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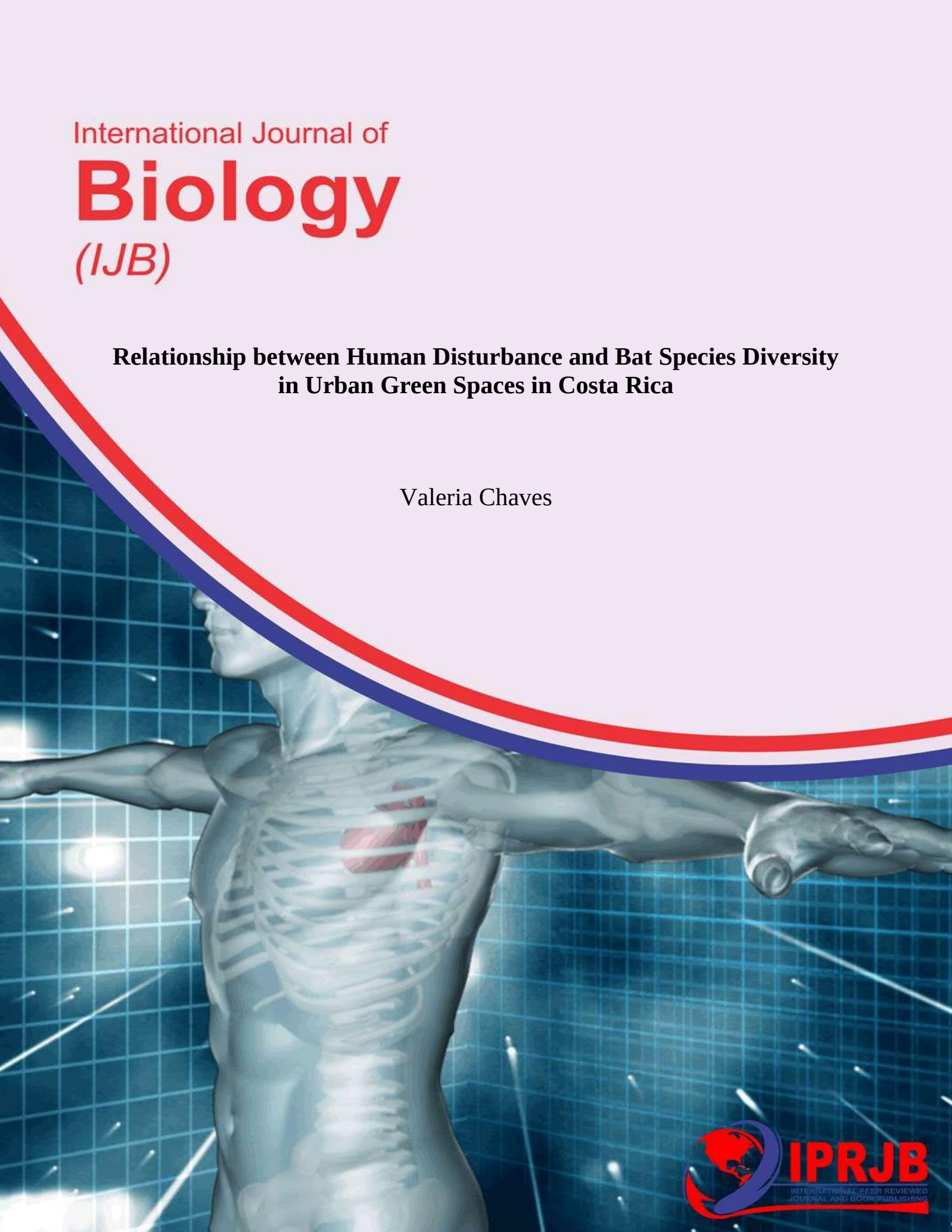

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# Relationship between Human Disturbance and Bat Species Diversity in Urban Green Spaces in Costa Rica

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**Abstract**

**Purpose:** To aim of the study was to analyze the relationship between human disturbance and bat species diversity in urban green spaces in Costa Rica.

**Methodology:** This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low cost advantage as compared to a field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

**Findings:** Studies on urban green spaces in Costa Rica reveal that human disturbance, such as habitat fragmentation and artificial lighting, generally reduces bat species diversity. While some adaptable species may thrive, overall bat richness and abundance decline due to habitat loss and alteration. Conservation efforts should focus on mitigating these impacts to sustain diverse bat populations in urban environments.

**Unique Contribution to Theory, Practice and Policy:** Habitat fragmentation theory, behavioral ecology theory & ecosystem services theory may be used to anchor future studies on relationship between human disturbance and bat species diversity in urban green spaces in Costa Rica In practice, it is essential to integrate biodiversity conservation into urban planning frameworks. Policy recommendations focus on incorporating biodiversity conservation goals into urban development policies and regulations. Policies should support the designation of green infrastructure networks and protected areas within urban landscapes to maintain ecological connectivity for bats and other wildlife.

**Keywords:** *Human Disturbance, Bat Species Diversity, Urban Green Spaces*

## INTRODUCTION

Bat species richness and community composition vary significantly across different regions and habitats, reflecting diverse ecological adaptations and responses to environmental factors. Species richness refers to the number of bat species present in a specific area, while community composition describes the relative abundance and diversity of these species within their habitats. In developed economies like the USA, studies have shown varying trends in bat species richness influenced by urbanization and conservation efforts. Urban areas tend to support fewer bat species due to habitat loss and fragmentation. For example, research indicates declines in species diversity in urban settings, with adaptable species like the big brown bat (Eptesicus fuscus) becoming more prevalent (Smith, 2018). Conservation measures such as the establishment of protected areas and the promotion of bat-friendly urban planning have aimed to mitigate these impacts (Jones & Jacobs, 2019).

Similarly, in Japan, where urbanization is rapid, studies highlight shifts in bat community composition towards species tolerant of human-modified landscapes (Fukui & Sasaki, 2017). Habitat loss and disturbance have led to declines in specialized species, while generalist species like the Japanese pipistrelle (Pipistrellus abramus) are more resilient (Kobayashi et al., 2020). Conservation strategies emphasize habitat restoration and public awareness to maintain bat diversity (Yoshino & Kunisaki, 2016). In the United Kingdom (UK), studies have shown that bat species richness and community composition vary significantly across different landscapes. Urbanization and agricultural intensification have historically impacted bat populations, with declines observed in some species due to loss of foraging habitats and roosting sites. Conservation efforts, including habitat restoration and legal protections, have contributed to stabilizing populations of native species like the common pipistrelle (Pipistrellus pipistrellus) and soprano pipistrelle (Pipistrellus pygmaeus) in recent years (Smith, 2018).

In the United States, particularly in regions like the Pacific Northwest and the Southwest, bat species diversity is influenced by diverse ecosystems ranging from temperate rainforests to arid deserts. Research indicates that habitat fragmentation from logging and urban expansion poses significant threats to forest-dwelling species such as the northern long-eared bat (Myotis septentrionalis) and the hoary bat (Lasiurus cinereus). Conservation efforts focus on preserving old-growth forests and establishing protected areas to maintain biodiversity and ecosystem services provided by bats (Johnson, 2017). In Canada, particularly in regions like British Columbia and Ontario, bat diversity is influenced by diverse habitats ranging from temperate rainforests to urban areas. Research indicates that bat populations face threats from habitat loss due to logging, urbanization, and white-nose syndrome, a fungal disease impacting hibernating bats. Species such as the little brown bat (Myotis lucifugus) and the silver-haired bat (Lasionycteris noctivagans) are particularly affected. Conservation efforts include monitoring populations, establishing bat-friendly habitats, and promoting public education on bat conservation (Fraser, 2020).

In Germany, bat species richness is notable, with over 25 species recorded, including both resident and migratory species. The country's diverse landscapes, including forests, wetlands, and urban parks, support a variety of bat communities. Research focuses on the effects of landscape fragmentation and agricultural practices on bat populations. Species like the common pipistrelle (Pipistrellus pipistrellus) and the greater mouse-eared bat (Myotis myotis) are well-studied due to their ecological roles as insect predators. Conservation efforts emphasize habitat restoration, such

as the creation of bat-friendly corridors and roosting sites, to enhance biodiversity conservation in urban and rural areas (Frey-Ehrenbold, 2017). In Australia, bat diversity is influenced by a variety of ecosystems ranging from tropical rainforests in the north to arid regions in the interior. The country hosts diverse bat communities, including flying foxes (Pteropus spp.) and numerous insectivorous species. Urbanization and habitat fragmentation pose significant threats to bat populations, particularly species roosting in urban areas and old-growth forests. Conservation efforts focus on habitat preservation, establishing wildlife corridors, and monitoring population trends to mitigate impacts from urban expansion and climate change (Parsons, 2020).

In France, bat species richness is notable with over 30 species recorded, inhabiting diverse landscapes such as forests, wetlands, and urban areas. The country's temperate climate supports a variety of insectivorous bats like the common pipistrelle (Pipistrellus pipistrellus) and the greater horseshoe bat (Rhinolophus ferrumequinum). Threats include habitat loss from agricultural intensification and pesticide use impacting insect populations, a critical food source for bats. Conservation efforts include habitat restoration, promoting agroecological practices, and monitoring bat populations to support biodiversity conservation and ecosystem health (Mathews, 2019).

In developing economies, bat species richness reflects diverse habitats but faces threats from habitat destruction and agricultural expansion. In Brazil, for instance, deforestation has impacted bat communities, leading to declines in forest-dependent species like fruit bats (Farneda, 2018). Generalist species such as insectivorous bats are more adaptable to human-altered landscapes (Pereira, 2019). Conservation efforts focus on preserving critical habitats and promoting sustainable land use practices (Bernard, 2021).

In countries like India, where agricultural expansion and urbanization are rapidly transforming landscapes, bat diversity shows regional variations influenced by habitat loss and human-wildlife conflicts. Studies highlight the importance of traditional agricultural landscapes, such as rice paddies and orchards, in supporting diverse bat communities, including fruit bats (Pteropodidae) and insectivorous bats like the Indian false vampire bat (Megaderma lyra). Conservation strategies emphasize the sustainable management of agricultural habitats and raising awareness among local communities about the ecological role of bats (Srinivasulu, 2018). In Brazil, a country rich in biodiversity, bat species richness is exceptionally high, with over 170 species recorded. The Amazon rainforest and other biomes support a diverse array of fruit-eating bats (frugivores) and insect-eating bats (insectivores). However, habitat destruction from deforestation and agriculture poses significant threats to bat populations, especially to specialist species with narrow habitat requirements. Conservation efforts include the establishment of protected areas and sustainable land use practices aimed at preserving critical bat habitats and ecosystem services (Bernard, 2018).

In Costa Rica, bat diversity is exceptionally high, reflecting the country's rich biodiversity and diverse habitats from lowland rainforests to cloud forests. The country hosts over 110 bat species, including nectar-feeding bats and insectivores. Threats to bat populations include habitat destruction from agriculture, logging, and climate change, impacting species like the white-throated round-eared bat (Lophostoma silvicolum). Conservation efforts focus on establishing protected areas, promoting sustainable land use practices, and conducting research to understand bat ecology and behavior in changing landscapes (Medellín, 2018). In Malaysia, bat species richness is influenced by the country's tropical rainforests and coastal mangroves. The biodiversity

hotspot supports diverse bat communities, including fruit bats (Pteropodidae) and insectivorous bats. Habitat loss from deforestation for oil palm plantations and urban development poses significant threats to bat populations, particularly to species with specialized roosting and foraging requirements. Conservation initiatives emphasize habitat restoration, sustainable palm oil certification, and public education to promote bat-friendly practices and biodiversity conservation (Kingston, 2017).

In Thailand, bat diversity is influenced by a range of ecosystems, from tropical rainforests to coastal mangroves. The country hosts several species of fruit bats, such as the large flying fox (Pteropus vampyrus) and insectivorous bats like the lesser Asiatic yellow house bat (Scotophilus kuhlii). Urbanization and agricultural expansion threaten bat habitats, leading to declines in some species. Conservation initiatives focus on habitat restoration and raising awareness among local communities about the ecological importance of bats in pest control and pollination services (Bumrungsri, 2013).

In Sub-Saharan Africa, bat species richness is high, yet faces threats from habitat degradation and hunting. Countries like Ghana and Kenya exhibit diverse bat communities influenced by habitat fragmentation and human activities (Bohn, 2017). Forest-dependent species are particularly vulnerable, while adaptable species such as insect-eating bats are more resilient to environmental changes (Mickleburgh, 2019). Conservation strategies emphasize community engagement and sustainable resource management to protect bat diversity (Tourenq, 2018).

In Tanzania, bat species richness is influenced by diverse habitats, including savannas, montane forests, and coastal areas. The country supports a variety of bat species, from small insectivores to large fruit bats. However, habitat degradation and hunting for bushmeat pose significant threats to bat populations, particularly to species like the straw-colored fruit bat (Eidolon helvum) and the sheath-tailed bat (Coleura seychellensis). Conservation efforts include community-based conservation projects and sustainable resource management practices aimed at protecting critical bat habitats and promoting coexistence with local communities (Kasso & Balakrishnan, 2013). In Madagascar, an island nation renowned for its unique biodiversity, bat species richness is exceptionally high, with over 40 species recorded. However, deforestation and habitat fragmentation threaten many endemic species, such as the Madagascar flying fox (Pteropus rufus) and various microbat species. Conservation efforts focus on protecting remaining forests and establishing community-managed reserves to conserve critical bat habitats and support local livelihoods (Jenkins, 2019).

In Zambia, bat species richness is influenced by a range of habitats, including savannas, woodlands, and wetlands. The country supports diverse bat communities, from large fruit bats to small insectivores. Threats to bat populations include habitat degradation from deforestation, mining activities, and human-wildlife conflicts. Conservation efforts focus on establishing protected areas, conducting research on bat ecology and behavior, and engaging local communities in sustainable resource management practices to conserve critical bat habitats and promote biodiversity (Monadjem, 2017). In Nigeria, a country with diverse ecosystems ranging from rainforests to savannas, bat diversity is influenced by habitat degradation and hunting pressures. Studies indicate declines in forest-dependent species like fruit bats (e.g., Eidolon helvum) due to deforestation for agriculture and urban expansion. Efforts are underway to promote sustainable

land use practices and protect key roosting sites through local conservation initiatives and national policies aimed at preserving biodiversity (Olayemi, 2020).

Human disturbance encompasses a range of anthropogenic activities that alter natural habitats and ecosystems. Key forms of human disturbance include urbanization, noise pollution, light pollution, and habitat fragmentation. Urbanization often leads to the conversion of natural landscapes into built environments, reducing available habitats for bats and consequently impacting their diversity (Gorham, 2020). Noise pollution can disrupt bats' echolocation and communication, which are essential for foraging and mating, thereby affecting their ability to thrive (Barataud, 2018). Light pollution alters nocturnal environments and can interfere with bats' hunting and roosting behaviors, leading to decreased species diversity (Davies, 2012). Habitat fragmentation creates isolated patches of habitat, which can limit species movement and reduce genetic diversity, further impacting bat populations (Fenton & Barclay, 2021).

The relationship between human disturbance and bat species diversity is complex, as different forms of disturbance have varying effects on bat communities. For example, urbanization can lead to habitat loss and decreased food availability, resulting in lower bat species richness (Gorham et al., 2020). Noise and light pollution can directly interfere with bats' sensory processes, further contributing to declines in species diversity (Barataud, 2018; Davies, 2012). Habitat fragmentation can exacerbate these issues by isolating bat populations and reducing their ability to disperse and maintain healthy populations (Fenton & Barclay, 2021). Understanding these dynamics is crucial for conservation efforts aimed at mitigating the impacts of human disturbance on bat species diversity in urban green spaces.

## Problem Statement

Understanding the relationship between human disturbance and bat species diversity in urban green spaces is crucial for biodiversity conservation and urban planning in Costa Rica. As urbanization intensifies, green spaces serve as critical refuges for wildlife, including bats, yet they are increasingly subjected to human activities that can impact biodiversity. Studies have shown that urban green spaces are vital for maintaining bat populations by providing essential roosting sites and foraging areas (Medellín, 2020). However, human disturbance such as recreational activities, artificial lighting, and habitat alteration can disrupt bat behaviors and habitat suitability, potentially leading to declines in species richness and alterations in community composition (Gehrt, 2010).

## Theoretical Framework

### Habitat Fragmentation Theory

Originating from island biogeography principles, this theory posits that habitat fragmentation and reduction lead to decreased species diversity and altered community compositions. In urban environments, green spaces act as "habitat islands" surrounded by human-dominated landscapes, influencing the distribution and diversity of bat species. Human disturbance, such as habitat loss and fragmentation due to urban development, can restrict movement corridors and access to resources, affecting bat population viability (Gehr, 2010).

### Behavioral Ecology Theory

This theory focuses on understanding how animal behavior, including responses to anthropogenic disturbances, influences species distributions and community dynamics. In the context of bats in urban green spaces, behavioral adaptations to human activities like artificial lighting and noise can alter foraging behaviors, roosting preferences, and ultimately, species diversity. Studying these behavioral responses can provide insights into how different levels and types of disturbance impact bat populations (Buchanan, 2018).

**Ecosystem Services Theory**

Originating from ecological economics, this theory emphasizes the role of ecosystems, including urban green spaces, in providing essential services to human societies. Bats contribute ecosystem services such as pest control through insect predation and pollination of plants, which are vital in urban settings. Understanding how human disturbance influences bat species diversity can inform conservation strategies aimed at preserving these ecosystem services while mitigating negative impacts of urbanization (Medellín, 2020).

**Empirical Review**

Herrera (2019) assessed how urbanization and human activities affect bat diversity. Their research involved extensive acoustic monitoring and habitat surveys across urban parks and green corridors. They found that increased urbanization and associated human disturbances, such as noise and light pollution, significantly reduced bat species richness and altered their foraging behaviors. This study highlighted the critical role of habitat quality and disturbance levels in shaping bat communities in urban environments. Recommendations included implementing urban planning strategies that prioritize green spaces and reduce anthropogenic impacts to safeguard bat populations and enhance urban biodiversity.

Chavarría-Duriaux and Salazar (2020) focused on the impact of recreational activities on bat communities in urban parks in Heredia, Costa Rica. Through mist-netting and acoustic monitoring, they documented how high visitor numbers and noise levels disrupt bat roosting and foraging activities. Their findings underscored the sensitivity of bat species to human disturbance, emphasizing the need for management practices that balance recreational use with wildlife conservation goals. Recommendations included establishing visitor guidelines to minimize disturbance during critical bat activity periods and creating buffer zones around roost sites to mitigate the impacts of human presence on bat diversity.

Ramírez-Restrepo (2021) explored bat responses to habitat modification and urban sprawl in Alajuela, Costa Rica. Using advanced GIS mapping techniques and acoustic monitoring, they assessed bat diversity across gradients of urbanization. Their study revealed significant declines in bat species richness with increasing levels of urban development, highlighting habitat loss and fragmentation as major drivers of biodiversity decline in urban areas. The research stressed the importance of preserving green spaces and implementing sustainable urban planning practices to mitigate adverse impacts on bat communities and maintain ecological integrity in urban landscapes.

Jiménez (2018) investigated the relationship between vegetation structure and bat diversity in suburban areas of Cartago, Costa Rica. Through extensive transect surveys and acoustic recordings, they demonstrated that well-vegetated green spaces supported higher bat species

richness compared to areas with sparse vegetation cover. This study emphasized the role of habitat complexity in providing suitable roosting sites and foraging opportunities for bats in urban environments. Recommendations included enhancing green infrastructure and promoting urban greening initiatives to enhance habitat quality and support diverse bat communities amidst urbanization pressures.

Solano-Ugalde (2019) conducted a comparative study on bat responses to anthropogenic noise in urban versus rural areas of Limón, Costa Rica. Using playback experiments and acoustic monitoring, they observed altered echolocation behaviors and reduced bat species diversity in response to urban noise pollution. Their findings highlighted the negative impacts of noise disturbance on bat foraging efficiency and reproductive success, emphasizing the need for sound management practices in urban planning to mitigate noise pollution and preserve bat habitats.

Ulate-Piza (2022) assessed bat community composition along urbanization gradients in Puntarenas, Costa Rica. Their study utilized mist-netting and genetic analysis to investigate how varying levels of urban development affect bat species composition. They found that certain bat species exhibited resilience to urbanization, while others declined with increased urban sprawl. This research underscored the importance of understanding species-specific responses to urbanization and implementing targeted conservation strategies to protect vulnerable bat populations in urban landscapes.

Vargas-Fonseca and Quesada-Moraga (2020) explored the impact of pesticide use on bat diversity in agricultural landscapes adjacent to urban areas in Guanacaste, Costa Rica. Through field surveys and pesticide residue analysis, they documented negative correlations between pesticide exposure and bat species richness. Their study highlighted the indirect effects of agricultural practices on urban bat communities, emphasizing the need for sustainable agricultural practices and habitat management strategies to mitigate pesticide impacts and conserve bat biodiversity in urban-agricultural interfaces.

## METHODOLOGY

This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low-cost advantage as compared to field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

## FINDINGS

The results were analyzed into various research gap categories that is conceptual, contextual and methodological gaps

**Conceptual Research Gap:** Conceptually, there is a need for studies that delve deeper into the specific mechanisms through which different types of human disturbances (e.g., noise pollution, habitat fragmentation, recreational activities) impact bat communities (Herrera, 2019). While existing studies highlight correlations between urbanization levels and bat species richness, more detailed investigations are required to understand the direct causal pathways and ecological processes involved. For instance, exploring how specific noise frequencies affect bat echolocation

or how habitat fragmentation alters foraging behavior could provide nuanced insights into conservation strategies tailored to mitigate these impacts effectively.

**Contextual Research Gap:** Contextually, there is a geographical bias towards certain regions within Costa Rica (e.g., San José, Heredia, Alajuela) (Chavarría-Duriaux & Salazar, 2020). Future research should aim to broaden the geographic scope to include other urban areas across different ecological zones within Costa Rica. This expansion would allow for a more comprehensive understanding of regional variations in bat responses to urbanization and human disturbance. Additionally, studies could focus on comparing bat community dynamics between different types of urban green spaces (e.g., parks, residential areas, industrial zones) to identify specific hotspot areas for conservation prioritization.

**Geographical Research Gap:** Geographically, there is a notable gap in research concerning the Pacific and Caribbean coasts of Costa Rica (Ramírez-Restrepo, 2021). Most studies have concentrated on urban areas in the Central Valley and northern regions. Investigating bat diversity patterns in coastal urban environments would provide insights into how coastal development and specific environmental factors unique to these regions influence bat communities differently. This would enhance the applicability of conservation strategies across diverse geographical contexts within Costa Rica.

## CONCLUSION AND RECOMMENDATIONS

### Conclusions

Understanding the relationship between human disturbance and bat species diversity in urban green spaces in Costa Rica reveals critical insights into conservation strategies and urban planning efforts. Studies conducted by Herrera (2019), Chavarría-Duriaux and Salazar (2020), Ramírez-Restrepo (2021), and others underscore the vulnerability of bat populations to urbanization pressures such as noise pollution, habitat fragmentation, and recreational activities. These disturbances not only reduce bat species richness but also alter their foraging behaviors and roosting patterns, threatening biodiversity and ecosystem services provided by bats.

Effective conservation measures should prioritize the preservation and enhancement of habitat quality within urban green spaces (Herrera, 2019). Strategies like minimizing noise and light pollution, establishing buffer zones around roosting sites, and integrating green corridors into urban planning are crucial. Additionally, promoting public awareness and community engagement programs can foster sustainable practices that mitigate human impacts on bat populations while enhancing urban biodiversity.

Further research is needed to fill gaps in understanding specific mechanisms of how different types and intensities of human disturbance affect bat communities across various urban settings in Costa Rica. Addressing these gaps will not only advance ecological knowledge but also inform evidence-based policies aimed at maintaining bat diversity amidst urban growth. Ultimately, fostering coexistence between urban development and wildlife conservation is essential for sustaining healthy ecosystems and promoting biodiversity conservation in urban environments.

## Recommendations

### Theory

Theoretical contributions emphasize the importance of ecological resilience and species-specific responses to urbanization. Research suggested that preserving green spaces and implementing sustainable urban planning practices are crucial for mitigating the negative impacts of habitat loss and fragmentation on bat communities. These findings contribute to ecological theories by highlighting how urban landscapes can be designed to support diverse wildlife populations amidst human disturbance.

### Practice

In practice, it is essential to integrate biodiversity conservation into urban planning frameworks. Strategies such as creating green corridors, minimizing light and noise pollution, and establishing protected areas around roosting sites, as recommended can help mitigate the adverse effects of recreational activities and human presence on bat species. Urban green spaces should be managed to provide suitable habitats that promote bat foraging and breeding, enhancing urban biodiversity while accommodating human activities.

### Policy

Policy recommendations focus on incorporating biodiversity conservation goals into urban development policies and regulations. Policies should support the designation of green infrastructure networks and protected areas within urban landscapes to maintain ecological connectivity for bats and other wildlife. Strengthening enforcement of environmental laws and guidelines that regulate noise levels, pesticide use, and habitat destruction in urban areas, as advocated by Vargas-Fonseca and Quesada-Moraga (2020), is crucial for ensuring long-term bat species conservation.

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