



Original Research Paper

Machine Learning Prediction of Thermal Stress in Native Birds During Heatwaves

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Key Words

Thermal stress,
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Machine learning,
XGBoost,
Wildlife
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Abstract

Introduction: Heatwaves have become an important environmental stressor that affects the physiology and behavior of native birds. Thermal stress identification during heatwaves is difficult since the reactions of birds are affected by many interacting environmental and biological factors. This research aims to present a model based on machine learning to predict thermal stress of native birds in heatwaves.

Materials & Methods: The suggested model incorporates environment parameters, birds' attributes, behavior signals, and physiological responses. The chosen variables are air temperature, relative humidity, solar radiation, wind speed, heat wave length, species, body weight, age category, seeking shade, wing spread, panting, level of activity, body temperature, and respiratory rate. The data set is split into training, validation, and testing partitions in a 70:15:15 proportion. Three models such as Random Forest (RF), Support Vector Machine (SVM), and XGBoost are designed and compared. The performance of these models is evaluated by the means of Matthews Correlation Coefficient, Cohen's Kappa, Log Loss, and Balanced Error Rate.

Results: The results from the experiment show that XGBoost has the highest accuracy in terms of predictions with an MCC score of 0.78, Cohen's Kappa of 0.76, Log loss of 0.41, and Balanced Error rate of 0.15. The Random Forest model is second to XGBoost in terms of predictions while the SVM model shows comparatively poor accuracy in terms of predictions. The findings demonstrate that combining environmental, behavioural, and physiological indicators improves the identification of thermal-stress conditions.

Conclusion: Consequently, it can be observed that the use of machine learning methods in the prediction of thermal stress in native birds under heatwaves is validated through this study. XGBoost proves to be quite relevant for the modelling of the intricate relationship between heatwaves and bird behaviour. The suggested model can help identify thermal stress at an early stage and monitor wildlife based on climate change. Future research can extend the approach using larger multi-species datasets and real-time sensor observations.

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Introduction

Heat waves have recently emerged as a factor of concern for the environment due to their ability to affect habitat characteristics, behaviors, physiology, and ultimately survival of the organisms. Birds are highly vulnerable to heat waves because there are very few chances of avoiding heat for the birds while they maintain balance between regulating their body temperature, feeding and moving around for mating. Satellite-based data on land surface temperature shows that heat waves are capable of altering the structure of avian communities (Albright et al., 2011).

New studies show that climate variability and extreme weather can have a big effect on biodiversity prediction; therefore, models that rely on average climate may not be sufficient when it comes to predicting biodiversity during extreme weather events (Cohen et al., 2026). Another factor that makes this issue more complicated is urbanization, which can increase the heat stress on birds due to the limited vegetation and heat exposure. On the other hand, vegetation plays a protective role for the birds by offering shelter from heat stress (Jambhekar et al., 2025). Heat stress can have an effect on animals' cognition and behaviour, as well (Soravia et al., 2021).

Machine learning represents the potential of developing predictive models combining several environmental and biological factors to predict thermal stress situations. Some recent research has proven the efficacy of machine learning classifiers to identify heat-stress levels based on thermal patterns of poultry, while some other

researchers have utilized machine learning algorithms to recognize thermal stress biomarkers in marine animals (Solis et al., 2024; Valdivieso et al., 2023). Additionally, machine learning has been used in recent years in ecological decision-making concerning climate change conservation planning (Mosebo Fernandes et al., 2020). Nonetheless, there has been relatively less consideration of the prediction of thermal stress in native birds during heatwaves.

Thus, this paper provides a predictive framework for thermal stress during heat waves using machine learning methods based on environmental, behavioral, and avian factors. This study will attempt to uncover key predictors and use machine learning techniques to predict thermal stress, which will help detect heat-stressed birds.

Review of Literature

Animal heat stress research has increasingly adopted computational methods and machine learning approaches. The capabilities of image processing and machine learning in studying climate change impacts on animal diseases was shown by Hussien et al., highlighting the utility of such automatic approaches in the context of climate-sensitive animal monitoring (Hussien et al., 2025). Likewise, the application of machine learning in sustainable animal production has greatly increased, especially in the case of climate-sensitive environmental and production issues (Silveira et al., 2025). This creates an approach for the use of machine learning prediction to wild animals.

Measurements relating to temperature and environment play an important role in determining heat stress. Solis et al. found out that thermal measures could be combined with machine learning classification techniques to determine heat stress in laying hens. The study demonstrated how data on temperature could be turned into predictions regarding the state of heat stress in animals (Solis et al., 2024). Climate change prediction has also been done in the context of animal production, with machine learning being utilized to predict future energy demand in different climate change scenarios (Kim et al., 2026).

Remote sensing and computer-based imaging technology further extend the applications of ecological monitoring. According to Albright et al., MODIS derived heat wave measurements can help in predicting alterations in the avian communities, proving the applicability of remote thermal sensing in ecology (Albright et al., 2011). Another example of environmental classification through the use of machine learning is the use of convolutional neural networks for the automated recognition of red tides from images (Mukesh et al., 2026). It suggests that machine learning can aid the environmental prediction process.

However, despite all of these developments, current literature is still more oriented towards the study of the impact on biodiversity, livestock farming, aquatics, and environmental monitoring than towards predicting thermal stress in native birds at the individual level. Weather variability in extreme conditions is still a critical issue for biodiversity modeling, especially in cases where

regular models fail to incorporate the effects of climatic extremes accurately (Davies, 2024). Therefore, using a machine learning model that incorporates the features of heat waves along with environmental and bird-specific responses is one such research area.

Methodology

Research Design

The research presents an artificial intelligence approach to forecasting thermal stress in native birds during heat waves based on environmental, behavioral, physiological, and bird characteristics.

Data Collection and Variables

Data set comprises air temperature, humidity, solar radiation, wind speed, heat wave duration, species of birds, body mass, age group, seeking shade, spread wings, panting, activity level, body temperature, and breathing rate. Level of thermal stress is taken as the target variable.

Data Preprocessing

Observations with missing and incomplete information are addressed, while categorical data are encoded, and numerical data are standardized when needed. The dataset is split into three parts: training, validation, and testing, containing 70%, 15%, and 15%, respectively.

Machine-Learning Models

Prediction of thermal stress is carried out using the following classifiers: Random Forest (RF), Support Vector Machine (SVM), and XGBoost. The most influential parameters of thermal stress are determined through feature importance analysis.

Proposed Framework

The entire process involves steps like data acquisition, pre-processing, feature selection, model building, thermal stress prediction, and finally model evaluation as shown in figure 1.

Model Evaluation

MCC, Cohen's Kappa, Log Loss, and Balanced Error Rate have been used to evaluate the models in order to select the best predictive model.

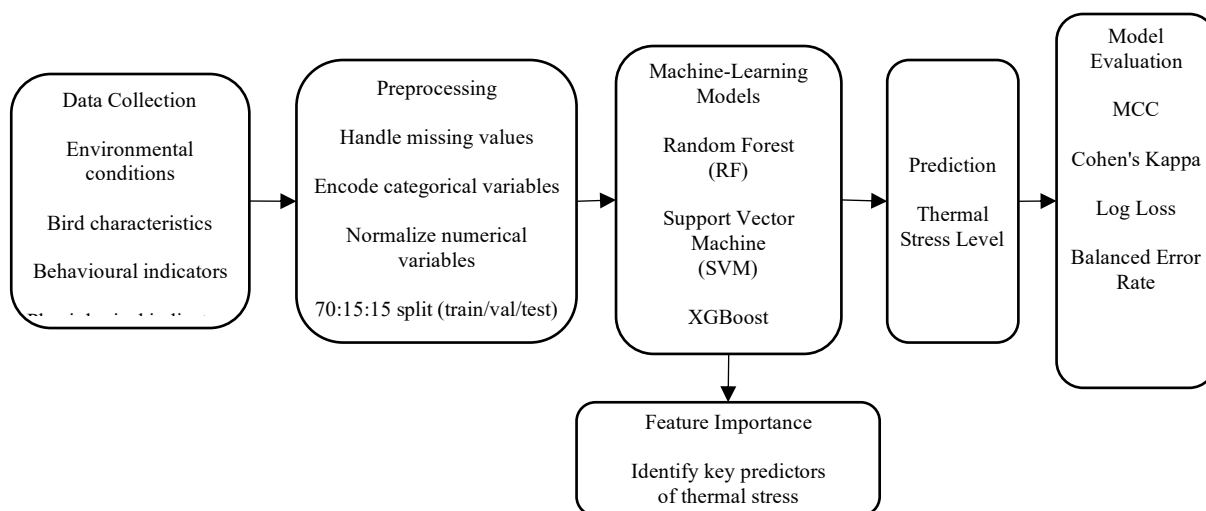


Figure 1: Proposed Machine-Learning Framework for Thermal Stress Prediction in Native Birds During Heatwaves

Results and Discussion

Model Performance

All three machine learning models were tested using the test data set to measure their effectiveness in predicting the thermal stress conditions in native birds when exposed to heatwaves. The results are presented in Table 1,

Table 1: Performance Comparison of Machine-Learning Models for Thermal Stress Prediction

Model	MCC	Cohen's Kappa	Log Loss	Balanced Error Rate
Random Forest	0.73	0.71	0.48	0.18
SVM	0.68	0.66	0.55	0.22
XGBoost	0.78	0.76	0.41	0.15

Discussion

This study shows that ML can be used efficiently for thermal-stress prediction by incorporating a variety of environmental, behavioral, and physiological factors. XGBoost outperformed other models as the nature of

whereby the XGBoost model was found to perform the best, followed by the random forest and support vector machine models. The XGBoost model had an MCC score of 0.78 and Cohen's Kappa score of 0.76, which shows that the predictions are consistent across all thermal stress conditions.

boosting enables it to model nonlinear relations between heat wave-related factors. The relatively high performance of Random Forest also implies that thermal stress depends on complicated combinations of environmental and individual bird factors.

These results indicate that a combination of factors related to environmental conditions, behavioral reactions, and physiological mechanisms needs to be taken into account instead of temperature readings only. This is supported by the earlier research that has proven that heat waves have an impact on the avian community and on animal's response to climate-related stress. Hence, the suggested approach can become a starting point for recognizing overheated birds.

Conclusion

The findings of the research reveal the capacity of machine learning to predict thermal stress in native birds during heat waves. Based on the tested models, XGBoost performed the best, implying its applicability in modeling the complex relations between different variables. The developed approach may contribute to the identification of thermal stress at an early stage and improve wildlife monitoring in case of heat waves. Future research may consider bigger datasets, more species of birds, and real-time sensors.

References

- [1] Albright, Thomas P., Anna M. Pidgeon, Chadwick D. Rittenhouse, Murray K. Clayton, Curtis H. Flather, Patrick D. Culbert, and Volker C. Radeloff. "Heat waves measured with MODIS land surface temperature data predict changes in avian community structure." *Remote Sensing of Environment* 115, no. 1 (2011): 245-254.
- [2] Chauhan, Srishti Singh, and Abhijeeta Nandha. "Biohybrid Urban Infrastructure Systems Incorporating Living Materials for Passive Mitigation of Urban Heat Islands and Improved Air Quality." In *Conference Archives*, pp. 37-55. 2026.
- [3] Cohen, Jeremy M., Diego Ellis-Soto, Shubhi Sharma, Frank A. La Sorte, and Walter Jetz. "Continental-Scale Biodiversity Predictions Are Influenced by Climatic Variability and Extreme Weather." *Global Change Biology* 32, no. 8 (2026): e71028.
- [4] Hussien, Gehad K., Mohamed H. Khafagy, and Hossam M. Elbehiery. "The Effect of Climate Change on Animal Diseases by Using Image Processing and Deep Learning Techniques." *International Journal of Advanced Computer Science and Applications* 16, no. 3 (2025).
- [5] Jambhekar, Ravi, Dilip GT Naidu, and Jagdish Krishnaswamy. "Effects of heat stress and green cover on urban birds in the megacity of Bengaluru." *Ecological Applications* 35, no. 3 (2025): e70039.
- [6] Kim, Jaeun, Kyeong-Seok Kwon, Soon-kun Choi, Jong-Bok Kim, Dong-Hwa Jang, Byeonghyeon Kim, and Seungsoo Kim. "BES-Driven Machine Learning Prediction of Future Energy Loads in Broiler Housing Under SSP Climate Scenarios in South Korea." *Animals* 16, no. 13 (2026): 2097.
- [7] Mosebo Fernandes, Ana Cristina, Rebeca Quintero Gonzalez, Marie Ann Lenihan-Clarke, Ezra Francis Leslie Trotter, and Jamal Jokar Arsanjani. "Machine learning for conservation planning in a changing

- climate." *Sustainability* 12, no. 18 (2020): 7657.
- [8] Mukesh, R., Deeptha, R., Sujatha, K., Dwarakanath, B., Arunkumar, S. M., & Sanmaya, G. (2026). A Coastal Case Study on Application of Convolutional Neural Networks for Red Tide Algal Bloom Image Classification. *Indian Journal of Information Sources and Services*, 16(2), 188–195. <https://doi.org/10.51983/ijiss-2026.16.2.20>
- [9] Silveira, Robson Mateus Freitas, Concepta Mcmanus, and Iran José Oliveira da Siva. "Global trends and research frontiers on machine learning in sustainable animal production in times of climate change: Bibliometric analysis aimed at insights and orientations for the coming decades." *Environmental and Sustainability Indicators* 26 (2025): 100563.
- [10] Solis, Isaac Lembi, Fernanda Paes de Oliveira-Boreli, Rafael Vieira de Sousa, Luciane Silva Martello, and Danilo Florentino Pereira. "Using thermal signature to evaluate heat stress levels in laying hens with a machine-learning-based classifier." *Animals* 14, no. 13 (2024): 1996.
- [11] Soravia, Camilla, Benjamin J. Ashton, Alex Thornton, and Amanda R. Ridley. "The impacts of heat stress on animal cognition: implications for adaptation to a changing climate." *Wiley Interdisciplinary Reviews: Climate Change* 12, no. 4 (2021): e713.
- [12] Valdivieso, Alejandro, Dafni Anastasiadi, Laia Ribas, and Francesc Piferrer. "Development of epigenetic biomarkers for the identification of sex and thermal stress in fish using DNA methylation analysis and machine learning procedures." *Molecular Ecology Resources* 23, no. 2 (2023): 453-470.