

VOCAL ACTIVITY PATTERNS IN THE CHIMANGO CARACARA DURING THE NESTLING-REARING PERIOD

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ABSTRACT: Vocal activity patterns in birds are shaped by both biotic and abiotic factors, resulting in seasonal variations that typically peak during the breeding season. During this period, vocalizations are driven by sexual selection and social interactions, such as territorial defense and parental provisioning. In this study, we evaluated: (1) the optimal confidence thresholds for identifying nestling and adult Chimango Caracara (*Daptrius chimango*) vocalizations using BirdNET to ensure high-probability detections; (2) the diel vocal activity patterns of both age groups during the rearing period; and (3) whether vocal activity shifts across different stages of nestling development. We deployed Autonomous Recording Units at 16 nests containing nestlings aged 1 to 30 days. BirdNET correctly identified nestling and adult vocalizations with 76% and 93% accuracy, respectively, confirming its reliability for age-group classification. Our results revealed a single daily peak in nestling vocal activity, whereas adults exhibited a bimodal pattern. Furthermore, younger nestlings showed increasing vocal activity throughout the day, while older nestlings displayed the opposite trend. Finally, adult vocal activity peaked during the mid-to-late stages of the nesting period. Our findings demonstrate that acoustic monitoring can effectively track developmental shifts and that Chimango Caracara vocal patterns are age-dependent during the rearing period.

KEYWORDS: *bioacoustics, ontogeny, passive monitoring, raptors*

Acoustic communication through vocal activity plays a key role in the social and reproductive behavior of many bird species. However, avian vocal activity is influenced by biotic and abiotic factors, such as sunlight hours, as well as intrinsic factors such as the stage of the breeding season and hormonal condition (Catchpole & Slater 2003, Pérez-Granados & Schuchmann 2022). For example, vocal activity patterns in birds vary significantly throughout the day and across seasons, typically reaching peak intensity during the breeding season (Pérez-Granados 2025, Mei et al. 2026). Vocalizations fulfill multiple functions during the breeding cycle, including mate attraction (Catchpole & Slater 2003, Liu & Kroodsma 2007), territorial defense (Liu & Kroodsma 2007), parent-offspring communication, coordination between pair members, and social interactions (Leonard & Horn

2001, Liu & Kroodsma 2007, Pérez-Granados et al. 2025).

While variation in adult vocal activity has been documented in several species, particularly during breeding periods, little is known about how vocal activity shifts once nestlings hatch. In contrast to adults, activity during early ontogeny is primarily shaped by intrinsic factors such as hunger levels or body condition (Kilner & Rufus 1997, Leonard & Horn 2001), rather than the exogenous drivers that dictate adult cycles. Consequently, quantitative information describing how vocal activity transitions across nestling development remains scarce.

Nestlings typically have short vocal repertoires composed of begging and distress calls (Kilner & Rufus 1997, Marchenko et al. 2018). Hence, begging calls

are the most commonly emitted vocalizations during early development, as nestling begging behavior must be strong enough to stimulate parental provisioning (Leonard & Horn 2001). However, this behavior involves a trade-off as nestlings grow, as intense vocal activity can increase predation risk (Ibañez-Álamo et al. 2012), while parental attendance at the nest tends to decrease with nestling age, leaving chicks unattended for longer periods (Cadiou & Monnat 2010). Despite the ecological importance of this vocal behavior for breeding season success, quantitative data on avian vocal activity patterns throughout development remain limited.

Vocal activity patterns have been documented in a limited number of raptor species, mostly in nocturnal raptors. Diurnal vocalizations of young Eagle Owls (*Bubo bubo*) have been successfully used to detect occupied nests (Penteriani et al. 2000), whereas studies on Barred Owls (*Strix varia*) and tropical owls have described temporal variation in vocal activity and its association with environmental conditions (Odom & Mennill 2010, Marin-Gómez et al. 2020). In contrast, studies addressing vocal activity patterns in diurnal raptors remain scarce, with only a few examples such as the Changeable Hawk-Eagle (*Nisaetus cirrhatus*) during the breeding season (Mah et al. 2023). Among other factors, this disparity may be largely due to the logistical challenges of conducting long-term audio recordings in this group of highly mobile and sparsely distributed bird species. To bridge this gap, Passive Acoustic Monitoring (PAM) has become an essential tool, effectively complementing field surveys and enabling continuous, long-term recordings without human intervention (Darras et al. 2019). This approach minimizes observer bias and reduces site disturbance (Darras et al. 2019, McLoughlin et al. 2019, Pérez-Granados & Schuchmann 2022). Since PAM, deployed via Autonomous Recording Units (ARUs), is a non-invasive method, it is particularly suited for studying vocal activity patterns. However, the large amount of data generated presents a significant processing challenge. To address this, recent studies have increasingly adopted automated acoustic recognition tools powered by machine learning, such as BirdNET (Kahl et al. 2021). BirdNET is a deep artificial neural network trained on several species' vocalizations, to date, the algorithm can detect over 6500 species (Pérez-Granados 2025). Several studies have tested its effectiveness, demonstrating high recognition rates, accurate focal species classification, and reliability in assessing the vocal activity patterns of wild bird species (Amorós-Ausina

et al. 2024, Pérez-Granados 2025, Mei et al. 2026, Singer et al. 2026).

The Chimango Caracara (*Daptrius chimango*) is a common diurnal raptor distributed from Peru to Argentina (Ferguson-Lees & Christie 2001). As an opportunistic and generalist raptor species, it is frequently found scavenging in both urban and rural environments across Argentina (Solaro & Sarasola 2023, Gallego-García et al. 2024). This species breeds colonially from October to January, typically laying two or three eggs in October. Following an incubation period of 26–32 days, the rearing period extends through December and January (Solaro & Sarasola 2015, 2023, Gallego-García et al. 2024). Despite its ecological abundance, its vocal behavior remains poorly understood; to date, only one study has formally described the species' repertoire, identifying nine distinct vocalizations that differ in their acoustic structure and occurrence frequency, with a single call type accounting for more than 50% of the recorded vocalizations (Solaro 2024). However, quantitative information on nestling and adult vocal activity patterns throughout the breeding period remains unavailable.

In this study, we aimed to: (1) determine the optimal confidence thresholds for identifying nestling and adult Chimango Caracara vocalizations using BirdNET, ensuring high-probability detections; (2) describe the daily vocal activity patterns of both age groups during the rearing period; and (3) evaluate whether vocal activity shifts across different stages of nestling development. We predict that vocal patterns will fluctuate throughout development and will be positively correlated with parental presence at the nest. Since parental attendance typically decreases as nestlings age (Gallego-García et al. 2024), we expect higher rates of attendance and provisioning to stimulate stronger vocal activity in young nestlings. Conversely, we expect that older nestlings will exhibit reduced vocal activity as an anti-predator strategy (Ibañez-Álamo et al. 2012) in the absence of constant parental protection. Similarly, we expect adult vocal activity around the nest to decline when nestlings reach around 30 days of age, reflecting the reduction in overall parental care.

METHODS

Study area

The study was conducted from October 2025 to January 2026 (austral spring and summer) in a breeding colony of Chimango Caracaras located at

La Cuesta del Sur (36°43'S, 64°16'W), which hosted more than 200 nests during the study period. This breeding colony is located on the outskirts of Santa Rosa, La Pampa Province, Argentina, and corresponds to a suburban environment characterized by houses interspersed with small grass patches and native vegetation such as Caldén (*Neltuma caldenia*), Molle (*Schinus fasciculatus*), and Chañar (*Geoffroea decorticans*), as well as some exotic plant species (Gallego-García et al. 2024). The study area lies within the ecotone between the Pampas and Espinal ecoregions, where during the austral summer sunrise occurs between 06:00 and 06:30 h and sunset between 20:15 and 20:45 h (Gallego-García et al. 2024).

Acoustic data collection

We recorded vocal activity patterns during the nestling-rearing period by installing automated acoustic recorders (Song Meter Micro 2; Wildlife Acoustics, Maynard, MA, USA) from the time the first nestling was detected on 10 November 2025 until the last nestling left the nest on 29 January 2026. We installed automated recorders at 16 nests separated by at least 60 m from other active Chimango Caracara nests, and positioned approximately 1 to 2 m from the focal nest. We recorded vocal activity in nests containing nestlings aged from 1 to 30 days old, which

encompasses the entire nestling development period (Solaro & Sarasola 2015, 2023, Gallego-García et al. 2024). The recorders were programmed to record in .wav format at a sampling rate of 44.1 kHz, 16-bit resolution in stereo, and 6 dB gain for the first 20 min of each hour from 05:00 to 21:00 h, across three consecutive days. This yielded a total of 867 audio recordings, totaling 17,340 recorded minutes.

Data classification

As part of an ongoing long-term vocal monitoring study within the Chimango Caracara colony, we previously identified, through active audio recordings, Chimango nestling begging calls at different developmental stages (unpublished data; examples in Fig. 1). Because vocalizations in this species remain poorly described, these recordings were used as reference material to distinguish nestling calls from adult vocalizations during acoustic analyses. In addition, previously published adult vocal descriptions (Solaro 2024) enabled the identification of adult vocalizations.

We randomly selected a subset of 200 audio recordings and generated spectrograms in Raven Pro 1.6 (version 1.6; K. Lisa Yang Center for Conservation Bioacoustics, Cornell Lab of Ornithology, Cornell University, Ithaca, NY, USA) using a Hann window, FFT

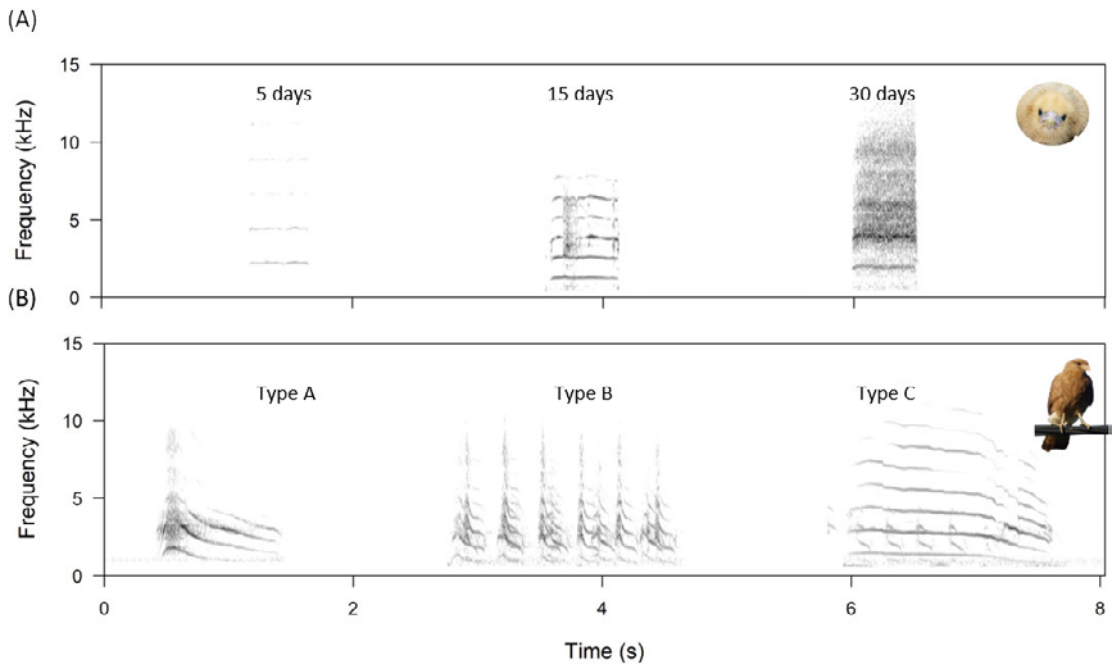


Figure 1. Spectrograms of (A) nestling begging calls at different developmental stages, and (B) adult calls of the Chimango Caracara (*Daptrius chimango*) recorded in the La Cuesta del Sur breeding colony during the 2025-2026 breeding season. The nestling photograph in panel A is courtesy of Angela Galarza, and the adult photograph in panel B is courtesy of Gallego García D.

= 512, overlap 50%, and 100% frame size. Using selection boxes, we labeled each vocalization as nestling or adult and extracted the start time, end time, maximum, and minimum frequencies. We also labeled and extracted data for other sounds such as background noise, insects, and dog barking. This process resulted in a dataset containing 7806 clips of acoustic data.

We then trained a BirdNET classification model using this dataset. The model was built through the 'Train' tab in the GUI interface of BirdNET-Analyzer (version 2.4.0; <https://github.com/kahst/BirdNET-Analyzer>). We selected our labeled dataset as training data and used Raven as the model output format. We ran BirdNET-Analyzer with the default parameters: epoch number = 50, batch size = 32, learning rate = 0.0001. After the training process, we analyzed all audio recordings using the GUI interface of BirdNET-Analyzer (version 2.4, <https://github.com/kahst/BirdNET-Analyzer>; Kahl et al. 2021). We used a confidence threshold of 0.1, a sensitivity parameter of 1.0, and a 2 s overlap. We increased the overlap parameter from the default value because preliminary tests showed that a 2 s overlap allowed BirdNET to detect a greater number of nestling calls. Previous studies have also suggested that increasing overlap can improve BirdNET performance at the vocalization level (Kahl et al. 2021, Fairbairn & Meyer 2025, Pérez-Granados et al. 2025, Thompson et al. 2025).

BirdNET performance

We evaluated the performance of BirdNET in detecting adult and nestling vocalizations of Chimango Caracaras separately. We assessed accuracy without applying any confidence threshold filtering; instead, accuracy was defined as the percentage of correctly identified predictions out of the total predictions reviewed (Knight et al. 2017, Amorós-Ausina et al. 2024). To validate the model outputs, we randomly selected a sample of 450 predictions for each category (adult and nestling) from the BirdNET-Analyzer output generated from the continuous recording data. The validation data were entirely separate and shared no overlapping audio files with the 200 recordings used for model training. This sample included 50 predictions from each 0.1 confidence score interval from 0 to 1 (Bota et al. 2023, Amorós-Ausina et al. 2024). For each prediction, a trained observer inspected and verified the presence or absence of the target sound in the audio spectrogram at the 3-s timestamp segment reported by BirdNET-Analyzer in Raven Pro 1.6 software. We estimated precision by dividing the number of correctly classified BirdNET predictions by the total number of

verified BirdNET predictions, reported as a percentage (Bota et al. 2023, Amorós-Ausina et al. 2024).

STATISTICAL ANALYSIS

BirdNET threshold

We used the 450 validated predictions obtained for each group to determine the confidence score threshold corresponding to a 95% probability of correct identification, following previous studies (Bota et al. 2023, Pérez-Granados 2025). This procedure enabled us to exclude predictions with low confidence scores (Bota et al. 2023, Pérez-Granados 2025). BirdNET confidence scores were back-transformed to their original logit scale following Kelly et al. (2023) and Pérez-Granados (2025) with the following formula:

Logit score = $\ln(\text{confidence score}/(1 - \text{confidence score}))$

We then fitted a logistic regression using the verified values of correct vs. incorrect identification as the response variable and the BirdNET logit-scale prediction score as the independent variable. To convert BirdNET scores into the probability of a given prediction suggested by the algorithm being correct, we used the formula applied in previous studies (Kelly et al. 2023, Pérez-Granados 2025):

$$\text{Threshold} = (\ln(p/(1 - p)) - \alpha)/\beta$$

In the formula, p represents the BirdNET score threshold corresponding to 95%, α is the intercept of the logistic regression, and β is the slope of the regression. The resulting score was used as a confidence threshold to consider BirdNET predictions as reliable identifications of nestlings and adults during the description of activity patterns. To ensure the statistical independence of vocalizations and avoid overcounting caused by the analysis of overlapping segments (overlap = 2 s), we treated detections of the same category (nestlings or adults) occurring within a 3-s window as a single detection. In these cases, we retained only the entry with the highest confidence score for further analysis.

Vocal activity patterns

We fitted Generalized Linear Mixed Models (GLMM) using the glmmTMB package (McGillcuddy et al. 2025) in R (R Core Team) to evaluate Chimango Caracara nestlings' vocal activity and the surrounding colonial adult activity during the nestling-rearing period. We used a Negative Binomial distribution (Type 2) to account for potential overdispersion in

the count data. We assessed model fit by inspecting residuals using the *DHARMA* package (Hartig 2024). We identified significant differences using Tukey's post-hoc tests via the *emmeans* package (Lenth & Piaskowski 2025).

To analyze the developmental patterns of vocal activity from day 1 to 30, we used the number of nestling vocalizations detected by BirdNET after filtering by our confidence threshold as the response variable. The model included six age categories (1–5, 6–10, 11–15, 16–20, 21–25, and 26–30 days) and Time of Day (treated as a categorical factor with four distinct levels: Dawn, Morning, Afternoon, and Dusk) as fixed effects, as well as the interaction between them to identify activity patterns during development. To account for variation in sampling effort, we included the log-transformed total effort (calculated as recording duration multiplied by the number of nestlings in the nest) as an offset. We included Nest ID as a random effect in the model.

We analyzed vocalizations as a proxy for parental attendance and localized activity levels near the focal nests. We fitted an additional GLMM using adult vocalization counts as the response variable to evaluate whether adult vocal activity changed with nestling age. The fixed effects were the Age Category of the focal nestlings and the Time of Day. In this model, the log-transformed recording duration was included as an offset. Nest ID was also included as a random effect.

RESULTS

BirdNET performance

BirdNET precision varied between adult and nestling vocalizations (Table 1). The lowest precision was observed for nestling calls, where 344 out of 450 verified predictions were correctly classified (76% precision, Table 1). In contrast, adult vocalizations showed the highest precision, with 418 out of 450 predictions correctly classified (93% precision, Table 1). The probability of correct classification increased with the confidence score of each prediction, resulting in higher precision at higher confidence values. In this context, the average BirdNET precision for both groups (nestling or adult) between confidence scores of 0.1 – 0.3 was 69% (134 Chimango Caracara vocalizations correctly classified out of 200 BirdNET predictions verified, Table 1). Precision increased to 79% for predictions with a confidence score between 0.3 – 0.5 (157 Chimango Caracara vocalizations correctly classified out of 200 BirdNET predictions verified, Table 1).

Logistic regressions showed that the minimum confidence score to consider detections with a 95% probability of correct identification was 0.838 for nestling vocalizations and 0.657 for adults (Fig. 2).

Vocal activity patterns

Vocal activity was described using detections after applying the confidence thresholds. Consequently, the dataset used to describe vocal activity patterns included 5773 vocalizations for nestlings and 9533 vocalizations for adults predicted by BirdNET (hereafter referred to as vocalizations). Daily vocal activity patterns differed between nestlings and adults (Fig. 3). Nestling vocalizations exhibited a homogeneous activity pattern with a single peak in activity during the central hours of the day, between 11:00 and 18:00 h (Fig. 3). In contrast, adult vocalizations exhibited a bimodal pattern, with the highest vocal activity occurring around sunrise at 6:00 h, followed by a decrease in vocal activity during the central hours between 11:00 and 18:00 h, and a second smaller peak of activity starting before sunset at 18:00 h (Fig. 3).

We did not find significant differences in nestling vocal activity across developmental stages ($X^2 = 3.614$, $df = 5$, $p = 0.606$). However, the interaction between developmental stages and hour of the day suggested differences in daily activity according to nestling age ($X^2 = 26.060$, $df = 15$, $p < 0.050$). Younger nestlings (1 to 15 days old) showed a progressive increase in vocal activity throughout the day, with the highest vocal activity near sunset and morning. In contrast, older nestlings (16 to 30 days old) showed a decrease in vocal activity throughout the day, with the highest vocal activity occurring around sunrise (Fig. 4). A parallel model treating nestling age as a continuous variable confirmed these identical daily patterns in the interaction ($X^2 = 13.250$, $p < 0.005$). In addition, a Generalized Additive Model (GAM) validation confirmed these trends.

On the other hand, despite the global effect of nestling age on adult vocal activity being significant ($X^2 = 20.255$, $df = 5$, $p = 0.001$), post-hoc comparisons revealed a peak in activity during the mid-to-late nestling stages. Compared to the early stage (days 1–5), adult activity was significantly higher when nestlings were 16–20 days old (Ratio = 4.487 ± 1.660 , $z = 4.050$, $p < 0.001$) and 21–25 days old (Ratio = 3.545 ± 1.240 , $z = 3.611$, $p < 0.005$). A similar significant trend was observed when nestlings were 26–30-days old (Ratio = 4.358 ± 2.180 , $z = 2.947$, $p < 0.050$). These specific comparisons (Fig. 5) indicate a marked increase in

Table 1. Number of BirdNET predictions correctly classified and precision for detecting adult and nestling Chimango Caracara (*Daptrius chimango*) vocalizations. Values are shown separately for each age group across the following confidence score intervals: 0.1-0.3; 0.3-0.5; >0.5; and for the entire range, 0.1-1. The total number of verified predictions is provided in brackets.

Group	Predictions	Confidence score interval classes			
		0.1-0.3	0.3-0.5	> 0.5	0.1-1
Adults	Correct	84 (100)	94 (100)	240 (250)	418 (450)
	Precision	84%	94%	96%	93%
Nestlings	Correct	54 (100)	63 (100)	227 (250)	344 (450)
	Precision	54%	63%	91%	76%

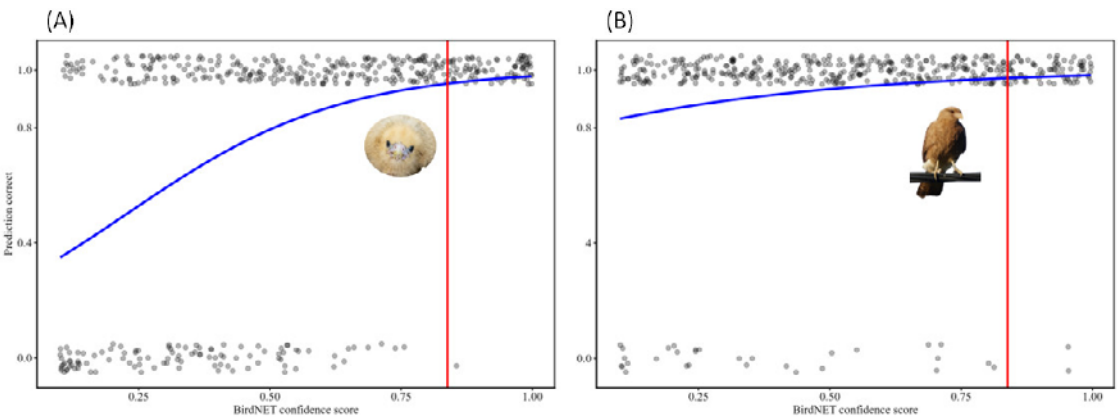


Figure 2. Relationship between the probability of correct identification by BirdNET and the confidence score of a given prediction for the Chimango Caracara (*Daptrius chimango*) for (A) nestlings and (B) adults, showing the logistic regression fit (blue line) and the optimal confidence score threshold identified for each group (red line). Statistical analyses were performed using the BirdNET logit-scale of the prediction score as the independent variable, but we represent the original confidence score of BirdNET for graphical purposes. The nestling photograph in panel A is courtesy of Angela Galarza, and the adult photograph in panel B is courtesy of Gallego García D.

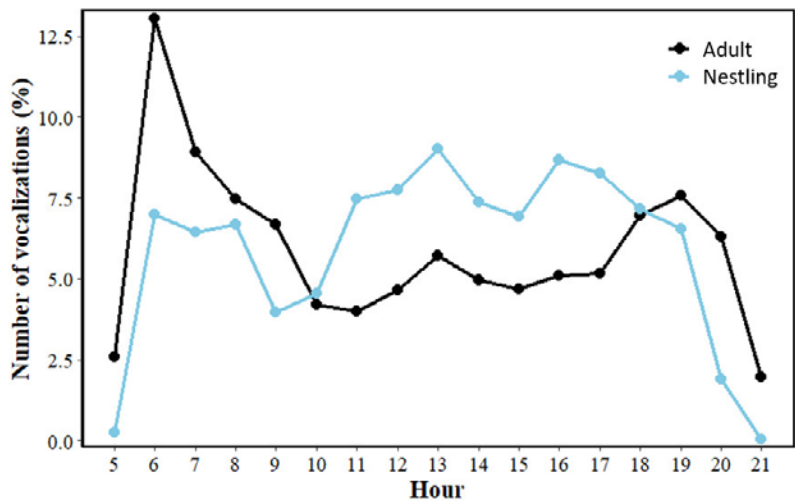


Figure 3. Daily vocal activity patterns of adult and nestling Chimango Caracaras (*Daptrius chimango*). Daily activity is expressed as the percentage of calls relative to the total number of calls detected per hour at 16 nests. Adult vocal activity was calculated as calls per recording duration, whereas nestling vocal activity was normalized by recording duration and the number of individuals present per nest. Adult activity is represented by the black line and nestling activity by the blue line.

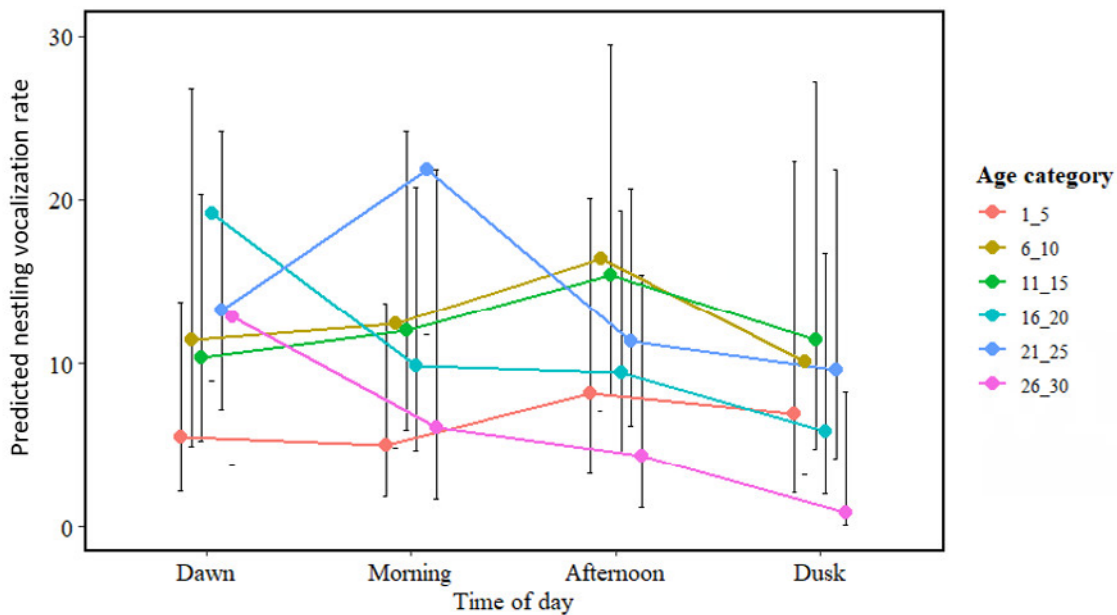


Figure 4. Predicted nestling vocal activity of the Chimango Caracara (*Daptrius chimango*) and the interaction between time of day and nestling developmental stages, categorized into five-day intervals (1–5 to 26–30 days). Each colored line represents a specific age group, with points indicating mean predicted values and vertical black whiskers representing 95% confidence intervals. Statistical analyses were performed using the BirdNET predictions as the dependent variable and age category and time of the day as independent variables.

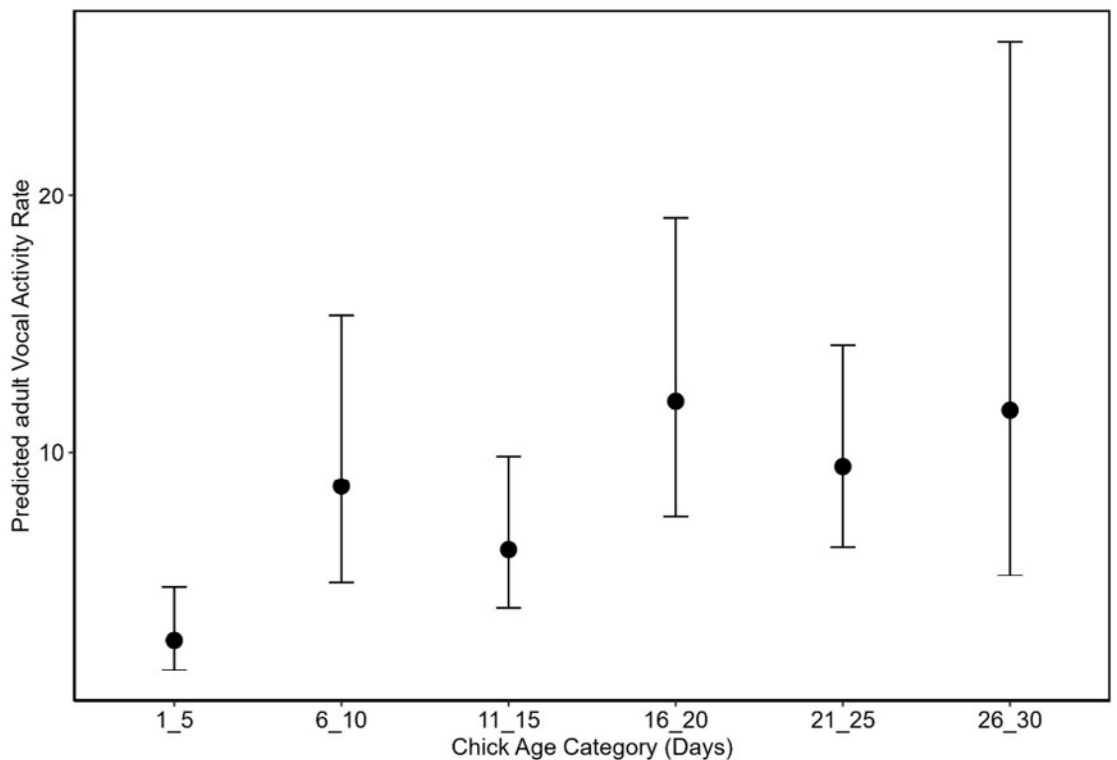


Figure 5. Predicted adult vocal activity of the Chimango Caracara (*Daptrius chimango*) across nestling developmental stages categorized into five-day intervals (1–5 to 26–30 days). The light grey circles represent observed data, the black circles represent the mean predicted values, while the vertical whiskers indicate the 95% confidence intervals. Statistical analyses were performed using BirdNET predictions as the dependent variable and age category and time of day as independent variables.

adult vocal activity during the mid-to-late nestling stages, with a substantial increase in parental effort, nearly quadrupling the initial rates in early stages. A parallel model treating nestling age as a continuous variable confirmed this significant increase in adult vocal activity across development ($X^2 = 7.111$, $p < 0.050$). Additionally, a GAM validation confirmed these trends.

DISCUSSION

This study provides one of the first quantitative descriptions of diel vocal activity patterns in both nestlings and adults of a raptor species during the breeding season. Using passive acoustic monitoring, we found that adult Chimango Caracaras exhibited a bimodal vocal activity pattern typical of diurnal birds, whereas nestlings called throughout the day with a pronounced peak around midday. Furthermore, the significant interaction effect indicates that the influence of nestling age on vocal activity is modulated by the time of day, with age-related changes appearing as a sharp decline in afternoon begging behavior. This suggests that while ontogenetic shifts do occur, they operate in tandem with short-term ecological factors, such as daily parental provisioning schedules and fluctuating hunger levels, to shape begging patterns.

Our results validate the efficacy of BirdNET for identifying the vocalizations of both nestling and adult Chimango Caracaras, provided that an optimized confidence threshold is applied. This aligns with previous research demonstrating that deep learning algorithms can successfully distinguish between different life stages, such as juvenile and adult, with high classification accuracy (Kelly et al. 2023). During preliminary testing, we observed that the begging calls of 15- and 30-day-old nestlings were frequently misidentified as those of the Great Kiskadee (*Pitangus sulphuratus*) and Monk Parakeet (*Myiopsitta monachus*), respectively, which are also common in the study area. However, this issue was largely mitigated by implementing a 2-s overlap in the analysis. Under these parameters, we recorded only 24 misclassifications out of 450 validated predictions, all of which occurred within a low confidence range (0.1–0.6). These findings suggest that fine-tuning specific detection parameters is essential for enhancing the algorithm's performance on species-specific vocal repertoires, as highlighted in recent studies (Fairbairn & Meyer 2025, Pérez-Granados et al. 2025). This also corroborates the high probability of correct identification we obtained after fitting the model for confidence scores above 0.8 for nestlings.

Adult Chimango Caracaras exhibited a bimodal pattern of vocal activity during the austral summer, particularly throughout the nestling-rearing period (November–January). Similar diel patterns have been documented in several bird species (Pérez-Granados & Schuchmann 2020, Amorós-Ausina et al. 2024). In that context, bimodal patterns of vocal activity are common in diurnal birds and frequently associated with daily light cycles, with peaks occurring near sunrise and sunset when environmental conditions favor acoustic communication and social interactions (Catchpole & Slater 2003, Gil & Llusia 2020). In contrast to adults, Chimango Caracara nestlings displayed a different vocal pattern, calling continuously throughout the day but with a pronounced peak during midday hours. Begging vocalizations in nestlings are closely related to hunger levels and parental provisioning rates, typically increasing when the interval between feeding events becomes longer (Kilner & Rufus 1997, Leonard & Horn 2001, Klenova 2015). Hence, the inverse pattern compared with adult vocal activity may be associated with periods of reduced parental attendance at the nest.

Interestingly, we did not detect differences in the overall vocal activity of nestlings across developmental stages, although clear diel variation was observed. Younger Chimango Caracara nestlings (≤ 15 days old) progressively reduced their vocal activity toward sunset, whereas older nestlings (≥ 16 days old) showed higher vocal activity during sunrise hours. This shift reflects changes in begging behavior associated with daily patterns of parental provisioning. In many bird species, nestling begging intensity reflects hunger levels and typically increases when feeding events are less frequent or predictable (Kilner & Rufus 1997). Accordingly, the elevated calling activity of older nestlings during early morning hours may be linked to increased parental activity and food delivery following nocturnal fasting. This pattern may reflect differences in how nestlings adjust their begging behavior to daily provisioning schedules during development, whereas parental attendance and provisioning are still relatively constant during early developmental stages (Leonard & Horn 2001). Similar diel patterns in nestling begging behavior have been reported in other bird species and are commonly associated with predictable daily rhythms in parental foraging and provisioning activity (Leonard & Horn 2001).

We also found that adult Chimango Caracara vocal activity increased when nestlings were aged between 15 and 30 days old. This result is noteworthy because previous studies on parental care in this species have

shown that direct parental attendance at the nest tends to decrease as nestlings grow older (Gallego-García et al. 2024). Our results suggest that although adults may reduce the time spent directly at the nest, they remain active and interact with the nestlings in the surrounding area. Such patterns have been observed in other raptor species, in which parental care gradually shifts from direct nest attendance to provisioning and monitoring from nearby perches as nestlings approach fledging (Sonerud et al. 2014).

Vocalizations produced by nestlings play a central role in parent–offspring communication, particularly as signals of hunger and condition that can influence parental provisioning decisions. Despite their importance, relatively few studies have quantified diel vocal activity patterns in nestlings. Using passive acoustic monitoring combined with automated sound recognition, our study provides new insights into the temporal dynamics of nestling vocal activity in the Chimango Caracara, revealing clear patterns of daily variation in calling behavior during the breeding season. These findings highlight the importance of diel behavioral dynamics in shaping vocal activity in developing birds and demonstrate the potential of acoustic monitoring approaches to investigate behavioral patterns that are otherwise difficult to observe continuously in the field, particularly in colonial raptors. Furthermore, this continuous acoustic monitoring approach can be leveraged to expand fine-scale behavioral knowledge by eliminating observer bias and providing uninterrupted information on how vocal behavior shifts across different seasons, developmental life stages, and fluctuating ecological contexts. Future research in this species should also focus on providing a detailed quantitative description of vocal ontogeny in Chimango Caracara nestlings, as well as conducting experimental trials to determine whether parents can recognize individual nestling calls within the colonial environment.

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USE OF ARTIFICIAL INTELLIGENCE

We used artificial intelligence for language review and editing.

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