Academe *Journal of Education & Psychology* *ISSN: 2249-040X*
Volume-16, Issue-1, (Special Issue: June 2026) *Peer Reviewed & Refereed Journal (IF: 6.25)*
PP: 297-303 *Journal Website: www.academejournal.in*

SMART WILDLIFE MONITORING: THE USE OF ARTIFICIAL INTELLIGENCE IN ANIMAL BEHAVIOUR RESEARCH AND ITS ETHICAL DIMENSIONS

PRABHAKAR

Assistant Professor
Department of Zoology, Government First Grade College, Channapatna.

MANJULA S

Associate Professor
Department of Botany, Government First Grade College, Channapatna.

ABSTRACT

The integration of Artificial Intelligence (AI) into the study of animal behaviour has revolutionized ecological research, conservation biology, and animal welfare science. Traditional behavioural studies relied heavily on manual observation, which was time-consuming, prone to human bias, and limited in scale. AI technologies—particularly machine learning (ML), deep learning (DL), computer vision, and bioacoustic analysis—have enabled automated, large-scale, and highly accurate monitoring of animal behaviour across diverse ecosystems. Studies show that AI-based systems can achieve classification accuracies exceeding **90–95% in behaviour detection tasks**, significantly outperforming conventional methods (Tuia et al., 2022; Hou et al., 2026). Additionally, AI-enabled tracking tools such as GPS collars and accelerometers generate high-frequency data streams (up to **10–100 Hz per individual animal**), facilitating continuous behavioural analysis (Yu et al., 2021).

Despite these advancements, the deployment of AI in animal behaviour research raises complex ethical issues. These include concerns related to animal welfare, privacy, ecological disruption, data misuse, and algorithmic bias. For instance, intrusive tracking devices and AI-powered drones may alter natural behaviours, potentially compromising both ethical standards and data validity (Goyal et al., 2025). Furthermore, the environmental cost of AI systems, including energy-intensive computation, adds another dimension to ethical evaluation (Tuia et al., 2022).

This paper provides a comprehensive review of AI applications in animal behaviour studies, outlines methodologies used in AI-driven research, presents quantitative findings, and critically examines ethical challenges. The study concludes by proposing a framework for responsible AI deployment that balances scientific advancement with ethical accountability.

1. INTRODUCTION

The study of animal behaviour is central to understanding ecological dynamics, species interactions, and conservation needs. Historically, behavioural ecology relied on direct observation, tagging, and manual recording, which limited both spatial and temporal resolution. The emergence of AI has fundamentally transformed this field by enabling automated data collection and analysis at unprecedented scales.

AI technologies—including machine learning, deep neural networks, and computer vision—are increasingly applied to interpret complex behavioural patterns. These tools can process vast datasets from camera traps, drones, acoustic sensors, and biologging devices. For

example, AI-powered camera traps can process millions of images and identify species with accuracies exceeding **95%**, reducing manual labour by up to **90%** (Green et al., 2020; Congdon et al., 2022).

The global biodiversity crisis further underscores the importance of AI in conservation. According to recent estimates, over **1 million species are at risk of extinction**, necessitating scalable monitoring solutions. AI enables real-time tracking of animal populations, detection of poaching activities, and prediction of behavioural changes due to climate change (Isabelle & Westerlund, 2022).

However, the rapid adoption of AI raises ethical concerns. Questions arise regarding the impact of monitoring technologies on animal welfare, the potential misuse of sensitive ecological data, and the broader environmental footprint of AI systems. This paper explores both the opportunities and ethical dilemmas associated with AI in animal behaviour research.

2. METHODOLOGY

This study adopts a **systematic literature review approach**, synthesizing findings from peer-reviewed journals, conference proceedings, and academic book chapters published between 2020 and 2026.

2.1 Data Sources

The review includes articles from:

1. Nature Communications
2. PLOS ONE
3. MDPI (Animals, Sustainability)
4. Springer and Elsevier journals
5. Wiley Online Library

A total of **20+ scholarly articles** were initially identified, with **12 key studies** selected based on relevance, methodological rigor, and citation impact.

2.2 Inclusion Criteria

0. Studies involving AI/ML applications in animal behaviour
1. Research addressing ethical considerations
2. Empirical studies with quantitative results
3. Publications in English (2020–2026)

2.3 Analytical Framework

The selected studies were analyzed based on:

- AI techniques used (e.g., CNN, RNN, reinforcement learning)
- Type of behavioural data (visual, acoustic, movement)
- Accuracy and performance metrics
- Ethical considerations discussed

2.4 Limitations

- Rapid evolution of AI technologies may render some findings outdated

- Limited availability of standardized ethical frameworks across studies

3. APPLICATIONS OF AI IN ANIMAL BEHAVIOUR STUDIES

3.1 Computer Vision and Image-Based Behaviour Analysis

Computer vision has become a cornerstone of AI-driven behavioural studies. Deep learning models such as Convolutional Neural Networks (CNNs) are used to analyze images and videos from camera traps and drones.

For example, Tuia et al. (2022) report that AI models can classify animal species and behaviours with **over 90% accuracy** using large annotated datasets. Similarly, Hou et al. (2026) demonstrated that AI-based systems achieved **92.3% accuracy** in detecting giant panda behaviours.

These systems enable:

- Automated species identification
- Behaviour classification (feeding, mating, resting)
- Population density estimation

3.2 Bioacoustic Monitoring

AI is widely used in analyzing animal vocalizations. Acoustic sensors collect sound data, which is processed using ML algorithms to identify species and behaviours.

Sharma et al. (2023) highlight that AI-based acoustic monitoring systems can process **thousands of hours of audio data** with high precision, enabling detection of rare or nocturnal species.

3.3 Movement Ecology and Biologging

AI-enhanced tracking devices such as GPS collars and accelerometers provide continuous data on animal movement.

Yu et al. (2021) report that next-generation trackers can collect data at **10–100 Hz**, enabling fine-grained behavioural analysis. Machine learning models classify behaviours such as walking, running, and resting with accuracies exceeding **85–95%**.

3.4 Drone-Based Monitoring

Drones equipped with AI algorithms are used to monitor wildlife in inaccessible areas. These systems can:

- Track herd movements
- Detect poaching activities
- Monitor habitat changes

However, studies indicate that drone noise can alter animal behaviour, raising ethical concerns (Goyal et al., 2025).

3.5 Predictive Modelling and Conservation

AI is used to predict behavioural changes due to environmental factors such as climate change. Predictive models help in:

- Identifying migration patterns

- Forecasting species decline
- Designing conservation strategies

4. NUMERICAL INSIGHTS AND PERFORMANCE METRICS

Several studies provide quantitative evidence of AI effectiveness:

- **Species identification accuracy:** 90–96% (Tuia et al., 2022)
- **Behaviour classification accuracy:** 85–95% (Hou et al., 2026)
- **Data processing efficiency:** Reduction in manual labour by up to 90% (Green et al., 2020)
- **Sensor data frequency:** 10–100 Hz (Yu et al., 2021)
- **Image dataset sizes:** Often exceeding **1 million images** in large-scale studies

These metrics demonstrate the scalability and precision of AI systems compared to traditional methods.

5. ETHICAL CONSIDERATIONS

5.1 Animal Welfare

The use of tracking devices and sensors may cause stress or injury to animals. Ethical guidelines emphasize minimizing physical and behavioural disruption.

Obisa et al. (2025) note that improper deployment of monitoring devices can interfere with natural behaviours, compromising both welfare and data integrity.

5.2 Privacy and Data Security

AI systems generate large datasets containing sensitive ecological information. Unauthorized access could facilitate illegal activities such as poaching.

Kumari & Prabha (2026) highlight the need for secure data management frameworks to prevent misuse.

5.3 Algorithmic Bias

AI models may be biased due to imbalanced training data. This can lead to inaccurate predictions, particularly for rare species.

Bossert & Hagendorff (2021) emphasize the importance of diverse datasets to ensure fairness and reliability.

5.4 Environmental Impact

AI systems require significant computational resources. Training large models can consume substantial energy, contributing to carbon emissions.

Tuia et al. (2022) argue that the environmental cost of AI must be considered in conservation efforts.

5.5 Human–Animal Interaction

Technologies such as drones and camera traps may alter animal behaviour. Ethical frameworks must ensure minimal intrusion.

6. CHALLENGES AND LIMITATIONS

Despite its advantages, AI in animal behaviour research faces several challenges:

- **Data scarcity for rare species**
- **High computational costs**
- **Lack of standardized ethical guidelines**
- **Integration of interdisciplinary knowledge**

Additionally, AI systems may struggle with complex behaviours that require contextual understanding.

7. FUTURE DIRECTIONS

Future research should focus on:

- Developing **explainable AI models** for transparency
- Creating **global ethical standards**
- Integrating AI with **citizen science initiatives**
- Reducing **energy consumption** of AI systems

Emerging technologies such as **edge AI** and **federated learning** may address some of these challenges.

8. CONCLUSION

The integration of Artificial Intelligence into the study of animal behaviour represents a transformative shift in ecological research, offering unprecedented capabilities in data collection, analysis, and interpretation. Across diverse applications—ranging from computer vision and acoustic monitoring to biologging and predictive modelling—AI has significantly enhanced the scale and precision with which researchers can observe and understand animal behaviour. Empirical studies consistently demonstrate high performance, with behaviour classification and species identification often exceeding 85–95% accuracy, highlighting AI's effectiveness as a scientific tool. These advancements not only improve research efficiency but also contribute directly to conservation efforts by enabling real-time monitoring, early detection of threats, and informed decision-making in wildlife management (Tuia et al., 2022; Congdon et al., 2022).

However, the growing reliance on AI in animal behaviour research necessitates a critical examination of its ethical implications. One of the central concerns is animal welfare. While AI technologies are often promoted as non-invasive alternatives to traditional observation methods, their implementation—through tracking devices, drones, and sensor networks—can inadvertently disrupt natural behaviours or induce stress. As highlighted in multiple studies, even subtle disturbances can affect behavioural patterns, thereby influencing both ethical considerations and the validity of scientific findings (Goyal et al., 2025; Obisa et al., 2025). Consequently, minimizing harm and ensuring that technological interventions do not compromise animal well-being must remain a foundational principle.

In addition to welfare concerns, issues of data governance and privacy are becoming increasingly relevant. AI systems generate vast amounts of ecological data, including sensitive information about species locations and movement patterns. If misused, such data could facilitate illegal activities like poaching or habitat exploitation. Scholars emphasize the

importance of secure data management systems and controlled access protocols to mitigate these risks (Kumari & Prabha, 2026). Furthermore, algorithmic bias presents another challenge, as AI models trained on limited or unbalanced datasets may produce skewed results, particularly for underrepresented or rare species (Bossert & Hagendorff, 2021).

Another critical dimension is the environmental impact of AI itself. The computational demands of training and deploying large-scale machine learning models contribute to energy consumption and carbon emissions, raising questions about the sustainability of AI-driven conservation strategies. As Tuia et al. (2022) argue, the paradox of using resource-intensive technologies to protect the environment must be carefully addressed through more energy-efficient approaches.

Looking forward, the future of AI in animal behaviour research depends on the development of responsible and transparent frameworks that integrate ethical considerations into every stage of technological deployment. This includes designing less intrusive monitoring systems, improving model explainability, and fostering interdisciplinary collaboration between ecologists, technologists, and ethicists. Emerging approaches such as edge computing and federated learning offer promising pathways to reduce environmental impact while maintaining analytical power.

In conclusion, AI holds immense potential to revolutionize the study of animal behaviour and support global conservation efforts. Yet, its success will ultimately depend on the ability of researchers and policymakers to balance innovation with ethical responsibility. By prioritizing animal welfare, data integrity, and sustainability, AI can serve not only as a powerful scientific tool but also as a means of promoting a more ethical and informed relationship between humans and the natural world.

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