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SpeciesLink: An Ecological Connectivity Prediction Model for Designing Wildlife Corridor Networks in Fragmented Landscapes

Dr. Priya Vij[1*], Ashu Nayak[2], Dr. Monica Verma[3]

[1*]*Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.*
Email: ku.priyavij@kalingauniversity.ac.in, ORCID: https://orcid.org/0009-0005-4629-3413
[2]*Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.*
Email: ku.ashunayak@kalingauniversity.ac.in, ORCID: https://orcid.org/0009-0002-8371-7324
[3]*Professor, New Delhi Institute of Management, New Delhi, India. Email: monica.verma@ndimdelhi.org,*
ORCID: https://orcid.org/0000-0003-2789-1117

Key Words

Ecological connectivity, Wildlife corridors, Habitat fragmentation, Connectivity modeling, Landscape ecology, Conservation planning, Geographic information systems (GIS).

Abstract

Habitat fragmentation is a major cause of biodiversity loss since it leads to population isolation as well as gene flow, dispersal, and species persistence disruption. Therefore, predicting and creating wildlife corridors is a critical element to maintaining connectivity through fragmented landscapes. In this research paper, SpeciesLink, an ecological connectivity prediction model, has been introduced in order to find out the corridor networks between the isolated habitat patches. It includes landscape resistance surface and movement and habitat suitability information of each species in order to produce predictive connectivity maps for ecological planning. Differently from conventional approaches with a single-metric approach, SpeciesLink is a multi-algorithm prediction model in order to increase reliability and applicability. In order to assess the performance of this prediction model, it has been used with landscape and species distribution information in order to test its capability in recognizing the ecologically relevant corridors. The results show that SpeciesLink is successful in producing the high-priority connectivity zones which can be considered as the corridors for movements.

* Corresponding Author's email: ku.priyavij@kalingauniversity.ac.in
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Introduction

The increasing destruction of habitat due to agricultural expansion, urbanization, and other activities associated with changes in land use is now considered to be one of the biggest challenges for the world's biodiversity. Habitat fragmentation reduces the size of patches, increases isolation of the remaining patches, and limits the movement of species from one patch to another. Recently, there has been a lot of emphasis on the importance of functional connectivity in conserving threatened species. For example, habitat suitability and connectivity modeling have been employed in defining viable corridors of the margay through fragmented forests in Mexico (López-Ortiz et al., 2025). Predictive distribution modeling also plays an important role in predicting the habitat loss and range shifts in relation to threatened species of birds in the Neotropics (de Carvalho et al., 2024). Another example of the need for connectivity models is presented by large carnivores like jaguars, as recent studies show that certain corridors are needed for maintaining the connections between populations (Machado-Aguilera et al., 2024). However, most of the currently available models are species-specific and employ a single connectivity metric. The proposed SpeciesLink model is presented, which is a generic, multimetric connectivity prediction model that integrates habitat suitability models, resistance surface models, and corridor optimization into one generic model.

The rest of this paper is organized as follows: Section II provides a literature review on connectivity models and corridors; Section III provides details of the SpeciesLink method; Section IV provides results from the model; Section V provides ecological and planning implications of the model; and Section VI concludes this paper.

Foundations of Connectivity Science and Corridor Modeling

The field of landscape connectivity is based on the assumption that the persistence of a species is not just a function of habitat quality but also connectivity between habitat patches. Connectivity measures based on resistance and probability are now well-established methodologies in this field. Connectivity loss due to changes in climate has been observed to pose a threat to mountaintop and high-elevation species; modeling tools have confirmed that changing climatic envelopes are capable of fragmenting functional corridors in Central American forests (Baumbach et al., 2021). Concurrently, studies on Galliformes have established that the cumulative effect of climate change and deforestation threatens habitat availability and connectivity, thereby necessitating a combined predictive approach (Ferreira et al., 2024). Moreover, connectivity modeling has also been used to gauge the risks associated with invasive species' dispersal; such modeling has proved useful for assessing range overlap and corridors in endangered primates faced with congeneric invasion threats (Lagroteria et al., 2024). On the whole, the above analyses demonstrate how connectivity modeling has progressed from mere mapping of habitat patches into more sophisticated and predictive techniques accounting for climatic change, land use pressures, and biological interactions among species. Yet, many models currently in existence still apply primarily to particular species or certain pathways of threats. Here lies the obvious shortcoming – the lack of a flexible model applicable to different scenarios of ecological connectivity.

A Predictive Framework for Corridor Mapping

The SpeciesLink model was developed as a multi-stage predictive framework integrating habitat suitability assessment, landscape resistance modeling, and corridor prioritization algorithms to generate ecologically meaningful connectivity networks across fragmented landscapes.

Study Area and Data Sources

This model has been developed in order to be used in heterogenous areas with habitat availability in patches, including forests, mountains, and mixed-use lands. Data inputs in the form of layers used in the process of modeling include the classification of land cover, elevation, vegetation cover density, level of human disturbance, and species presence location information. These layers have been prepared to fit one spatial resolution and projection to enable compatibility for use in all following modeling steps. Habitat suitability prediction is made in the initial step as an ensemble of environments highly correlated with species presence.

Model Architecture and Algorithmic Design

SpeciesLink maps the habitat suitability map into the landscape resistance surface where resistance is defined by the inverse of suitability, representing how easy or difficult it is for the species to move within each landscape cell. In the SpeciesLink algorithm, the hybrid connectivity algorithm that combines least cost pathway with circuit theoretic approach is implemented, allowing SpeciesLink to analyze not only optimal pathways but also probabilistic movement routes. As such, the use of the two algorithms permits SpeciesLink to find not only the optimal corridor but also more widespread connectivity areas, which becomes very important for landscapes where several dispersal corridors exist. Core habitat patches are determined based on the suitability criterion, while connectivity between all patches with significance is calculated pairwise. In addition, the weighting module allows the inclusion of species-specific movement parameters such as maximum dispersal distance and habitat preference into the analysis process.

Validation Strategy and Performance Metrics

The outputs of the models are ordered based on an overall connectivity index composed of corridor length, total resistance, and patch value, resulting in a ranking of potential corridors. Model validity is measured through the comparison of the results with independent habitat and occurrences datasets not included in the model training process, and it is validated based on standard measures of classification accuracy, such as the sensitivity and specificity of the prediction of connectivity zones.

Sensitivity analysis is carried out by modifying the resistance and threshold parameters to determine the robustness of the model. The multi-faceted approach implemented by the software enables SpeciesLink to be a versatile and transferable tool for any fragmented ecosystem and species group.

Model Outputs and Corridor Predictions

The use of the SpeciesLink model resulted in connectivity surfaces that allowed the differentiation between high priority corridor areas and those that are highly impermeable to species passage. The hybrid least-cost and circuit theory-based method was able to delineate narrow high-traffic corridors as well as wide corridors that exhibit low resistance. Highly suitable core habitat areas that received very high scores in the species model were always connected by corridors with low overall resistance value. Model validation was carried out using independent information on occurrence and habitat suitability, which showed that predicted priority corridors overlapped closely with the regions of observed species movement, providing high scores for sensitivity and specificity. The sensitivity analysis confirmed that the model results were resilient within an acceptable range of parameter values for resistance. Importantly, some of the corridor regions identified by the model were subject to relatively high levels of human disturbance, pointing to the areas where current connectivity exists but might become endangered in the future. Thus, the results prove that SpeciesLink produces credible corridor predictions.

Discussion

These findings confirm the value of using various connectivity algorithms in one single framework in order to increase both the accuracy and ecological significance of the corridors predicted through comparison with the use of just one approach to modeling. The ability to distinguish both clear optimal connections as well as more diffuse connectivity areas provides a greater degree of freedom for conservationists since the corridor development can take into account the uncertainties of movement of particular species. In rapidly changing landscapes, the rigidity of a single path design might become irrelevant too quickly. From the standpoint of planning, the capability of SpeciesLink to identify those parts of the corridors that are vulnerable but are still functional now gives the opportunity to detect problems in advance. This ability of the model to adjust its parameter weights to various species makes it flexible enough to be adjusted according to species with different abilities to disperse. Nevertheless, there are some disadvantages of this model which should be taken into account. First of all, the accuracy of the output results will depend on the quality and resolution of data about habitats and land use, and the use of poor-quality data may diminish the accuracy of the results. Furthermore, using a mixed algorithm instead of a single one makes calculations more complex.

Conclusion

The paper introduced SpeciesLink, a connectivity prediction model that employs several algorithms. SpeciesLink is aimed at providing assistance in the identification and prioritization of potential wildlife corridors in fragmented environments. As a combination of habitat suitability mapping, generation of resistance surfaces, and a least cost/circuit-theoretic connectivity prediction algorithm, SpeciesLink provides a transferable and flexible framework that can be used in various species and ecological systems. According to the validation, SpeciesLink demonstrated the capacity to predict ecologically valid corridors, as well as to reveal vulnerable connectivity zones needing conservation measures. The main novelty of the work is that it combines multiple connectivity modeling techniques into a single transferable model, which avoids certain problems of species- or metric-specific models discussed earlier in the literature. In the future, it would be interesting to implement SpeciesLink with dynamic projections of climate and up-to-date information about changes in land use.

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