



Original Research Paper/Review Paper

Restoration Ecology Approaches for Enhancing Native Species Recovery in Fragmented Wildlife Habitats

Dr. Parvinder Kaur Chhabda^{1*}, Dr. Arvind Kumar Saxena², Dr. Parul Malik³

^{1*}Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.

Email: ku.parvindarkaurchhabda@kalingauniversity.ac.in, ORCID: <https://orcid.org/0009-0006-9775-7254>

²Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.

Email: ku.arvindkumarsaxena@kalingauniversity.ac.in, ORCID: <https://orcid.org/0009-0003-8827-0493>

³Professor, New Delhi Institute of Management, New Delhi, India.

E-mail: parul.malik@ndimdelhi.org, ORCID: <https://orcid.org/0009-0009-4711-501X>

Key Words	Abstract
Restoration ecology, Habitat fragmentation, Native species recovery, Ecological restoration, Wildlife habitat connectivity, Biodiversity conservation, Habitat corridors, Landscape restoration, Ecosystem recovery, Species recolonization.	Fragmented habitats remain among the major causes of species decline, causing isolation and disruption of biological interactions in the habitats. Ecological restoration is slowly shifting from mere revegetation to landscape-scale approaches aimed at restoring habitat connectivity and the disrupted ecosystem functions in fragmented habitats. This paper reviews scientific literature on the efficacy of the approaches focusing on restoration corridors, functional connectivity restoration, and landscape-scale approaches to ecological restoration. Long-term experimental evidence shows that habitat restoration corridors result in continuous increase in the native plant diversity without plateauing over the decades due to increased colonization and reduced extinction rates in connected patches. Habitat corridors also restore animal-driven ecosystem functions such as pollination which are not possible in isolated patches, and the evaluation of restoration corridors has confirmed reconnection of isolated animal species, including mammals and birds. In terms of larger-scale studies, global meta-analysis has shown that habitat restoration results are greatly dependent on the time passed since disturbance, previous disturbance level and context of the landscape, and they have been found to be more effective where fragmentation and disturbance level is low.

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

Introduction

Fragmentation not only decreases the overall availability of habitat for native species, but also the connectivity between the patches, causing fragmentation of populations, restricting genetic exchange, and disrupting various mutualisms, including pollination and seed dispersal, which most of these species require. The field of restoration ecology has met this problem with developing various methodologies for dealing with fragmented habitat, starting from local-scale revegetation and removing invasive species, up to large-scale interventions aimed at reestablishing connectivity between the isolated patches. Among these methodologies is a technique of creating habitat corridors – structurally continuous lines of native vegetation connecting isolated patches of habitat (Saunders & Norton, 2001). The present paper aims to summarize the current knowledge of this technique and its effectiveness for restoration, by reviewing long-term experimental data on corridors, the research on functional connectivity, and global meta-analyses of the restoration efforts (Koch et al., 2021).

Corridor-Based Restoration and Long-Term Biodiversity Recovery

The clearest evidence of corridor effectiveness has been found in a large, replicated study of habitat fragmentation carried out over an 18-year span at the Savannah River Site in South Carolina, where fragments connected by corridors have been shown to exhibit colonization and extinction rates per year that are 5% greater and 2% lesser, respectively, than

those of corresponding disconnected fragments; such dynamics yielded an ever increasing, non-plateauing number of species with an increase in number of 14% in connected fragments after an 18-year period (Damschen et al., 2019). More importantly, this gain has not yet begun to plateau after 18 years of monitoring, thus revealing that the benefits in terms of biodiversity that can be derived from restoration of connectivity are realized only over long periods and will thus be greatly underestimated through short-term monitoring following restoration (Damschen et al., 2019). In terms of practical application, as the colonization and extinction dynamics work cumulatively, planning and carrying out such restoration earlier, rather than later, will yield more of the biodiversity benefits possible.

Restoring Ecological Function, Not Just Species Presence

Species restoration is not simply a matter of maintaining the presence of the species in question within the landscape; it also requires the maintenance of functional ecological interactions, including pollination, seed dispersal, and predation/antipredation relationships, that are necessary for sustaining a viable population. Habitat corridors were found to reconnect forest fragments via an experimental study carried out in fragmented Neotropical forest landscapes, such that forest fragments linked by corridors supported more than fourteen times the pollinators found in fragments without corridors, thus resulting in higher pollen transfer and pollination efficacy (Kormann et al., 2016). Importantly, plants growing in fragments without

corridors were found to exhibit pollination levels that were statistically similar to those of flower buds that were experimentally bagged and prevented from pollination, suggesting that pollination had been lost completely in fragments even in the absence of the actual plant species (Kormann et al., 2016).

Field Evidence from Applied Wildlife Corridor Restoration

Besides studies conducted in controlled settings, actual applied restoration corridors in working landscapes have shown that connectivity restoration can help in benefiting populations of wildlife species requiring active conservation measures. An assessment of the restoration corridors which involved creation of planted corridors consisting of native trees linking isolated patches of forest within the highly fragmented middle Magdalena River valley region in Colombia revealed that the corridors contained greater taxonomic and functional richness of medium and large mammals and birds than open pastures, with the corridor species assemblages being similar to those of native forest, together with strong indications that both terrestrial and arboreal species, some of which were of conservation concern like brown spider monkey and blue-billed curassow, used the corridors for movement between isolated patches (Montes-Rojas et al., 2024). Notably, there was no evidence of any negative impacts resulting from the implementation of the corridors (Montes-Rojas et al., 2024).

Landscape Context and Determinants of Restoration Success

Due to the constraint of resources for restoration, it is just as significant to know what affects success between projects as it is to show how some technique will be successful in some particular case. A worldwide analysis of 269 cases of forest restoration in 221 landscapes from 53 countries revealed that forest restoration increases biodiversity by 15-84% and the vegetation structure by 36-77%, compared to degraded baselines, with the main factors affecting the success of restoration being the period since restoration, the nature of disturbance prior to restoration, and the context of the landscape (Crouzeilles et al., 2016). This indicates that the success of restoration was higher when prior disturbance was of a lesser intensity and surrounding habitat less fragmented, therefore, suggesting that connectivity restoration is more likely to be effective when done before a landscape reaches the state of severe fragmentation, with restoration being much less effective in highly fragmented and intensively disturbed landscapes (Crouzeilles et al., 2016).

Discussion

Altogether, this body of research points towards connectivity-based restoration techniques, especially habitat corridors, as among the most consistently successful tools for aiding native species recovery in fragmented landscapes, from the perspectives of species richness, ecological process, and actual wildlife conservation application, in both temperate

experimental and tropical field settings. A common thread throughout the research reviewed above is that the benefits of restoration build up and, in some cases, take effect only on a time scale too long to be revealed by studies covering just the first few years of the restoration program – that is, early-stage assessment of any restoration project will likely underestimate its conservation effectiveness, and late-stage intervention once fragmentation has become acute will lead to poorer results compared to timely restoration (Kormann et al., 2016). That tropical forests lose all of their pollination activity after becoming disconnected is yet another demonstration that simply having native species there does not define restoration success; restoration must also address the ecological interactions necessary for the population survival. Practical applications of corridor projects within working landscapes provide evidence that not only does this approach work in terms of theory and practicality but also yields conservation results for the endangered species involved without causing any adverse effects, thus proving that corridor restoration is a viable solution to the problem of fragmentation regardless of whether habitat consolidation is politically and economically possible (Montes-Rojas et al., 2024). In addition to this, high sensitivity of restoration results to the conditions of the given landscape suggests that connectivity restoration should be considered as an urgent matter in moderately fragmented landscapes rather than a way out in a critical situation.

Conclusion

Connectivity-based approaches in restoration ecology, specifically the restoration of habitat corridors connecting fragmented fragments of habitat, have provided compelling proof of their effectiveness in the form of a multi-decade track record of successful use for native species conservation efforts, providing not only greater numbers of species, but also restoration of important ecological functions like pollination which would otherwise be disrupted by the process of fragmentation. Field evidence supports the idea that the results of such experiments apply to conservation of wildlife in actual human-altered landscapes, since the positive effects of such restoration actions accumulate slowly and require specific landscape conditions. Therefore, the most efficient approach for restoration investments is pre-emptive creation of corridors from relatively fragmented habitat.

References

- [1] Crouzeilles, Renato, Michael Curran, Mariana S. Ferreira, David B. Lindenmayer, Carlos EV Grelle, and José M. Rey Benayas. "A global meta-analysis on the ecological drivers of forest restoration success." *Nature communications* 7, no. 1 (2016): 11666. <https://doi.org/10.1038/ncomms11666>
- [2] Damschen, Ellen I., Lars A. Brudvig, Melissa A. Burt, Robert J. Fletcher Jr, Nick M. Haddad, Douglas J. Levey, John L. Orrock, Julian Resasco, and Joshua J. Tewksbury. "Ongoing accumulation of

- plant diversity through habitat connectivity in an 18-year experiment." *Science* 365, no. 6460 (2019): 1478-1480.
<https://doi.org/10.1126/science.aax8992>
- [3] Koch, Jennifer, Dean E. Pearson, Cynthia D. Huebner, Michael K. Young, and Richard A. Snieszko. "Restoration of landscapes and habitats affected by established invasive species." In *Invasive Species in Forests and Rangelands of the United States: A Comprehensive Science Synthesis for the United States Forest Sector*, pp. 185-202. Cham: Springer International Publishing, 2021.
https://doi.org/10.1007/978-3-030-45367-1_8
- [4] Kormann, Urs, Christoph Scherber, Teja Tschardt, Nadja Klein, Manuel Larbig, Jonathon J. Valente, Adam S. Hadley, and Matthew G. Betts. "Corridors restore animal-mediated pollination in fragmented tropical forest landscapes." *Proceedings of the Royal Society B: Biological Sciences* 283, no. 1823 (2016): 20152347.
<https://doi.org/10.1098/rspb.2015.2347>
- [5] Montes-Rojas, Andrés, Nicolás Alejandro José Delgado-Morales, Rafael S. Escucha, Laura C. Siabatto, and Andrés Link. "Recovering connectivity through restoration corridors in a fragmented landscape in the Magdalena River's valley in Colombia." *Biodiversity and Conservation* 33, no. 11 (2024): 3171-3185. <https://doi.org/10.1007/s10531-024-02907-9>
- [6] Saunders, A., and D. A. Norton. "Ecological restoration at mainland islands in New Zealand." *Biological Conservation* 99, no. 1 (2001): 109-119.
[https://doi.org/10.1016/S0006-3207\(00\)00192-0](https://doi.org/10.1016/S0006-3207(00)00192-0)