven by any number of value systems.

Results

To characterize the relative popularity of 621 study species across the United States, we quantified public interest in each taxon using summaries of Google searches from 2008 to 2017 while controlling for bias arising from differences in public exposure to each species (*Materials and Methods*). We employed linear regression to describe the relationship between $\log_{10}$-transformed interest and encounter rates (Fig. 1, $P < 0.0001$, $R^2_{adj} = 0.26$). Then we used model residuals as metrics of how much more, or less, interest each species generated than expected for a given encounter rate (i.e., their popularity). Residual values ranged from −1.66 to 1.91, indicating that the most popular species in our study attracted ~3.6 orders of magnitude more exposure-corrected interest than the least popular species.

We also quantified the position of birds within American culture from a geographic perspective. One can imagine public interest in some species transcending the boundaries of their ranges (12), while interest in other species might be restricted to areas where they are frequently encountered. For each species, we used linear regression to quantify the relationship between state-level interest and encounter rates (Fig. 2). Slopes near 0 indicated low congruence between the geographic distributions of state-level interest and encounter rates. Values near 1 indicated a high level of congruence. The mean slope across 621 species-specific

Significance

Conservation of species is driven largely by human decisions, so it is important to understand how and why people value species differently. We combine information from Google searches with millions of bird observations to characterize public interest in North American birds. We describe different relationships between people and birds based on the volume and spatial patterns of these searches. For example, "celebrity" birds attract high numbers of Google searches, even where they do not occur; large birds are generally more popular than small birds; and endangered species attract interest in the regions where they occur. Our results provide a framework for beginning to explore complex relationships between humans and other species and help to inform bird conservation strategies.

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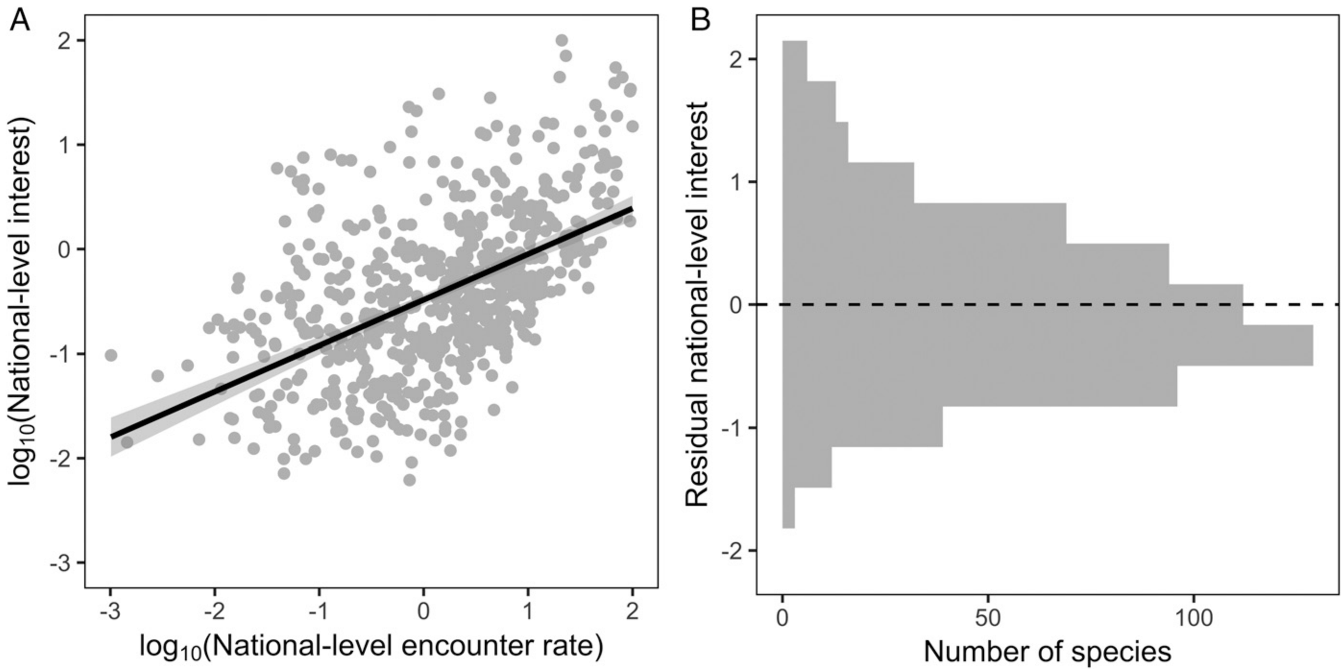

Fig. 1. Quantifying the relative popularity of North American birds. (*A*) Linear regression describing the relationship between normalized national-level interest and encounter rates (n = 621 species). (*B*) Distribution of residual national-level interest values (n = 621 species). Residual values indicate whether species are more or less popular than expected given encounter rates.

regression analyses was 0.46, but many taxa exhibited slopes near 0 or 1.

After analyzing relationships between interest and encounter rates, we defined a 2D cultural niche space bounded by our popularity and congruence metrics. We divided the surface into quadrants and identified four niches that species might inhabit within contemporary culture, each representing a different type of collective relationship between Americans and their birds (Fig. 3). By partitioning cultural niche space, we sought to facilitate conversations around large numbers of taxa.

We described niches in terms of human relationships that vary in intensity and intimacy, without making judgments about the value, importance, or utility of those relationships. "Celebrity" species generated interest beyond the boundaries of their geographic distributions (i.e., low congruence) and attracted more interest than expected given national-level encounter rates (i.e., above average popularity). "Friends or enemies" elicited interest primarily in states where they were encountered (i.e., high congruence) and attracted more interest than expected (i.e., above average popularity). "Neighbors" generated interest in states where they were found (i.e., high congruence), but commanded less interest than expected given encounter rates (i.e., below average popularity). "Strangers" showed a lack of alignment between state-level interest and encounter rates (i.e., low congruence) and generated relatively little attention throughout the United States (i.e., below average popularity).

Using multivariate multiple regression, we explored whether species traits (i.e., taxonomic affinity, size, color, migratory strategy, association with bird feeders, and head plumage) influenced the distribution of taxa across our 2D cultural niche space. We also examined whether socially constructed labels assigned to some species (i.e., "federally protected," team mascot, introduced species, or "game bird") were associated with niche positions. Statistically significant effects emerged for all of the covariates we investigated except head plumage and game bird, suggesting that both observable characteristics of birds and cultural labels influence their positions in American culture (Fig. 4).

We detected a positive association between body size and popularity. Resident species were slightly less popular than migrants but showed higher congruence of state-level interest and encounter rates. Taxa with colorful or contrasty plumages were slightly more popular than dull species, and showed closer alignment of state-level interest and encounter rates. Species that regularly visit feeders were slightly more popular than species that rarely visit feeders.

While only 77 species in our study (12%) bore one or more of the labels team mascot, introduced species, or federally protected, their positions in cultural niche space were strongly associated with those designations (Fig. 4). All six species adopted as professional team mascots were located in the celebrity niche and, on average, exhibited higher popularity and lower geographic congruence than nonmascots. Introduced species were more popular than native taxa and showed lower congruence of interest and encounter rates across states. Internet searches for federally protected species—and species containing federally protected subspecies—were significantly more popular than unprotected taxa. In addition, state-level interest and encounter rates were more closely aligned for protected species.

Cultural niche positions were influenced by the taxonomic Order to which species belonged. Owls (Strigiformes) were the most popular Order of birds, followed by falcons (Falconiformes), grouse and their relatives (Galliformes), and hawks (Accipitriformes). Grebes (Podicipediformes) were the least popular Order, but petrels (Procellariiformes) and shorebirds and gulls (Charadriiformes) were also relatively underrepresented in Internet searches.

Discussion

The magnitude and distribution of public interest in North American birds, as measured by Google search volumes, varied markedly among species. Even after controlling for the fact that some species were much more likely to be encountered than others, the difference in search activity between the most and least popular species spanned nearly four orders of magnitude. There were also clear differences in how closely the geographic distribution of Google searches for particular species aligned with their actual geographic distributions. For some species, state-level search activity and encounter rates were highly congruent, while for other species there was no relationship between

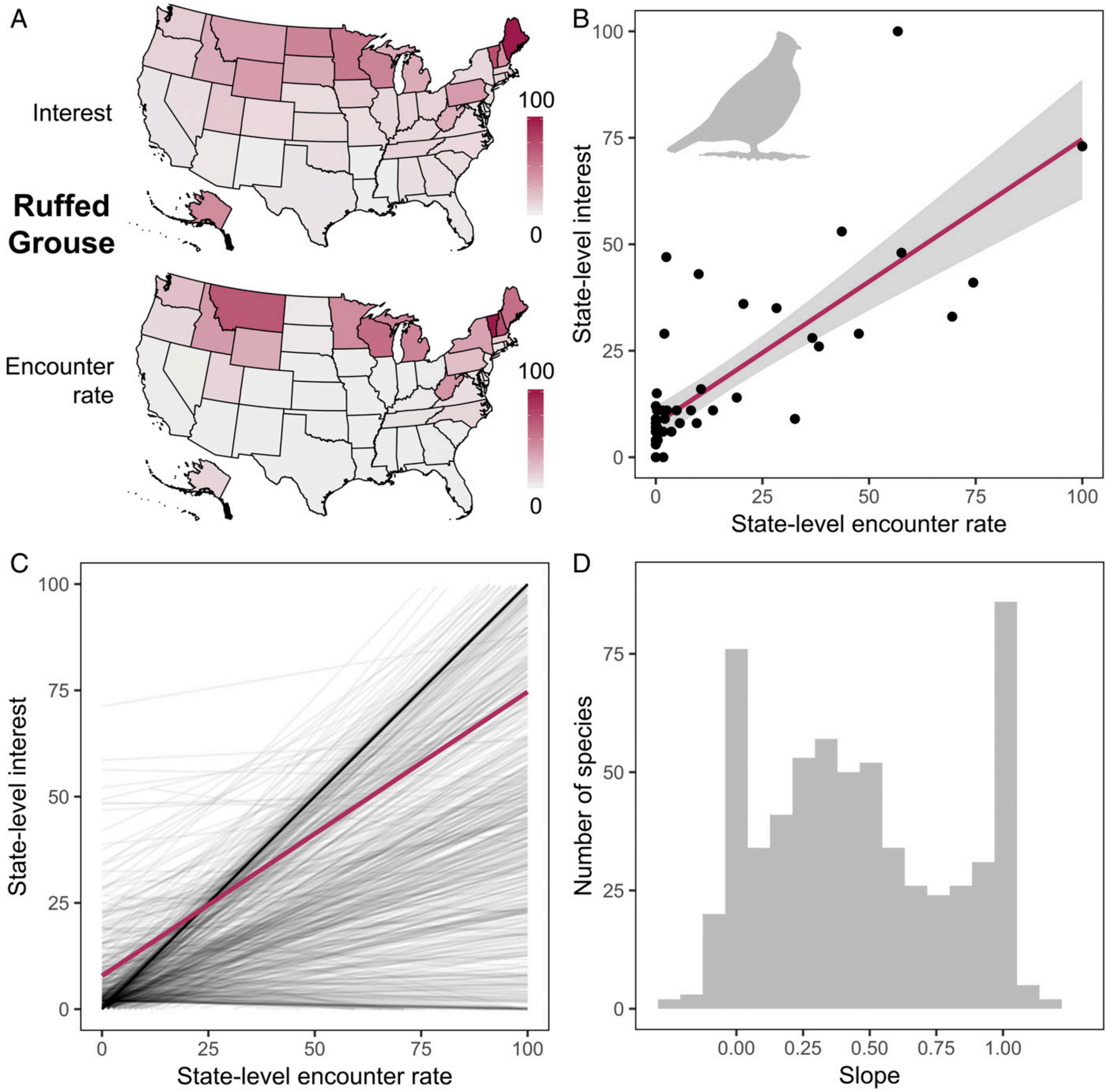

Fig. 2. Quantifying congruence of state-level interest and encounter rates. (*A*) Maps of normalized state-level interest and encounter rates for ruffed grouse (*Bonasa umbellus*). (*B*) Linear regression describing relationship between state-level interest and encounter rates for ruffed grouse (n = 51, 50 states plus the District of Columbia). (*C*) Regression results for all study species (n = 621 species), including ruffed grouse in red. (*D*) Distribution of slopes from all regression analyses (n = 621 species).

where birds were encountered and where interest in them was expressed. Our metrics of relative popularity and congruence cannot capture all of the ways in which birds might be culturally significant, but they were useful for assigning species to four broad cultural niches that suggest a range of relationships between Americans and their birds.

After defining our 2D cultural niche space using popularity and congruence values, we were able to show that several aspects of species' appearance and ecology were strongly associated with their niche positions. The positive association we found between body size and popularity echoes results from studies showing greater public interest in, or conservation advocacy for, larger taxa (13–15). Higher congruence values associated with resident species suggest that people become habituated to birds that they are able to see throughout the entire year and/or that migrant species excite public interest in areas where they are encountered less regularly. The relatively small effect of color on niche position mirrors findings from other studies that show noncolor characteristics have a larger influence on species' likability or perceived value (16). In addition, greater curiosity about "feeder species" may have arisen from people engaging with those taxa in their backyards and deriving psychological benefits from resulting interactions (17, 18).

Cultural labels that are frequently assigned to species were also strongly associated with species' niche positions, but the reasons for

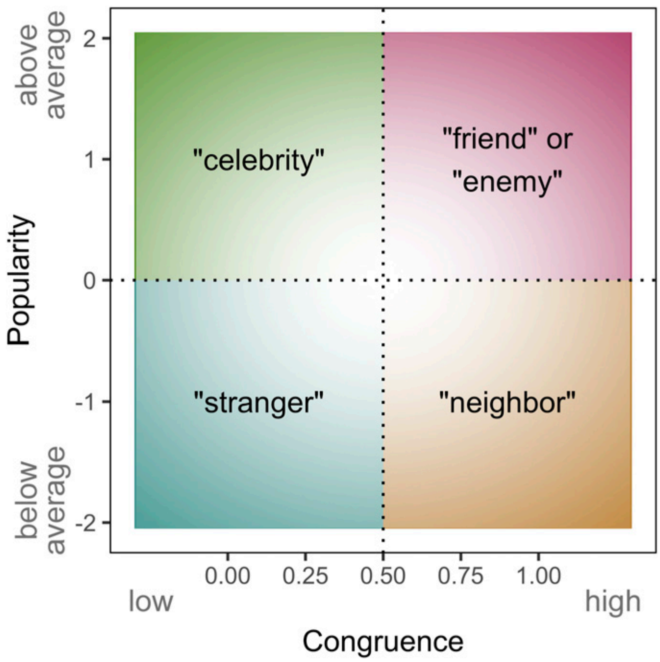

Fig. 3. Definition and division of cultural niche space. Popularity values are residuals describing relative interest in species after controlling for national-level encounter rates. Congruence values are slopes describing the degree to which state-level interest and encounter rates are geographically aligned. Labels in each quadrant characterize our collective relationships with different species.

those associations were not always clear. We found that "mascots" were relatively popular birds, but it was not clear whether being chosen as a mascot inflated the popularity of species—as was the case for the three-banded armadillo (*Tolypeutes tricinctus*) in the 2014 FIFA World Cup (19)—or whether species were picked as mascots because they were already popular. Brown pelican (*Pelecanus occidentalis*), recently adopted as mascot for the New Orleans professional basketball team, provided support for the second explanation (*SI Appendix*, Fig. S3), but results for other species were less conclusive. It seems likely that wide-ranging interest in introduced species emerged as a result of their vilification rather than admiration even though we were not able to test this hypothesis explicitly. Interpreting patterns of heightened local interest in endangered species also presented challenges. Multiple studies have shown that people assign greater value to species in need of conservation (11, 20, 21); however, it is also clear that protected species may attract attention for a variety of reasons (22).

Cultural niche positions were also influenced by taxonomic Order, potentially because there are additional species traits that are aligned with taxonomic Order and that play a role in shaping public interest. For example, Owls (Strigiformes), which appear frequently in myths, legends, and popular culture (23), emerged from our analyses as the most popular Order of birds. Their position in cultural niche space may be a product of distinctive life histories (24) and human-like faces (25), a suite of characteristics that we did not consider explicitly in our analyses.

It is important to note that we were unable to assess whether Internet searches were motivated by generally positive or negative sentiments toward species (e.g., whether they were "friends" or "enemies"), or whether different groups of Americans were motivated by different sentiments when searching for information about particular taxa. One might imagine curiosity about European starlings arising because they are viewed as pests or, alternatively, because they are remarkable vocal mimics. Similarly, interest in golden eagles might arise from genuine awe, concern about risks to the species from energy development, or ambivalence about their role as predators. It is also unclear how closely the population of people that search for information using Google represent the American population as a whole. While the digital divide appears to be closing, and Google Trends data minimize the influence of repeated searches by the same individual, Internet resources are not accessed or used in the same manner across all geographies, income levels, educational backgrounds, and ages (26).

To the degree that they represent the interests and values of Americans, our results have practical and theoretical implications for conservation efforts aimed at birds. We offer a quantitative perspective on the positions of individual species in contemporary American culture and describe factors associated with their cultural niche positions. We also show that while humans have preferences for particular species traits, our relationships with species are not fixed. The ways in which we discuss the biology and legislate the status of taxa can have significant effects on public interest in them. In addition, the relative popularity of "feeder species" suggests the potential consequences of promoting public engagement with birds and encouraging a sense of responsibility for them.

Traditionally, conservationists might have focused on using our results to identify "flagship" species that attract attention and funding to specific conservation issues (16, 27). Carefully choosing species to represent conservation campaigns likely has benefits, and our findings should enable more informed decision-making by a variety of organizations. For example, local or regional conservation organizations may want to use our results to identify species that are more popular than expected within their specific geographic area and then develop conservation programs that reinforce a sense of regional pride and stewardship. In contrast, national or international organizations may want to identify species that attract public attention beyond their geographic ranges, so as to consolidate interest among their supporters. We caution against thoughtless promotion of celebrity species, however, which may only reinforce current perceptions of particular birds, or even reduce prospects for their long-term survival (28).

Our results should also enable development of communication strategies for lesser-known taxa in need of conservation. We quantify perceptual and cultural biases that limit species' appeal and in doing so make clear the nature and magnitude of the challenges that need to be overcome with creative messaging and public engagement. Furthermore, by characterizing the niches of birds within contemporary culture, we offer an alternative framework for conservation thinking; one that avoids assigning values to species in currencies that may ultimately justify their sacrifice and, instead, focuses on the possibility of deepening our collective relationships with the species around us.

Materials and Methods

Study Species, Study Area, and Study Period. Approximately 765 bird species have bred in North America over the last century (29). Interest data and encounter rate data, which we used to understand the position of birds within contemporary culture, were available within our study area (United States) and study period (January 1, 2008 to December 31, 2017) for 622 of those taxa.

Interest Data. Google Trends summarizes the relative abundance of Google searches through space and time. Trends data are derived from an unbiased sample of Google searches, all of which have been anonymized, categorized, and associated with a topic (i.e., a group of terms that share the same concept, as inferred by Google). To reduce the influence of individual people on Trends estimates, Google ignores duplicate searches made by the same person over a short period of time. We assumed that searches indicated a desire for information about a particular topic and that searches might be motivated by any number of economic, aesthetic, or cultural values.

We collected data describing interest in North American birds by entering their common names on the Google Trends website. Only common names that were annotated by Google as "Topics" or "Birds" were considered in our analyses. Names that were annotated as "Search terms" were excluded. In some cases, Google summarized queries for a particular species using a spelling or a name that differed from American Ornithological Society

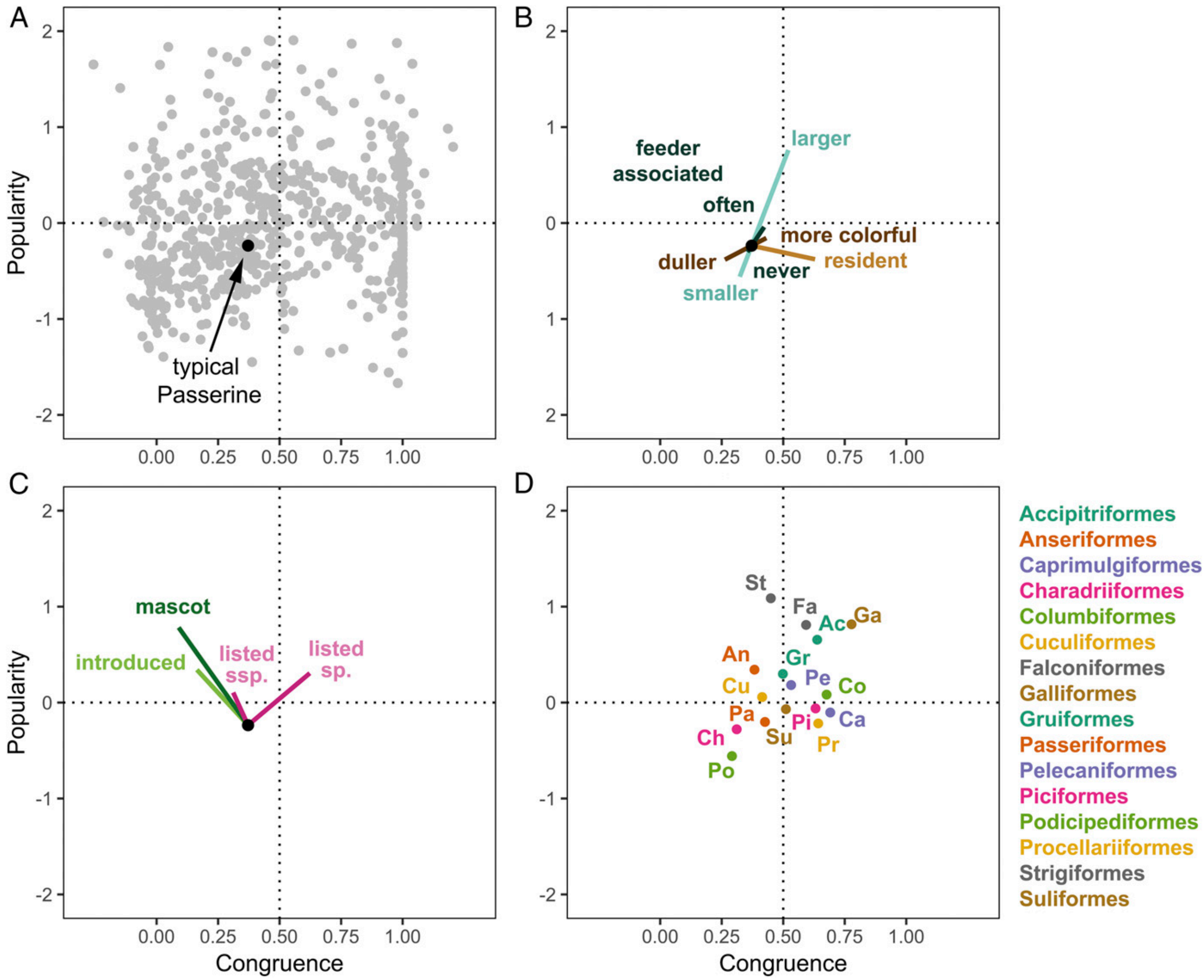

Fig. 4. Factors associated with cultural niche positions of North American birds. (*A*) Distribution of species across cultural niche space (n = 621 species). An interactive view is available in *SI Appendix*, Fig. S4 (https://alijohnston.shinyapps.io/bird_niches_app/). (*B*) Effects of species traits on niche position relative to the reference Passerine. Lines indicate marginal effect sizes. (*C*) Effects of socially constructed labels on niche position. (*D*) Modeled position of an average species in each Order containing more than five taxa (n = 16 Orders).

convention (e.g., "great grey owl" rather than "great gray owl" or "painted whitestart" rather than "painted redstart"). We accepted these variants after confirming, through additional queries, that they represented the same biological entities.

Google Trends offers "Interest over time" data and "Interest by subregion" data to describe the relative frequency of Google searches. Interest over time data describe the distribution of public interest in a topic over a specified time period within a given geography. Estimates of interest are normalized relative to the time interval (e.g., month) with the highest ratio of topic searches to total searches. This reference time interval is assigned a value of 100, and all other intervals are assigned values proportionally. For example, a month in which the ratio of topic searches to total searches is half as large as the reference ratio would be assigned a value of 50.

By entering common names of multiple species, we were able to use Interest over time data to compare national-level interest among taxa. Google Trends allows a maximum of five topics to be compared at one time. Interest estimates are normalized across the entire set of months and species relative to the single month–species combination with the highest ratio of topic searches to total searches. Google assigned this reference month–species a value of 100, and all other months–species were assigned values in relation to the reference. We averaged the normalized monthly values for each species to summarize relative interest in each taxon at a national level across our 10-y study period.

To understand how interest varied across the entire set of species in our study, we sequentially rescaled and joined interest values from groups of five species that shared a single taxon (*SI Appendix*, Fig. S1). After assembling estimates of relative interest for all 622 species, we normalized values so that bald eagle, the second most popular search topic, was assigned a value of 100, and all other taxa were assigned values proportionally. Wild turkey was the focus of more interest than bald eagle, but we considered the species an outlier (i.e., it received more than an order of magnitude more searches than bald eagle) and did not include it in our core analyses.

We downloaded Interest by subregion data separately for each species. Interest by subregion data describe the distribution of public interest in a topic over a specified set of geographies (e.g., states) in a given time period. Interest estimates are normalized relative to the subregion with the highest ratio of topic searches to total searches. This reference subregion is assigned a value of 100 by Google, and all other subregions are assigned values proportionally. For example, a subregion in which the ratio of topic searches to total searches is one-fifth as large as the reference ratio would be assigned a value of 20.

Encounter Rate Data. eBird, a citizen science project managed by the Cornell Lab of Ornithology, aims to improve descriptions of bird distributions and abundances through space and time (30). Observers enter information about when, where, and how they went birding and then contribute checklists of birds they detected. To reduce the chance of misidentifications entering the database, eBird provides observers with a list of species likely to be detected at their location and date during the data submission process. When rare species or unusually high counts are reported, records are vetted by regional experts. As of November 2018, more than 420,000 people had contributed ∼31 million complete checklists to the eBird database.

While analyses of bird distributions and abundances often rely on models that aim to separate observation processes from underlying ecological processes, that was not the goal of our analyses. We sought to estimate the rates at which people encounter birds using checklist data that reflect the interaction of observation and ecological processes. We only used complete checklists in which people report all birds they detect and can identify. We defined encounter rate as the proportion of complete checklists that report a given species. Encounter rates provide useful indices of public exposure to different bird species because they integrate information about where species occur and how likely they are to be detected given that people are not evenly distributed across the landscape and that some species are more conspicuous than others. A strong association between the number of checklists submitted in each state and state population sizes (*SI Appendix*, Fig. S2, linear regression, $P < 0.0001$, $R^2_{adj} = 0.85$) also suggests that eBird checklist data offer a consistent perspective on potential public exposure to birds across the United States.

We calculated annual encounter rates for birds in all 50 states and the District of Columbia using seasonal histogram data files downloaded from the eBird website for the period January 1, 2008 to December 31, 2017. Files contained counts of complete checklists submitted for each week of the annual cycle and the proportion of those complete checklists that reported each species. To improve the readability of histograms – especially for rarely detected species—eBird algorithms insert a value of 0.015 in data sets when species are known to be present during a particular week but are not reported on complete checklists. We converted values of 0.015 into 0 and then aggregated weekly checklist summaries to generate a state-specific average annual encounter rate for each species.

We normalized encounter rates across states to mirror the range of values used to describe interest across states. For each species, all state-level encounter rates were divided by the maximum encounter rate for that species and then multiplied by 100. Thus, the state with the highest encounter rate for each species received a normalized value of 100, and encounter rates in all other states were adjusted proportionally. States in which a species was not encountered were assigned values of 0.

We generated equivalent national-level encounter rates for each species by aggregating checklist data across all states. Data were normalized relative to the species that appeared most frequently on checklists throughout the United States (i.e., mourning dove), and all other taxa were assigned values in proportion to the reference species.

Analysis of National-Level Interest and Encounter Rates. We used linear regression to quantify the relative popularity of our study species using national-level interest information derived from Google Trends data and national-level encounter rate information derived from eBird checklist data. Residuals from the model were interpreted as metrics of species' relative popularity. Positive values indicated taxa that attracted more attention than expected given the rate at which they were encountered. Negative values indicated species receiving less attention than expected.

Analysis of State-Level Interest and Encounter Rates. We used linear regression to characterize alignment between state-level interest and state-level encounter rates for each species. Model slopes were used as a measure of the geographic congruence of interest and encounter rates for each species. Values near 0 indicated a very weak relationship between where birds were encountered and where interest in them was expressed via Internet searches (i.e., low congruence). Values near 1 indicated a very strong relationship between state-level estimates of interest and encounter rates (i.e., high congruence).

Analysis of Variables Associated with Niche Positions. We used multivariate multiple regression to explore whether species traits (i.e., taxonomic Order, migratory strategy, mass, color, feeder association, head plumage) and socially constructed labels assigned to species (federally protected, team mascot, introduced species, game bird) influenced their distribution across 2D cultural niche space. Popularity values and geographic congruence values were specified as the two response variables. All species traits and socially constructed labels were included in a global model as fixed effects. Because log likelihood values were not available for multivariate multiple regression models, we employed backward variable selection to sequentially eliminate covariates until all of the remaining variables were statistically significant (*SI Appendix*, Table S1). Marginal effect sizes in both geographic congruence and popularity dimensions are provided in *SI Appendix*, Tables S2 and S3.

Data and Materials Availability. All data are available in Dataset S1.

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