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EcoLandscape Intelligence Model for Assessing Habitat Fragmentation Impacts on Wildlife Movement Patterns

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Key Words

Habitat fragmentation, Wildlife movement, Landscape ecology, Ecological modeling, Habitat connectivity, Spatial analysis, Conservation planning.

Abstract

One of the most concerning factors contributing to biodiversity reduction in terrestrial habitats is habitat fragmentation, which influences the natural dispersal patterns of wildlife. When fragmentation patches become smaller and farther from each other, there is higher dispersal difficulty, reduced gene flow, and a higher risk of extinction for certain species. The current paper presents Eco Landscape Intelligence Model, a conceptual analytical model that helps to determine the relationship between the degree of habitat fragmentation and changes in the movement patterns of wildlife based on landscape ecological data. The model takes into consideration fragmentation indices such as size of patch, edge density and connectivity index along with wildlife movement data obtained through telemetry or field observation in order to find out how landscape affects animals' movement and their utilization of wildlife corridors. Landscape data was examined in the context of a representative case of a fragmented landscape with different habitats and selected focal species. The results demonstrate a correlation between the level of fragmentation and changes in movement efficiency, corridor choice and animal behavior in general. The current paper shows that intelligence-based methods can be used to identify key corridors for wildlife and fragmentation sites that need further protection.

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Introduction

The fragmentation of habitat, which is a process where large and continuous habitats are split into small and isolated fragments, is one of the main threats to the animal populations around the world. The fragmentation changes the landscape structure, restricting the mobility of the animals, affecting their migration paths, and reducing their genetic interactions as the characterization of the landscape of movement has been found to be necessary in determining the critical habitat areas and corridors (Bastille-Rousseau & Wittemyer, 2021).

With the recent developments in the field of artificial intelligence, some new approaches have emerged in ecological research. The use of AI-based methods has been found to allow the evaluation of animal health conditions and predicting the effects of degradation of the habitat in ways that go beyond field-based studies (Mangaiyarkarasi et al., 2025). Machine learning algorithms can also be used for monitoring endangered animals and evaluating the effects of the habitat fragmentation (Manikandan et al., 2025).

An innovative EcoLandscape Intelligence Model has been developed in this research by combining the fragmentation indices with information on wildlife mobility to produce a comprehensive predictive analysis of the landscape connectivity.

This paper proceeds as follows: In Section II the literature is discussed; in Section III methodology is presented; in Section IV results are presented; in Section V results are analyzed; and finally in Section VI conclusions are drawn.

Literature Review

The phenomenon of habitat fragmentation should be analyzed not only from the perspective of the structural characteristics of landscapes but also from the point of view of ecological connectivity providing the survival of species. There is an increasing number of studies focusing on the way vegetated and green infrastructure elements in built-up areas can provide valuable assistance for creating habitat connectivity and facilitating species' movements.

Greeneries on tall buildings have already been studied in order to understand the potential role of structural greening interventions as additional elements of habitats within the context of fragmented urban matrix (Al-Kodmany, 2023). Following this line, biophilic design principles in 3D green spaces have already been discussed as guidelines concerning the building technology, selection of plants, and maintenance issues showing that vertical ecosystems have more than merely aesthetic functions (Zhong et al., 2024). Confirming this trend, nature-based solutions including vertical greenery systems have been considered in terms of their advantages and implementation issues in urban buildings (Theodoridou et al., 2025).

In summary, these researches collectively indicate that landscape connectivity does not necessarily emerge from natural habitat structures alone; rather, it can significantly depend on human-made green infrastructure

placed in modified landscapes. Although the reviewed papers do not provide modeling wildlife movements, they highlight one general ecological idea: the increase of vegetative cover structure, either natural or man-made, has an impact on fragmentation isolation effect. It is the direct insight into the current study's approach to designing an intelligence-based model of landscape connectivity as a continuous multi-source variable, which includes both natural habitat structure and additional green infrastructure.

Methodology

This investigation made use of an integrated, data-centric approach to analyze the link between habitat fragmentation and wildlife movement in a sample fragmented landscape.

3.1 Study Site and Target Wildlife

The research took place in a diverse landscape that had forests, grasslands, and land areas modified by human activities. Focal wildlife was those that depended on habitat connectivity in terms of dispersal, foraging, and migrations. The landscape was one that provided a spectrum of fragmentation levels from continuous blocks of habitat to highly fragmented patches.

3.2 Data Collection

Three main sources of data were collected. The first source was the data related to animal movement patterns. They included GPS telemetry collar data on individual animals and camera trap data at corridor pinchpoints to confirm the existence of movement corridors. The second source of data was related to the landscape structure, which comprised patch boundaries, vegetation cover and land use. Finally, environmental covariates such as elevation, proximity to water bodies and seasonal vegetation cover were used to control the impacts of factors other than fragmentation on animal movement patterns.

3.3 Fragmentation Metrics

Landscape fragmentation was measured by the conventional ecological indices such as patch size (average area of contiguous habitat patches), edge density (perimeter to area ratio of patches measuring patch boundary exposure), isolation index (distance-based measure of patch isolation), and the connectivity index that integrated the patch proximity and matrix permeability.

3.4 Framework of EcoLandscape Intelligence Model

The EcoLandscape Intelligence Model is an analytical framework that incorporates movement and fragmentation data to predict the connectivity assessment based on them. The framework uses movement trajectories and fragmentation metrics in order to determine the patterns of corridor usage, movement resistance and behavioral reaction to landscape fragmentation. The movement trajectories have been split into particular steps and assigned to the fragmentation conditions of the patch or matrix elements where the particular movement occurred. As a result, it became possible for the model to assess how the efficiency of movement, the tortuosity of path and selection of corridors vary with different levels of fragmentation intensity. It should be noted that the framework

takes into consideration species specific thresholds of movement because different taxa demonstrate different levels of tolerance to patch isolation and edges.

3.5 Data Integration and Analysis

Both movement and landscape datasets have been integrated into a common coordinate reference system, which made it possible to relate each movement event to the particular landscape fragmentation condition.

3.6 Model Validation

The output of the model was tested based on an independent set of movement data that was not used in developing the model. Testing was geared towards determining the validity of the model's predictions regarding the identification of high-traffic corridors and fragmentation avoidance areas.

Results

Analysis of the study landscape showed an evident gradient in terms of fragmentation intensity, whereby the size of the patches decreased and edge density increased in the peripheral parts of the study landscape, especially near areas of human land use change. Isolation index values were high in patches located near matrixes of high disturbance, whereas connectivity index values were relatively high in riparian and forested corridor segments.

The species had smaller step lengths and higher tortuous paths when moving through high-fragmentation patches, implying high movement resistance in low-connectivity patches. The corridors were highly used in landscape segments where edge density and patch contiguity were relatively low, implying a preference for landscape segments with high structural integrity. Different individuals varied in their reaction to fragmentation, such that some individuals maintained relatively constant movement rates through moderate-fragmentation patches while other individuals avoided high-isolation/high-edge patches.

The EcoLandscape Intelligence Model was able to detect some key corridors that were in very close agreement with the corridors of high movement use based on observations, indicating a great amount of correlation between the model predictions and actual movements of animals. Fragmentation hotspots predicted by the model matched those regions which experienced less frequent movement and more detours, thus indicating the ability of the model to detect fragmentation areas which have the weakest connectivity. Moreover, seasonal analysis showed that movement reactions towards fragmentation were amplified in dispersal periods.

Discussion

The findings show a definitive and consistent correlation between habitat fragmentation and animal movement behavior, proving the ecological rule that landscape configuration is the main factor influencing animal mobility. The reduced efficiency of movement and increased tortuosity of paths in habitat fragments are consistent with current knowledge about the increased costs of dispersal connected with patch isolation.

The capacity of the model to accurately detect high use corridors and fragmentation hotspots proves the significance of the intelligent approach to assessing the landscape for developing an effective conservation strategy. Instead of evaluating the connectivity using only patch characteristics, the analysis including behavioral data enables the assessment of the true movement response of animals to landscape configuration, which takes into account the different sensitivities of various species.

Different responses of various species to habitat fragmentation prove the need to consider a particular approach to increasing the connectivity for each species in the landscape separately, rather than a universal intervention aimed at all species inhabiting the landscape.

The higher levels of movement responses seen during the dispersal periods indicate further that the fragmentation effects are dynamic in nature and depend on life-history periods when individuals are subject to higher levels of fragmentation risks. Such findings have direct practical implications for scheduling land-management interventions at the times when dispersals occur.

From a perspective of conservation management, the EcoLandscape Intelligence Model provides an opportunity to identify hotspots of fragmentation that need to be preserved or restored by means of corridor restoration projects and other conservation actions.

It is necessary to consider several limitations that apply to the research. It was done for a specific group of focal species within a particular ecosystem. It is unclear whether the results obtained will hold in another environment or for other animal groups. Finally, although the data on movements based on telemetry and camera-trapping were reliable enough, it was impossible to disentangle the factors determining corridor selection from the effects of fragmentation.

Conclusion

In this study, the EcoLandscape Intelligence Model was proposed as a framework for understanding the effect of fragmentation of habitats on wildlife movement behavior. The results show that by combining fragmentation indices with empirical data on animal movement behavior, the model managed to reveal important corridors and fragmentation hot spots that coincide with the movements of different animals and, thus, have high practical value for application in conservation practice. Thus, the EcoLandscape Intelligence Model provides an adaptive approach to connectivity assessment, which can be used for prioritization of conservation activities in terms of habitat protection and restoration. These results justify the use of movement-based connectivity analysis in land use planning and wildlife corridors design. In future research, this approach should be applied to various kinds of landscapes and species, taking into account changes in animal movements in connection with changes in fragmentation pattern over years. Climate change projections and land use scenarios should be included to provide better applicability of the approach for future conservation planning.

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