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Original Research Paper

GreenCorridor Optimization Framework for Designing Wildlife Movement Pathways in Fragmented Habitats

Anjali Goswami[1*], Anjali Krushna Kadao[2], Dr. Nidhi Mathur[3]

[1]Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.*
Email: ku.anjaligoswami@kalingauniversity.ac.in, ORCID: https://orcid.org/0009-0004-6330-7883
[2]Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.
Email: ku.anjalikrushnakadao@kalingauniversity.ac.in, ORCID: https://orcid.org/0009-0002-4900-4910
[3]Professor, New Delhi Institute of Management, New Delhi, India. Email: nidhi.mathur@ndimdelhi.org, ORCID: https://orcid.org/0000-0003-0650-4667

Key Words

Habitat fragmentation, Wildlife corridors, Animal movement ecology, Landscape connectivity, Focal species, Conservation planning.

Abstract

Habitat fragmentation still creates barriers for the natural movement of wildlife, leaving the animals isolated on their own patches of habitat and minimizing chances for foraging, dispersal, and mating. Wildlife corridors seem like a biologically informed way to combat these issues; however, there is a prevalence of current designs, which focus on spatial considerations rather than on the needs of the target species in terms of movement ecology. This paper outlines the Green Corridor Optimization Framework (GCOF), which represents an animal behaviour-informed approach to designing the corridors for the movement of wildlife across the fragmented landscapes. This framework considers the species' habitat preferences, tolerance to gap crossing, sensitivity to edges and activity patterns in selecting corridor location and width. This framework was applied to a mixed forest-agriculture fragmented landscape in order to examine its effectiveness for four target species, belonging to different movement guilds. It was found that behaviourally informed approach to corridor design significantly increases the success of animal movement when compared to standard geometric designs, especially for the most fragmentation sensitive species.

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

One of the major factors responsible for the decrease in wildlife populations is the fragmentation of natural habitats due to agricultural development, urbanization, and expansion of infrastructure. Habitat fragmentation reduces the ability of animals to move within their natural ranges in order to access food sources, migrate, disperse, and reproduce; this usually leads to isolation of populations and increases their risk of local extinction due to limited gene flow. Wildlife corridors have been recognized as a way to connect fragmented populations and restore landscape connectivity.

Recently developed methods for identifying corridors include ecological modeling and multi-scenario simulations of avian movement corridors in highly urbanized areas, as well as least-cost path analysis for creating networks of green infrastructure to support bird connectivity (Zhang & Zhang, 2025; MacKinnon et al., 2023). More general frameworks for biodiversity conservation include the use of spatial pattern analysis to define the optimal locations for habitat restoration and corridor creation for multiple species (Velázquez et al., 2022). However, many of these frameworks still focus on the geometrical efficiency of the corridors, rather than the actual behavior of animals.

This work provides an optimization method for multi-species corridors using behavioural information of animal movements and evaluates the effectiveness of the method using simulated animal dispersal results. This paper is structured in the following manner. Section II covers the literature review and some important findings from the literature that have guided this research effort. Section III gives the details of the methodology employed. Section IV discusses the results. Section V discusses the findings and Section VI concludes the paper.

Literature Review

However, corridor optimisation studies are shifting away from distance-driven connectivity towards more holistic methods considering ecological and spatial factors. There have been some corridor optimisation approaches considering the suitability of an area for species against spatial restrictions showing that a corridor designed considering both factors is superior to one where the main concern is only distance (Wang et al., 2022). The notion of ecological peace corridors has also emerged where connectivity enhancement is not considered as a local approach for habitat improvement, but rather as a wider ecological strategy connecting biodiversity and stability of the landscape (Gatti, 2025). Moreover, there is also a proposed calculation algorithm for the development of urban ecological corridors stressing that the efficacy of corridors can only be established through monitoring (Massarelli, 2024).

Together, these sources demonstrate three consistent deficiencies that are addressed by this research: first, the tendency to undervalue the importance of ecological suitability and

behavioural restrictions compared to spatial or cost efficiency; second, the lack of consideration of corridor design within a larger, multispecies conservation plan despite recommendations for such an approach; and third, the lack of a process for evaluating the validity of the design of a corridor after its construction. These deficiencies form the basis of the GreenCorridor Optimization Framework, which accounts for species-specific behavioural resistance, considers multiple focal species at once, and validates the simulation of movement through the corridor.

Methodology

The Green Corridor Optimization Model was designed and implemented within an area of fragmented mixed-use landscape containing remnant forest fragments, riparian corridors, agricultural landscape, and isolated human settlements. Instead of corridor design aimed at linking patches with closest proximity, the model takes into account animal point of view and addresses the way in which the animals perceive, move through and avoid different elements of the landscape.

The four focal species were chosen to belong to different behavioural guilds typical for fragmented ecosystems: large carnivorous animal with a high tendency to avoid open areas and human presence, mesocarnivorous animal that is small in size and nocturnal, with a moderate tendency to use vegetated edges; bird guild depending on uninterrupted canopy cover and avoiding open areas and a generalist species, used to represent lower sensitivity to fragmentation among all species. Such approach allowed to make sure that the corridor network would have to account for diversity of movement patterns rather than for movement pattern of just one easy-to-satisfy species.

Habitat preference for each of the focal species has been considered by evaluating their association with specific land-cover type, that is, forest interior, riparian vegetation, open agricultural land, and built-up land. These preferences have been used to develop a species-specific movement resistance surface based on their cost of moving through a particular landscape region from the point of view of an animal itself. Regions of dense cover with low human disturbance have been considered to be low-resistance regions with high suitability for movement, while open agricultural areas, roads, and developed regions have been considered to be high-resistance regions with varying costs according to the species-specific disturbance tolerance level.

Based on these movement resistance surfaces, potential corridors have been evaluated between different habitat patches, especially by identifying the presence of natural bottlenecks, i.e., those regions where most movements of the animal will take place due to surrounding barriers. Width and vegetation cover in these bottleneck regions have been considered based on species-specific sensitivities.

In order to analyze the ability of the proposed corridors to serve their purpose, the behavior of virtual animals traversing the landscape was analyzed. For each focal species, virtual individuals of the species were allowed to move step by step following the species' movement

patterns which consisted of the average movement distance, the average directionality of movement, and probability of avoidance of high-resistance regions. The number of successful individuals that reached the target habitat was measured as an indicator of the corridor's efficiency. Such behavior-based analysis provided a means of evaluating the efficiency of the corridors not based on geometry, but on movement behavior of the species.

Results

For all four focus species, the corridors constructed on the basis of the behaviourally informed approach provided greater simulated movement success when compared to those created according to the principles of minimal distances between patches. The largest increase was achieved for the two species that were highly susceptible to gaps, edges, and disturbances from humans in the early stage of the research – the large carnivores and forest-dependent birds. The adjustments made to the pinch points were particularly helpful for those species because larger width of corridors and vegetation coverage helped them overcome their hesitation of crossing certain areas.

The mesocarnivore with the average edge-tolerance also achieved greater success in moving, although not as much as the highly sensitive animals. The generalist species experienced comparatively small improvement in its simulated movement success due to low initial sensitivity and sufficient ability to move through less favourable environment.

Pinch-point analysis additionally showed that very few landscape strips contributed a significantly disproportionate amount of movement through simulation for all species. Some of the landscape strips were either in the form of existing road networks or human settlements, and were therefore considered to be priority areas where mitigation measures, such as vegetative screening, would be most effective given the small size of the area involved.

Generally, the behaviorally informed corridor network was able to improve movement success while maintaining land area efficiency similar to that of a traditional distance-based corridor network, demonstrating that ecological efficiency and land use efficiency are not necessarily incompatible.

Discussion

The findings of this study add to the increasingly widespread understanding that for wildlife corridors to be successful, their design should account for the behavioral requirements of the species, not merely spatial factors. The higher effectiveness of corridors among the guilds of large carnivores and forest birds demonstrates that species with greater fragmentation sensitivity are also those which can respond better to design efforts that target their behavior—either through the expansion of the corridor or the addition of more vegetation to certain locations in it. This is consistent with the general rule according to which designing corridors with the most sensitive species in mind will provide connectivity benefits to other animals sharing the same habitat.

The discovery of specific pinch points of heavy use has significant practical implications for the conservation practice. Instead of implementing costly and inefficient design solutions for the entire length of corridor networks, the framework reveals specific areas for concentrated conservation efforts—such as decreasing disturbance near roads and settlements—which will generate substantial ecological dividends. Such a strategy becomes especially beneficial in situations of scarce financial and land resources.

On the other hand, the comparatively low improvements seen in habitat-generalist animals provide an important reminder that not all animals will react in equal measure to changes made in corridor design. Using easily adaptable generalists when making such designs may result in a failure to adequately cater for other animals which may have specific needs. The use of the behavioural guild strategy in this study ensures that this does not happen.

It is important to note that the results of the current research should be treated cautiously, since the analysis of animal behaviour was done through simulations only and there is no real-world validation yet. Using techniques such as tracking collared animals or monitoring corridor use through camera traps would be a great way forward in this respect.

Conclusion

This paper shows that using animal behavior explicitly as a factor in the design of wildlife movement paths through fragmented habitat could significantly enhance their functionality as compared to using the more traditional factors of distance or geometry. The biggest gains from incorporating animal behaviors were seen in those species that are more sensitive to fragmentation, thus highlighting the importance of using animal behaviors from a wide array of different guilds rather than a few species whose needs are easy to accommodate. Using specific pinpoints in which the targeted interventions will give the greatest ecological benefit, the GreenCorridor Optimization Framework gives the planner of conservations a useful tool by which he can allocate his scarce resources to the areas in which their impact will be greatest.

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