

Acoustic detection of Red-capped Manakin (*Ceratopipra mentalis*) in Sarapiquí, Costa Rica.

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Abstract—Most of the vast biodiversity of the Caribbean foothills of Costa Rica is poorly studied. Passive acoustic monitoring is useful for collecting large datasets of wildlife and apply them for conservation initiatives, but handling these large datasets can be impractical if automated detection algorithms are not applied to reduce labeling time. The use of Pattern Machine (PM) and Random Forest Models (RFM) helps to identify single species through a dataset, simplifying the work. We sampled a private reserve in the Caribbean foothills of Costa Rica with 10 Audiomoth recorders. We used PM and RFM to label the presence of the Red-capped Manakin (*Ceratopipra mentalis*) in the recordings based on a portion of its distinctive vocalization. The RFM scored 0.86 of accuracy and 0.82 of precision to detect the species within the recordings. Three sites showed the highest number of detections. The acoustic activity of the bird got three different peaks during the day. The peak of detections took place in March. Based on the results, we recommended several conservation actions to the reserve on how to reduce the impact of tourism in the trails and how to rehabilitate the landscape with assistance of the bird and its activity as seed disperser.

Index Terms—Manakin, acoustic detection, random forest, pattern machine, conservation

I. INTRODUCTION

The Caribbean foothill of Costa Rica has a high diversity given its climate, geographic conditions and extensive relicts of mature forest [1]. Due to its irregular topography, much of the natural history of the species that occupy these ecosystems is unknown [2].

The Red-capped Manakin (*Ceratopipra mentalis*) is a small frugivorous bird of the humid evergreen forest and tall second growth with a large range from southeast Mexico to northwest Ecuador [3].

Despite its Least Concern population status [4], it is of particular importance in conservation of the tropical rainforest for its role in dispersing seeds of Flacourtiaceae, Lacistemataceae and Melastomataceae plants throughout the landscape it occupies [5], [6].

C. mentalis presents several vocalizations during mating leks with a song characterized by two or three introductory notes followed by a high and thin bell-shaped, sometimes concluded with an explosive note [7].

Acoustic detection is an important tool for monitoring bird populations in the tropics [8] because this group produce distinguishable vocalizations that are useful in acoustic monitoring initiatives [9].

The most recently used methods for the acoustic detection of birds are Convolutional neural networks (CNN) [10], dense and deep CNN [11], Convolutional recurrent neural networks [12], Hidden Markov Models, Gaussian Mixture Models and Support Vector Machines [13].

Passive acoustic monitoring produce large data sets useful for acoustic recognition projects where Pattern Machine (PM) and Random Forest Model (RFM) are the two of the most commonly used classifier next to Support Vector Machine, Tree-based classifiers and Template based classification among others algorithms [14].

Information on the ecology of frugivorous birds in the tropics is of critical importance for conservation efforts in these areas [15]. Knowledge about feeding, altitudinal movements, vocalizations, breeding periods, and interactions with other species provide important data for these conservation processes [16].

In this study, we used a Pattern Machine method to label the presence of the bell-shaped note of the Red-capped Manakin to build a Random Forest Model in the Arbimon Platform to detect the species note in hundreds of recordings in a reasonable time and use the results for recommendations directed to tourism and research aspects in the reserve.

II. METHODOLOGY

A. Data Collection

The sampling sites were located in Las Arrieras Nature Reserve in Sarapiquí, Heredia, Costa Rica ($10^{\circ}18'44''\text{N}$, $85^{\circ}2'30''\text{W}$), in the Caribbean foothills of the Central Volcanic Range. The variety of life zones and its geographic location allow the establishment of an exceptional biological richness.

On the site it is possible to find species such as the Great Green Macaw (*Ara ambiguus*), the Ocellated Antbird (*Phaenostictus mcleannani*), the Cerulean Warbler (*Setophaga cerulea*) and the Red-fronted Parrotlet (*Touit costaricensis*) that have important conservation level due to their reduced and threatened populations [17].

The acoustic soundscape was remotely monitored using Audiomoth recorders, where seven recorders were located in the underwood (at 2 meters high) and three in the canopy (at 10 meters high) (Fig.1).

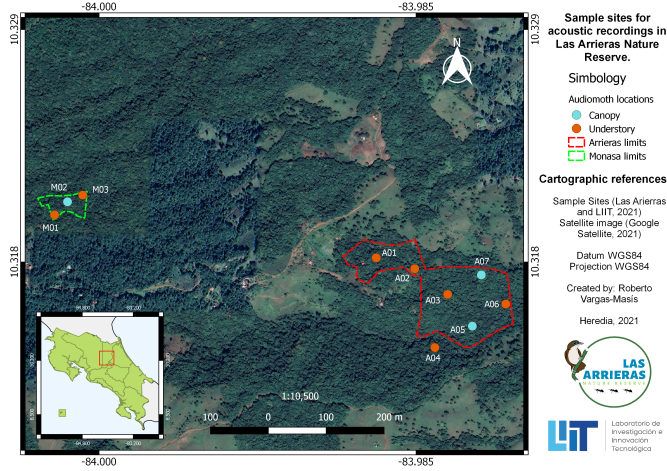


Fig. 1. Sample sites for acoustic recordings in Las Arrieras Nature Reserve.

The recordings were made in digital wav format, using a sampling rate of 48 kHz and 16-bit resolution. One-minute recordings were made at ten-minute intervals at each site from december 2020 to may 2021. We uploaded 108,626 recordings at the ARBIMON platform (<https://arbimon.rfcx.org/>) [18].

B. Data Processing

We used a template sound collected at Las Arrieras Nature Reserve from the ARBIMON Visualizer feature that only considered the bell-shaped note for this analysis. That note varied between 3.96 to 6.58 kHz (Bandwidth = 2.62 kHz) with 1.69 seconds of duration (Fig. 2).

Even though numerous pattern recognition methods have been used to detect the presence or absence of bird song notes in recordings we choose the binary classification RFM feature of ARBIMON considering its improved analysis efficiency in passive acoustic monitoring [19].

The ARBIMON Pattern Matching feature was configured in a playlist of 63,585 recordings between 5:00 to 18:00 with 0.1

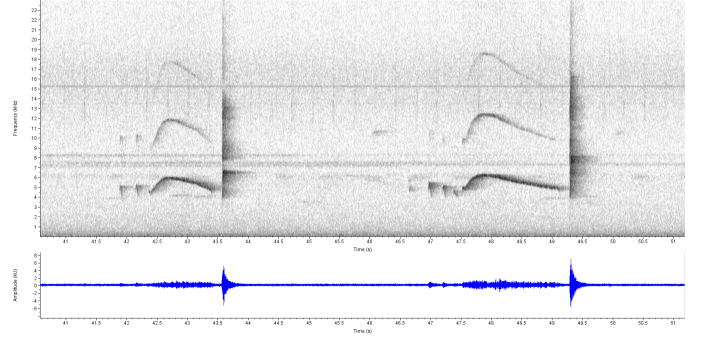


Fig. 2. Complete song of *Ceratopirra mentalis* in Las Arrieras Nature Reserve.

threshold value and a maximum of five matches per recording as parameters. This tools creates multiple Regions of Interest (ROI) to assist in the validation process (Fig. 3).

Each ROI was created using the template and detecting the signals with a correlation equal to or greater than a threshold assigned previously and then computed in the spectrogram (time-frequency) domain [20].

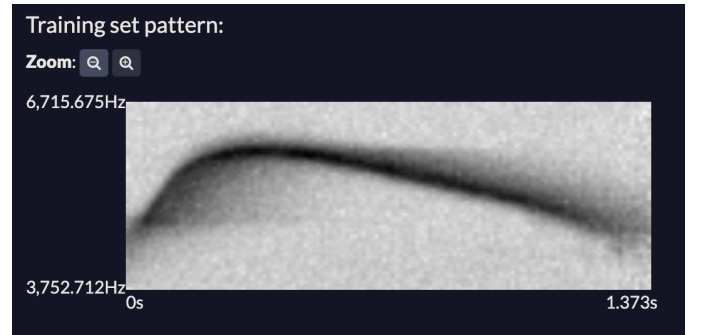


Fig. 3. Training set pattern of the note of *Ceratopirra mentalis* created in ARBIMON from ROI in the validation process.

Subsequently, we validated 347 recordings where the species note was present (True Positive or *TP*) and 347 recordings where it was absent (True Negative or *TN*) using the ROI created by the Pattern Matching feature.

These validations are determined by matching with the present or absent checkbox in the visualizer created for validate the detections on the platform. Then we create ROI in the Training Set feature necessary to run the Random Forest Model.

The model creates a vector with 12 acoustic statistical features (mean, median, minimum, maximum, standard deviation, maximum–minimum, skewness, kurtosis, hyper-skewness, hyper-kurtosis, Histogram and Cumulative frequency histogram) to train the random forest model, which will be used to detect the species note [21].

C. Data Analysis

In the ARBIMON Random Forest Model feature, the 347 *TP* and 347 *TN* recordings were set 100 for fitting the model

and 247 for verification of the model.

The performance of the model was quantified by several metrics provided by the platform like the Accuracy, Precision and a Confusion Matrix following recommendations of Rainforest Connection Support Team [22].

Accuracy indicates overall how often the classifier is correct where $TP + TN + FP + FN = \text{total no. of validated recordings}$.

$$Accuracy = \frac{(TP + TN)}{(TP + TN + FP + FN)} \quad (1)$$

Precision indicates how often the classifier is correct when it predicts that the species is present where $TP + FP = \text{is the predicted species presence}$.

$$Precision = \frac{(TP)}{(TP + FP)} \quad (2)$$

The confusion matrix provides a model validation statistic describe the performance of the binary Classifier (i.e. species presence or absence). Each column of the matrix represents the number of cases or values in a predicted class, while each row represents the values in an actual class.

III. RESULTS

The final performance evaluation metrics on the test set for the RFM are shown in Table 2. The model accuracy score (0.86) was higher than the precision score (0.82) which means that the model in the 86% of validated recordings was correct and in 82% the model predicted correctly the presence of the species.

According to validations in the performance of RFM, the TP (228) was higher than the FP (50) and the FN (19) was lower than TN (Table 2). This means that the classifier predicts the presence correctly in higher number for true positives and true negative records and showed a lower number of records for false positives and false negatives cases.

TABLE I
VALIDATIONS OF THE PERFORMANCE OF RFM FOR DETECTION OF RED-CAPPED MANAKIN BELL-SHAPED NOTE.

Species	Predicted	
	Present	Absent
Present	228 (TP)	19 (FN)
Absent	50 (FP)	197 (TN)

The RFM execution time was approximately 11 hours. The analysis classify 58,310 recording as absent (91.7%), 5,017 as present (7.9%) and 258 was skipped (0.4%).

We use the classifications to describe the number of detections on each recording site. One objective is to provide information about the distribution and ecology of the species in the Las Arrieras Nature Reserve.

We found a higher number of detections in Arrieras 03, Arrieras 07, and Monasa 01. These sites were previously known to contain active leks of the Red-capped Manakin. The lowest number of detections was found in Arrieras 02, Arrieras

04, Arrieras 05 and Monasa 02. The sites Arrieras 05, Arrieras 07 and Monasa 02 correspond to Audiomoth recorders placed in the forest canopy (Figure 3).

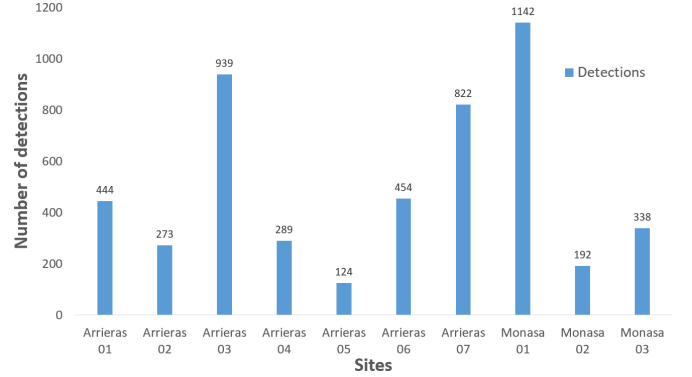


Fig. 4. Detections of *Ceratopira mentalis* by site in Las Arrieras Nature Reserve.

Another important aspect of species ecology is peak acoustic activity. Figure 5 shows an increase in activity from 5 am with a maximum between 6 to 7 am. Subsequently there is a decrease in activity (lower than the previous one), to return between 11 am to 3 pm. Finally, a small increase in activity is observed between 4 pm to 6 pm approximately.

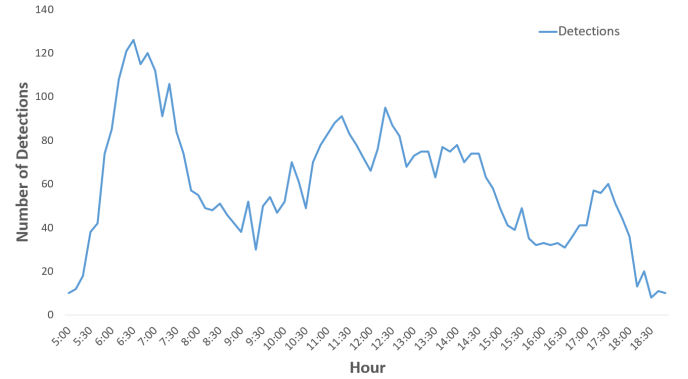


Fig. 5. Detections of *Ceratopira mentalis* by hour in Las Arrieras Nature Reserve.

Subsequently, the detections during the study between November 2020 and May 2021 were analyzed. A significant increase in the number of detections was found starting in January with a peak of detections in March 2021. A decrease in detections was found from April to May 2021 (Figure 4).

The RFM found a total of 27 records of the species' vocalizations in November, 40 in December, 89 in January, 166 in February, 325 in March, 269 in April and 72 in May.

IV. DISCUSSION

RFM have been widely used for bird acoustic detection studies and allows to refine detections based on methods such as PM by discarding many of the false positives [23]

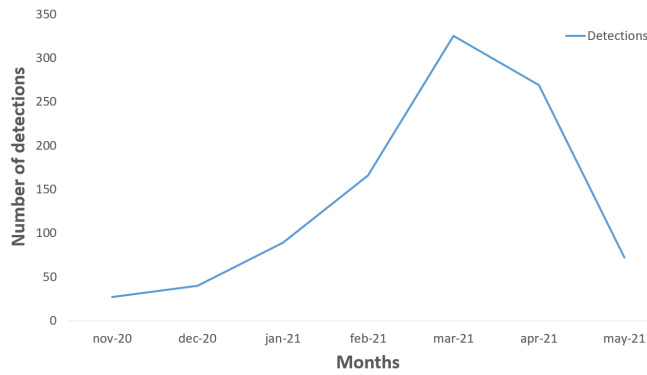


Fig. 6. Detections of *Ceratopira mentalis* by month in Las Arrieras Nature Reserve.

and eliminate most of false detections without further human inspection [19].

Previous works carried out in nearby areas such as La Selva Biological Station in Sarapiquí report precision and accuracy values between 83% and 99% for species such as *Ramphastos swainsonii* and *Tinamus major* in validation data sets similar to those presented in this study. [24].

In [21], similar RFM values were found between 47% and 60% of both precision and accuracy for other species found in the surroundings of Las Arrieras Nature Reserve such as *Microcerculus marginatus* and *Formicarius analis*.

Previous works focused on Multiple Instance Learning found high precision and accuracy (greater than 90%) in the detection of bird sounds when analyzing the data combining methods such as log mel-scaled spectrogram (LMSS) and mel-frequency cepstral coefficients (MFCCs) [9].

Similar values of precision and accuracy in the detections were found in research that used Convolutional Neural Networks (CNNs) with results between 79.1-90.7% [10], [11], Binary Neural Networks (BNNs) with 88.7-95% [25] and PM based on frequency bands or spectrogram correlations with 66-92% [26].

Acoustic detection can improve model accuracy and precision by increasing the number of sampling sites and the number of observations within a site [27]. Currently, biological and acoustic monitoring continues in the reserve, and we pretend to run the model for the totality of data from a complete year of sampling.

The acoustic detections by sampling site indicate the presence of territories of the species within the reserve, this aspect have particular importance in the redesign of tourist trails to minimize the impact of the trails on the behavior of species such as *C. mentalis*.

Sites such as Arrieras 03, Arrieras 07 and Monasa 01 were identified as sites with high acoustic activity of the species. *C. mentalis* congregates in breeding leks where several males vocalize to attract females [28]. The number of detections may be an indicator of the establishment of such leks.

Arrieras 02 was not considered as a site where the species could be detected because it is an area dominated by ferns

and the lack of forest canopy. However, several individuals were recorded possibly vocalizing on plants that emerge in this habitat. Melastomataceae plants are dispersed by manakins and benefits in vegetation regeneration in areas with active management due to their fast growth [29].

Most of the sites presented characteristics of suitable habitats for the development of the species. The sites with the most active leks are in agreement with [30]) who indicate that the species is found in the understory, midstory of humid evergreen forest and adjacent tall second growth.

C. mentalis acoustic activity characterization based on daily and monthly detections, allows the reserve management to generate information for decision making to program the touristic use of the trails during critical breeding season in order to guarantee the effective reproduction of the species in the reserve.

The analysis generated provide information about the habitat requirements of the species for establishing territories, which allows an active management of areas in restoration process to accelerate the the growth of the vegetation by attracting this and other seed dispersing species.

We pretend to analyze acoustic metrics through soundscape indices and vegetation variables associated with each territory to provide an specific evaluation of the habitat requirements [31] in the reserve to benefit the conservation in Costa Rica and along the distribution range of *C. mentalis*.

Acoustic monitoring using autonomous recording units (ARUs) provides an opportunity to understand species vocalization patterns, improve traditional counting techniques, identify changes in ecosystems, forest vegetation recovery, migratory movements (latitudinal and altitudinal), habitat use and other behaviors of avifauna in the tropics [32].

This monitoring generate a baseline information for the management and conservation of *C. mentalis* and sites with increased anthropogenic pressure such as the Caribbean foothills, so it is important to expand bioacoustic studies in sites adjacent to protected areas.

V. CONCLUSIONS

The acoustic detections provided the identification of potential breeding activity of *C. mentalis* in a spatiotemporal range, enabling land management and conservation decisions.

The selection of Pattern Matching and Random Forest Model in ARBIMON is simple and easy to implement with large datasets of soundscape recordings, helping to understand the data in an ecological approach and simplifying the work for biologists, ecologists, and conservationists.

Accuracy and precision values in detections were similar to other bird acoustic detection research, however it is recommended to analyze the data with other methods in a comparative way to improve data processing and ecoacoustic monitoring.

Accuracy and precision can be improved by preprocessing data with noise filters or assembling different detection methods to improve data processing.

Acoustic monitoring enhance the traditional sampling techniques in field biology, reducing costs, bias, and environment alterations for species with particular conservation importance.

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