Preliminary analysis of acoustic detection of the Red-throated Caracara in northern Costa Rica

Análisis preliminar de detección acústica del Caracara Avispero en el norte de Costa Rica

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Keywords

Birds; acoustic detection; machine learning; passive acoustic monitoring; sound.

Abstract

The noisy Red-Throated Caracara (*Ibycter americanus*) is a species whose population has inexplicably declined across much of its range and is now rare in the Pacific and Caribbean slopes of Costa Rica. Advances in automatic acoustic detection have transformed bird ecology, allowing researchers to analyze bird populations using pattern matching algorithms, machine learning, and random forest models. Although these studies are limited in the country, it represents an area with great interdisciplinary potential for technological advances. This study focused on the use of Pattern Matching to detect the presence of the Red-Throated Caracara in northern Costa Rica using a large number of sound recordings and its validation with metrics such as Accuracy, Precision Negative predictive value, Sensitivity, Specificity and Unweighted average recall. The results showed a moderate performance of the model by obtaining accuracy and precision values of 0.71 compared to the values obtained in other investigations in which the reported model was used. Therefore, we suggest exploring new techniques and methods to improve the detection of the species, considering the particular acoustic structure, the repertoire of sounds of the species and similarities with vocalizations of other species. This similarity could indicate a supposed anti-predator defense behavior by “imitating” the sounds of other species with which it shares habitat. To optimize this acoustic detection, we recommend using complementary techniques such as noise filters that improve the quality and precision of the data.

Palabras clave

Aves; detección acústica; aprendizaje automático; monitoreo acústico pasivo; sonido.

Resumen

El ruidoso Caracara de Garganta Roja (*Ibycter americanus*) es una especie cuya población ha disminuido inexplicablemente a lo largo de su área de distribución y es ahora rara en ambas vertientes de Costa Rica. Los avances en la detección acústica automática han transformado la ecología de las aves, permitiendo a los investigadores analizar poblaciones de aves utilizando algoritmos de coincidencia de patrones, aprendizaje automático y modelos forestales aleatorios. Aunque estos estudios son limitados en el país, representan un área con gran potencial interdisciplinario para avances tecnológicos. Este estudio se centró en el uso de algoritmos de coincidencia de patrones para detectar la presencia del Caracara avispero en el norte de Costa Rica utilizando una gran cantidad de grabaciones sonoras y su validación con métricas como Exactitud, Precisión, Valor predictivo negativo, Sensibilidad, Especificidad y Recall medio no ponderado. Los resultados mostraron un desempeño moderado del modelo al obtener valores de exactitud y precisión de 0.71 en comparación con los valores obtenidos en otras investigaciones en las que se utilizó el modelo reportado. Por ello sugerimos explorar nuevas técnicas y métodos para mejorar la detección de la especie, considerando la particular estructura acústica, el repertorio de sonidos de la especie y similitudes con vocalizaciones de otras especies. Esta similitud podría indicar un supuesto comportamiento de defensa anti-depredador al “imitar” los sonidos de otras especies con las que comparte el hábitat. Para optimizar esta detección acústica recomendamos hacer uso de técnicas complementarias como los filtros de ruido que mejoren la calidad y precisión de los datos.

Introduction

The lowlands of the Caribbean slope of northern Costa Rica constitute one of the priority hotspots for biodiversity conservation in Mesoamerica. Nevertheless, the landscape has undergone a process of strong fragmentation that threatens its connectivity between protected areas in Costa Rica and southeastern Nicaragua [1] which impacts species with particular conservation status in these habitats [2].

Red-Throated Caracara (*Ibycter americanus*) is a noisy and widespread forest caracara. Pairs and family groups are very vocal, and their calls often can be heard from great distances in lowlands and lower mountain areas from southern Mexico to southern Brazil [3].

The species is a highly territorial cooperative breeder and groups often stay together for many years. In Costa Rica, formerly widespread and common in the forests but its population has inexplicably disappeared from most of this range, although in recent years its population apparently increase again in northeastern Costa Rica and Osa Peninsula [4].

Important advances in the field of bird ecology have been made possible by techniques such as automatic acoustic detection to understand many aspects of bird populations and their ecosystems through sound. These techniques not only improve scientific understanding of bird communities, but also hold great promise for biodiversity conservation [5].

Methods such as Pattern Matching Algorithms, Machine Learning, Random Forest Models (RFM), Hidden Markov Models, Support Vector Machines, Mel-Frequency Cepstral Coefficients, and Convolutional Recurrent Neural Networks are leading the field of automatic bird acoustic detection [7, 8].

In Costa Rica some studies of automated acoustic detection of birds have been developed, [9, 10]. In this study, we used a Pattern Matching method to label the presence of the Red-throated Caracara in northern of Costa Rica through a preliminary analysis of the acoustic detection for recommendations of future research and analysis.

Methodology

Data Collection

The study site is located in the Monterrey district of San Carlos, Costa Rica (10.642271° N, -84.664404° O). A farm of approximately 250 hectares used as a cattle ranch for beef. The area has irregular topography with pastures that are surrounded by fragmented patches of tropical lowland rainforest, with high precipitation, humidity and temperatures that average 30 degrees Celsius throughout the year.

The acoustic soundscape was monitored using four Wildlife Acoustic Micro recorders, placed in strategic sites where the species was previously observed. A total of 221,016 recordings of one minute were uploaded in ARBIMON platform.

Data Analysis

Then we used a sample of 64,736 recordings and the pattern of one vocalization of the caracara to run a Pattern Matching feature with 0.1 threshold value and one match per recording to assist the validation process. The sound selected to this study presents a Bandwidth of 6533 Hz, and its length is about 0.53 s (Figure 1).

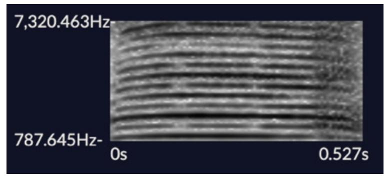

Figure 1. Training set pattern of the sound of Red-throated Caracara.

We used the output of the Pattern Matching to check and mark the presence (30 tags) and absence (40 tags) of the Caracara. We used 70/30 ratio for training and validation data. The presence or absence in the validations are contrasted with the ROI used in the Pattern Matching function (template of the sound of interest) to validate the detections in the platform (True Positive or *TP*, True Negative or *TN*, False Positive *FP* and False Negative *FN*).

To perform model validation, we used a confusion matrix that describes the performance of the binary classifier (presence or absence of the species). Taking as reference the research of Vargas-Masís and collaborators [9, 10] we calculated the same metrics to validate the model (the formula for each metric is described in reference papers) using Accuracy (*Ac*), Precision (*Pr*), Negative predictive value (*Npv*), Sensitivity or recall (*Se*), Specificity (*Sp*), F_1Score measure as 2*(precision*recall)/(precision+recall), Area Under the Curve (AUC) and Unweighted average recall (*UAR*).

Results

Model performance

The confusion matrix for the test dataset based on validations of the RFM shows for that TP (5) was higher than FP (2) and FN (4) was lower than TN (10). This means that the classifier correctly predicts the presence in a higher number of true positives and true negative records compared with the false positives and false negatives in the evaluated models.

Table 1. *Accuracy (Ac), Precision (Pr), Negative predictive value (Npv), Sensitivity (Se), Specificity (Sp),* F_1*Score Area Under the Curve (AUC) and Unweighted average recall (UAR) of Red-Throated Caracara in northern of Costa Rica.*

Metrics	Ac	Pr	Npv	Se	Sp	F_1Score	AUC	AUR
Caracara	0.71	0.71	0.71	0.56	0.83	0.63	0.87	0.69

Table 1 shows the results of the confusion matrix that will subsequently allow measuring the performance of the RFM. For the proposed model, the ratio of TP and FP, as well as FN and TN agree with a classifier that will correctly predict the presence in a larger number of true positives and true negatives of a larger dataset considering the selected acoustic pattern.

In the case of this model (Table I), the *Ac* was lower than the *Pr* and in this case it will correctly predict about 71% of the data for the species. An *Npv* of 71% indicates that the test has a moderate ability to rule out the identification of the acoustic pattern in negative cases. It is not a high *Npv*, however, it is still useful for acoustic pattern identification.

In addition, *Se* shows low ability of the model to find positive cases with only 56% of True Positives. For the *Sp* indicator it shows a high ability of the model to predict true negatives in 83% of the cases. *F1score* combines accuracy and sensitivity into a single value, and the result (63%) shows moderate model performance.

Finally, *AUC* presents a value between 0.80-0.90 which is considered good for discriminating in the model between positive and negative classes. But in the case of *UAR*, it was obtained that 69% of the classification model performs moderately well in terms of its ability to recognize the acoustic pattern of the species in a dataset with unbalanced classes.

Conclusions

In general, a moderate performance was obtained in terms of its ability to recognize the acoustic pattern of the species in the analyzed data set, it is important to study the technical factors of this vocalization that could affect its detection.

This sound is composed of a large number of harmonics that in addition to its intensity (dB) and frequency bandwidth (Hz) resembles to a great extent the sounds of other common species of the Psittacidae family (macaws, parrots, and parakeets). This similarity could indicate a hypothesized anti-predator defense behavior by “mimicking” the sounds of predators or prey in order to go unnoticed in the environment [11].

Based on the performance indicators of the model, we recommend studying other techniques that may benefit the detection of Caracara. Mel-Frequency Cepstral Coefficients (MFCCs) has presents benefits in detecting complex sounds such as the human voice and bird sounds [12] with a large number of harmonics.

Although when compared to recent studies, differences in model performance metrics are found, studies such as Sun and collaborator show similar values that can be improved by increasing the amount of data available using a convolutional neural network model [13].

In future projects it is important to consider a combination of techniques or through an ensemble approach [8] that integrate the entire repertoire of sounds of *I. americanus* to better characterize the acoustic activity of the species [14]. It is even necessary to consider the use of different detection techniques to take into consideration the acoustic structure which, although it makes the work more complex, could benefit its detection.

For bioacoustic data we recommend using typical ratios (70-30 or 80-20 in training-validation) depending on the amount of data available because this provides sufficient data to effectively train the model, validate its performance, and assess its generalizability on unvalidated data [15]. It is necessary to apply noise filtering techniques that can improve the detection process in recordings that have a greater number of environmental interactions (wind, rain, insects) that can interfere in the correct detection [16].

Through this acoustic monitoring it has been possible to determine the use that these individuals make of the site during this monitoring, which is key to better understand their behaviors, habitat preferences and resource needs, interaction with other species and thus better understand the dynamics among these populations.

The challenge of this project is to determine where and when *I. americanus* moves to and from given the area’s need for resources. Obtaining more data on its distribution, time spent in the area and vocalization periods will help to create proposals for habitat management of the forest matrix that this species needs for its activities.

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