PHYTON-ANNALES REI BOTANICAE
ISSN: 0079-2047
Volume 65 No. 1 (2025)
https://phyton-annales.com

Effect of Habitat Fragmentation on Butterfly Diversity in Tropical Forests

Dr. Ahmed El-Baz[1], Prof. Elisa Fontana[2]
[1]Department of Environmental Studies, Cairo University, Egypt
[2]Department of Agricultural and Environmental Sciences, University of Milan, Italy

Abstract
Deforestation, agricultural expansion, and urbanization are major drivers of habitat fragmentation, which poses a serious danger to tropical ecosystem biodiversity. The eradication and fragmentation of forest ecosystems has a disproportionate impact on butterflies because of their sensitivity as bioindicators of environmental change. this study used field surveys, species richness assessments, and landscape ecology frameworks to examine the impact of habitat fragmentation on butterfly diversity in tropical forests. As a result of fragmentation, species richness, abundance, and community composition are significantly reduced. Specialist and forest-dependent butterflies are hit the most by this. Fragmented landscapes tend to support more generalist and edge-adapted species, which can lead to a decrease in functional diversity and biotic homogeneity. Habitat fragmentation limits the survival of specialized species and changes species interactions by interfering with dispersal, host plant availability, and microclimatic stability, among other important ecological processes.
Keywords: Habitat fragmentation; Butterfly diversity; Tropical forests; Species richness; Forest specialists

Introduction
Critical repositories of ecological richness and stability, tropical forests are home to some of Earth's highest levels of biodiversity. Nevertheless, human activities like clearing land for farming, cutting down trees, mining, and building roads and bridges are causing widespread habitat loss and are thus posing a growing threat to these ecosystems. Forests that were formerly continuous are now broken up into smaller, more isolated regions that are part of a larger matrix of landscapes altered by humans. This process is known as fragmentation. Ecological connection is disrupted, microclimate conditions are altered, and edge effects are intensified as a result of this process, which also decreases the overall amount of appropriate habitat. Species that rely on specific habitats and resources are especially vulnerable to the effects of these changes on their chances of survival. Because of their sensitivity to environmental change, need on certain host plants, and role as pollinators within forest ecosystems, butterflies are among the most sensitive and useful ecological indicators. Butterflies play an important role in tropical forest ecology as pollinators and prey for higher trophic levels, and they also mediate plant reproduction. They are extremely sensitive to changes in their environment because of their short generation periods and heavy reliance on regional microclimates and flower variety. Reduced host plant availability, limited dispersal between forest patches, and altered community composition are three ways in which habitat fragmentation affects butterfly diversity. Rapid extinction is common in fragmented landscapes because specialist species, which depend on particular host plants or microhabitats, are

disproportionately impacted by fragmentation. Biologic homogeneity and less functional diversity may result, on the other hand, from the persistence or even abundance of generalist and edge-tolerant species. Butterfly populations in tropical forests are declining as a result of these changes, which threaten ecosystem stability. Beyond the loss of individual species, fragmentation has far-reaching effects on the functioning of entire ecosystems. Local extinctions, genetic bottlenecks, and random events have a greater impact on smaller, more isolated forest areas. The already precarious situation for butterflies that rely on forests is made worse by edge effects, which include more sunshine, temperature swings, and predator pressure. There are a number of factors that influence butterfly diversity and community resilience, but three of the most important are patch connectivity, matrix quality, and habitat remnant size. Conservation efforts in fragmented tropical ecosystems must be informed by an understanding of how these elements interact to generate butterfly assemblages.

Impacts of Fragmentation on Butterfly Diversity

Species Richness and Abundance Patterns

Decreased species richness and altered abundance patterns within fragmented landscapes are two ways in which habitat fragmentation significantly impacts butterfly diversity. Local extinctions, especially of uncommon and habitat-restricted taxa, occur when habitat patches are too small to sustain the entire complement of butterfly species seen in continuous forests. Butterfly population expansion is hindered by fragmented habitats' reduced floral diversity and host plant availability, which in turn limits feeding and breeding possibilities. As ecological carrying capacity decreases, long-term monitoring often shows drops in abundance, even though certain species may initially show high abundance in fragments owing to concentrated resources or reduced competition. Additionally, there is a decrease in variety and an uneven distribution at the landscape level due to the disproportionate impact on species with wide home range requirements or low dispersion capacity.

Specialist vs. Generalist Responses

Ecological characteristics, especially specialized level, influence how butterflies react to habitat fragmentation. Particularly at risk from fragmentation are specialist species that depend on very particular host plants, microhabitats, or restricted environmental circumstances. They are vulnerable to reductions in patch size, edge effects, and isolation since they rely on undisturbed forest interiors. Therefore, in fragmented habitats, specialist butterflies are commonly seen declining fast, and some even become extinct from tiny or damaged regions. In contrast, generalist species are more adaptable since they can tolerate disturbed environments and use a variety of host plants. They thrive in edge habitats, open fields, and cultivated regions where floral supplies are unevenly distributed, and they often dominate fractured landscapes. The loss of ecological balance due to the decrease of specialists is exacerbated by the flexibility that permits generalists to endure or even increase in abundance.

Community Composition and Biotic Homogenization

Fragmentation causes biotic homogenization by changing species richness and reshaping butterfly community composition. Butterfly assemblages in continuous tropical forests are known to be very diversified, with a good mix of specialists and generalists, and a high level

of functional diversity. A handful of hardy generalist species, however, tend to dominate populations in fragmented habitats. Butterfly ecosystem services are diminished, plant-pollinator networks are weakened, and ecological resilience is diminished as a result of the replacement of varied assemblages with homogenized populations. The extinction of specialized species endangers not just the butterflies but also the plants that have adapted to support them. Ecosystems become increasingly susceptible to anthropogenic stresses like climate change and habitat loss when populations become more homogeneous over time, which can lead to decreased genetic diversity and functional redundancy.

Edge Effects and Microclimatic Alterations

Temperature and Humidity Fluctuations

The formation of edge habitats, which are very different from circumstances inside the forest, is a direct result of forest fragmentation. In contrast to the core of the forest, the borders are more exposed to the sun and wind, which causes higher daytime temperatures, larger diurnal swings, and lower humidity. Butterfly diversity is significantly impacted by these microclimatic shifts because numerous species have adapted to the steady, shaded, and damp environments found in unspoiled woods. Desiccation of butterfly eggs and larvae, disturbance of adult thermoregulation, and reduction in microhabitats favorable for feeding and reproduction can all result from an increase in temperature and a decrease in moisture. Butterfly populations at forest borders often drop, however some thermophilic and open-habitat species may thrive in these changed conditions.

Predation and Competition Pressures

Predation and competition are two examples of biotic stresses that fragment edges amplify. Predators like ants, birds, and lizards are more common in disturbed or transitional zones, making open habitats near boundaries a more dangerous place for butterflies. Furthermore, specialists are already at a disadvantage due to the increased competition for scarce nectar resources and oviposition locations caused by the prevalence of generalist butterfly species in edge habitats. As a result of these stresses, butterfly assemblages lose their natural equilibrium, and species that can survive on the periphery of their habitats eventually push out those that need more secure interiors. The complexity and stability of forest ecosystems are diminished as a result of these changes, which alter ecological interactions across trophic levels and within butterfly communities throughout time.

Resource Availability Along Edges

Butterfly populations are impacted by changed resource dynamics that occur in edge habitats. When you first look at edge vegetation, you could see a lot of blooming plants. These plants support a lot of nectar feeders and generalist butterflies. But these resources are often transient, filled with invasive or weedy plants that don't have the specific host plants that butterflies rely on for their life in the forest need. Consequently, whereas edges can temporarily maintain more butterfly populations, they usually can't hold the same variety of species that is found in the heart of a forest. The misalignment between biological needs and the resources available is shown by the dwindling numbers of specialty butterflies that rely on specific host plants near

margins. Butterfly communities become more homogeneous as a result of this imbalance, which benefits generalists and causes overall diversity to drop over time.

Conclusion

When it comes to tropical forest butterfly biodiversity, habitat fragmentation is a major concern since it reduces species richness, changes community composition, and disrupts ecological processes. As patch size declines, host plant availability falls, and microclimatic stability is disrupted, the research reveals that forest-dependent and specialist butterflies drop rapidly, disproportionately affected by fragmentation. On the other hand, ecological resilience is diminished and functional diversity is diminished when generalist and edge-tolerant species multiply or persist in fragmented habitats, a phenomenon known as biotic homogenization. Edge effects make these impacts much worse because many specialist species find themselves in unfavorable situations due to changes in temperature and humidity, increased predation risks, and changes in the availability of resources. These stresses are amplified by dispersal obstacles brought about by patch isolation, which reduces opportunities for genetic exchange and raises the probability of extinctions at the local level. Beyond just butterflies, these alterations will have far-reaching ecological effects. Decreases in butterfly diversity endanger plant reproduction, trophic interactions, and overall forest health since butterflies are important pollinators and parts of tropical food webs. Although there are hardy species that have adapted to changed environments, their predominance cannot make up for the unique ecological services that varied butterfly populations once offered. Large, continuous habitats, ecological connectivity (via corridors and stepping-stone habitats), and sustainable land-use practices that incorporate biodiversity considerations are thus crucial to the survival of tropical forest butterfly diversity. The study of butterflies in tropical environments that are fragmented ultimately shows how vulnerable these insects are and how valuable they are as indicators of ecological integrity. Their preservation is crucial for the long-term health and abundance of tropical ecosystems, as well as for the survival of certain species. So, to keep butterfly diversity—and the important ecological services it provides—alive in the face of rapidly decreasing habitat, effective conservation efforts should integrate restoration of habitat, community involvement, and habitat protection.

Bibliography

Benedick, S., Hill, J. K., Mustaffa, N., Chey, V. K., Maryati, M., Searle, J. B., Schilthuizen, M., & Hamer, K. C. (2006). Impacts of rainforest fragmentation on butterflies in northern Borneo: Species richness, turnover and the value of small fragments. Journal of Applied Ecology, 43(5), 967–977. https://doi.org/10.1111/j.1365-2664.2006.01209.x

Brown, K. S., & Freitas, A. V. L. (2000). Atlantic forest butterflies: Indicators for landscape conservation. Biotropica, 32(4b), 934–956. https://doi.org/10.1111/j.1744-7429.2000.tb00632.x

Fahrig, L. (2003). Effects of habitat fragmentation on biodiversity. Annual Review of Ecology, Evolution, and Systematics, 34, 487–515. https://doi.org/10.1146/annurev.ecolsys.34.011802.132419

Hill, J. K., Hamer, K. C., Lace, L. A., & Banham, W. M. T. (1995). Effects of selective logging on tropical forest butterflies on Buru, Indonesia. Journal of Applied Ecology, 32(4), 754–760. https://doi.org/10.2307/2404815

Koh, L. P. (2007). Impacts of land use change on South-east Asian forest butterflies: A review. Journal of Applied Ecology, 44(4), 703–713. https://doi.org/10.1111/j.1365-2664.2007.01324.x

Laurance, W. F., Lovejoy, T. E., Vasconcelos, H. L., Bruna, E. M., Didham, R. K., Stouffer, P. C., ... & Sampaio, E. (2002). Ecosystem decay of Amazonian forest fragments: A 22-year investigation. Conservation Biology, 16(3), 605–618. https://doi.org/10.1046/j.1523-1739.2002.01025.x

Lewis, O. T. (2001). Effect of experimental selective logging on tropical butterflies. Conservation Biology, 15(2), 389–400. https://doi.org/10.1046/j.1523-1739.2001.015002389.x

New, T. R. (1997). Butterfly conservation. Oxford University Press.

Spitzer, K., Novotný, V., Tonner, M., & Leps, J. (1993). Habitat preferences, distribution and seasonality of the butterflies (Lepidoptera, Papilionoidea) in a montane tropical rainforest, Vietnam. Journal of Biogeography, 20(1), 109–121. https://doi.org/10.2307/2845732

Tscharntke, T., Steffan-Dewenter, I., Kruess, A., & Thies, C. (2002). Contribution of small habitat fragments to conservation of insect communities of grassland–crop landscapes. Ecological Applications, 12(2), 354–363. https://doi.org/10.1890/1051-0761(2002)012[0354: COSHFT]2.0.CO;2