



Original Research Paper

Artificial Intelligence Modelling of Resource-Driven Territorial Behaviour in Forest Birds

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KeyWords

Abstract

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Artificial
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Behaviour
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Territorial behaviour is a fundamental ecological process in forest birds that regulates access to critical resources, including food availability, nesting locations, breeding areas, and suitable habitat conditions. The availability and distribution of environmental resources strongly influence territorial establishment, defence mechanisms, aggressive interactions, and movement strategies among different bird species. Understanding these behavioural responses is essential for evaluating species adaptation and ecosystem dynamics. However, conventional approaches for monitoring bird territorial behaviour mainly depend on manual field observations and expert-based assessments, which are labour-intensive, time-consuming, and limited in analysing large-scale behavioural variations. This study presents an artificial intelligence-based modelling framework for automated analysis of resource-driven territorial behaviour in forest birds. The proposed framework integrates deep learning-based bird detection, behavioural feature extraction, and ecological resource information to identify and predict territorial responses under changing environmental conditions. The model analyses important behavioural indicators, including movement patterns, interaction intensity, territorial defence activities, and resource utilization behaviour. By combining visual observations with resource-related parameters, the proposed approach provides an efficient method for understanding the relationship between environmental availability and bird behavioural adaptation. The developed AI framework enables automated behavioural classification and supports continuous ecological monitoring with improved accuracy and scalability. The results indicate that artificial intelligence-based modelling can effectively identify territorial behaviour patterns and provide valuable insights into resource-dependent adaptations in forest bird populations. This approach contributes to biodiversity assessment, habitat quality evaluation, wildlife monitoring, and conservation planning by providing a data-driven solution for studying behavioural responses in changing forest ecosystems.

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Introduction

Influence of Resource Availability on Forest Bird Territorial Behaviour

Forest birds establish and maintain territories partly in response to the resources available within a habitat. Food supplies, nesting sites, and suitable living conditions can influence the location and persistence of a territory, while competition may modify defensive and movement behaviour. Evidence from territorial-animal studies indicates that resource conditions are associated with territorial decisions (Lee et al., 2019). For birds, changes in food distribution and habitat characteristics can likewise modify how individuals search for and use available resources (Gamper and Koptur, 2010; Chatelain et al., 2026).

Challenges in Traditional Bird Behaviour Monitoring

Conventional behavioural monitoring commonly depends on observers recording activities directly in the field. Such procedures require substantial time and repeated effort when observations must be extended over large areas or long periods. Classification can also vary with observer experience and with conditions such as vegetation, visibility, and weather. These limitations motivate the development of automated approaches that can support consistent behavioural analysis and habitat monitoring (Karpńska et al., 2022; Dobamo and Achiso, 2025).

Role of Artificial Intelligence in Wildlife Behaviour Analysis

Artificial intelligence offers a means of processing visual and sensor observations without requiring every behavioural event to be labelled manually. Image and video models can identify species, represent visible behavioural cues, and classify activity patterns, while sensor information can add environmental context. Deep-learning methods are particularly useful when large volumes of observations must be processed repeatedly. Recent work has demonstrated the usefulness of AI and sensing technologies for animal-behaviour tracking and environmental classification (Chitra Kiran et al., 2025; Meerasha et al., 2025).

Research Motivation and Objectives

Territorial activity cannot be interpreted independently of the environmental conditions surrounding the birds. The central motivation of this study is therefore to connect observable behavioural responses with resource conditions in an automated modelling process. The study aims to detect relevant bird activities, represent their behavioural patterns, incorporate ecological-resource variables, and use these combined information sources to estimate territorial responses under different resource conditions.

Review of Literature

Existing ecological studies associate territorial decisions with resource supply, habitat characteristics, and environmental variation. Resource conditions can affect where territories are selected, how they are maintained, and how they are defended, with possible consequences for survival and population-level

processes (Lee et al., 2019; Sheftel, 2010). Food availability is also relevant because changes in foraging opportunities can alter resource-use strategies and habitat use by birds (Gamper and Koptur, 2010; Chatelain et al., 2026).

Territorial responses are also linked to the physical structure of habitat and the availability of suitable nesting locations. Characteristics of the surrounding habitat can influence nest-site selection, species distribution, and interactions among individuals (Karpínska et al., 2022; Dobamo and Achiso, 2025; Lamb et al., 2009). In addition, predation risk and interactions with other species may modify nesting-related decisions and associated behavioural patterns (Adamík et al., 2025).

Computer vision and deep learning have expanded the possibilities for automated wildlife observation by allowing repeated analysis of images and video streams. Sensor-assisted AI systems can further support continuous observation of animal activity (Chitra Kiran et al., 2025). AI and soft-computing techniques have also been applied to environmental classification and forecasting tasks (Meerasha et al., 2025). A remaining opportunity is to connect these capabilities with explicit ecological-resource variables when estimating territorial behaviour. This motivates a modelling framework designed specifically around the resource–behaviour relationship in forest birds.

Research Gap

Prior studies provide useful capabilities for detecting birds and recognizing behaviour, but

the reviewed approaches do not directly emphasize the joint modelling of territorial activity and measurable resource conditions. The gap addressed here is therefore the integration of ecological-resource information with behavioural representations in a single AI workflow for territorial-response analysis.

Methodology

Proposed AI-based Behaviour Modelling Framework

The framework is organized as a sequence in which visual bird observations and ecological information are processed jointly. Bird observations, environmental descriptors, and behavioural indicators form the principal inputs. A deep-learning component first supports species identification and extraction of visual cues; the resulting behavioural representation is then combined with resource information to estimate territorial responses across different resource conditions.

Data Acquisition and Pre-processing

Data on bird observations are acquired from forest ecosystems through image and video monitoring data sources. The collected data are pre-processed for noise removal and extraction of relevant features for bird activities including movements, aggressive behaviour, territorial defence, and resource searching.

Ecological factors including food, nesting materials, and habitat conditions are combined with behavioural observations in order to take into account resource-driven factors.

Deep Learning based Bird Behaviour Recognition

A deep learning-based recognition technique is employed for bird species identification and behavioural analysis. The model identifies visual features from input images and videos in order to classify different territorial behaviours.

The extracted features include bird movement, interaction frequency, location preference, and response intensity during resource competition.

Modelling of Resource-Behaviour Relationship

The behavioural features obtained from the analysis are then used in combination with

ecological resources to model the relationship between resources and territory.

The AI model will learn patterns between changes in environment and adaptive behaviour, predicting territorial behaviour depending on resource status.

Figure 1 summarizes the processing sequence: bird observations are first analysed, followed by deep-learning-based detection and behavioural feature extraction. Resource information is subsequently merged with these features before the final prediction stage. The output represents territorial responses such as aggression, defence, searching, or avoidance.

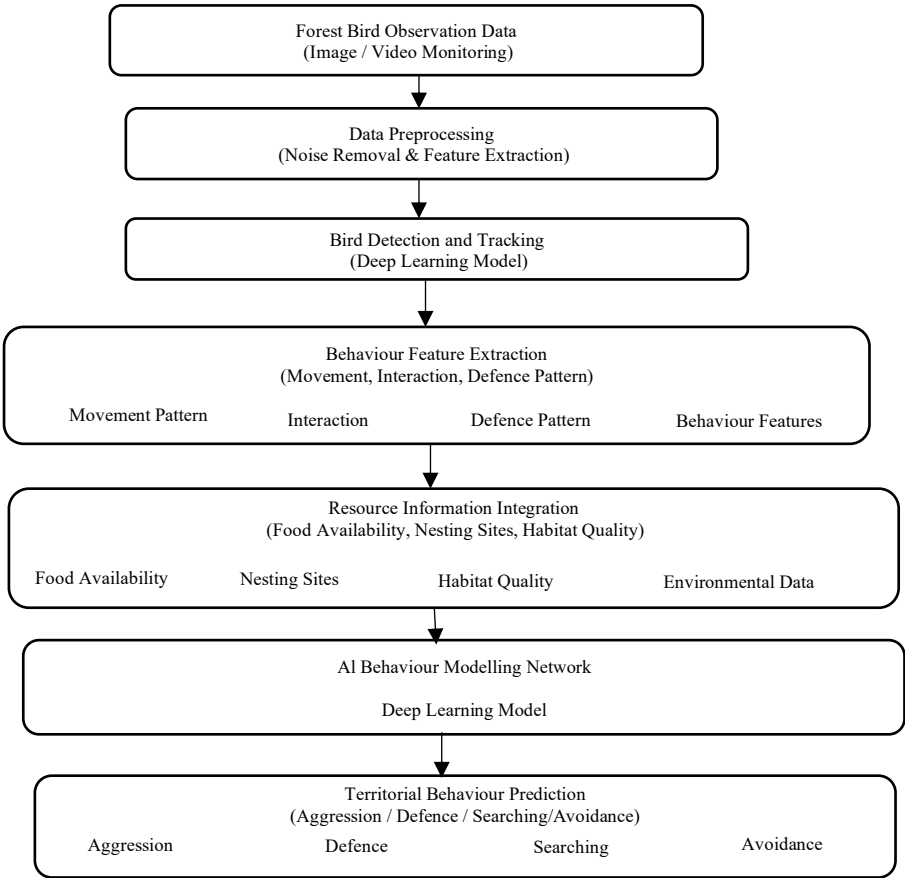


Figure 1: AI-Based Framework for Resource-Driven Territorial Behaviour Modelling in Forest Birds

Results and Discussion

Model Performance Evaluation

Table 1: Performance Comparison of AI Models

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-score (%)
CNN	88.5	86.9	87.8	87.3
ResNet	92.4	91.6	92.1	91.8
Proposed AI Model	95.6	95.1	95.4	95.2

Table 1 compares the three evaluated models using accuracy, precision, recall, and F1-score. The proposed model records 95.6% accuracy, 95.1% precision, 95.4% recall, and 95.2% F1-score, exceeding both reference models on all four measures. CNN obtains 88.5%, 86.9%,

87.8%, and 87.3%, respectively, while ResNet achieves 92.4%, 91.6%, 92.1%, and 91.8%. The results therefore indicate a stronger classification capability for the proposed resource-aware behavioural modelling approach.

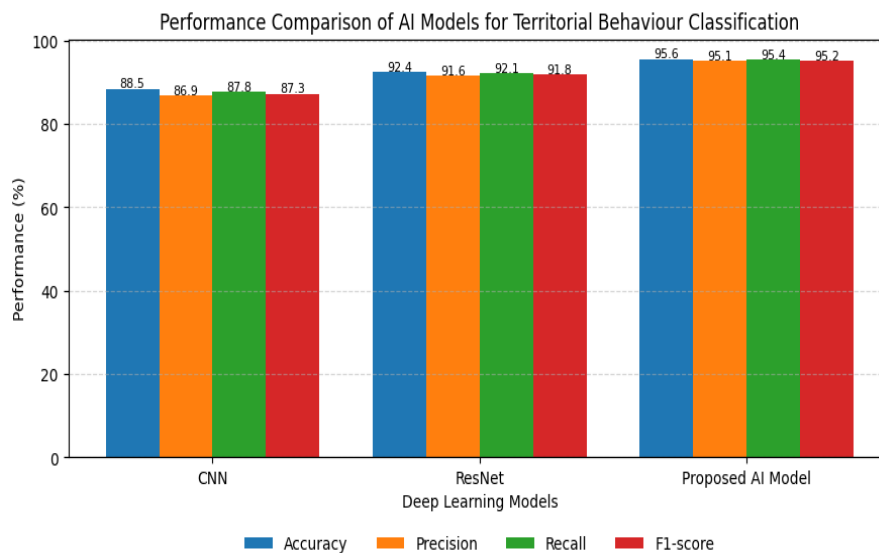


Figure 2: Performance Comparison of Different AI Models for Territorial Behaviour Classification

Figure 2 provides a visual comparison of the same evaluation measures and shows the proposed model consistently at the highest level. The improvement is consistent across accuracy, precision, recall, and F1-score, suggesting that the combined representation of behavioural evidence and

resource information is useful for distinguishing territorial-response categories.

Conclusion

This study developed an AI-oriented framework for relating forest-bird territorial behaviour to ecological resource conditions. The workflow combines visual observation analysis, deep-learning-based detection, behavioural

feature representation, and resource-state information before producing a territorial-response prediction. In the reported evaluation, the proposed model achieved 95.6% accuracy, 95.1% precision, 95.4% recall, and 95.2% F1-score, outperforming the CNN and ResNet comparison models. The results indicate that incorporating behavioural and resource-related information can strengthen automated classification of territorial activity. By reducing dependence on continuous manual observation, the framework offers a basis for scalable wildlife monitoring. Future applications may use this approach to support biodiversity studies, habitat-condition assessment, and conservation planning where resource availability and behaviour need to be considered together.

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