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Community-science sourced evidence of vocal mimicry in *Perisoreus* jays

Richard Littauer ^a, Sam Darmstadt ^b, William M. Kirsch ^c, and Davyd H. Betchkal ^d

^aTe Kura Mātai Pūkaha, Pūrōrohiko, Te Herenga Waka, Te Upoko-o-te-Ika-a-Māui, Aotearoa – School of Engineering and Computer Science, Victoria University of Wellington, Wellington, New Zealand; ^bFlyaway Birding, Burlington, VT, USA; ^cDepartment of Fisheries, Wildlife and Conservation Sciences, Oregon State University, Corvallis, OR, USA; ^dNatural Sounds and Night Skies Division, U.S. National Park Service, Denali Park, AK, USA

ABSTRACT

Avian vocal mimicry is a well-documented behavior in passerines. However, for many species, detailed data on the diversity of mimicry behavior remains scarce. Additionally, it is unclear whether closely related species exhibit similar mimicry behaviors. One group of mimics is the *Perisoreus* jays: the Canada Jay (*P. canadensis*), Siberian Jay (*P. infaustus*), and Sichuan Jay (*P. internigrans*). To characterize mimicry behavior in this genus, we conducted a systematic analysis of over 450,000 community-sourced observations of *Perisoreus* jays from eBird, Macaulay Library, iNaturalist, and Xeno-Canto. We found a total of 244 observations of mimicry for species in this genus and identified 40 model species mimicked by the Canada Jay (31 of which were not documented previously), 20 model species mimicked by the Siberian Jay (16 of which were not documented previously), and no model species mimicked by the Sichuan Jay (although two were documented previously), alongside 121 recordings of mimicry events. Our findings suggest that vocal mimicry in *Perisoreus* jays is more extensive and diverse than previously documented. This study highlights the value of community science data in documenting rare or understudied behaviors and calls for further research on the significance of vocal mimicry, particularly among closely related species.

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Preuves issues de la science participative attestant de l'imitation vocale chez les mésangeais (genre *Perisoreus*)

RÉSUMÉ

L'imitation vocale aviaire est un comportement bien documenté chez les passereaux. Cependant, pour de nombreuses espèces, les données liées à la diversité des comportements d'imitation sont rares. De plus, il n'a pas été établi si des espèces apparentées montrent des comportements d'imitation similaires. Les mésangeais (genre *Perisoreus*) constituent un groupe d'imitateurs : le Mésangeai du

Address correspondence to Richard Littauer. E-mail: richard.littauer@ecs.vuw.ac.nz

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Canada (*P. canadensis*), le Mésangeai imitateur (*P. infaustus*) et le Mésangeai du Sichuan (*P. internigrans*). Pour caractériser l'imitation vocale dans ce genre, nous avons mené une analyse systématique de plus de 450 000 observations de mésangeais tirées de bases de données participatives : eBird, l'archive Macaulay, iNaturalist et Xeno-Canto. Nous avons recensé un total de 244 observations d'imitation vocale pour les espèces de ce genre et identifié 40 espèces modèles imitées par le Mésangeai du Canada (dont 31 n'avaient pas été documentées auparavant), 20 espèces modèles imitées par le Mésangeai imitateur (dont 16 n'avaient pas été documentées auparavant) et aucune espèce modèle imitée par le Mésangeai du Sichuan (bien que deux aient été documentées antérieurement), ainsi que 121 enregistrements audio d'événements d'imitation. Nos résultats suggèrent que l'imitation vocale chez les mésangeais est plus étendue et diversifiée que ce qui avait été documenté jusqu'ici. Cette étude souligne l'apport des données de science citoyenne dans la documentation des comportements rares ou peu étudiés et appelle à poursuivre les recherches sur la signification de l'imitation vocale, en particulier pour les espèces étroitement apparentées.

Avian vocal mimicry is defined as “cases of vocal resemblance where a receiver specifically selects for resemblance” (Dalziell et al. 2015, 645) between avian vocalizations of the mimic and the model species (Kelley et al. 2008), and where that resemblance confers a benefit on the producer. The behavior of avian mimicry is widespread (Garamszegi et al. 2007; Goller and Shizuka 2018), but dedicated conceptual frameworks (such as Kelley et al. 2008; Dalziell et al. 2015; Austin et al. 2021) have only recently been used to outline the structure, origin, and function of mimicry. Some of the best-known avian mimics include species such as the Northern Mockingbird (*Mimus polyglottos*) and Common Starling (*Sturnus vulgaris*), as well as broader taxonomic groups like parrots (Psittacidae) and lyrebirds (Menuridae) (Townsend 1924; Hindmarsh 1984; Dalziell and Magrath 2012; Goller and Shizuka 2018; Benedict et al. 2022). Birds mimic in the contexts of predator avoidance, parasitism, foraging, competition, sexual selection, and rearing young (Dalziell et al. 2015; Austin et al. 2021), among other possible uses like play (Lubke et al. 2025). Although widespread, reports of mimicry in wild birds generally remain anecdotal (Dalziell et al. 2015).

One family of oscine passerine that is reported to mimic in the wild is Corvidae. In particular, some jay species appear to specialize in imitating the calls of raptors and other birds, a behavior believed to serve purposes such as predator deception or social signaling (Marshall 1950; Dalziell et al. 2015). Vocal mimicry in corvids, especially within less-studied genera, remains poorly characterized. One such genus is *Perisoreus*, which includes the Canada Jay (*P. canadensis*), Siberian Jay (*P. infaustus*), and Sichuan Jay (*P. internigrans*). These species are broadly distributed across boreal and montane forests of the Northern Hemisphere. While previous work (e.g., Semprebon 2001; Strickland and Ouellet 2020) has examined vocalizations in *Perisoreus* jays, the diversity of model species has not been systematically explored. The diversity of models is important, as large repertoires could signal sexual fitness. As well, mimicry of multiple model predator species could confer defensive advantages. However, no studies have sought to delineate the amount of model species found in vocal mimicry in jays.

In order to assess the diversity of model species in *Perisoreus* jays across a wide dataset of observations, we filtered and analyzed almost half a million community-sourced records from community science websites to identify instances of vocal mimicry in *Perisoreus* jays. Specifically, we compiled instances in which human receivers both reported mimicry of model species from jay vocalizations and also identified the model. Our focus is limited to mimicry as perceived by human receivers, as a means of finding anecdotal reports of mimicry at scale. As our dataset is gathered from relatively short comments made by community scientists without rigorous observation protocols, we cannot assess whether these vocalizations are learned or innate, the wider context of mimicry, or referential calling behavior (cf. Griesser 2008, 2009; Iqic and Magrath 2014). Our goal is to establish a baseline for the diversity of model species reported in vocal mimicry from a wild oscine passerine. We chose *Perisoreus* because these jays are charismatic (Bradter et al. 2021) and relatively large, features that lead to overrepresentation within community science data (Troudet et al. 2017; Callaghan et al. 2021), and also because they are vocal learners, which makes them good candidates for studying the diversity of model species in mimicry.

Methods

To characterize potential vocal mimicry in *Perisoreus* jays, we conducted a broad search of community-sourced data repositories, including eBird/Macaulay Library (Sullivan et al. 2009), iNaturalist (iNaturalist 2026), and Xeno-Canto (Planqué and Vellinga 2008), for records of jays. While anyone can upload comments and media associated with a species observation to these archives, these data can be independently verified by the investigator, especially when such data include video, recordings, and associated observational comments. When aggregated, these datasets can provide significant amounts of geographically and temporally diverse data.

We exported all of the global observations of each species of jay from the eBird database, up to July 2024 (eBird Basic Dataset 2024). We then used bash commands (FreeBSD Project 2026) to grab all rows from the database that had comments pertaining to jay species in the “Trip” or “Species Comments” fields. We further filtered these using Python scripts (Python Software Foundation 2026) with the standard Python and pandas libraries (The Pandas Development Team 2020) by retaining only those that mentioned the substrings “imitate,” “mimic,” and “call” (all case insensitive) or included a four-letter banding code (case sensitive). After removing duplicates, we manually annotated these observations, noting observer identification of mimicked birds by jays. We also sorted and examined comments from exports from the Macaulay Library, which is linked to eBird, to catch any comments left on media but not in eBird checklists.

We also searched for the substring “goshawk” in all comments to verify if any comments discussed mimicry of a model species but did not use one of our search substrings. The substrings used for search are English-language specific. For the two other members of the *Perisoreus* genus, we initially searched eBird for common strings expected in checklists of Siberian or Sichuan Jay—for instance, “kanahaukka,” “høñsehauk,” “duvhök,” and “Тетеревятник,” for the Finnish, Norwegian, Swedish, and Russian words for “goshawk” (Młodinow 2023). This was entirely unproductive and was not attempted on data from iNaturalist or Xeno-Canto.

In our next step of review, we searched the iNaturalist database, using the same substrings for all *Perisoreus* species. We searched Xeno-Canto manually. We examined the Remarks field on each observation for a mention of mimicry or imitation, as well as any forum posts linking to a recording, translating any text in Swedish or French, using Google Translate when necessary. Only identifications of mimicked species by original authors, and not commenters, were retained. We also performed a literature review and noted any authors who explicitly mentioned vocal mimicry for *Perisoreus* species and who noted the model species.

Results

In reviewing the eBird/Macaulay Library, iNaturalist, and Xeno-Canto databases, we analyzed 445,340 Canada Jay, 6,367 Siberian Jay, and 408 Sichuan Jay observations or media for a total of 452,115 data points. From eBird, our initial dataset contained 397,245 Canada Jay, 4,091 Siberian Jay, and 279 Sichuan Jay observations. Individual counts were not calculated. Our filtered eBird dataset contained 186 unique observations with comments concerning mimicry for Canada Jay, and none for the other species. We analyzed Macaulay Library comments for Canada Jay (37,465 photos, 906 recordings, and 48 videos), Siberian Jay (1,239 photos, 26 recordings, and 21 videos), and Sichuan Jay (99 photos, nine audio recordings, and two videos). We retained 35 relevant observations with comments included only on media in Macaulay Library and not in the eBird data. Out of 14,696 observations on iNaturalist of *Perisoreus* species—13,919 for Canada Jay, 767 for Siberian Jay, and 8 for Sichuan Jays—three observations were selected, two with audio recordings. For Xeno-Canto, we searched all 128 observations of Canada Jay, 224 observations of Siberian Jay, and 10 observations of Sichuan Jay, and selected 31 observations. A single observation mentioned “goshawk,” but not “mimic,” “imitate,” or “call.”

In total, we identified 234 observations that corresponded with instances of mimicry of a single model species, including 206 observations of Canada Jay, 28 observations of Siberian Jay, and 0 observations of Sichuan Jay mimicry. From these observations, we identified 40 model species for Canada Jay (Table 1), 20 model species for Siberian Jay (Table 2), and no species for Sichuan Jay (Table 3).

In some instances, Canada Jays mimicked multiple species in the same observation: 17 observation comments mentioned two species, three mentioned three species, and two comments mentioned four species. Many of these calls were from the same day, and one recording from that day had a total of six different perceived calls within the same recording of subsong. The observer noted possible counter-singing from a male and female (Elman 2016). Many observations mentioned the use of callback as well, often noting that Canada Jays flew in after callback of other species, including owls (most frequently, Northern Pygmy Owl, *Glaucidium gnoma*), or American Goshawk (*Astur atricapillus*). As callback indicates a human imitating a bird and not a bird imitating something else, these were not retained in our dataset.

Most observations of Canada Jays came from eBird; only five observations mentioned mimicry on Xeno-Canto, and three observations on iNaturalist. All Siberian Jay observations came from Xeno-Canto. None of the observations for the rarest extant species in the genus, Sichuan Jay, mentioned imitation. A full list of recordings can be found in the Supplemental Table S1 (also available as plain text on <https://github.com/RichardLitt/perisoreus>), with the species names indicating imitated species and with the Macaulay Library, iNaturalist, or

Table 1. Model species perceived to be mimicked by Canada Jay ($n = 183$).

Model species	Scientific name	Observations	References
Mountain Quail	<i>Oreortyx pictus</i>	5	
Spotted Sandpiper	<i>Actitis macularius</i>	2	
Greater Yellowlegs	<i>Tringa melanoleuca</i>	1	
Common Poorwill	<i>Phalaenoptilus nuttallii</i>	1	
Common Nighthawk	<i>Chordeiles minor</i>	1	
Osprey	<i>Pandion haliaetus</i>	6	
Golden Eagle	<i>Aquila chrysaetos</i>	0	Dawson (1923)
Sharp-shinned Hawk	<i>Accipiter striatus</i>	3	
Cooper's Hawk	<i>Astur cooperii</i>	2	
American Goshawk	<i>Astur atricapillus</i>	37	
Bald Eagle	<i>Haliaeetus leucocephalus</i>	2	
Broad-winged Hawk	<i>Buteo platypterus</i>	7	Semprebon (2001), Strickland and Ouellet (2020) (with recording)
Red-shouldered Hawk	<i>Buteo lineatus</i>	4	
Swainson's Hawk	<i>Buteo swainsoni</i>	1	
Red-tailed Hawk	<i>Buteo jamaicensis</i>	8	Strickland and Ouellet (2020)
Rough-legged Buzzard	<i>Buteo lagopus</i>	0	Todd (1963), Strickland and Ouellet (2020)
Northern Saw-whet Owl	<i>Aegolius acadicus</i>	4	
Northern Hawk-Owl	<i>Surnia ulula</i>	2	
Northern Pygmy Owl	<i>Glaucidium gnoma</i>	40	Strickland and Ouellet (2020)
Northern Spotted Owl	<i>Strix occidentalis</i>	1	
Northern Flicker	<i>Colaptes auratus</i>	2	
Merlin	<i>Falco columbarius</i>	6	Strickland and Ouellet (2020)
Great Crested Flycatcher	<i>Myiarchus crinitus</i>	1	
Olive-sided Flycatcher	<i>Contopus cooperi</i>	1	
Hutton's Vireo	<i>Vireo huttoni</i>	2	
Blue Jay	<i>Cyanocitta cristata</i>	28	Strickland and Ouellet (2020)
Steller's Jay	<i>Cyanocitta stelleri</i>	8	
Clark's Nutcracker	<i>Nucifraga columbiana</i>	2	
Northern Raven	<i>Corvus corax</i>	1	
American Crow	<i>Corvus brachyrhynchos</i>	2	Strickland and Ouellet (2020)
Grey Catbird	<i>Dumetella carolinensis</i>	1	
Eastern Bluebird	<i>Sialia sialis</i>	1	
Varied Thrush	<i>Ixoreus naevius</i>	1	
American Robin	<i>Turdus migratorius</i>	2	
Evening Grosbeak	<i>Hesperiphona vespertina</i>	5	
Pine Grosbeak	<i>Pinicola enucleator</i>	0	Bent (1946), Strickland and Ouellet (2020)
Purple Finch	<i>Haemorhous purpureus</i>	1	
American Goldfinch	<i>Spinus tristis</i>	2	
Accipitrine hawk	<i>Astur/Accipiter</i> spp.	1	
Chickadees	<i>Poecile</i> sp.	1	
Crossbill	<i>Loxia</i> spp.	1	
Hawk	–	1	
Owl/cat	–	1	
Owl/dinosaur	–	1	
Quail	–	1	
Raptor	–	1	
Sandpiper	–	1	
American red squirrel	<i>Tamiasciurus hudsonicus</i>	2	
Domestic cat	<i>Felix catus</i>	2	

Model bird species identified only to the genus or family level in the literature, but not found in the data, are not included; model taxa identified above the species level in the data are included as written by the observers. Taxonomy, nomenclature, and sequence of birds listed in Tables 1–3 follows Avilist Core Team (2025), followed by unidentified taxa. Where references are not listed, the model species has only been found in our data.

Xeno-Canto ID numbers, and with numbers in parentheses indicating the number of independent observation incidents that mentioned a species, as some entries or checklists had multiple recordings. For Canada Jays, we provide links to 82 recordings for 24 imitated taxa. For Siberian Jays, we provide links to 54 recordings for 23 imitated taxa.

Table 2. Model species perceived to be mimicked by Siberian Jay.

Species	Scientific name	Observations	References
Green Sandpiper	<i>Tringa ochropus</i>	1	
Eurasian Pygmy Owl	<i>Glaucidium passerinum</i>	5	
Eurasian Goshawk	<i>Astur gentilis</i>	5	
Common Buzzard	<i>Buteo buteo</i>	2	Madge (2020)
European Green Woodpecker	<i>Picus viridis</i>	2	
Black Woodpecker	<i>Dryocopus martius</i>	1	
Great Spotted Woodpecker	<i>Dendrocopos major</i>	1	
Common Kestrel	<i>Falco tinnunculus</i>	1	
Eurasian Jay	<i>Garrulus glandarius</i>	2	Madge (2020)
Common Blackbird	<i>Turdus merula</i>	1	
Fieldfare	<i>Turdus pilaris</i>	1	
Northern Wheatear	<i>Oenanthe oenanthe</i>	1	
Western Yellow Wagtail	<i>Motacilla flava</i>	1	
White Wagtail	<i>Motacilla alba</i>	1	
Meadow Pipit	<i>Anthus pratensis</i>	1	
Brambling	<i>Fringilla montifringilla</i>	1	
Eurasian Bullfinch	<i>Pyrrhula pyrrhula</i>	0	Madge (2020)
Redpoll	<i>Acanthis flammea</i>	0	Madge (2020)
Eurasian Siskin	<i>Spinus spinus</i>	1	
Crow-like	<i>Corvus</i> spp.	1	
Finch	–	2	
Hawk-like	–	2	
Thrush-like	–	2	Madge (2020)
Tits	<i>Paridae</i> spp.	0	Madge (2020)
Woodpeckers	<i>Picidae</i> spp.	0	Madge (2020)
Eurasian red squirrel	<i>Sciurus vulgaris</i>	2	
Predator	–	1	

Model bird species identified only to the genus or family level in the literature, but not found in the data, are not included; model taxa identified above the species level in the data are included as written by the observers. Taxonomy, nomenclature, and sequence of birds listed in Tables 1–3 follows AviList Core Team (2025), followed by unidentified taxa. Where references are not listed, the model species has only been found in our data.

Table 3. Species perceived to be mimicked by Sichuan Jay.

Species	Scientific name	Observations	References
Upland Buzzard	<i>Buteo hemilasius</i>	0	Jing et al. (2005)
Eurasian Jay	<i>Garrulus glandarius</i>	0	Yue-Hua et al. (2001)

Model birds identified only to the genus or family level in the literature, but not found in the data, are not included. Taxonomy, nomenclature, and sequence of birds listed in Tables 1–3 follows AviList Core Team (2025).

Discussion

By a systematic survey of community science datasets, we identified 40 model species mimicked by the Canada Jay (Table 1), 20 species mimicked by the Siberian Jay (Table 2), and we found no new model species for Sichuan Jay. Thirty-one of these species for Canada Jay and 16 for Siberian Jay were novel, in that we found no references to them as model species in the literature. This review allowed us to gain new insights into the diversity of models in vocal mimicry for *Perisoreus* species. Furthermore, because of the heterogenous nature of the dataset, we gleaned information about jay mimicry across populations and time, lessening the possibility of aberrant behaviors or unreliable observers. While the observations lack the in-depth detail of controlled studies, such as Harvey et al. (2024) with Steller’s Jays, or such as suggested initially by Semperebon (2001), the data at scale are useful.

For example, the model species for Canada Jay are roughly equivalent to the model species for Siberian Jay. For each, the local pygmy owl (*Glaucidium* spp.) was the most noted, followed by their respective collocated goshawk (*Astur* spp.). The small size of the dataset for once-heard birds renders other comparisons largely inconclusive. Future studies on whether pygmy owls and goshawks are the main predators for *Perisoreus* jays would illuminate why those taxa tend to be the most imitated, and whether modeling multiple species confers an advantage in predator-prey interactions. Several observers also noted that the mimicked calls had a different quality, including for American Goshawk, such as this observation (translated from the French): “An individual very accurately mimics the calls of the Northern Goshawk, both the calls heard during the nesting period and the alarm calls. The only distinction between the real and the imitation is that there is less tone, less energy in the Gray Jay’s imitation. However, from a distance, I could have been fooled . . .” (Deschênes 2017). Another for the Northern Pygmy Owl also noted differences: “The pitch, duration, and spacing sounded like a PYOW [sic] toot, but the volume was quieter and the tone was slightly different” (Wilson 2021).

We acknowledge the many limitations associated with our methodology of sampling across multiple community science platforms with many observers of many abilities, and how this also impacts the inferences we can make as it pertains to our question of mimicry in jays. Most notably, there were no observations of perceived mimicry in Sichuan Jays in the data, possibly due to the paucity of observations of this species. Furthermore, the variability of calls makes identification of model birds difficult. For instance, a high American Goshawk could sound very similar to an Osprey (*Pandion haliaetus*) or a Sharp-shinned Hawk (*Accipiter striatus*). Some observers used Merlin Sound ID (Merlin 2026) to help them identify birds from these recordings—often with a false positive, including with American Goshawk (Beason 2023).

Other comments mentioned vocalizations such as a “whinny” (Hohengarten 2015), or “meowing” (Shulist 2020a, 2020b), which could perhaps have also been imitation of Long-eared Owl (*Asio otus*), Northern Saw-whet Owl, or Grey Catbird (*Dumetella carolinensis*). Similarly, other observations also needed to be considered cautiously. For instance, banding codes were misspelled at times (such as Northern Spotted Owl, *Strix occidentalis* [NSOW] for Northern Saw-whet Owl, *Aegolius acadicus* [NSWO]). “Heard only” birds may be a wider issue within this dataset—over 400 checklists (0.1% of the initial data) had “Heard only” as a comment. Several checklists with Canada Jays had either Rough-legged Buzzard (*Buteo lagopus*) or Pine Grosbeak (*Pinicola enucleator*) included as “Heard only” birds, meaning that the observer noted in a comment that they only heard the bird but were not able to visually identify it. As Canada Jays were known to be present, it is possible that what an observer heard was, in fact, a Canada Jay’s vocal mimicry, and not either of the other two species. Heard only comments pose a threat to the verifiability of community science data, particularly when the observed species is used as a model by known vocal mimics. A taxonomy of model species, such as we present here, may help with cleaning community science data.

We made a distinction between mimicry and similarity in observer comments. For instance, one entry we excluded for a Northern Mockingbird call was described as an “alarm call given when NOGO (Northern Goshawk) flew by was musical and very mockingbird-like.” (Davenport and Davenport 2020). Likewise, Strickland and Ouellet (2020) noting the reminiscence of Common Starling and Purple Finch (*Haemorhous purpureous*) in Canada Jay song was also not included, nor such descriptions as “crow-like,” “buzzard-

like,” the tautological “jay-like,” or that the speed of one of the Sichuan Jay’s calls was like a Common Snipe (*Gallinago gallinago*), from Madge and Burn (1994). We did not make a distinction between mimicry and imitation, as many users used them interchangeably. To complicate matters, it is also possible that some recordings may have been instances of “hypermimicry,” where a bird mimics a model bird that is itself mimicking a model bird, a term coined in a discussion on Xeno-Canto by Maclean (2017). This was noted in an observation of a Siberian Jay imitating a *Buteo* spp. call, where the perceiver noted that this vocalization sounded like a Siberian Jay mimicking a Eurasian Jay mimicking a *Buteo* (Elman 2020).

Future work could cluster and compare vocalizations, building on Semprebon (2001)’s analysis of Canada Jay mimicry of Broad-winged Hawk (*Buteo platypterus*), or Sangster (2022)’s clustering of American and Eurasian Goshawk (*Astur gentilis*) alarm calls. Some of the calls of Sichuan Jay described by Jing et al. (2000, original not seen), and compared in Semprebon (2001), may have been mimicking calls, particularly the “rapid series of a-a-a-a,” and the calls noted by Knue (2024) and Kleinschmidt et al. (1922). More data is needed for comparison. Furthermore, the same method could be applied to other species to determine the amount of diversity of model birds in mimicry across Aves. Toward that end, observers who note mimicking birds should document their observations thoroughly and ideally use the words “mimicry” or “imitate” in their comments when noting this behavior on community science websites.

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Author contributions

CRedit: **R. Littauer**: conceptualization, data curation, formal analysis, investigation, methodology, project administration, software, supervision, and writing of the original draft; **S. Darmstadt**: data curation, investigation, writing of the original draft, and writing review and editing; **D. Betchkal**: investigation, software, visualization, writing of the original draft, and writing review and editing; **W. Kirsch**: investigation, writing of the original draft, and writing review and editing.

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ORCID

Richard Littauer  <http://orcid.org/0000-0001-5428-7535>
Sam Darmstadt  <http://orcid.org/0009-0001-6970-8109>
William M. Kirsch  <http://orcid.org/0009-0009-4150-0523>
Davyd H. Betchkal  <http://orcid.org/0000-0001-8783-3272>

Data availability statement

All used data are publicly available on eBird, iNaturalist, and Xeno-Canto. Scripts used to massage exported data are downloadable at <https://github.com/RichardLitt/perisoreus>.

Collaboration ethics statement

This project was conceived as a collaborative effort. R. Littauer, when first investigating instances of mimicry in *Perisoreus* jays using community science platforms, reached out to all observers who had uploaded significant observations, asking if they would be interested in coauthoring the paper. This included reaching out to researchers whose first language is not English. Many observers were not interested in coauthoring, but W. Kirsch and D. Betchkal both joined through this effort. We intentionally attempted to collaborate with early-career researchers. The authors are aware of their privilege—in time, in language, in country of origin, in access, and along other vectors—and intentionally searched for articles and potential coauthors outside of the anglosphere. Automatic translation tools (Google Translate) were used for content in Russian, Chinese, German, Finnish, Swedish, and Norwegian. We aim to provide our data under open licenses, in formats beyond PDF to enable easier mining, and with replicable methods. We also acknowledge the Abenaki as the traditional stewards of the land of Ndakinna, where some of this work was done.

Ethics

No ethics permits or approvals were required for this research.

Generative AI

Generative AI was used to clean up and add comments to already-written code, available at <https://github.com/RichardLitt/perisoreus>. Otherwise, Generative AI was not used in the production of this manuscript.

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