Journal of Animal Environment
(E-ISSN 2717-1396, ISSN 2717-1388)
Journal homepage: https://aejournals.org/

Original Research Paper

Eco Stress Prediction Model for Assessing Combined Effects of Climate Change and Human Disturbances on Wildlife

Dr. Sandeep Soni[1*], Dr. Rajvir Saini[2], Praveen Kumar Joshi[3]

[1]Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India. Email: ku.sandeepsoni@kalingauniversity.ac.in, ORCID: https://orcid.org/0009-0000-3692-6874*
[2]Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India. Email: ku.rajvirsaini@kalingauniversity.ac.in, ORCID: https://orcid.org/0009-0000-6644-0795
[3]Assistant Professor, New Delhi Institute of Management, New Delhi, India. Email: praveen.joshi@ndimdelhi.org, ORCID: https://orcid.org/0009-0007-7777-8178

Key Words

Multiple stressors, Climate change, Human disturbance, Cumulative risk, Wildlife behavior, Population decline, Resource selection.

Abstract

Traditional wildlife conservation hotspots may no longer be ecological priorities for the future as climate change continues to alter environmental circumstances. The present strategies primarily rely on current species distributions and habitat suitability, for which future conservation effectiveness under climate change cannot be assured. This paper, therefore, presents a Climate Risk Mapping Approach to identify the future conservation hotspots and potential climatic refugia, which combines species occurrence data, habitat traits, potential climate risk, perturbation, and anthropogenic impact. Combining knowledge from climate risk assessment, species range dynamics, fire vulnerability, biodiversity hotspot research, and human-wildlife interactions, this approach aims to support effective adaptive conservation management. It enhances future foresight of ecological persistence and potential deteriorations with efficient conservation resource allocation and climate-ready biodiversity conservation in various environments, although it needs extensive field validation.

* Corresponding Author's email: ku.sandeepsoni@kalingauniversity.ac.in
Received: 25th May, 2026; Revised: 6th June, 2026; Accepted: 8th June, 2026; Available Online: 07th August, 2026
(DOI): 10.70102/AEJ.2026.18.3s.76

Introduction

Wildlife populations worldwide face pressures of climate change and human disturbances, leading to the need for an understanding of the interactions of these two types of stressors. It has been shown that interactions between stressors may or may not result in predictable outcomes since the effects can be greater or lesser than the mere sum of effects observed for each individual stressor. Studies assessing the effects of stressor interactions have demonstrated that can be synergistic, additive, or antagonistic depending on the combination of stressors employed, and that prior adaptation to the first stressor may change how the affected organism responds when the second stressor is introduced (Shahid et al., 2024). Meanwhile, research showing how human activity affects globally endangered terrestrial mammals has indicated that human pressure alone is capable of causing significant changes in behavior, which can often be detected even before population decline (Zhang et al., 2023). Research aimed at establishing a cumulative risk method for managing the impact of various stressors on wildlife populations has additionally shown that evaluating stressors separately often leads to the underestimation of the true risk a population is exposed to. This is due to the likelihood that the stressors interact, thereby resulting in effects that are higher than those predicted by a single-stressor risk assessment (Tyack et al., 2022).

The proposition of the Eco Stress Prediction Model is a response to the gap that is indicated in various studies as those studies have shown that while the interaction effects of stressors; behavior change in humans due to climate; and cumulative risk approach have individually been proved to work as predicted wildlife risk assessment does not yet have a robust prediction framework which would visualize the interactions between climate and human disturbance taking these and other key elements.

This article has three major contributions. The first contribution is the development of the model structure, which establishes the link between climate stressors and human disturbance with regard to joint effect rather than additive impact. The second contribution of the paper is the premise that behavior change may act as a first indicator of joint stress exposure based on the fact that change in behavior precludes the observation of the decline in population. Finally, the article is pioneering the use of the model and prediction by focusing on the outcomes at the population level.

The rest of this paper is structured as follows. Section II discusses a review of stress assessment methods using a single factor. Recent studies on the influence of weather and human activities on species distribution, the expected timing of extinction, and the cumulative effect on the selection of resources throughout the seasons are used here. Section III presents the proposed model schematics. Section IV provides outcome analysis and the performance of the model when compared with the single-factor methods reviewed in Section II. Finally, Section V lists the conclusions and possible routes or directions for future validation.

Review of Single-Factor Stress Assessment Approaches

The research conducted on the influence of human activities and climate conditions on the distribution of the pine wood nematodes in China concluded that climate suitability and human impact explain some of the distribution pattern when considered separately. Thus, models based on one factor fail to identify large risk areas compared to models incorporating both factors (Zhang et al., 2024). In assessing animal population drop predictors, it has been shown that signals indicating population collapse appear before the actual drop, but the problem is that methods aimed at measuring a single factor rarely see these signals at an earlier time, as factors producing the signals are actually associated with different sources of impacts, making the signals unclear (Cerini et al., 2023). The presented study about the overall impact of human influence, environmental factors, and over-predation risk on the choices made by white-tailed deer when selecting resources demonstrates that models based on the combination of all of these factors perform much better in explaining the data than models focused on only one type of data (Darlington et al., 2022).

Recent studies highlight a common limitation of single-factor stress assessments across diverse species and ecosystems. Species distribution studies show that ecological influences such as climate and human activity give only partial explanation when taken separately but are much more accurate when combined in models than would be when considered individually. Population crash studies demonstrate that signals of impending decline tend to arise from interactions of stressors rather than from any single indicator, which means that monitoring processes that use one pressure only can be ignorant of alerts that enable timely actions. Resource selection studies indicate that using a combination of anthropogenic disturbances, habitat characteristics, and predation risk provides more accurate predictions than considering each of the variables independently. Taken together, these studies indicate that evaluating climate change and anthropogenic disturbance as separate and additive stressors is not sufficient for accurate prediction of impacts on extinction risk and underline the importance of a model considering stressor interactions, using behavioral or resource selection indicators as early signals of negative processes caused by combined stressors, and taking into account the scale of stressor interactions as compared to effects of individual stressors.

Model Design for Combined Disturbance Prediction

Stressor Characterization and Interaction Structure

At the outset, the model identifies separately the type of climate stress and anthropogenic pressure affecting a population, whether it is temperature shock and change in precipitation patterns or habitat alteration and the existence of human infrastructures and actions. Instead of simply considering stressors as being additive, the model incorporates interactions among the stressors based on the notion that particular stressor pairs can result in either synergistic or antagonistic effects depending on specific composition and intensity. The interaction structure also takes into account previous adaptation, meaning that a particular population is already sensitized to stressor influence before being exposed to another stressor.

Behavioral Response and Resource Selection Layer

The behavioral response model built on this stressor interaction structure, documents alterations in an activity timing, movement, and habitat use a as an early warning signal for exposure to multiple stressors, relying on existing evidence that behavioral adjustment often anticipates measurable reductions in population numbers. The addition of a resource selection sub-model that simultaneously predicts use of 3 major explanatory components (predation risk, natural habitat selection, and human impact) leverages information that multiple parameter resource selection models substantially exceed single parameter selection models, in doing so enabling the model to document changes in the way a population utilizes available habitats in response to increasing or decreasing combined stress levels over time.

Population Risk and Early Warning Signal Layer

The final level of the model then synthesizes interaction between stressor, behavioral or habitat change into a prediction of risk to the population. Within this last level prediction based on the pattern of a progression through a series of early warning indicators, as in several prediction of population collapse. Essentially, this will allow the model to detect populations going through a recognizable pre-collapse warning pattern, in the few cases when such patterns can be observed by means of direct population monitored at all, at a level which is expected to allow the detection before the pre-collapse pattern starts to evolve.

Outcome Analysis and Comparative Performance

Anticipated Model Outcomes

As yet the model has not been used with field measured population data, so base predictions of its behavior on trends found in other multi-stressor literature: 'Since that it have shown that the interactions among stressors could result in positive or negative effects depending of history of adaptative exposure to them the structure of the model of interactions should show significant difference from linear combination of stresses when it's used for populations with history of previous exposition to stresses, and As shown there are many reports of behavioral change in threatened mammals exposed to disturbance, this phenomenon indicate that human disturbance should be an interesting independent variables and model for behavioral changes should be robust to include many mammals.

Comparison with Single-Factor Assessment Approaches

In comparison to assessment methods, which analyze climatic and anthropogenic influences separately, this model is expected to result in superior risk prediction capabilities, in line with species distribution studies indicating that models employing combined climate and human activity variables yield better explanatory power than models using only one factor. In comparison to population monitoring approaches that rely entirely on demographic data for detection of decline, this model is equipped with supplementary behavioral and resource components, which should allow for earlier detection. In comparison to resource selection models that are based on either anthropogenic disturbances or natural habitat characteristics alone, this model is expected to improve the predictive accuracy of the results by taking into account the human footprint, habitat characteristics, and predation risk collectively as evidenced in the research on the resource selection of white-tailed deer.

Implications and Limitations

Early warnings triggered not just when demographic factors turn negative but from the interaction of stressor components has direct implications for the timeliness of conservation intervention; for instance, future interventions for combined-climate and human impact-stress might target populations displaying early combined-stress warning signs before condition deteriorates towards a predictable population collapse. The main constraints of this model are that it has not yet been applied and validated on field-monitored populations; for it to be reliable requires time series of behavioral, habitat-use, and demographic factors within the same population and over sufficient duration to allow for assessment of interactions-a type of information seldom obtained in the wild for most taxa. The combinatorial information on the model might also require a sufficient, long-term stressor exposure history, a prerequisite which might not be met in species or areas of the world not been extensively investigated.

Conclusion

In this paper, the authors introduce the Eco Stress Prediction Model, which serves as a conceptual framework that can allow the examination of the effects of climate change as well as the human effects on animal populations that articulates interaction in detail and connects such an interaction with behavioral, resource selection and population outcomes. The Eco Stress Prediction Model has considered the weaknesses of the existing approach to analyzing climate change or anthropogenic activity impacts on wildlife that includes a lack of the analysis of issue of the effects three different organisms experience at once and the application of combined assessment technique resulting in accurate predictions related to impacts of climate changes on animal species. Further testing of the Eco Stress Prediction Model in animals, ecosystems, and interactions between anthropogenic effects and climate changes remains vital for future studies on stressors.

References

[1] Shahid, Naeem, Ayesha Siddique, and Matthias Liess. "Predicting the combined effects of multiple stressors and stress

adaptation in Gammarus pulex." *Environmental science & technology* 58, no. 29 (2024): 12899-12908. https://doi.org/10.1021/acs.est.4c02014

[2] Zhang, Chao, Yumei Li, Xiaoyu Hu, Xiaofan Ma, Wei Jia, Kai Liu, and Yonggang Nie. "Human-induced behavioural changes of global threatened terrestrial mammals." *Global Ecology and Biogeography* 32, no. 9 (2023): 1645-1659. https://doi.org/10.1111/geb.13710

[3] Tyack, Peter L., Len Thomas, Daniel P. Costa, Ailsa J. Hall, Catriona M. Harris, John Harwood, Scott D. Kraus et al. "Managing the effects of multiple stressors on wildlife populations in their ecosystems." *Proceedings: Biological Sciences* 289, no. 1987 (2022): 1-15. https://doi.org/10.1098/rspb.2022.2058

[4] Zhang, Liang, Ping Wang, Guanglin Xie, and Wenkai Wang. "Evaluating the impact of climate change and human activities on the potential distribution of pine wood nematode (Bursaphelenchus xylophilus) in China." *Forests* 15, no. 7 (2024): 1253. https://doi.org/10.3390/f15071253

[5] Cerini, Francesco, Dylan Z. Childs, and Christopher F. Clements. "A predictive timeline of wildlife population collapse." *Nature Ecology & Evolution* 7, no. 3 (2023): 320-331. https://doi.org/10.1038/s41559-023-01985-2

[6] Darlington, Siobhan, Andrew Ladle, A. Cole Burton, John P. Volpe, and Jason T. Fisher. "Cumulative effects of human footprint, natural features and predation risk best predict seasonal resource selection by white-tailed deer." *Scientific Reports* 12, no. 1 (2022): 1072. s://doi.org/10.1038/s41598-022-05018-z