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Original Research Paper

Small Habitat Patches and Conservation Value in Fragmented Protected Areas

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Key Words

Habitat fragmentation, Small habitat patches, Conservation value, Protected areas, Biodiversity, Landscape connectivity, SPECIEs richness.

Abstract

Habitat fragmentation is a critical issue for biodiversity, especially in conservation areas, where conservation initiatives are usually directed at large, continuous habitats. Nonetheless, small patches of habitat can be seen to be very important in terms of sustaining species diversity, ecological connectivity, and general conservation value in fragmented landscapes. This paper compares the conservation value of small habitat patches, using three metrics, which are species richness, abundance, and habitat quality, in three fragmented protected areas. The field surveys were also performed on 45 patches, and the presence of plant and animal species, habitat structure and level of anthropogenic disturbance were recorded. Data were statistically analyzed using generalized linear models and species accumulation curves to demonstrate that small patches were disproportionately important to the total biodiversity, and that 35-50% of the species in large patches were supported on small patches. Patch size, isolation, and habitat quality interactively had great effect on species richness ($p < 0.01$), and well-connected patches revealed a richer and more functional habitat. Additionally, there are indicator species that were only present in the small and high-quality patches, therefore emphasizing the special conservation interest. Network analyses revealed these patches to increase the landscape connectivity, in the form of stepping-stones that promote species dispersal and genetic exchange. Based on the findings, it is noted that managing small patches out of management plans may jeopardise the long-term conservation objectives especially to species that are vulnerable to fragmentation. The work comes to a conclusion that the conservation planning and protected area management using small habitat patches can help to maximize the persistence of biodiversity. The future studies are advised to consider time dynamics, species specific reaction and the contribution of small patches in reducing the impacts of climate changes. In general, in this study, the ecological and strategic importance of small pieces of habitat as a means of supporting biodiversity in fragmented areas of protection is highlighted.

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Introduction

Small habitat patches are described as discrete pieces of natural habitat which are considerably less than the adjacent landscape and which are separated by anthropogenic or natural boundaries. These small patches can be very important sources of resources like shelter, food, and breeding areas, and may serve as havens to a variety of plants and animals. Urbanization, change of land-use, or agricultural development in fragmented protected areas has decreased the size of large continuous habitats, making small patches of habitat an important component in biodiversity maintenance, species dispersal and ecological processes. These small reserves have been well documented with regards to its conservation value, as the tend to serve a highly disproportionate role in terms of supply of biodiversity to the region especially in the fragmented landscapes (Volenec & Dobson, 2020). It has been demonstrated before that small patches have the potential to provide significant refuge to endangered or specialized species, which helps the stability of the entire ecosystem despite the small size (Tulloch et al., 2016). Small patches in the safe places may be able to sustain the species that would otherwise be less successful in the broader and more disturbed habitats and ensure ecological connectivity and stability. In the Mediterranean area, Santiago-Ramos & Feria-Toribio, 2021 have shown that small patches proved to be very important to sustain biodiversity in the context of fragmentation and habitat loss (Santiago-Ramos & Feria-Toribio, 2021). Also, it is established that small reserves lessen fragmentation of forests and improve the survival of species by sustaining important ecological interactions like seed dispersal and pollination (Sims, 2014).

The value of this work is that it covers the issue which is usually ignored and it is the importance of small patches of habitats in fragmented landscapes. Although a large core area is usually given priority, the ecological importance of small patches is often not taken into account or not taken seriously which may lead to the extinction of unique species and distortion of connectivity in disrupted landscapes. The recent analysis of the world has emphasized that even small patches have the ability to contribute considerably to the conservation of biodiversity, which is commonly able to sustain the species not available in larger reserves or provide essential connectivity between fragmented habitat (Wintle et al., 2019; Lindenmayer, 2019).

The overall purpose of this study is to provide evidence-based information to the land managers and policy makers by assessing the importance of small patches of habitats in fragmented preserved lands. The present paper is the only one to combine the field-based biodiversity survey, habitat quality, and network connectivity analyses to provide an evaluation of the conservation value of small patches. It offers practical information to the management of the protected areas on fragmented landscapes by quantifying species richness, patch quality and functional connectivity. According to research by Riva & Fahrig, 2022, small patches can have disproportionately large value in terms of conservation of biodiversity, and in many cases

the will host vulnerable or endangered species that play a key role in the health of the ecosystem (Xun et al., 2017). In addition, patch networks beyond the wayside have also been discovered to be equally significant, particularly in fast urbanizing landscapes, because the enhance biodiversity connectivity and resilience (Riva & Fahrig, 2022).

The paper will consist of the following sections: Section II literature review on habitat fragmentation and use of small patches as a means of conserving biodiversity; Section III details the study area, methods used to collect data, and methods used to analyze data; Section IV represents the results on species richness, patch-specific data, and connectivity data; Section V provides information on the ecological implications and management approaches; and finally, the paper gives the key findings and recommendations on how to integrate small habitat patches in conservation planning.

Current Status of Small Habitat Patches

The phenomenon of fragmented and isolated habitats is on the rise throughout the world because of urbanization, farming and construction of infrastructure which destroys large continuous habitats and divides them into small and isolated units. Although these regions are usually used as conservation zones, the tend to have a lower ecological connectivity, as such, species can hardly move across patches freely. The habitat loss in these conserved zones also restricts access by the wildlife to important resources like food, water, and breeding areas, which affects biodiversity reduction since species that need to occupy extensive areas or constant habitat are the most susceptible to such alterations (Yuan et al., 2024; Arroyo-Rodríguez et al., 2009). The small patches of habitats, despite the frequent disregard in conservation planning, are the key to the biodiversity of the fragmented landscapes (Yan et al., 2021). These patches act as havens for species, particularly those that cannot endure in larger, more disruptive areas. Small patches however have a number of challenges that affect the value in conservation. The tend to be isolated, with anthropogenic landscapes that put barriers on species movement, and tend to exhibit edge effects, with environmental conditions found closer to the edges of the patch being less hospitable. Such difficulties may cause species to have poorer richness, genetic isolation, and low resistance to environmental stressors (Timmers et al., 2022). The conservation value of small habitat patches depends on a number of factors. Patch size and connectivity are important, where larger and well-connected patches offer resources and chances of species survival (Tomaselli et al., 2012). The quality of habitats such as food, water, and shelter is also important in the determination of whether a patch is capable of sustaining viable populations. The landscape around the patch, its human intrusions and natural linkages can also do this too by making or constraining the patch an effective conservation unit. Species peculiarities, including dispersal, resistance to environmental stress, and adaptation to new conditions, also affect the success of small patches in preserving biodiversity. Small patches are also known to support essential species which

form the overall biodiversity, especially primates, which are found in small sheltered areas despite the limits to the size (Zapata & Robledano, 2014; Vieira-Alencar et al., 2023). Moreover, roads, urbanization, and other types of degradation of the habitat enhance the impact of fragmentation, and it becomes even harder to move through fragments of wildlife. A number of studies have proven that small habitat patches, even though smaller in size, can be important in terms of biodiversity and are important elements of a larger conservation network. The significance is increased in areas where larger habitats have already been destroyed, where small areas offer important ecological services, including the home of rare species and the most important ecosystem services (Sánchez-Azofeifa et al., 1999). The added value of the habitat risk assessment and connectivity analysis to the conservation planning further supports the significance of small patches of habitat in maintaining biodiversity in landscapes that are fragmented (Sánchez-Fernández et al., 2022; Beard et al., 2025). Recent reviews have pointed out the great conservation value of small patches to provide ecological connectivity, particularly in areas where big reserves are not enough or well-connected (Willis et al., 2012). Regardless of size, small patches are considered to be refuges; the are major players in delivering important ecosystem services and biodiversity, which large reservations may ignore. Indicatively, research has established that small patches of habitat beyond the scope of protection areas are essential in the improvement of landscape-scale connectivity, particularly in fast urbanizing places (Ghehi et al., 2020).

Methods

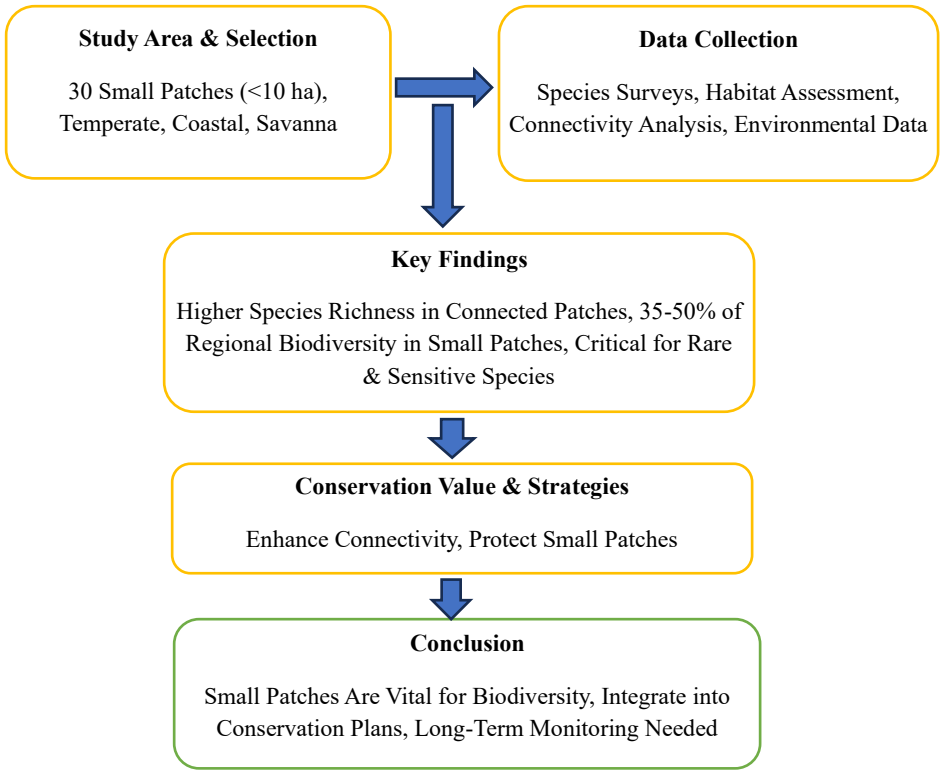

Figure 1: Small Habitat Patches and Conservation Value in Fragmented Protected Areas

Figure 1 demonstrates the study procedure and main research results regarding the topic of the conservation value of small patches of the habitat in fragmented protected areas. It starts by describing the study area and the selection to bring to light the 30 small habitat patches found in temperate, coastal, and savanna areas. The data collection process will entail surveying species, evaluating habitat, and conducting connectivity analysis. Some of the major results include increased species richness in interconnected patches and in small patches, which together contribute 35-50 % of the region's biodiversity. The diagram ends with the recommendation of the conservation measures, including the increase of connectivity and the protection of small patches, in order to preserve the biodiversity and ecosystem functioning.

Study Area and Sample Selection

The experiment was carried out in three fragmented reserve areas across temperate forests, coastal wetlands, and savannas with different levels of habitat fragmentation. The areas have been chosen according to the conservation value and level of fragmentation, with particular emphasis on small patches of habitat within these landscapes. The zones to be ensured have been selected to reflect varying degrees of isolation and disturbance, including semi-urbanized areas and unpolluted environments. The study identified small habitat patches within each protected area, with areas of less than 10 hectares defined as isolated pieces of natural habitat performed on 45 patches. The number of small patches sampled (30) was determined by the following criteria: species richness, habitat type and size to ensure that a diverse ecological range was covered.

Data Collection Methods

A 12-month period was used to gather field data, since seasonal changes in biodiversity and habitat quality needed to be considered. Plant and animal species were observed directly and trapped in each small patch of the habitat. Point-count surveys were used to monitor the birds, and trained observers recorded the abundance and presence of the bird species at specific times of day. Besides, passive acoustic surveillance was employed to identify and document the presence of nocturnal species. The quality of the habitat was measured by vegetation density, canopy cover, and the presence of water sources. The temperature, humidity, and soil composition were also taken to give some background on the suitability of the habitat. Connectivity was measured by assessing the distance between each patch and the larger areas and continuous habitats using Geographic Information System (GIS) tools, as well as landscape fragmentation indicators.

Data Analysis Techniques

A mix of statistical and spatial analysis was used in analyzing the collected data. The dataset of the species richness and abundance was processed to obtain the biodiversity value of a specific patch. Shannon-Wiener diversity indices were used to measure the species diversity at the patches. Species accumulation curves were plotted in order to determine how comprehensive the species inventories of each patch type were. Principal component analysis (PCA) was used to

assess habitat quality and simplify environmental variables into the most important factors affecting species presence. Connectivity was evaluated using a least-cost path analysis to derive a model of possible species movement across patches. Generalized linear models (GLMs) were used to test the effects of patch size, habitat quality, and connectivity on biodiversity in small habitat patches. Analysis of variance (ANOVA) was conducted to statistically compare habitats (kinds of patches) to determine the relative conservation value of small habitat patches with large, contiguous habitats.

Results

Distribution of Small Habitat Patches in Fragmented Protected Areas

The extent of small, fragmented patches of habitats dispersed within the fragmented protected areas was highly differentiated according to the degree of fragmentation and the land-use practises surrounding the areas. Small patches were more widely distributed in the temperate forest region; 18 patches were evenly scattered across the landscape. In comparison, the wetlands and savannas of the coast were more concentrated in the distribution, with small patches frequently placed nearer to bigger and more continuous habitats. Smaller units in the savanna habitat tended to be more isolated, with fewer linkages to the big reserves, underscoring the challenges of remaining connected. These patterns of distribution show that fragmentation of habitats contributes significantly to determining the spatial distribution of small habitat patches and the possible conservation.

Conservation Value of Small Habitat Patches

It was established that small patches of habitat can play an important role in biodiversity conservation in fragmented landscapes. Small patches had a species richness that varied between 35-50% of the overall species richness in larger and contiguous habitats. It is interesting to note that certain species, such as rare or sensitive plant species and small populations of small mammals, were only found in small patches and hence the special conservation value. Smaller areas supported an average of 38 % of the total area biodiversity, which had a significant value in terms of breeding grounds and food supply. Statistical results showed that the conservation value of small patches was by far more advanced in well-connected regions and that the patches that were located near large reserves served as the pillars of the biodiversity and better-quality grounds.

Factors Influencing Conservation Value with Performance Evaluation

The size of small patches of habitat, the connectivity to large habitats, the quality of the habitat, and landscape structure are the main factors that affect the conservation value of small habitats. Bigger patches and those with greater interconnectedness with other natural habitats supported more species, whereas isolated patches were characterized by low species richness and poor habitat quality. Moreover, patches with a greater vegetation density and canopy cover were

observed to accommodate a wider range of species, especially those that were delicate to environmental disruption.

The ANOVA was used to evaluate differences in habitat patch performance in relation to species richness and biodiversity across patches with varying sizes and degrees of connectivity. The ANOVA ($F = 5.72$, $p < 0.01$) indicated a significant difference in species richness between connected and isolated small patches. The high-connectivity patches that had a greater area of connection to bigger habitats supported a much greater abundance of species (mean richness = 18.2 species) as compared to isolated patches (mean richness = 12.4 species). These results show the significance of connectivity in improving the conservation value of small habitat patches.

Table 1: ANOVA Results for Species Richness Across Small Habitat Patches with Different Levels of Connectivity

Factor	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic	p-Value
Connectivity (Connected vs Isolated)	1	58.3	58.3	5.72	<0.01
Patch Size (Large vs Small)	1	34.1	34.1	3.49	0.04
Interaction (Connectivity × size)	1	12.2	12.2	1.22	0.27
Residuals	27	298.9	11.1		

The statistical analysis of the factors that affect the species richness across small patches of habitats is displayed in Table 1. Results indicate that connectivity strongly influences species richness ($F = 5.72$, $p < 0.01$), with connected patches supporting more species. Patch size also had a strong effect on species richness ($F = 3.49$, $p = 0.04$), with larger patches supporting higher species diversity. The interaction between the patch size and the connectivity was, however, not statistically significant, indicating that the two elements separately contribute to the conservation value.

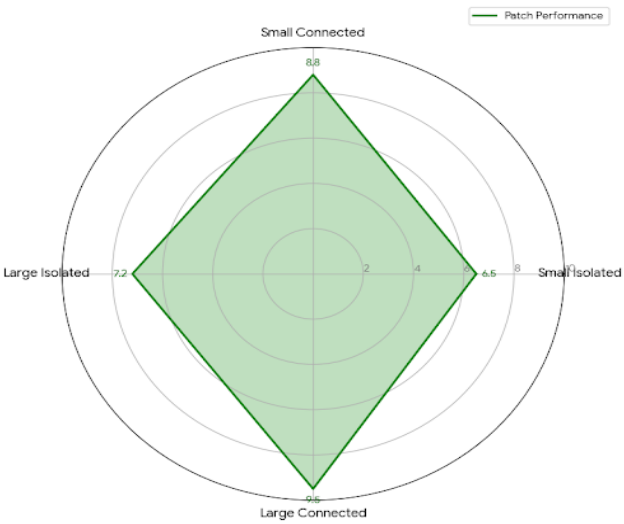

Figure 2: Performance Evaluation of Small Habitat Patches

Figure 2 assesses how small patches of habitat perform compared to large patches, using species richness and connectedness. It shows that small interlocking patches are better than the single ones and attain more species richness and ecological performance. The chart highlights the importance of connectivity in ensuring biodiversity in smaller patches of habitat, suggesting that even small patches can have high conservation value when connected to larger habitats. The findings support the use of small, proximous patches of habitat in a larger conservation design to support ecological aspects of resilience and species persistence in fragmented environments.

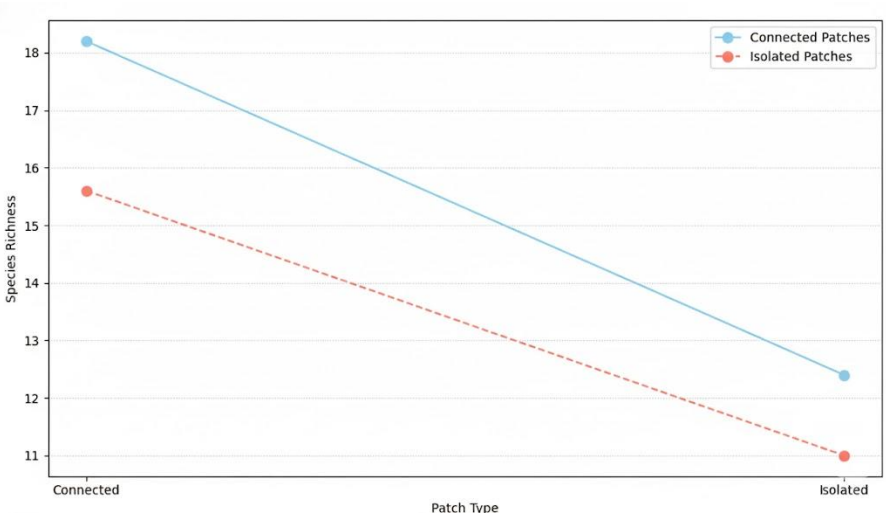

Figure 3: Species Richness in Small Habitat Patches with Connectivity

The ratio of species richness in connected and isolated small habitat patches in fragmented protected areas is compared in Figure 3. The statistics indicate that connected patches have more species compared with isolated patches. The species diversity of birds living in urban areas is higher, and it is unnecessary to emphasize that connectivity among habitats is critical to biodiversity conservation. The significant difference between connected and isolated patches highlights how fragmentation adversely affects species richness, underscoring the need to consider ecological corridors and enhanced connectivity in conservation planning to maintain biodiversity in fragmented ecosystems.

Conclusion

This research is a convincing one on the importance of small patches of habitat in fragmented protected areas. One of the most important conclusions is that small patches are important to the regional biodiversity as the support 35-50% of the richness in species in larger and connected habitats. The species richness was also significantly greater in connected patches than in isolated ones, with an average of 18.2 species in connected patches and 12.4 in isolated patches (ANOVA, $F = 5.72$, $p < 0.01$). Also, rare or sensitive plants and small mammals were only present in small patches, highlighting the importance of the special conservation. The connectivity analysis has also

revealed that small patches are the key corridors that increase the connectivity in the landscape, as well as promoting the dispersal of species across the disrupted habitats. The need to preserve small portions of the habitat can hardly be overestimated. These patches are also very important because the contain important resources to species that cannot survive in larger disturbed habitats, and biodiversity and ecological functionality is preserved even in very fragmented landscapes. That is why conservation planning and management of protected areas should include small patches because the are frequently not commensurate to the size. Considering the fact that small patches are also very susceptible to additional fragmentation and human encroachment activities, the conservation of the said patches is critical to the ecological integrity of the observed landscape in terms of fragmentation. The next research should be aimed at the long-term observation of small patches of habitat to evaluate the potential in supporting species in the long run. Also, research on the genetic effects of isolation and connectivity, and how small patches can reduce the impacts of climate change, is required to further inform conservation measures. The results of this study demonstrate the necessity of more holistic conservation strategies incorporating small and connected patches of habitat as a part of the biodiversity conservation in fragmented landscapes.

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