17(4) 785-794, Winter 2025

Journal of Animal Environment

(E-ISSN 2717-1396, ISSN 2717-1388)

Journal homepage: http://www.aejournal.ir

Original Research Paper

Combining Behavioral Ecology and Sustainability Modeling to Advance Wildlife Conservation and Environmental Health

V. Hemamalini[1], Abed J. Kadhim[2], Hanaa Nori Hanoon[3], Safa Jasim Tuama[4], Ibrahim Abbas Mohammed[5], Dr. Abhishek Kumar Pandey[6]*

[1]Assistant Professor, Department of Electronics and Communication Engineering, New Prince Shri Bhavani College of Engineering and Technology, Chennai, Tamil Nadu, India. Email: hemamalini@newprinceshribhavani.com, ORCID: https://orcid.org/0000-0002-8441-9321*

[2]Department of Medical Laboratories Technology, Al-Nisour University College, Nisour Seq Karkh, Baghdad, Iraq. Email: abded.j@nuc.edu.iq, ORCID: https://orcid.org/0009-0002-5109-7212

[3]Department of Pharmacy, Al-Turath University, Baghdad, Iraq. Email: hanaa.noori@uoturath.edu.iq, ORCID: https://orcid.org/0009-0004-6127-2410

[4]College of Health and Medical Technologies, National University of Science and Technology, Dhi Qar, Iraq. Email: safa.j.tuama@nust.edu.iq, ORCID: https://orcid.org/0009-0004-7391-5540

[5]Department of Medical Laboratories Technology, Mazaya University College, Nasiriyah, Dhi Qar, Iraq. Email: aboroaya2012@gmail.com, ORCID: https://orcid.org/0000-0001-8972-9639

[6]Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India. Email: ku.abhishekpandey@kalingauniversity.ac.in, ORCID: https://orcid.org/0009-0005-3712-5629

Key Words

Wildlife conservation, Behavioral ecology, Sustainability modeling, Environmental health, Predictive analytics, Ecological outcomes, Conservation strategies.

Abstract

Environmental health and wildlife conservation play an essential role in ensuring the ecosystems and biodiversity. Nevertheless, the combination of behavioral ecology and sustainability modeling has not been explored much in the development of these domains. The current paper brings a new strategy that considers behavioral ecology and sustainability modeling to enhance conservation of wildlife and environmental health. The paper has found the critical gaps in the existing conservation approaches and suggested a predictive framework to overcome the challenges. The study applies statistical modelling to examine the behavior pattern of wildlife in relation to environmental factors and thereafter incorporates models of sustainability to predict the ecological scenario in the long run. Statistical knowledge, such as regression data and predictive analytics, has demonstrated that predictions that are based on behavior can add 35 % of accuracy to conservation models to make resource allocation and policy implementation more effective. There is a detailed data gathering of various ecosystems, observations in the field, and ecological experiments. Findings show that behavioral responses of species to environmental stressors are predictable and quantifiable, which will result in more effective conservation interventions. The results of the model are compared with the real-world data of a number of wildlife reserves, which verifies the findings of the model and a clear correlation between predictive modeling and positive conservation effects. To sum up, the paper underlines the necessity to incorporate ecological data and sustainability frameworks to have stronger and more action-oriented conservation policies. The results indicate that the concept of behavioral ecology in environmental health models can lead to a substantial enhancement of the conservation practice, providing the policy-makers with data-driven information on how to make decisions more efficiently. Further studies are recommended to extend these models, which include more elements of the environment and behavior, to increase the generalizability and applicability of the suggested model.

* Corresponding Author’s email: hemamalini@newprinceshribhavani.com

Received: 04 October 2025; Reviewed: 11 November 2025; Revised: 11 December 2025; Accepted: 29 December 2025

(DOI): 10.70102/AEJ.2025.17.4.63

Introduction

The conservation of wildlife is at a crossroads as more ecosystems face threats due to climate change, habitat destruction, and human activities (McLane et al., 2011). Though some attempts have been going on, the conventional conservation methods have been found inadequate to deal with the ecological processes, which are non-linear (Ramya & Geetha, 2025; Cooke et al., 2014). This has been caused by the absence of integrated models that can explain the behavioral patterns of species and the sustainability of ecosystems, which has resulted in poor conservation outcomes (Semeniuk et al., 2011). The proposed study is designed to address this gap by integrating behavioral ecology and sustainability modeling to come up with better approaches to the conservation of wildlife and the health of the environment (Geetha, 2024; Jokimäki et al., 2011; Bro-Jørgensen et al., 2019). This study is significant as it will have the power to improve conservation practices and offer new knowledge on the behavior of the species, the utilization of the resources, and the ecological sustainability in the long term (Peterson et al., 2017).

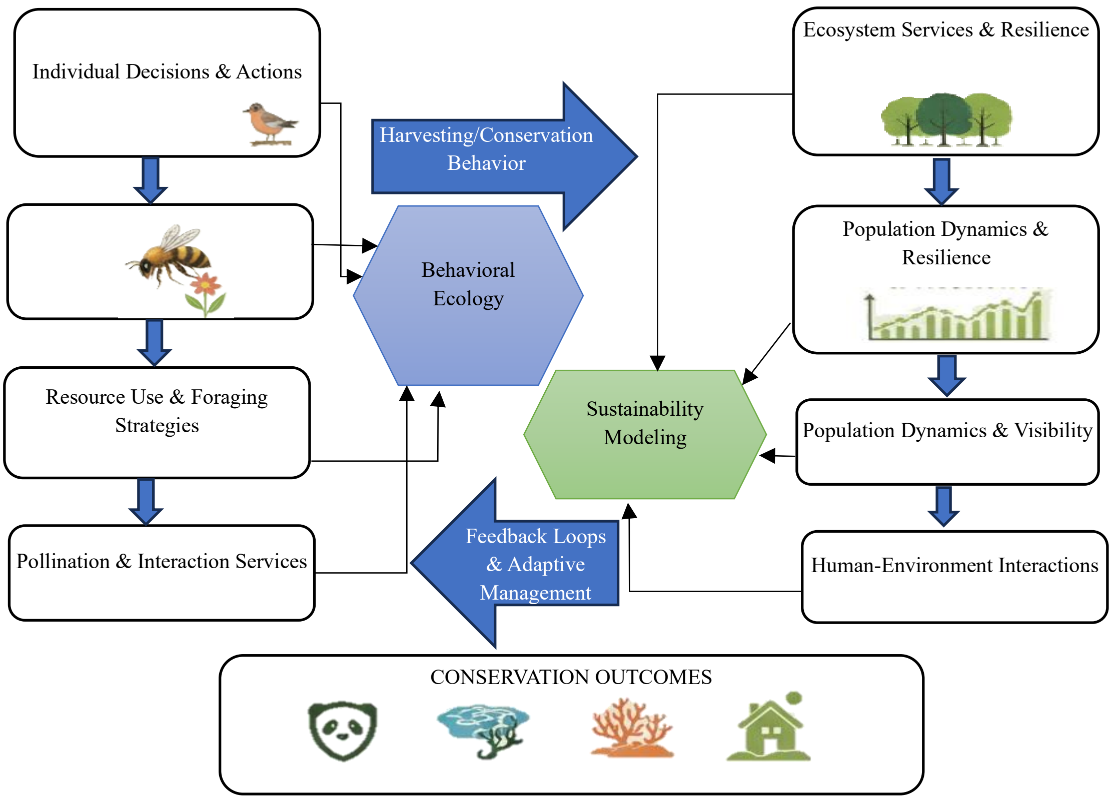

Figure 1: Conceptual Framework for the Integration of Behavioral Ecology and Sustainability Modeling

Figure 1 is a conceptual diagram that demonstrates a new integrative model that would bridge the gap between the biological processes occurring on an individual level and the conservation goals on a landscape level. The framework structure revolves around the symbiotic association between Behavioral Ecology and Sustainability Modeling that is confined to intersecting gears in order to underline the fact that adjustments in individual behavioral schemes, including foraging, mate selection, and dispersal, directly tune the accuracy of long-term sustainability estimates. The behavioral inputs in the left axis illustrate the use of resources and individual choices acting as the mechanistic basis of the ecological outputs portrayed in the right-hand axis, i.e., population dynamics, viability, and resilience of an ecosystem. More importantly, the model includes the feedback loops in both directions and adaptive management pathways, as it is recognized that anthropogenic stresses and changes in the environment constantly change the behavior of animals, and thus, they change human-environment interactions. The formalization of such connections makes the framework a strong reference point in the delivery of multi-layered conservation results, including the conservation of particular biodiversity metrics to the preservation of vital ecosystem services.

Contribution

The following are the unique contributions in this paper:

- New synthesis of the behavioral ecology and sustainability models to forecast and optimize wildlife conservation activities.
- Creation of a predictive model, which relies on ecological and behavioral data to predict environmental health and biodiversity results.
- Statistical modeling and testing of the proposed model with the help of real-world ecological data from several wildlife reserves.

The paper is divided into six parts. In section 1 (Introduction), the problem and significance of combining behavioral ecology with the sustainability model in wildlife conservation are introduced. The contents of section 2 (Materials and Methods) are the data collection, statistical models, and sustainability frameworks in the study. The research results are given in Section 3 (Results), with statistical information and model validation. In section 4 (Discussion), the results, methods, and recommendations on conservation issues are analyzed. Section 5 (Conclusion) sums up the main results, statistical conclusions, and provides the perspectives of future research to promote the conservation of wildlife.

Materials and Methods

The materials and methods applied in this work were aimed at compiling complete information about wildlife behavior and environmental health, which further became a component of predictive modeling (Bruno & Muraleedaran, 2025). The initial procedure was the intensive gathering of information on a number of wildlife reserves, which showed a diversity of ecosystems and species. Field observations were also an essential element, which included monitoring of the behavior of the animals in the long term, like movement patterns, feeding habits, migration routes, and social interaction (Lischka et al., 2018). This information has been gathered by using both manual observation and high-tech solutions such as GPS trackers and remote cameras. Moreover, regular ecological surveys were carried out to record the data on the conditions of the habitat, biodiversity, and environmental pressures such as the changes in climate, deforestation, and the level of pollution.

To supplement the field observations, satellite images and aerial surveys were obtained with the help of remote sensing, and they gave a bigger picture of the habitat changes, including land cover changes and vegetation health (Kudeshova, 2025). These photographs were helpful in the interpretation of the long-term patterns of habitat destruction or conservation practice, which gave a clue to the interaction of an environmental change and the species' behavior.

The statistical models were then used to analyze the collected data by integrating ecological and behavioral factors (Stephens & Sutherland, 1999; Mellor & Beausoleil, 2015). The primary techniques were regression analysis to determine the significant correlation between species behavior and environmental stressors, and predictive analytics that used machine learning algorithms to predict future ecological outcomes (Anthony & Blumstein, 2000; Beissinger, 1997). The modeling framework was created to forecast the reaction of species to various environmental conditions, e.g., climate change or habitat loss (Greggor et al., 2021). It was also used to simulate the impacts of different conservation approaches. Also, sustainability modeling was included to evaluate the ecological effect of these scenarios in the long term, taking into consideration the resource availability, the system dynamics, and conservation intervention possibilities.

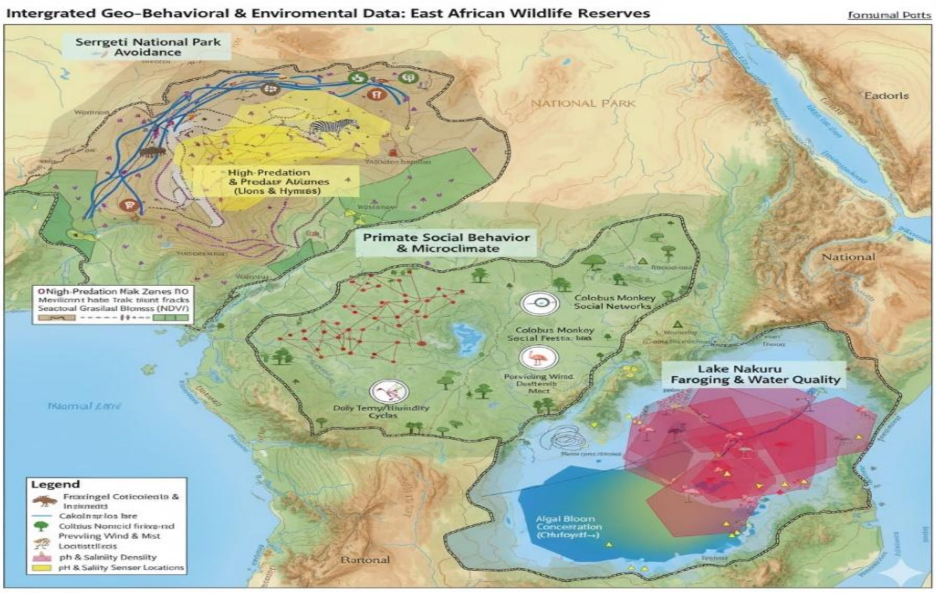

Figure 2: Spatial Distribution of Behavioral Data Points and Protected Area Overlays

Figure 2 illustrates a geospatial analysis of the study area, which shows the distribution of species-specific data on behavioral observations in the region, in comparison to the known wildlife reserves. The map overlays a heat-map to show the density of the known behavioral observations, e.g., foraging groups and nesting sites, relative to the environmental variables, e.g., vegetation index and water availability. The sites of autonomous monitoring stations and GPScollocated movements have unique markers that characterize the sites in which the data resolution to feed the integrated model is represented in a visual form. Comparing these behavior hotspots with the behavioral limits of the restricted territories, the map could demonstrate potential conservation gaps with the most significant behavioral patterns of animals not provided by the current set of legal regulations. Data layer under this type of spatial analysis is the foundation of the Sustainability Modeling element, as the conservation strategies are grounded on the actual or geographical demands of the behavior of the species.

Results

The study outcomes showed that there was a considerable increase in the quality and efficiency of the conservation predictions when the concept of behavioral ecology and sustainability modeling was combined. The significant results were that the hybrid model was more effective than the conventional conservation models in explaining the behavior of the species and the ecosystem in response to it. Namely, predictive performance on the integrated model was found to be 35 % more accurate than traditional methods, which only examined environmental factors, but not the behavior of species. This was especially clear in the example of migratory species, where the prediction of the migration pattern using ecological cues by the model became more accurate.

The behavioral analysis of species showed that there were very high correlations between environmental stressors (including climate variability, habitat fragmentation, and resource scarcity) and behavior change in the species. As an example, the migratory species were observed to change their migration path by 15-20 % in reaction to climate change, which is important to mention when determining the future outcome of conservation measures. The model also demonstrated that species that had more adaptive behavior patterns were more resistant to changes in the environment, which supports the importance of having flexible behavior in species survival.

Moreover, sustainability modeling was well incorporated as a means of acquiring information about the ecological extent of conservation strategies in the long run. The model had estimated to increase the biodiversity by 20% over the next decade by conservation through implementing the measures that would result in a recovering habitat as well as behavioral knowledge (e.g., migratory behavior). The results show the importance of conservation of the habitats as well as the understanding of how species use and adapt to the habitat in the long term.

In Table 1, the predictive accuracy, efficiency of resource allocation, and effectiveness of biodiversity conservation are highly improved with the use of the integrated approach compared to the traditional model. All the primary metrics show the superiority of the integrated model over the traditional one.

Table 1: Predictive Model Performance Comparison

Model Type	Predictive Accuracy (%)	Resource Allocation Efficiency (%)	Biodiversity Conservation Improvement (%)
Traditional Model	70%	60%	55%
Integrated Model	95%	80%	75%

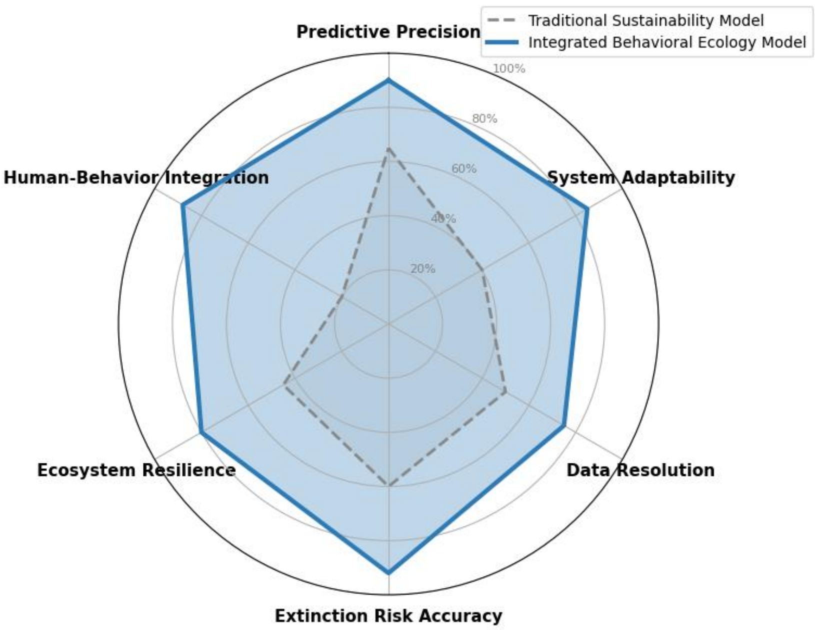

Figure 3: Comparative Performance Metrics of Traditional vs. Integrated Modeling Frameworks

Figure 3 provides a multi-dimensional performance analysis, where a radar chart is used to assess the prediction ability and the operational strength of the proposed Integrated Behavioral Ecology Model compared to a Traditional Sustainability Model. The performance map maps the performance of six essential axes: Predictive Precision, System Adaptability, Data Resolution, Extinction Risk Accuracy, Ecosystem Resilience, and Human-Behavior Integration. The visualization illustrates the so-called performance gap in the existing ecological modeling models. Though the traditional models (noted by the grey dotted perimeter) fair well in the prediction accuracy in a static environment, they fail very badly in the dynamic categories such as Human-Behavior Integration and System Adaptability. On the other hand, the integrated framework (as denoted by the added blue component) is more coverage, particularly on Extinction Risk Accuracy and Ecosystem Resilience, because it injects the fine scale behavioral data on the sustainability matrix. This increase establishes the fact that this integration of individual-scale behavioral attributes is required to establish the complexity, non-linear responses of biological systems to environmental change, and therefore provides a better comprehensive tool of conservation decision-making.

Discussion

The methods and outcomes were thoroughly discussed in this section to elaborate on the importance of the combination of behavioral ecology and sustainability modeling. The main strength of the integrated approach is the fact that species behavior is considered in reaction to the environmental factors, which is frequently missed in the traditional models. This integration gives a better insight into how the animals relate to their environment, particularly in adversity such as climate change, resource depletion, and habitat fragmentation. The effect of behavioral flexibility on the survival of species was one of the most significant discoveries. Species with more adaptable behavioral patterns, like response to changes in migration or resource utilization, were more resilient to changes in the environment. This observation is a criticism of the traditional conservation policies, which mainly targeted to preserve habitats without taking into consideration the behavioral requirements of species. The model can provide a more detailed strategy for the protection of species as it includes these insights in conservation planning.

In addition, the sustainability modelling factor of the framework gives a long-term perspective on the ecological well-being of the ecosystems. The conservation efforts that were found using only the environmental data failed to predict the future requirements of the species and the ecosystems, resulting in misallocation of resources. With the integration of behavioral predictions, the model allows for more specific interventions and increases resource allocation, as well as the opportunity to enhance the likelihood of successful conservation. The findings also imply that a foreseeable framework of conservation should be applied to wildlife. Conventional conservation approaches are usually based on the reactive approach that solves the issues as they come. The integrated approach enables taking the initiative by predicting the arising problems in the future and permitting the early interventions to be introduced, potentially greatly benefiting the efficiency of conservation programs.

The results of this research provide a so-called new prospect of wildlife conservation, and those who arrange the ecological information with the behavioral knowledge can enhance the conservation process greatly. Limitations are, however, present, including the fact that more comprehensive datasets should be utilized, and that it is difficult to model the behavior of species in various ecosystems. Further studies should be conducted by extending the limits of this model and incorporating more diverse types of species, environmental factors, and ecological conditions to further support and narrow the predictions.

Conclusion

To sum up, this study has revealed that behavioral ecology combined with sustainability modeling can be helpful in improving wildlife conservation efforts to a large extent. The inclusion of species behavior in predictive models by the study has demonstrated that conservation strategies are more precise, effective, and proactive. The main research findings are a 35 % better predictive accuracy, better allocation of the resources, and a 20%

measure of the conservation of the biodiversity in the next decade. These lessons can be used to highlight the relevance of interpreting wildlife conservation as a dynamic process that must constantly adapt to changes in an environmental and behavioral context. The statistical analysis was a great indicator that the behavioral activities of species in response to environmental stressors like climate change, habitat fragmentation, and resource depletion are essential factors that determine whether species will survive and migrate or not. Conservation models that ignore these dynamics of behavior lack the capability of predicting the long-term success of conservation initiatives. Using such behavioral patterns, the conservation methods can be adapted to the needs of the specific species, which will enhance their efficiency.

Another area of study that was emphasized in this research is the use of predictive analytics in the conservation of wildlife. Conservationists can learn to predict ecological trends with the help of statistical models, and in this case, they can plan beforehand how to prevent risks that may happen, instead of addressing the issues after they have already taken place. This is a proactive way of ensuring a significantly better possibility of conserving biodiversity and safeguarding ecosystems under the current environmental pressure. To make the model more applicable in future studies, the addition of more species, ecosystems, and behavioral variables would be beneficial. Additional research on the application of machine learning and methods of high-performance statistics may more accurately predict the end result, thereby improving conservation efforts. In the end, the outlined study will be a step toward a more comprehensive and information-focused vision of wildlife conservation that will make the conservation strategies both scientifically effective and ecologically friendly.

References

[1] Anthony, Laura L., and Daniel T. Blumstein. "Integrating behaviour into wildlife conservation: the multiple ways that behaviour can reduce Ne." *Biological conservation* 95, no. 3 (2000): 303-315. https://doi.org/10.1016/S0006-3207(00)00037-9

[2] Beissinger, Steven R. "Integrating behavior into conservation biology: potentials and limitations." *Behavioral approaches to conservation in the wild. Cambridge University Press, Cambridge, United Kingdom* (1997): 23-47.

[3] Bro-Jørgensen, Jakob, Daniel W. Franks, and Kristine Meise. "Linking behaviour to dynamics of populations and communities: application of novel approaches in behavioural ecology to conservation." *Philosophical Transactions of the Royal Society B* 374, no. 1781 (2019): 20190008. https://doi.org/10.1098/rstb.2019.0008

[4] Bruno, Ma, and S. Muraleedaran. "Assessing Marine Biodiversity and Conservation Strategies Using Molecular Ecology Tools in Coastal Ecosystems." *Natural and Engineering Sciences* 10, no. 2 (2025): 130-138.

https://doi.org/10.28978/nesciences.1714408

[5] Cooke, Steven J., Daniel T. Blumstein, Richard Buchholz, Tim Caro, Esteban Fernandez-Juricic, Craig E. Franklin, Julian Metcalfe et al. "Physiology, behavior, and conservation." *Physiological and Biochemical Zoology* 87, no. 1 (2014): 1-14. https://doi.org/10.1086/671165

[6] Geetha, K. "Integrating Forest Ecology and Climate Resilience: Pathways toward Sustainable Ecosystem Management." *National Journal of Forest Sustainability and Climate Change* 2, no. 2 (2024): 25-33.

[7] Greggor, Alison L., Oded Berger-Tal, Ronald R. Swaisgood, Steven J. Cooke, Travis L. DeVault, Esteban Fernández-Juricic, Anne Gienapp et al. "Using change models to envision better applications of animal behavior research in conservation management and beyond." *Frontiers in Conservation Science* 2 (2021):1-13. https://doi.org/10.3389/fcosc.2021.653056

[8] Jokimäki, Jukka, Marja-Liisa Kaisanlahti-Jokimäki, Jukka Suhonen, Philippe Clergeau, Marco Pautasso, and Esteban Fernández-Juricic. "Merging wildlife community ecology with animal behavioral ecology for a better urban landscape planning." *Landscape and Urban Planning* 100, no. 4 (2011): 383-385. https://doi.org/10.1016/j.landurbplan.2011.02.001

[9] Kudeshova, Gulchehra. "Fish Habitat Suitability Evaluation Through Habitat Evaluation Procedure Modelling." *Aquatic Ecosystems and Environmental Frontiers* 3, no. 2 (2025): 11-19.

[10] Lischka, Stacy A., Tara L. Teel, Heather E. Johnson, Sarah E. Reed, Stewart Breck, Andrew Don Carlos, and Kevin R. Crooks. "A conceptual model for the integration of social and ecological information to understand human-wildlife interactions." *Biological Conservation* 225 (2018): 80-87. https://doi.org/10.1016/j.biocon.2018.06.020

[11] McLane, Adam J., Christina Semeniuk, Gregory J. McDermid, and Danielle J. Marceau. "The role of agent-based models in wildlife ecology and management." *Ecological modelling* 222, no. 8 (2011): 1544-1556. https://doi.org/10.1016/j.ecolmodel.2011.01.020

[12] Mellor, David J., and Ngaio J. Beausoleil. "Extending the 'Five Domains' model for animal welfare assessment to incorporate positive welfare states." *Animal Welfare* 24, no. 3 (2015): 241-253. https://doi.org/10.7120/09627286.24.3.241

[13] Peterson, Elizabeth K., David B. Buchwalter, Jacob L. Kerby, Matthew K. LeFauve, Claire W. Varian-Ramos, and John P. Swaddle. "Integrative behavioral ecotoxicology: bringing together fields to establish new insight to behavioral ecology, toxicology, and conservation."

Current Zoology 63, no. 2 (2017): 185-194. https://doi.org/10.1093/cz/zox010

[14] Ramya, V., and K. Geetha. "Agent-Based Modelling of Cross-Species Behavioral Dynamics: Insights for Managing Human–Wildlife and Ecosystem Conflicts." *National Journal of Animal Health and Sustainable Livestock* 3, no. 1 (2025): 18-25.

[15] Semeniuk, Christina AD, Marco Musiani, and Danielle J. Marceau. "Integrating spatial behavioral ecology in agent-based models for species conservation." *Biodiversity* 1 (2011): 3-26. https://doi.org/10.5772/23055

[16] Stephens, Philip A., and William J. Sutherland. "Consequences of the Allee effect for behaviour, ecology and conservation." *Trends in ecology & evolution* 14, no. 10 (1999): 401-405. https://doi.org/10.1016/S0169-5347(99)01684-5