DOI: 10.61782/fa.2023.1246

forum acusticum 2023

THE BIOACOUSTIC SOUNDSCAPE OF A PANDEMIC IN AGMON HULA LAKE PARK: CONTINUOUS ANNUAL MONITORING USING A DEEP LEARNING SYSTEM

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ABSTRACT

Continuous bioacoustic monitoring is an emerging treasure and a challenge. Allowing to detect cryptic species activity while producing high computational demands. In this work, we present an automated framework that allows the monitoring of a large number of bird species by their vocalizations over extended periods. The framework relies on the BirdNet Analyzer deep learning model, and also on a simple deep learning model with few convolutional layers, AgmoNet. Both models were tested on more than 80 species, and 20 with the highest identification scores were selected for further analysis. We used the framework to analyze acoustic signals recorded using autonomous recorders at various locations in Agmon Hula, Israel, and recorded continuously for more than two years. During the recordings there was an acute outbreak of avian-flu in the area. We analyzed differences in acoustic occupancy for various species between two consecutive years and found significant decline in vocal activity between the two years for certain species. We examine the life history of these species and assume that this decline may be related to avian-flu outbreak, suggesting that the impact of the pandemic may be more widespread and affected a greater number of local species than was previously realized.

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Keywords: *Long-term Bird monitoring, BirdNET, Convolutional Neural Network, Bioacoustics, Soundscape, Autonomous Recording Units, Deep Machine Learning.*

1. INTRODUCTION

Continuous monitoring of birds through their vocalizations offers new possibilities but also poses challenges. On one hand, it provides a high level of resolution to monitor numerous species across time and space. This enables the monitoring of species occupancy and density, the identification of previously overlooked changes in habitat, and the detection of changes in biodiversity [1]. On the other hand, the extensive data generated by continuous monitoring necessitates the creation of efficient computational tools for identifying and characterizing the soundscape. This will facilitate the tracking of changes in populations and habitats.
Among the deep learning models developed in recent years for bird species identification, BirdNET [2] is probably the leading tool. This established a platform for researchers to monitor and study diverse soundscapes across habitats [3]-[7].
In this work, we present an automated framework that allows the monitoring of a large number of bird species by their vocalizations over extended periods. The framework relies on the BirdNET Analyzer deep learning model, as well as on a simpler deep learning model with few convolutional layers, AgmoNet. Using passive acoustic monitoring with several recorders deployed in different locations within Agmon Hula lake park, upper Galilee, Israel, we produced an annotated dataset of over 50 species,

containing more than 8000 recordings and 25,000 vocalization samples. We utilized this dataset to evaluate the performance of BirdNET and AgmoNet. Subsequently, we employed our long-term analysis framework that harnesses BirdNET or AgmoNet to monitor the acoustic behavior of several species and compare their vocalization activity between two consecutive years. We examine these annual differences in light of an extreme avian flu outbreak that occurred during that year. The influenza outbreak caused the death of over 8000 cranes (*Grus grus*) and impacted great white pelicans (*Pelecanus onocrotalus*), and apparently affected other avian species [8].

2. METHODS

2.1 Recording and Research Area

Two autonomous recording devices (SM4, Wildlife Acoustics) were deployed in two locations in the Agmon lake park. This area was selected due to its diverse range of bird species, both migratory and resident, within a relatively compact space. The recordings were carried out from November 2020, 24x7, with a regime of 30 minutes of recording for every hour

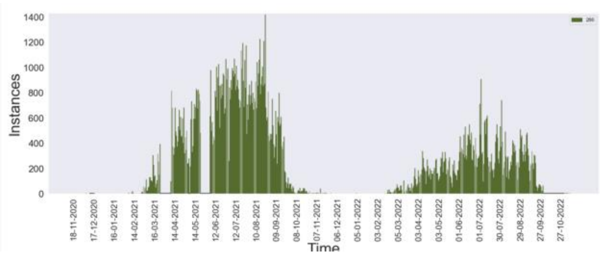

Figure 1. Two years of vocal activity for one location of the Eurasian Collared dove. Each individual bar in the histogram represents either one day (sunrise-sunset) or one night.

2.2 BirdNet

Our monitoring framework relies mainly on BirdNet analyzer, version V2.2 [3]. We used a threshold confidence score value of 0.35 for the top identification when applying our pipeline to conduct long term analysis.

2.3 AgmoNet

The AgmoNet is a relatively simple Convolutional Neural Network, composed of 5 Resnet blocks. It was trained on both Agmon dataset (see below) and also on a larger dataset extracted from xeno-canto (https://xeno-canto.org) on more than 80 species and over 70,000 spectrograms. Each mel-spectrogram was computed from a one-second segment from the original annotated recordings, using 50 mel-filters.

2.4 The Agmon dataset

We created the “Agmon dataset” to train and test AgmoNet and evaluate BirdNet's performance. The dataset comprises over 8000 annotated recordings of more than 50 species. Experts in bird vocalizations identified and annotated the species in each recording.

2.5 Pre validation of BirdNet analyzer.

Although BirdNet is claimed to identify the vocalizations of over 3000 species, it is crucial to carefully evaluate its performance on target species for monitoring purposes [7]. For this purpose, we utilized the Agmon dataset to compute the recall and precision for species commonly found in Agmon Lake Park.

2.6 The monitoring framework

For each 3 seconds segment, we utilize the BirdNet analyzer to identify the species present, extracting the top species with the highest confidence scores, applying a threshold value of 0.35 to filter out predictions with lower confidence score. Next, we sum the number of vocalizations for each species to produce the total number of vocalizations per hour, and for each day or night. This data allows us to analyze and compare the acoustic activity of each species over various time periods. By using a moving average of the activity over multiple days we can evaluate the diel activity along the year.

2.7 Statistical analysis

In order to analyze between year differences in acoustic activity, we first, using t-test, examined whether the species is vocally diurnal or nocturnal and filtered out the quiet period of the day. We then examined each species seasonal variation in acoustic presence using one-way ANOVA. If specific months created a significantly higher statistical group, we detected these subsequent months as the activity period (usually breeding or migration) and filtered out the rest. Finally, a mixed model was utilized, were year was a fixed effect, recorder id a random effect and number of daily species acoustic counts as the dependent variable.

3. RESULTS

3.1 BirdNet accuracy for different species

In this analysis we used the annotated calls of 23 species, recorded in the Agmon Hula lake park between November 2020 and August 2022. The average recall is 29.7%, and the average precision is 80.9%. For most species the precision is consistently above 70%, indicating reliable species detections for subsequent analysis.

3.2 Long-term Analysis

Our analysis demonstrates the effectiveness of our pipeline in generating annual graphs of vocal activity. Figure 1 shows the activity for the Eurasian Collared dove based on recordings taken over almost two years. The results clearly show that the Eurasian Collar dove exhibits high levels of vocal activity during the spring and summer months, but very little in the autumn and winter, which is consistent with long-term manual observations.

3.3 Diel activity

In addition to the long-term activity, it is possible to obtain diel activity patterns by calculating the average number of vocalizations for each species in each hour over several days. Figure 2 illustrates this for the kingfisher (*Halcyon smyrnensis*). The vocal activity pattern indicates diurnal activity exclusively, with increased activity after sunrise.

3.4 AgmoNet evaluation

The AgmoNet was evaluated on a test set of 13,500 mel spectrograms of one second, extracted from both Agmon and xeno-canto datasets. The AgmoNet achieves a total correct identification rate of 77% when applied to this dataset. In addition, it was found that for several low latitude species, AgmoNet outperformed BirdNet.

3.5 Between years differences in species acoustic presence 2021 vs 2022

We analyzed differences in acoustic occupancy for each species between two consecutive years (11.2020 to 10.2022). An acute outbreak of avian flu occurred in the area during the recordings. We found a significant decrease in vocal activity between the two years for 10 out of 17 monitored species

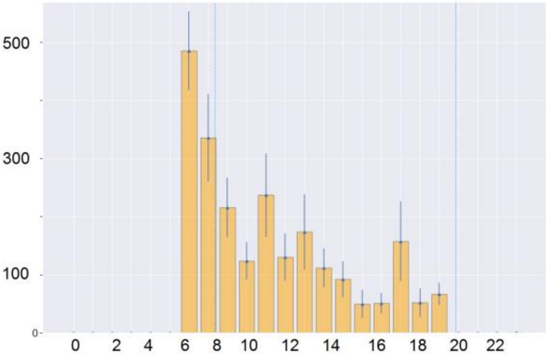

Figure 2. Averaged diel activity of kingfisher (Halcyon smyrnensis). The horizontal axis represents time along the day, while the vertical axis indicates the average number of vocalizations (two weeks average).

4. SUMMARY AND CONCLUSIONS

In this study we demonstrated the usage of our monitoring pipeline for computing both long and short term activity behavior of several species recorded continuously for more than two years in the Agmon lake park.

The long term vocal activity behavior of several species, as well as their diel patterns are shown. The vocal activity patterns were found to be consistent with long-term manual observations. We found a significant decline in vocal activity of 10 out of the 17 monitored species. We could verify that some of these decreases detected acoustically are also evident by other methods. We assume that this general decrease may be linked to the outbreak of the avian flu in the area in the recording period. If that is the case, our acoustic monitoring indicates that many overlooked species (including resident species) have been significantly affected by the pandemic.

Overall, the study highlights the potential of using BirdNet combined with our pipeline for bird monitoring to better understand the vocal activity patterns of various species, to track changes in occupancy and activity, and to relate them to other environmental events.

5. ACKNOWLEDGMENTS

This work was supported by KKL–JNF research grant.

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