Vocal mimicry in corvids

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Abstract

Vocal mimicry, the copying of sounds produced by another species or the environment, is commonly described in vocal learners, such as songbirds. Understanding the functions of vocal mimicry can help to uncover the evolutionary drivers of vocal learning. Different adaptive functions like interspecific and intraspecific communication have been suggested, as well as the possibility of vocal mimicry to be a mistake during vocal learning. In the present study, we review the occurrence of mimicry in the family of corvids and investigate the socio-ecological factors driving the evolution of vocal mimicry in this group of birds. We recorded evidence of vocal mimicry from primary (xeno-canto recordings) as well as secondary sources (published literature) and found evidence for vocal mimicry in 31 out of 128 corvid species (24%). Smaller species were described as mimics more compared to larger species. Other socio-ecological factors like breeding status, habitat and trophic niche did not have a significant effect. More mimicry was recorded during the non-breeding season compared to the breeding season. We used Bayesian modelling based on existing data from primary and secondary sources to estimate the occurrence of mimicry, suggesting that vocal mimicry may be more widespread among corvids than currently documented, with many species potentially being 'hidden mimics'. Our study for the first time systematically reviews the occurrence of vocal mimicry across the family of corvids and investigates a range of socio-ecological factors driving the behaviour. Our analysis suggests many corvid species likely to be 'hidden' mimics and we provide specific suggestions for species which according to our statistical model are most likely mimicking corvid species, hopefully inspiring future field work on those species.

Key words: *Corvidae*, deterrent mimicry, heterospecific vocal mimicry, vocal communication,

Introduction

Vocal mimicry, the copying of sounds produced by another species or the environment, is commonly described in songbirds (Kelley et al. 2008; Dalziell et al. 2015) and also has been reported in mammals including an Asian elephant, *Elephas maximus* (Stoeger et al. 2012), a white whale, *Delphinapterus leucas* (Ridgway et al. 2012), a harbor seal, *Phoca vitulina* (Duengen et al. 2023), and greater mouse-eared bats, *Myotis myotis* (Ancillotto et al. 2022). Mimics usually acquire sounds through vocal production learning, the ability to produce novel signals through imitation or modification of existing vocalisations (Janik and Knörnschild 2021). Vocal production learning in animals has parallels with human vocal ontogeny (Ter Haar et al. 2021), as it requires an individual to process acoustic information from an appropriate model, engage in vocal practice and evaluation through auditory feedback, and requires enhanced forebrain control of the vocal organ (Nieder and Mooney 2020).

According to Dalziell et al. (2015), vocal mimicry is defined as vocalisations resembling heterospecific or environmental sounds which change the behaviour of the receiver after perceiving the acoustic resemblance between the mimic and the model, and the behavioural change confers a selective advantage on the species mimicking. This definition excludes other forms for vocal resemblance, for example as a result of chance or common ancestry. Vocal mimicry may be a result of mistakes during vocal learning and have no function (Kelley et al., 2008). In contrast to this, a number of different potential functions of vocal mimicry have been previously suggested, broadly falling into two categories (a) interspecific communication, to avoid threats, dissuade competitors, or imitate threats to allow access to food resources and (b) intraspecific communication, in the context of sexual selection or for social affiliation (reviewed by Kelley et al., 2008). For example, mimics are suggested to produce vocalisations from predatory or agonistic species to deter competitors or potential predators from their territories (Dobkin 1979). Australian magpies, *Gymnorhina tibicen*, mimic several potential nest predators, for example the barking owl, *Ninox connivens*, and the boobook owl, *Ninox novaeseelandiae* (Kaplan 1999). Fork-tailed drongos, *Dicrurus adsimilis,* mimic alarm calls of other species to deter heterospecifics from food sources, in order to steal the food (Flower et al. 2014). Individuals might also benefit from vocal mimicry when used to attract other individuals. For example, greater racket-tailed drongos, *Dicrurus paradiseus,* mimic songs and contact calls to attract other species, which increases foraging efficiency (Goodale and Kotagama 2006a) and alarm calls of other species alongside their own mobbing calls, potentially attracting other species to support them when mobbing predators (Goodale and Kotagama 2006b). This shows that some species flexibly use vocal mimicry, and this may be context dependent. Finally, mimicked calls are sometimes incorporated into song or sexual displays and might play a role in sexual selection (Kelley et al., 2008). Overall, surprisingly little empirical research on the functional explanations of vocal mimicry is available.

Phylogenetic analysis has previously shown that vocal mimicry is unlikely to be an ancestral state in songbirds, meaning that it may have evolved independently on multiple occasions (Goller and Shizuka 2018). A review of European passerines estimated approximately 40% of songbird species to mimic (Garamszegi et al., 2007). Sounds mimicked by songbirds include birdsong (northern mockingbird, *Mimus polyglottos*: Gammon and Altizer 2011), alarm calls of other species (spotted bowerbird, *Ptilonorhynchus maculatus*: Kelley and Healy 2011; red-capped robin-chat, *Cossypha natalensis:* Oatley 1969; thick-billed euphonia, *Euphonia laniirostris*: Morton 1976), calls of birds of prey (blue jay, *Cyanocitta cristata*: Hailman 1990), and human voices (European starlings, *Sturnus vulgaris*: West et al. 1983). As suggested by Gammon (2013), the 'model selection', *i.e.* type of sound mimicked, can provide valuable insight into the potential functions of vocal mimicry. For example, northern mockingbirds, *Mimus polyglottos,* preferentially mimic species whose sounds are acoustically similar to their non-imitative song, supporting the acoustic similarity hypothesis, and suggesting a non-adaptive explanation of vocal mimicry (Gammon, 2013). Mimicry of predator calls by Steller's jays, *Cyanocitta stelleri,* is also linked to mate selection, with mimicry occurring more frequently during the breeding season and when in the presence of their mates (Tippin 2017).

Corvids *(Aves: Corvidae),* are a large and diverse group with over 120 species split between 21 genera, an array of which can be found on all continents except Antarctica (Madge and Burn 1994). Many corvid species have demonstrated advanced cognitive abilities in the social and physical domain (Taylor 2014). Corvids belong to the suborder of oscine passerine birds, where the vocal organ (syrinx) is highly developed to produce vocalizations (Suthers and Zollinger 2004). Vocalisations in corvids present a wide range of ecological and social adaptations, such as communicating information about predators such as predator type or level of risk or individual recognition (Wascher and Reynolds 2025). Corvids are open-end vocal learners, which means they can acquire new vocalisations throughout their lives and not only in a specific sensitive period (Brenowitz et al. 1997). Carrion crows are capable of volitional control of vocalisations, *i.e.* can be trained to vocalise and withhold vocalisations in response to arbitrary stimuli (Brecht et al. 2019). Vocalisations in New Caledonian crows, *Corvus moneduloides* (Bluff et al. 2010) and common ravens, *Corvus corax* (Enggist-Dueblin and Pfister 2002) are socially learned from conspecifics. Several species of corvids have demonstrated the ability to mimic human speech when hand-raised and kept in close proximity to humans (Bluff et al., 2010). Mimicry of predator calls has been documented in several corvid species including Steller's jays (Hope 1980; Tippin 2017), Sri Lanka blue-magpies, *Urocissa ornata* (Ratnayake et al. 2010), Florida scrub-Jays, *Aphelocoma coerulescens* (Woolfenden and Fitzpatrick 2020), blue jays, *Cyanocitta cristata* (Hailman 1990), and Eurasian jays, *Garrulus glandarius* (Goodwin 1951). Tippin (2017) conducted an in-depth study of vocal

mimicry in Steller's jays, which found significant differences in age and sex between mimicking and non-mimicking individuals, where males were less likely to mimic compared to females, and the likelihood of an individual mimicking decreased with age.

Missing data presents a significant challenge in the study of animal behaviour, limiting our understanding of key phenomena (Garamszegi and Møller 2012; Nakagawa 2015). Factors such as habitat inaccessibility (Evans et al. 2018), species rarity (Roberts et al. 2016), human-centric biases in study design (Archer et al. 2014; Ellison et al. 2021; Bowler et al. 2025; Daw et al. 2025), and technological constraints (Hebblewhite and Haydon 2010) contribute to missingness. In evolutionary biology, missing data can skew our understanding of trait evolution, obscuring the selective pressures and socio-ecological contexts that drive behavioural adaptations. The problem of missing data can be addressed with more systematic data collection, e.g., planned missing data design (Noble and Nakagawa 2018), application of emerging technologies and statistical approaches, such as imputation procedures (Augustine et al. 2014), and a recognition that the absence of evidence is not evidence of absence in behavioural research.

The aim of the present study is to describe the occurrence of mimicry in corvids. We investigated the evidence for mimicry from primary, i.e. recordings on Xeno-canto, and secondary sources, i.e. published literature. Further, we investigate empirical support for mimicry in corvids to serve an interspecific or intraspecific function or whether evidence base hints more towards mimicry as an error during vocal learning. If vocal mimicry in corvids serves a function of interspecific communication, we expect smaller corvid species to mimic more, as they are more at risk of predation (Dierschke 2003). Further, if mimicry in corvids functions to avoid threats, we would expect them to mainly mimic birds of prey. If vocal mimicry serves intraspecific communication, such as sexual selection, we expect mimicry to mostly occur during the breeding season. We further investigate the relationship between size of the vocal repertoire and the occurrence of vocal mimicry, as we expect species with larger repertoires to mimic more. In addition to biological factors driving vocal mimicry in corvids, species differ significantly in terms of study effort (Wascher & Reynolds, 2025). We investigate how differences in recording effort affect the detection of mimicry in corvids and evaluate the likelihood of 'hidden' mimicry.

Methods

Data on vocal mimicry

The present study was approved by the School of Life Sciences departmental ethics panel at Anglia Ruskin University (ETH2223-3747). This is a desk-based study, and no animals have been used for the research. Data were compiled from a variety of primary (Xeno-canto) and secondary sources (Birds of the World and Handbook of the Birds of Europe the Middle East and North Africa). Scientific and common names were standardized using a combination of the IOC Bird list version 14.1. (Gill et al. 2024) and the 'Clements checklist' (Clements et al. 2024) and 128 species of corvids were included. A Xeno-canto advanced search was conducted between the 27th of April and the 1st of May 2023 (searches have been updated on the 22nd of June 2023 and 5th May 2024). The Xeno-canto search yielded a total of 19,566 audio recordings of corvid calls from 128 different species (mean±SD per species: 153 ± 360), belonging to 21 genera (mean±SD per genus: 889 ± 1,767). The number of recordings per species ranged from zero to 2,272 recordings. All recordings with mentions of 'mimicry', 'imitation' or 'production of heterospecific calls' in the comments or labels section were identified. For the purpose of this study, we defined vocal mimicry as the occurrence of any type of non-conspecific sound. We noted the duration of the recording, date, whether the recording was taken during the breeding season or not, latitude and longitude and type of sound mimicked. Recordings were then listened to by GW and CAFW, and if both observers agreed that they contained convincing evidence for production of mimicry, the type of sound was noted (*e.g.*, species mimicked) and the observation was considered as evidence of mimicry. A total of 447 recordings containing mimicry have been identified. For 297 recordings it was indicated that the vocalising bird was seen by the recorder, for 106 recordings the bird was not observed and for 44 recordings this information was unknown. Additionally, secondary literature was searched for additional reports, resulting in additional records of mimicry from 22 species (Cramp and Perrins 1994; Poole and Gill 2020). For each species, the number of entries in the corvids literature database (Droege and Töpfer 2016) plus one entry in Birds of the World (Poole & Gill, 2020) was used as an estimate of the volume of secondary literature available (range: 1-423 entries). For each piece of evidence of vocal mimicry, CAFW allocated a 'reliability score' of high, moderate or low. Sixty-five percent of recordings have been rated as 'high', 23% as 'moderate' and 12% as 'low' reliability.

For each of the 128 species, we recorded body mass (information available for 121 species), vocal repertoire (98 species), habitat (coastal, desert, forest, grassland, human modified, rock, shrubland, woodland; reported for 124 species) and trophic niche (frugivore, granivore, invertivore, omnivore; reported for 124 species).

Statistical analysis

Description of the dataset

All analyses were conducted in R version 4.3.1. (R Core Team 2019). We constructed a phylogenetic tree for the Corvidae family using data from the Open Tree of Life (OTL). The tree was retrieved from the Open Tree of Life database (OpenTreeOfLife et al. 2019) using the rotl R package (Michonneau et al. 2016). We employed Bayesian generalized linear mixed-effects models built with the MCMCglmm package (Hadfield 2010) to determine effects of body size, vocal repertoire size, habitat and trophic niche on vocal mimicry in corvids. Genus was included as a random factor and the OTL tree served as the foundational phylogeny for the MCMCglmm. We ran Markov chain Monte Carlo (MCMC) chains for 3,000,000 iterations, thinned by 2000, and employed a burn-in of 2,000,000. All main effects were given normal(0, 0.5) log-odds prior, with a normal(0, 1) log-odds intercept prior. Random effects by genus were given an inverse Wishart prior with V = 1 and nu = 10.

To investigate whether corvids mimicked birds of prey more often compared to other types of sound and whether more recordings occurred during the breeding season compared to the non-breeding season, we conducted Wilcoxon signed rank tests. Data and code of the present study are published as online supplementary materials (Supplementary File 2; supplementary File 3).

Estimating the occurrence of mimicry

In order to estimate the occurrence of mimicry, we have developed a Bayesian model of evidence updating, assuming that for any specific kind of evidence (database entries, audio recordings), there is a corresponding rate ρ at which mimics are detected per-unit evidence. The model enables the calculation of the posterior probability a species in which no mimicry is detected is, in fact, a mimic. Full details of the model are presented in the supplementary materials.

Results

Description of the dataset

We recorded evidence of vocal mimicry in 32 species of *Corvidae*, belonging to twelve genera (25% of species; Figure 1). Twenty-two species of corvids are described as mimics in the literature and recordings from 18 species have been identified on xeno-canto, including nine species not previously described as mimics (Indochinese green-magpie, *Cissa hypoleuca;* pied crow, *Corvus albus;* hooded crow, *Corvus cornix;* carrion crow, *Corvus corone;* black-chested jay, *Cyanocorax affinis;* plush-crested jay, *Cyanocorax chrysops;* white-naped jay, *Cyanocorax cyanopogon;* Yucatan jay, *Cyanocorax yucatanicus;* clark's nutcracker*, Nucifraga Columbiana;* Table 1). One to 71 different types of sounds were mimicked (mean ± standard deviation: 5.687 ± 12.568). Sounds have been mimicked from a wide range or birds (Accipitriformes, Anseriformes, Charadriiformes, Cuculiformes, Falconiformes, Galliformes, Gaviiformes, Gruiformes, Pelecaniformes, Passeriformes, Piciformes, Strigiformes), mammals (Artiodactyla, Carnivora, Perissodactyla, Primates (human voice), Rodentia) amphibian (Anura) and insect species (Hemiptera) as well as anthropogenic sounds, such as bells, lawnmower, motorbike (see supplementary materials for full list of mimicked species). Corvids did not mimic predator sounds more often compared to sounds of non-predatory species (Wilcoxon signed-rank test: V=215, n=32, p=0.792). On xeno-canto mimicry more files containing mimicry were recorded outside of the breeding season compared to during the breeding season (Wilcoxon signed-rank test: V=16.5, n=18, p=0.002).

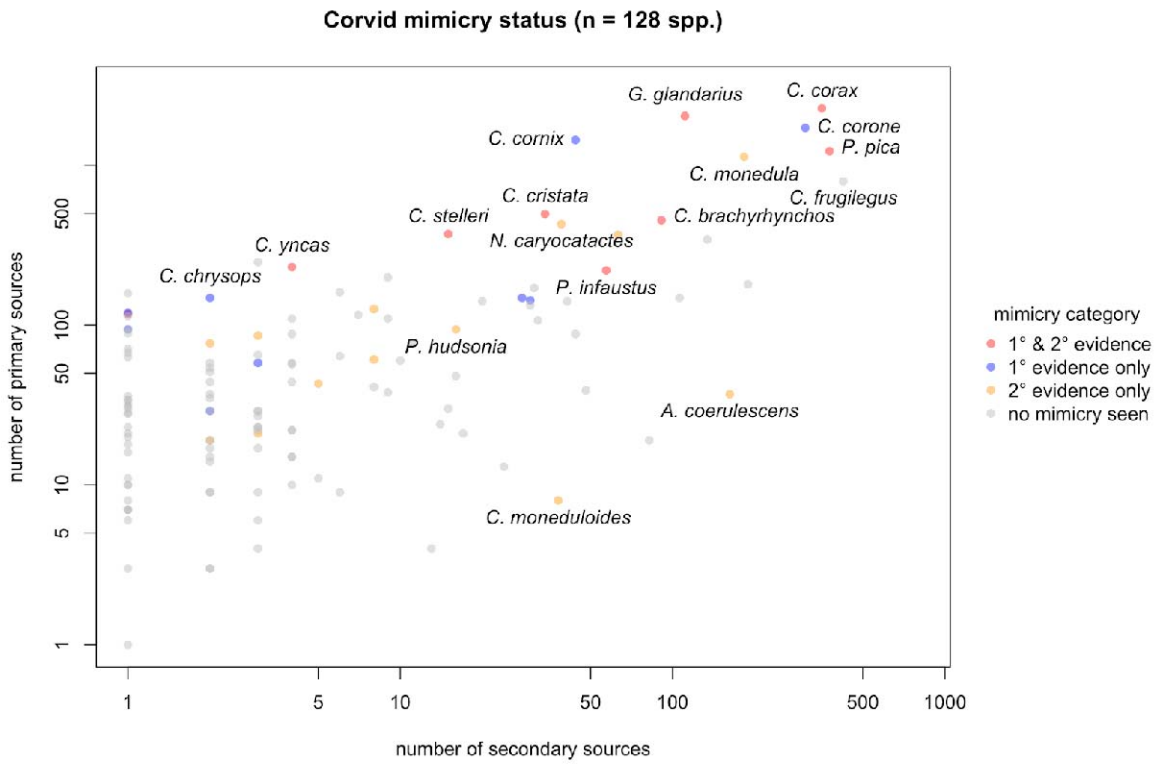

Figure 1: Vocal mimicry in 128 species of corvids. Grey points indicate species with no mimicry reported, red points indicate species with recordings of mimicry on xeno-canto and reported as mimics in the literature, blue points illustrate species with recordings of mimicry on xeno-canto but no records in the literature and yellow dots indicate species only reported as mimics in the literature but no recordings of mimicry are available on xeno-canto.

Table 1: Cross-table indicating the number of species detected as mimics in the literature (2°) and on xeno-canto (1°). Records per species indicate number of records in the covid literature database (2°) and xeno-canto (1°)

mimicry category	n.species	2° records per species	1° records per species
no mimicry seen	97	15	60
2° evidence only	13	40	192
1° evidence only	9	45	433
1° & 2° evidence	9	115	825

Body mass significantly affected the occurrence of mimicry, with smaller species being detected as mimics more compared to larger species (Table 2, Figure 2). Repertoire size, habitat, breeding system and trophic niche did not affect mimicry status (Table 2).

Table 2. Results of Markov chain Monte Carlo generalized linear mixed-effect model (MCMCglmm). Factors with significant effects ($p \leq 0.05$) are shown in bold.

parameters	post.mean	l-95% CI	u-95% CI	eff.samp	pMCMC
(intercept)	-0.109	-1.783	1.998	500	0.916
body mass	**-0.229**	**-0.541**	**-0.004**	**405.738**	**<0.002**
repertoire	0.237	-1.141	1.283	617.836	0.704
habitat breadth (generalist relative to hypergeneralist)	0.011	-1.179	1.54	598.69	1
habitat breadth (generalist relative to specialist)	-0.054	-1.279	1.443	500	0.908
breeding system (cooperative breeding relative to groups)	-0.013	-1.583	1.221	500	0.988
breeding system (cooperative breeding relative to territorial pairs)	-0.021	-1.322	1.274	500	0.968
trophic niche (frugivore relative to granivore)	0.024	-1.278	1.538	500	0.972
trophic niche (frugivore relative to invertivore)	-0.042	-1.535	1.214	500	0.928
trophic niche (frugivore relative to omnivore)	0.056	-1.228	1.502	500	0.94

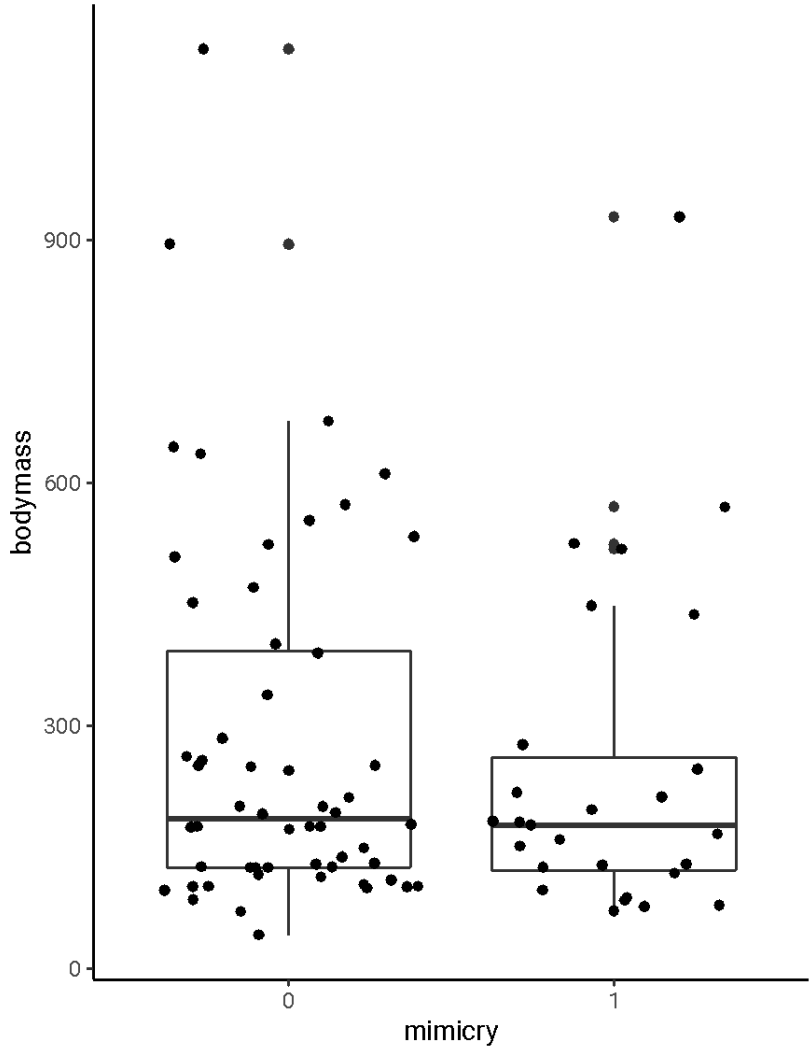

Figure 2: Body mass (g) in species with no mimicry detected (0) and mimicry detected (1)

Estimating the occurrence of mimicry

Parameter estimates for estimates of occurrence of mimicry from primary sources and secondary sources are presented in supplementary materials. Figure 3 shows how different information sources update the detection of occurrence of mimicry, both by increasing the average but also decreasing the posterior uncertainty about that average.

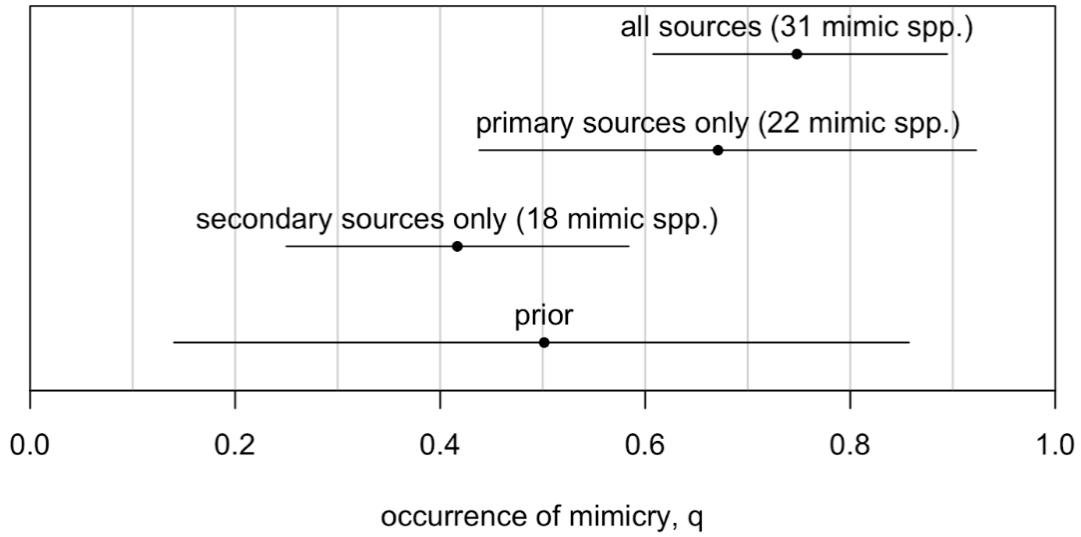

Figure 3: Prior and posterior estimates (means and 89% HPDI) of the frequency of occurrence of mimicry across corvid species conditioning on different information evidence (primary sources, secondary sources, and both combined).

Using this model, we can calculate a composite evidence score, in practice converting a count of recordings on xeno-canto into the equivalent number of corvid database entries (or vis versa), which is useful to understand how the hidden mimicry probabilities for each species relates to research attention (Figure 4).

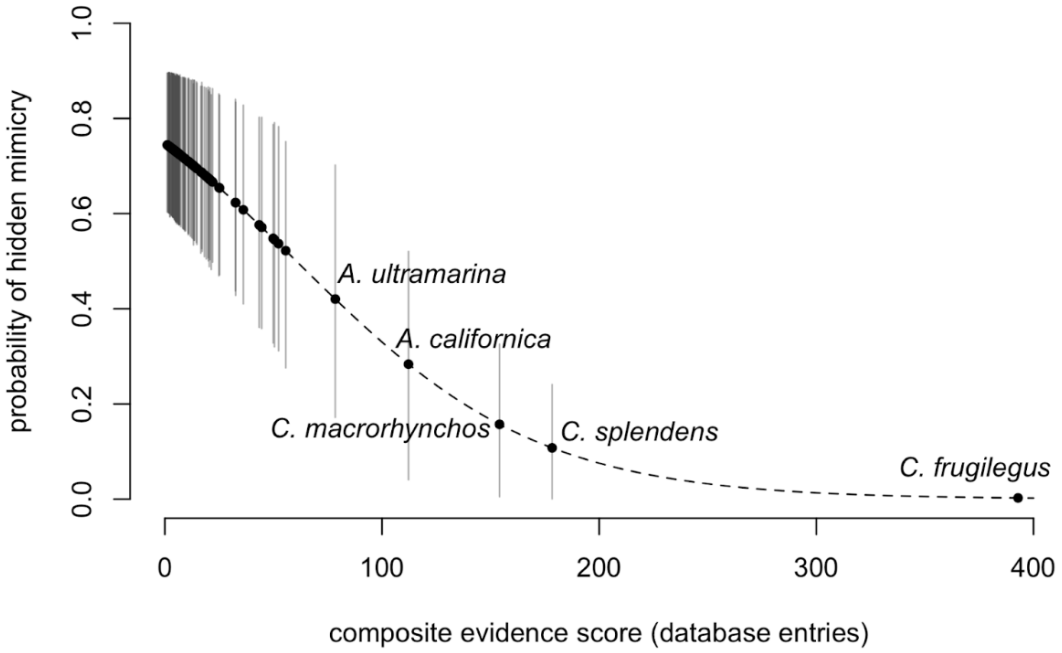

Figure 4: Composite evidence score related to the probability of hidden mimicry.

Looking at posterior probabilities of hidden mimicry for each species individually. The ten species which are predicted as least likely to be mimics and ten species nominated as most likely to be mimic are presented in the supplementary materials.

Discussion

In the present study, we describe vocal mimicry in 32 species of corvids belonging to twelve genera, showing that vocal mimicry is widespread across this family of birds. With 24% of corvids known to mimic, it is more prevalent in this group, as opposed to the 8.9% observed in the entire suborder of songbirds (Goller and Shizuka 2018). Additionally, because mimicry detection is strongly associated with the amount of research effort directed at any specific corvid species, there is reason to believe that the occurrence of vocal mimicry is starkly underestimated by the current empirical evidence and many species of corvids are likely to be 'hidden mimics', meaning they are undetected as mimics by the currently available literature and data.

Our study underscores the importance of crowd-sourced databases, such as xeno-canto, revealing potentially overlooked or underreported behaviours, such as vocal mimicry. We have identified nine species of corvids as mimics based on xeno-canto recordings, which have not previously been reported as mimics. Xeno-canto has previously been used scientifically to develop machine learning methods for automatic detection and classification (Ovaskainen et al. 2018), describing geographic variation (Deng et al. 2019), and interspecific variation (Benedetti et al. 2018). Our analysis also highlighted the utility of combining primary and secondary data sources in assessing the occurrence of mimicry. By using a Bayesian model to integrate these data, we were able to generate more robust estimates of mimicry occurrence across species, reducing uncertainty in our findings. The composite evidence score, which converts xeno-canto recordings into a standardized measure comparable to traditional literature-based records, provides a valuable tool for assessing the hidden probabilities of mimicry within under-studied species. This model also offers insights into how research attention and available data influence our understanding of mimicry, suggesting that species with more extensive documentation are more likely to be perceived as mimics, while those with less attention may still exhibit mimicry but remain underreported. These calculations are useful starting places for future fieldwork focusing on vocal mimicry and can already be subjected to an empirical test. White-necked Ravens (*Corvus albicollis*) are not described as mimics in either primary or secondary data sources used here, though based on only three entries in the corvid literature database and 57 Xeno-Canto recordings. Given this, the model predicts white-necked ravens to have a 71 % chance of being a hidden mimic, among the more likely candidates, and indeed vocal mimicry of human speech has been documented on social media (Bucalo 2015).

Another novel aspect the Bayesian modelling allowed us to do is performing several robustness checks to our interpretation of data. For example, supplying the empirical estimates and evidence distribution as a simulation input for 1,280 corvid species, which presents ten times the real number of species in

the group, the posterior estimates of occurrence of mimicry consistently approach the true value of each data sources (primary only, secondary only, primary and secondary). We have also scored the reliability of each report of vocal mimicry as high, moderate or low. Most recordings were rated as high reliability; however mimicry was only identified on a low number of low reliability recordings, hence increasing the likelihood of type I error. To check for sensitivity of false positives, we built models under the assumption that all low reliability records are false and another model that only high reliability records are true. Changes in the model did not substantially shift the estimate of occurrence, with still being above 70% in the most conservative false positive models. This means we can assume the evidence presented in the current study to be robust.

Corvids mimicked a wide range of different sounds, including calls from birds of prey or other non-predatory bird species, human speech, and mammalian vocalisations. The fact that corvids are capable of mimicking such a wide range of sounds further highlights their cognitive flexibility and auditory learning abilities. The type of sound mimicked can provide insights regarding potential functions of vocal mimicry (Gammon 2013). Interestingly, contrary to our expectations, we found no evidence that predator-related sounds were mimicked more often than non-predator sounds. This result contrasts with some studies in other avian species, where mimicry of predator calls has been hypothesized to serve as a defensive or deceptive strategy (Igic et al. 2015). On the other hand, we found smaller species more often to be identified as mimics compared to larger corvid species, with body size being linked to risk of predation, this could suggest that vocal mimicry could serve a 'deterrent', e.g. anti-predator and decrease competition, function in corvids. This is supported by anecdotal reports in the literature, for example Steller's jays mimicked hawk calls while being mobbed by hummingbirds, as reported in the notes on xeno-canto and green jays are reported to disperse a foraging group of plain chachalacas (*Ortalis vetula*), whereupon jay moved in to consume seeds being eaten by chachalaca (Gayou 2020) and in Canada jays most sounds mimicked are known or potential predators of adults or nests, hence mimicking predators is assumed to serve as a warning call to other group members, to confuse the predator itself, or merely to signal in a general way that a threat is present (Strickland and Ouellet 2020). Blue jays, *Cyanocitta cristata,* have been observed to mimic several species of birds of prey and other bird species, in order to make other species to leave food sources, *e.g.*, feeder and therefore reduce competition (Hailman 2009). This suggests vocal mimicry in corvids to have an adaptive evolutionary function and heterospecific sounds might not, as previously suggested, be learned by mistake (Kelley et al. 2008), however in order to investigate functional contexts of vocal mimicry behavioural observations of context or experimental tests on behavioural responses of receivers are necessary. An overabundance of mimicry of sounds from alarm and aggressive contexts has been also described for example in spotted bowerbirds, *Ptilonorhynchus maculatus* (Kelley and

Healy 2011). Fork-tailed drongos have been described to mimic in order to deceive heterospecific, for example to lead pied babblers, *Turdoides bicolor,* and meerkats, *Suricata suricatta,* away from food sources in order to steal the food (Flower et al. 2014). Mimicry by female birds has been observed to deter nest predators and protect eggs and nestlings (Igic et al., 2015).

Interestingly, there were more recordings of mimicry on Xeno-Canto recorded outside of the breeding season compared to the breeding season. Sexual selection has been proposed as one of the potential selective drivers of vocal mimicry, especially in birdsong, where mimicked vocalisations could provide an honest indicator of male quality (Dalziell et al. 2015). We did not find empirical support of this hypothesis, although we have to acknowledge that our categorization of breeding season was done per species and based on rough estimates, ignoring potential geographical variation between species. However, the fact that recordings of vocal mimicry existed year-round on Xeno-Canto is encouraging to support our claim that vocal mimicry is not sexually selected in corvids.

Vocal mimicry has previously been described to be driven by social factors. Parrots for example preferentially mimic socially relevant vocalisations (Bradbury and Balsby 2016) and budgerigars, *Melopsittacus undulatus,* converge contact calls from group members (Hile and Striedter 2000). Choughs*, Pyrrhocorax pyrrhocoraxc* and *Pyrrhocorax graculus*, have been shown to imitate calls of individuals they are closely socially bonded with (Sitasuwan and Thaler 1985). In our study, we showed that the social system (territoriality, family groups and cooperative breeders) does not seem to affect the occurrence of mimicry. This does not mean that social factors do not affect vocal mimicry in general. Corvids generally are a group of highly social birds (Wascher, 2018) forming strong social relationships within their groups (Fraser and Bugnyar 2010) and memorizing vocalisations of social partners for several years (Boeckle and Bugnyar 2012).

To summarize, our study contributed to a broader understanding of vocal mimicry. Vocal mimicry in birds has been described to have evolved several times in different families and independently of vocal learning (Goller and Shizuka 2018). A better understanding of the socio-ecological drivers of the behaviour offers valuable insights into the evolution of communication systems in birds and other animals. By investigating mimicry in corvids, we gain an opportunity to explore how complex vocal behaviours evolve, including vocal learning.

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