



Original Research Paper

Deep Learning Acoustic Monitoring of Bird Diversity in Fragmented Forests

Dr. Nishtha Sharma^{1*}, Dr. Ankita Nihlani²

^{1*}Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.

Email: ku.nishthasharma@kalingauniversity.ac.in, ORCID: <https://orcid.org/0009-0006-4689-2712>

²Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.

Email: ku.ankitanihlani@kalingauniversity.ac.in, ORCID: <https://orcid.org/0009-0002-7447-8544>

Key Words

Abstract

Deep learning,
Acoustic
monitoring,
Bird diversity,
Forest
fragmentation,
Bird sound
classification,
Bioacoustics,
Biodiversity
conservation.

Biodiversity of birds is one of the most significant indices of ecological condition, whereas fragmentation may have significant impacts on the habitat structure, species' composition and ecological relationships. Traditional techniques for bird biodiversity monitoring such as direct observations and manual acoustic recognition are usually quite costly and time-consuming processes. This paper suggests the development of the deep learning technique of bird diversity assessment based on acoustic monitoring in fragmented forests. The suggested technique employs passive acoustic recordings obtained from various fragments of forests and involves acoustic recordings processing, noise filtering, segmentation and spectrograms extraction of the acoustic signals. Machine learning methods are then applied to detect and classify bird sounds and determine the species in a complicated audio environment. The detected species will be used to measure and analyze bird biodiversity in different forest patches. This strategy aims to enhance the effectiveness and scalability of biodiversity monitoring and minimize human involvement in this process. This research analyzes the influence that differences in acoustic behavior and species presence may have on understanding the ecological impacts of forest fragmentation. The suggested framework will be helpful for wildlife scientists, conservationists, and forest managers in developing automatic approaches for assessing bird biodiversity.

* Corresponding Author's email: ku.nishthasharma@kalingauniversity.ac.in

Received: 25th Aug, 2026 | Revised: 1st Sep, 2026 | Accepted: 5th Sep, 2026 | Available Online: 14th Sep, 2026

(DOI): 10.70102/AEJ.2026.18.5s.93

Introduction

Bird Diversity, Forest Ecosystems and Fragmentation

Birds have significant roles in forest ecosystems, and diversity in birds indicates the quality of the environment and how it is changing. Fragmentation of forests leads to the creation of smaller and fragmented fragments that affect the structure of the habitat and bird communities. Changes in vegetation and habitat connectivity can also affect bird diversity. It is possible to monitor the diversity of birds in various fragments of forests (Jena et al. 2026).

Acoustic Monitoring and Automated Bird Diversity Assessment

The use of acoustic monitoring offers a non-intrusive approach to the recording of bird sounds at different sites and over extended periods. Bird songs may offer information on the presence, behavior, and composition of the avian community. The properties of the soundscape may also help in the identification of variations in environmental disturbances. Nonetheless, continuous monitoring leads to the production of large amounts of data that include both environmental and human noises. The analysis of these large data sets requires extensive effort and time.

Deep Learning for Bird Sound Classification and Research Problem

Deep learning approaches can be used to examine spectrogram images of bird sounds for classification and identification of the birds. The use of deep learning for automatic detection and

classification of bird vocalization is a faster approach compared to manual examination. Furthermore, automated detection and classification methods can be used in the analysis of bird sounds at multiple locations in a forest environment Almolhis and Nawaf Abdualaziz (2025). However, issues of background noise, overlapping sounds, environmental factors, as well as the variations in vocal features between birds pose challenges in the identification process.

Review of Literature

Acoustic Monitoring and Bird Diversity Assessment

Acoustic monitoring serves as a non-invasive approach to evaluating bird diversity, bird presence, and acoustic activity over time. Acoustic data can reveal differences in bird communities between sites. Some research indicates that soundscape analysis and passive acoustic monitoring could help assess species presence and biodiversity (Sethi et al., 2022; Müller et al., 2023; Li et al., 2024). Machine learning is an additional tool that will help in processing complex acoustic data related to biodiversity (Xie et al., 2025; Vargas Rivera, 2025).

Machine Learning and Deep Learning for Bird Sound Recognition

Machine learning and deep learning algorithms facilitate the automated identification and classification of bird sounds. The use of deep learning can help recognize patterns in soundscapes through spectrograms to help in identification (Wang et al., 2025). This is

illustrated by BirdNET in using deep learning in automated avian sound recognition (Kahl et al., 2021; Perea and Santiago 2025). Deep learning technology can also be used to recognize changes in the environment through soundscapes, although challenges still exist.

Existing Research and Research Gap

Earlier works have shown the applicability of acoustic monitoring, machine learning, and deep learning for biodiversity evaluation. But still, problems such as ambient noise, call overlaps, environmental variations, and species detectability persist. There is thus a requirement for an integrated technique where passive acoustic monitoring, bird detection using deep learning, and comparative biodiversity evaluation among forest fragments are taken into account. The current work fills this gap through a deep learning-based acoustic monitoring system for bird biodiversity evaluation.

Methodology

Research Design, Study Area and Acoustic Data Collection

The current research employs a quantitative and experimental methodology for studying the application of deep learning in acoustical monitoring of bird diversity in fragmented forests. The research considers selected fragments of forests characterized by different structures and levels of fragmentation. The acoustic recordings are acquired by passive acoustic recorders that are placed in selected locations of the chosen forest fragments. The recordings are done during high activities of the

birds and also at different sample locations to capture variation among the bird communities.

Audio Pre-processing and Feature Extraction

Pre-processing is performed on the recorded audio data to make it more appropriate for automatic processing. Such pre-processing involves eliminating or reducing undesirable background noise, normalizing audio signals, splitting continuous audio data into segments, and extracting bird sounds. After that, pre-processed audio data are converted into spectrogram features that describe temporal and spectral changes. Such features form appropriate input features for deep learning models. It is possible to use data augmentation as well.

Deep Learning Model Development, Training and Testing

The proposed deep learning model is created for automatic detection and classification of the birds' vocalization according to the species. The spectrograms created during pre-processing are inputted to the deep learning model. A CNN or appropriate deep learning model is utilized for learning acoustic features of various birds. Dataset is split into training, validation, and testing sets. Training dataset is employed for learning the model parameters while validation set is used for monitoring of the model performance and adjusting the model during the process of development. Testing dataset that is independent is used for evaluation of the classification performance of the developed model.

Bird Diversity Estimation and Performance Evaluation

The bird species determined from the deep learning model are then utilized to estimate and compare the bird diversity among the chosen forest fragments. Information about species presence, species detection rates, and others could be summarized per sampling sites. Diversity indices could be used to compare the bird communities among the fragmented areas.

Results and Discussion

Deep Learning Model Performance and Bird Species Classification

The deep learning model is applied in automatic recognition and classification of bird sounds based on audio recordings. The spectrogram provides the ability for the model to recognize the acoustic features of various species. Performance of the model can be assessed using metrics such as accuracy, precision, recall, F1 score, and confusion matrix. Additionally, the classification output gives insights into species presence and detection rate at sampling sites.

Bird Diversity and Acoustic Patterns Across Fragmented Forests

This list of bird species is used to make comparisons concerning their diversity in forest fragments. Differences in species richness,

frequency of detection, and indices of diversity could show differences in birds' communities. Different patterns of vocalizations could be associated with different vegetation and environmental conditions, different species composition, and different disturbance levels. Therefore, sound monitoring could provide some valuable information regarding both birds' presence and differences between fragmented forest areas.

Discussion of Findings and Implications

Conclusions

It is obvious that the obtained results indicate the possibilities of using deep learning in combination with PAM for assessing bird diversity in an efficient and scalable way. Automation saves the time needed for manual processing and allows for further monitoring of large acoustic datasets. This method allow identifying shifts in bird communities and habitat states. Nevertheless, it is important to take into account the impact of background noise, recording conditions, differences in species' vocalization, and misclassification on the obtained results.

Figure 1 illustrates that there is a reduction in bird detection rate from Fragment A through to Fragment D. Fragment A detects the highest number of birds (42) while Fragment D has the least number of birds detected (19).

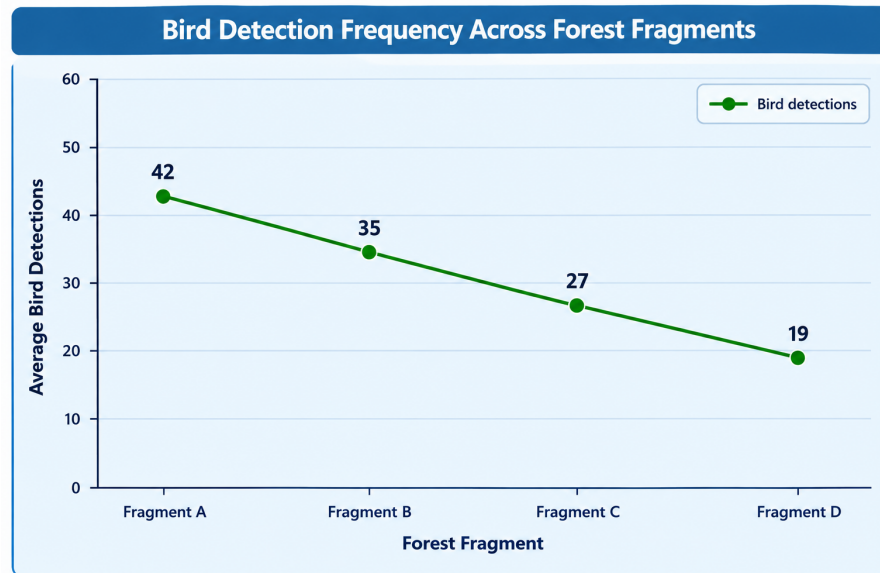


Figure 1: Bird Detection Frequency Across Forest Fragments

Conclusion

This research shows how machine learning-based acoustic monitoring of birds is capable of being used in fragmented forests. Using passive acoustic recordings along with spectrograms in the process of deep learning makes it possible to automatically detect and classify bird vocalizations, making manual work unnecessary. Differences in frequencies of detection and acoustic activity can provide valuable data regarding different bird communities as well as habitats. It is also worth mentioning the decrease in detection frequency when moving from Fragment A to Fragment D.

This strategy can help in achieving long-term, efficient, and scalable biodiversity monitoring as well as providing valuable information to researchers and conservationists. Nevertheless, the issue of background noise, recording conditions, overlapping sounds, and errors in classification must also be taken into account. In summary, the application of deep learning

acoustic monitoring represents a promising way of data-driven bird diversity assessment and conservation in fragmented forests.

References

- [1] Almolhis, Nawaf Abdualaziz. "Intrusion Detection Using Hybrid Random Forest and Attention Models and Explainable AI Visualization." *J. Internet Serv. Inf. Secur.* 15, no. 1 (2025): 371-384.
- [2] Jena, D., S. Swain, P. Mishra, S. Samantaray, M. R. Behera, and A. K. Mohanty. 2026. "Assessing the Socio-Economic Impacts of the Forest Rights Act on Tribal Communities in Odisha: An Empirical Study of the Juang Tribe." *Indian Journal of Information Sources and Services* 16 (2): 508–516.
- [3] Kahl, Stefan, Connor M. Wood, Maximilian Eibl, and Holger Klinck. "BirdNET: A deep learning solution for avian diversity monitoring." *Ecological Informatics* 61 (2021): 101236.

- [4] Li, Le, Chengyun Zhang, Nancai Pei, Bingtao Gao, Na Wang, Jiarui Li, Ruichen Wu, and Zezhou Hao. "Correlation analysis of urban green landscape patterns and bird diversity based on passive acoustic monitoring technology." *Biodiversity Science* 32, no. 10 (2024): 24296.
- [5] Müller, Jörg, Oliver Mitesser, H. Martin Schaefer, Sebastian Seibold, Annika Busse, Peter Kriegel, Dominik Rabl et al. "Soundscapes and deep learning enable tracking biodiversity recovery in tropical forests." *Nature communications* 14, no. 1 (2023): 6191.
- [6] Perea, Santiago. "Listening to forest recovery: Biodiversity conservation." *Nature Reviews Biodiversity* 1, no. 8 (2025): 496-496.
- [7] Sethi, Sarab S., Robert M. Ewers, Nick S. Jones, Jani Sleutel, Adi Shabrani, Nursyamin Zulkifli, and Lorenzo Picinali. "Soundscapes predict species occurrence in tropical forests." *Oikos* 2022, no. 3 (2022): e08525.
- [8] Vargas Rivera, Carlos Alberto. "Hearing the Forest: Machine Learning for Biodiversity Monitoring Using Soundscapes." PhD diss., Technische Universität Wien, 2025.
- [9] Wang, Shizheng, Yuxuan Duan, Ranxing Cao, Jiawei Feng, Jianping Ge, and Tianming Wang. "Road disturbance drives a more simplified soundscape in temperate forests revealed by deep learning and acoustics indices." *Biological Conservation* 306 (2025): 111115.
- [10] Xie, Jiangjian, Shanshan Xie, Yang Liu, Xin Jing, Mengkun Zhu, Linlin Xie, Junguo Zhang, Kun Qian, and Björn W. Schuller. "Decoding nature's melody: significance and challenges of machine learning in assessing bird diversity via soundscape analysis." *Artificial Intelligence Review* 59, no. 1 (2025): 10.