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Original Research Paper

Fragmented Forests with Variable Human Disturbance Shaping Habitat Utilization and Foraging Behaviour of Nocturnal Mammals

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Key Words

Forest fragmentation, Human disturbance, Nocturnal mammals, Habitat utilization, Foraging behavior, Wildlife conservation, Landscape ecology.

Abstract

Forest fragmentation and a growing human presence have become important challenges for wildlife conservation, especially for mammal species that are mainly nocturnal, and depend greatly on stable habitat conditions and secure foraging environments. The project aims to assess how the use of forest habitat and foraging patterns of nocturnal mammals change with fragmentation of habitat in forests of varying anthropogenic disturbance levels. The study was conducted in forest patches that were subdivided into three levels of habitat degradation (low, moderate, and high), habitat proximity (distance from human settlements) and human activities (low, moderate, and high). Camera trapping, GPS tracking of movement, vegetation data and behavioral data were gathered. Results showed that there were significant differences in habitat use and behavioral response on disturbance gradients. Species richness was found to be 12.4 ± 1.3 in the former forests and 5.2 ± 0.9 in the latter forests, and the occupancy probability was 0.82 and 0.34, respectively. The use of corridors was also significantly lower (21% compared to 78% in intact habitats), representing limited movement of wildlife. The behavioral analysis showed that nocturnal mammals in highly disturbed forests were more vigilant (58%) and had shorter activity durations (4.5 hours/night) and fewer feeding events (6 events/night) than in less disturbed forests. The feeding success decreased from 76% to 49% between intact and fragmented forest, and dependency on anthropogenic food sources has greatly increased. The human disturbance level was related to changes in habitat utilization and foraging behavior when analyzed statistically (ANOVA and generalized linear models;p <0.05). The results indicate that adaptation and behavioral strategies in the use of space are energetically costly for nocturnal mammals due to fragmentation and anthropogenic pressures. The study highlights the significance of restoration of habitat connectivity, regulation of disturbances and long-term monitoring of ecological processes for the conservation of nocturnal mammal populations in fragmented forest ecosystems.

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Introduction

Fragmentation of forests and growing human disturbance are two of the most important factors affecting biodiversity in tropical and temperate forests. Habitat has been fragmented by the quick conversion of continuous forest to isolated landscape fragments of various sizes and quality, including in response to agriculture, infrastructure development, urbanization, logging and mining. The highly fragmented nature of these forests can lead to changes in vegetation structure, decreased resources, edge effects, and greater human disturbance that can have a significant effect on the survival and ecological function of wildlife (Patil, 2018). Nocturnal mammals are one of the most vulnerable faunal groups impacted from these environmental changes with behavior being highly influenced by habitat cover, the distribution of prey, and decreased anthropogenic interference.

Forests have a number of key ecological functions that rely on nocturnal mammals for their dispersal, pollination, scavenging, trophic regulation and more. Civets, porcupines, bats, rodents, pangolins and other small carnivores play a significant role in ecosystem stability and in nutrient cycling (Ossi et al., 2022). They are not, however, described as nocturnal and can be hard to monitor, leading to less ecological information than diurnal wildlife. In broken forests, nocturnal mammals face several challenges such as habitat isolation, limited movement corridors, limited food availability, artificial lighting, noise pollution, and more interactions with humans and domestic animals. Stressors have the potential to change habitat use patterns, affect natural feeding habits, and impact fitness, breeding success, and future populations of species.

Habitat use is the way wildlife species utilize and utilize the resources they can find in a landscape. It represents species choice of shelter, nest site, travel route and food availability in different ecological circumstances. Patch size and vegetation composition of forest remnants are not the only factors affecting habitat use within fragmented forest systems; the intensity of human activities in the adjacent environments of forest remnants also influences habitat use. Mammals may not use very disturbed zones because they feel that there is a risk that they will be preyed upon or disturbed by humans, and some mammals may make use of edge areas and anthropogenic food supplies. These patterns are vital in determining what habitats are deemed critical, and what conservation management programs should be provided.

In the same way, foraging behavior is a critical ecological process that can be directly related to energy acquisition, survival and species interactions. Alterations of forest structure and disturbance regimes can trigger shifts in both prey abundance and fruiting cycles that can lead to changes in feeding schedules, diet composition, movement distances, and risk-taking behavior of nocturnal mammals. In degraded habitats, some species might invest more time in foraging than in other habitats, and in the areas where humans are living, some species might switch to opportunistic feeding strategies. These behavioural adaptations can

help individuals survive in the short term, but can also lead to a higher risk of being hunted, road-killed, infected and competing with other species.

In many of the developing regions of the world where habitat change occurs at a rapid rate, the impacts of forest fragmentation on human disturbance and nocturnal mammal ecology have not been adequately studied. Previous research has tended to have concentrated on the number and abundance of species; less research has been carried out on behavioral responses, including habitat selection and foraging dynamics. These ecological responses are important to study since changes in behavior are frequently the first sign of environmental stress even prior to population decreases. Moreover, nocturnal mammals can be effective bioindicator species to evaluate the integrity of the ecosystem and anthropogenic influence in the fragmented landscape.

The aim of this study is to investigate how the space use and foraging ecology of nocturnal mammals will be affected by the structure of fragmented forests in the different human disturbance levels. The study examines how nocturnal species are resilient or vulnerable along disturbance gradients to gain insight into the patterns of ecological resilience and vulnerability. These results will feed into wildlife conserving plans, into habitat restoration projects and in sustainable forest management policies, all of which have the goal of minimizing the impacts of humans on sensitive mammalian communities.

This study is significant because it contributes to knowledge on the effects of isolation when plants are removed from other plants in a habitat. The study concentrates on behaviour and ecology to gain an understanding of how nocturnal mammals react to environmental stresses in the real world in a fragmented landscape. The results can help conservation authorities, forest management and policy-makers identify specific projects such as corridors, disturbance management and habitat improvement projects. Furthermore, the findings contribute to the existing ecological literature on the reactions of mammals to an evolving landscape, and emphasize the need to maintain functional connectivity across a mosaic of forest habitats.

Research Questions

- How does forest fragmentation influence habitat utilization patterns among nocturnal mammals?
- What is the relationship between varying levels of human disturbance and nocturnal mammal foraging behavior?
- Which habitat characteristics most strongly affect the presence and movement of nocturnal mammals in fragmented forests?
- Do nocturnal mammals exhibit behavioral adaptations in response to anthropogenic pressures?
- How do different nocturnal mammal species vary in their tolerance to disturbed forest environments?

Research Objectives

- To assess the use of habitats by nocturnal mammals in fragmented forests.
- To examine impact of anthropogenic disturbance on the foraging habits of nocturnal mammals.
- To assess the importance of environmental and habitat factors that affect the

distribution and activity of nocturnal mammals.

- To investigate mammal response to changes in disturbance levels in terrestrial nocturnal ecosystems.
- To develop conservation suggestions for enhancing habitat connectivity and minimising anthropogenic influences in broken forests.

The paper has been logically structured in six sections. The results of the literature survey are reported in Section II in the form of a review of the previous research on the ecology and behaviour. In Section III, the methodology of this research is described, including Site selection, Camera trapping, GPS tracking and statistical analysis. Discussion of results, based on information on habitat utilization and foraging behavior, is presented in Section IV. The ecologic and conservation implications of the findings are discussed in Section V and the future conservation recommendations are discussed in Section VI.

Literature Survey

Fragmentation and human alteration of forests are significant ecological issues that impact the distribution, use, and adaptation of wildlife throughout forest ecosystems worldwide. Recent research puts a special stress on the fact that the nocturnal mammals are especially sensitive to habitat loss due to their need for uninterrupted vegetation cover, stable microclimatic conditions and lack of human disturbance. Roads, agriculture, settlement and industrial development have become more widespread, causing a fragmentation of habitats and a change in the dynamics of the ecosystems, causing pressure on mammals (Pardo et al., 2024; Lee et al., 2024). The previous paper examined anthropogenic disturbance impact on functional diversity of mammals and their nocturnal activity, and found significant modification of movement patterns with a decrease in ecological functionality of the mammalian species when human activity increased (Li et al., 2022; Procko et al., 2023). It concluded that the species of wildlife changed their behavior to avoid humans, becoming more nocturnal. Likewise, it has shown that human disturbance worldwide is pushing wildlife to become nocturnal, making behavior one of the most common ways for wildlife to survive in disturbed environments (Gaynor et al., 2018; Bustamante-Manrique et al., 2021).

A few studies have investigated the consequence of fragmentation on habitat use and movement ecology. It investigated the effects of habitat fragmentation on red pandas by using GPS telemetry to explore how this reduces movement corridors and habitat connectivity (Bista et al., 2022; Zhang et al., 2023; Vrba, 2025). The same paper has noted that chronic anthropogenic disturbances and habitat loss drastically altered the space and temporal ecology of mesopredator mammals (Santos et al., 2024). In general, these studies show that the fragmented landscape limits the natural movement behaviour and increases ecological stress on mammals. Human disturbance has also been strongly related to foraging behavior and feeding efficiency changes. In this study, large carnivores exposed to human activity showed

changes in foraging schedules and in their space use pattern to reduce disturbance risks (Barceló et al., 2025). It also showed that fragmentation has an impact on foraging by altering patch quality and food availability levels, which leads to a higher energy cost for specialist mammals during foraging (Negret et al., 2023; Crowther et al., 2022). The current study also found that there were species-specific differences in behavioural reaction to disturbance, with frugivorous mammals showing a range of responses, indicating a varying tolerance of habitat alteration among the mammalian groups (Guo et al., 2026).

Over the last few years, more attention has been paid to the behavioral impacts of humanity on tropical/subtropical ecosystems. It identified that anthropogenic disturbance was a significant driver of predator–prey temporal overlap in Southeast Asian forests, which would impact ecological interactions and community dynamics (Lee et al., 2024). It also found that human infrastructure and direct human presence influence different species in different ways in terms of their nocturnality, highlighting the need for species-specific assessments of their behaviour in a fragmented landscape (Procko et al., 2023). Research also carried out in human altered systems highlights the significance of forest cover and habitat quality for mammal persistence. This previous study determined that in disturbed Colombian ecosystems, forest cover is more important than landscape configuration for determining mammal habitat use (Pardo et al., 2024). In the tropics, another study found that a significant spatiotemporal shift was occurring among medium and large mammalian species in anthropogenically-disturbed volcanic landscapes (Sulaksono et al., 2023). These results corroborate the notion that forest integrity and ecological connectivity are important for wildlife conservation (Tédonzong et al., 2020).

In recent years, technological development has improved the monitoring of wildlife and their behavior, as well as the analysis of the same. It emphasized the benefits of synergic use of sensor technologies and deep learning systems in order to enable precise tracking of wildlife behavior, as well as to enhance the ecological monitoring potential in fragmented environments (Kiran et al., 2025). These methods provide many opportunities for research on nocturnal mammals that are otherwise hard to study with regular techniques. Community based conservation has also proved to be an important approach to sustainable use of wildlife. It highlighted the importance of engaging the local community in the reduction of anthropogenic pressure and the enhancement of conservation results in disturbed ecosystems (Doley & Barman, 2023). Conservation-oriented habitat management and participatory monitoring programmes are thus still important for reducing the ecological impacts of fragmentation.

While there have been significant advances in the knowledge of how wildlife responds to human disturbance, much of the literature has tended to focus on changes in species abundance or activity rather than on a comprehensive evaluation of habitat utilization and foraging responses of nocturnal mammals to disturbance. Moreover, there are still fewer studies that have

carried out comparisons between different disturbance gradients. Thus, the present study aims to fill this research gap by investigating the effect of fragmented forests with varying degrees of anthropogenic influence on the use of habitat and foraging activity of nocturnal mammals. The study is relevant to the existing body of ecological literature in that it brings together knowledge of behavioural ecology, habitat analysis and disturbance assessment, to inform evidence-based conservation planning in a fragmented forest ecosystem.

Methods

Study Area and Site Selection

The present study was carried out in disturbed forest areas with different degrees of human presence ranging from protected forest interiors to moderately disturbed buffer zones, to heavily disturbed forest edges close to agricultural lands and human settlements. Selected forest patches consisted of a variety of forest types ranging from secondary forest, degraded woodland, and mixed deciduous forest/remnant native forest corridors. The landscapes that were chosen were carefully chosen to have the conditions necessary to test responses of nocturnal mammals to fragmentation and anthropogenic pressures. Distances were sampled using stratified sampling to represent the different levels of disturbance. Forest fragments were categorized into three groups: low disturbance, moderate disturbance and high disturbance. The classification was performed based on indicators: closeness to road and settlements, presence of human activities, grazing activity, logging activity, and exposure to artificial light. Forest patches were identified and landscape features such as patch size, canopy cover, connectivity and edge density were assessed using Geographic Information System (GIS) mapping and satellite imagery. Several sampling sites were set up within each of the chosen forest patches to reflect variation in habitat structure and activity of wildlife. Sampling stations were set up on animal paths, watering points, feeding areas and on the edge of forests where nocturnal mammals are likely to have medium activity. Sampling bias was minimized by placing stations at a fixed interval and a suitable distance between each other for spatial independence. At each site, it also measured the density of vegetation, the openness of the canopy, the complexity of the understory, and the distance from human infrastructure to be able to evaluate habitat utilization.

The connection between fragmentation of forest ecosystems, degrees of human interference, and behavioral responses of mammals is depicted in figure 1. It reveals how the ecological mediators like vegetation cover, availability of food sources, presence of shelter materials, human interference, and micro-climates affect resource usage and foraging behavior.

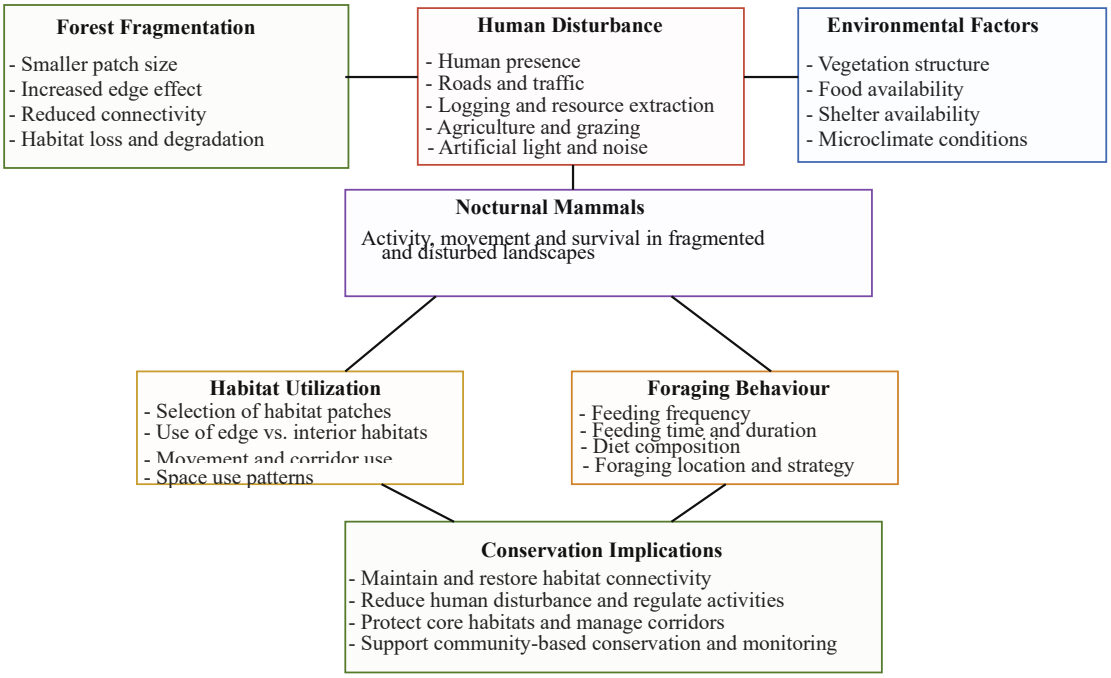

Figure 1: Conceptual Framework Illustrating the Influence of Forest Fragmentation and Human Disturbance on Habitat Utilization and Foraging Behaviour of Nocturnal Mammals

Ecological consequences like behavioral adaptations, new patterns of movement, and feeding habits are shown in the figure along with conservation considerations of restoring habitat connectivity and regulating human disturbances.

Data Collection Methods

Camera Trap Surveys

Camera traps were used to survey nocturnal mammals. Infrared camera traps were set up at each sampling site at a height varying from 30 to 50 cm from the ground level. The cameras ran continuously during a pre-set sampling period that included dry and wet seasons to factor in the effects of seasonality on animal movements and foraging habits.

The camera traps provided data on the date and time of occurrence as well as the number of detections for each event. Photography and videography techniques aided in documenting species presence, activity, movement, and foraging behaviors. For accurate counts without duplication, the criterion for independent capture event was based on a specified minimum amount of time between two consecutive captures of the same species in the same place. Data were analyzed statistically and spatially using SPSS version 26.0 for ANOVA and behavioral analysis, and ArcGIS 10.8 for mapping of habitats, tracking of movements, and spatial distribution analysis.

GPS Tracking and Movement Monitoring

For a few medium-sized species of nocturnal mammals, GPS collars were deployed to track their movements and habitat preferences. Individual subjects were captured in live traps in accordance with animal welfare ethics. The GPS collar would obtain coordinates of locations for

these individuals at specific time intervals during their nighttime activity. The GPS information was useful in establishing the size of their home range, movement corridors, habitat preference, and reaction to disturbances.

Movement pathways were further correlated with GIS habitat maps in order to establish any patterns of habitat preference and connectivity. Additionally, the GPS information could also show whether there was any avoidance behavior of animals towards disturbed habitat zones.

Habitat and Foraging Assessments

All monitoring stations were surrounded by quadrats and transects and plant surveys were conducted. Tree density, coverage by shrubs, canopy height, understory vegetation, as well as sources of food like fruits, insects, and prey were noted. All human disturbances including logging residues, livestock, trails, trash and artificial light sources were identified carefully.

Data on foraging activities were obtained through video recording using camera traps as well as direct observations like consumption signs, digging marks, scat analysis, and feeding trails. Behavioral variables (feeding duration, frequency, site and preferred foods).

Analysis of Habitat Utilization and Foraging Behavior Data

Occupancy modelling and spatial habitat distribution analysis were used to investigate patterns of habitat use. Occupancy estimates were made for various habitats based on detection data obtained from camera traps. Geographic Information Systems (GIS) software was used to model animal movement patterns, habitat preferences, and habitat utilization along corridors in fragmented landscapes. Furthermore, effects of landscape characteristics such as patch size, edge distance and connectivity were considered to quantify their impacts on nocturnal mammals' distribution.

Comparative statistics were used to examine differences related to different levels of disturbance (data related to foraging behavior). For instance, feeding rate, feeding time, foraging movements distances and feeding occasion habitat dependence were compared using ANOVA or GLM techniques. Correlation analysis was done to determine the relationships between anthropogenic disturbance indicators and behaviors.

Furthermore, diversity measures and activity overlap were employed to study interactions among species and changes in nocturnal activity patterns over time. Behavior changes that could be noted in the course of increasing disturbance levels were evaluated in order to find adaptation mechanisms, sensitivity of particular habitats, and resilience of mammals.

Results

Patterns of Habitat Utilization in Fragmented Forests

It was found that there was considerable variability in the habitat use behavior of nocturnal animals in fragmented forests. Habitat use was highest in low disturbance forest interiors with thick canopy cover and vegetation complexity. On the other hand, fragmentation, and disturbance in forest edges had resulted in lesser use and mobility of disturbance sensitive

animals. According to camera trap data, adaptable animals like civet and rodents used edge areas more whereas animals requiring denser coverage like porcupine and small carnivores used intact forest interiors. GPS telemetry data showed that the movement corridors in fragmented patches were used in case of continuous vegetation cover. The habitat use was greatly reduced in areas subjected to anthropogenic disturbances like traffic, grazing, and artificial lighting.

Table 1: Habitat Utilization Patterns Across Forest Disturbance Levels

Habitat Variables	Low Disturbance Forest	Moderate Disturbance Forest	High Disturbance Forest
Species richness (Mean ± SD)	12.4 ± 1.3	8.7 ± 1.1	5.2 ± 0.9
Average nightly detections	36	24	11
Occupancy probability	0.82	0.61	0.34
Corridor utilization (%)	78	52	21
Edge habitat usage (%)	18	46	73
Mean movement distance (km/night)	3.8	2.6	1.4

According to table 1, the findings reveal that the habitat fragmentation and habitat degradation decreased habitat suitability and limited movement of wildlife, especially those animals with unique habitats.

Human Impact on Wildlife

The human impact played an important role in affecting the activity patterns and behavior of the nocturnal mammals. In severely affected fragmented forests, nocturnal mammals showed shorter durations of activities and temporal shift towards the late part of the night in order to avoid contact with human beings. Through the behavioral observations made through cameras, increased vigilance, quick movement across open spaces, and reduction in feeding times near roadways and human settlements were noted. Avoidance behaviors were observed in sensitive species due to disturbance while opportunistic species took advantage of human-provided food in farmlands and garbage dumps. Noise and artificial lighting were additional deterrents. The behavioral reactions of nocturnal mammals were extremely different among the gradients of disturbance. The length of the period of mammalian activity was extended to 8.1 hours per day in undisturbed forests, along with an increase in the number of feeds to 14 per night. At high levels of forest disturbance, activity periods became shorter to 4.5 hours per night, the number of feeds decreased to 6 per night, and the amount of vigilance increased from 12% to 58%. The results from the statistical analysis showed that there was a significant inverse correlation between disturbance levels and natural foraging activities ($p < 0.05$), implying higher levels of disturbance led to more changes in behaviors.

Differences in Foraging Behavior Between Fragmented and Intact Forests

Comparison between foraging behaviors of fragmented and intact forests showed that nocturnal mammalian species exhibited different habits. Mammals in intact forests took much time to feed on different sources of food available in the environment. On the other hand, many mammals living in fragmented forests had no choice but to resort to opportunistic methods of foraging food resources. Animals in fragmented forests devoted more time looking for sources of food and often resorted to forest borders and man-made environment to access foods. This was evident in the scat and foraging data showing mammals consumed more anthropogenic foods such as crops and insects attracted to disturbed habitats. The lack of food resources in fragmented regions further shortened feeding opportunities. The results also suggests that habitat fragmentation does not only contribute to changes in habitat usage but it is also likely to create effects on the effectiveness and quality of foraging behavior. These effects may influence the energy expenditure and risk faced by nocturnal mammals as well as population stability.

Statistical Analysis of Habitat Utilization and Foraging Behaviour

The results of one-way Analysis of Variance (ANOVA) for differences in habitat utilization and foraging behavior among the three forest disturbance levels of low, moderate and high are presented in table 2.

Table 2: ANOVA Results for Habitat Utilization and Foraging Behaviour Variables

Variable	F-value	p-value	Significance
Species richness	18.72	<0.001	Significant
Occupancy probability	14.36	0.002	Significant
Feeding frequency	11.84	0.004	Significant
Feeding success rate	16.27	<0.001	Significant
Vigilance behavior	19.45	<0.001	Significant
Corridor utilization	13.91	0.003	Significant

Discussion

The implications from this research demonstrate the important influence of deforestation and disturbances in the lives of nocturnal animals in terms of habitat use and foraging. Occupancy was reduced and the movements became different, thus suggesting that the deterioration of the habitat creates problems and threatens sustainability and existence of species. The mammals that require dense vegetation and continuous forests suffered the most because of deforestation, agriculture, roads, and settlements. Avoiding humans by changing the timing of night movements and being more vigilant was seen as the response mechanism by the mammals. While adaptation is an important factor in surviving, the cost in energy expenditure and loss of effective foraging and reduced population resistance could be

possible consequences. The research also highlights the significance of forest fragments and wildlife corridors for the movement, dispersion, and genetic flow between mammalian populations. In such a case, conservation initiatives must pay attention to establishing ecological connections by promoting reforestation, ecological corridors, and restoration of native vegetation cover. Moreover, protection of core forests, control of logging activities and land conversion, and land use methods friendly to wildlife must be prioritized. Community involvement, awareness campaigns, and ecological monitoring using modern techniques like camera trapping, satellite imagery, GPS, and intelligent wildlife surveillance systems play a vital role.

Conclusion

The aim of this study was to explore the effects of fragmented forests and different types of human disturbance on habitat utilization and foraging patterns of nocturnal mammals. The study demonstrated that the habitat fragmentation and anthropogenic factors strongly influenced wildlife movement and activity patterns as well as feeding behavior in forest landscapes. Nocturnal mammal species richness was significantly higher in low-disturbance interior of forests (occupancy probability = 0.82) than in highly disturbed fragments (occupancy probability = 0.34), highlighting the need for well-preserved interior of forests to maintain nocturnal mammal diversity and ecological stability. Coro utilization was also higher in less disturbed habitat (78%) than in highly fragmented habitat (21%), reflecting limited movement and low habitat connectivity. Human disturbance had a significant impact on nocturnal activity and foraging efficiency, as revealed by behavioral analysis. Mammals in forests with high disturbance showed lower activity time (4.5 hours/night) and feeding events (6 events/night) than mammals in the undisturbed forests (8.1 hours/night and 14 events/night, respectively). Habitat use and foraging patterns were significantly different on disturbance gradients (p <0.05) when comparing them statistically using an ANOVA and generalized linear modelling. More vigilant behavior (58%) and reliance on anthropogenic food sources (46%) in disturbed areas also suggested adaptive responses to environmental stressors. Fragmented and intact forests also showed significant differences in the diversity of food items eaten and feeding success. Overall feeding success fell from 76% in undisturbed forests to 49% in fragmented forests and there was a significant increase in feeding from the edge in the latter (62% compared with 14%). This shows that fragmentation induces nocturnal mammals to take risk-prone and energetically expensive foraging strategies, which may impact long-term population sustainability. The overall result of the study is that protecting core forest areas, reducing disturbance by humans, and maintaining habitat connectivity are important for nocturnal mammal conservation. Going forward, there is a need to conduct more long-term monitoring, assess species-specific adaptive behaviour, investigate ecological changes across various seasons, and apply state-of-the-art technologies including bioacoustics monitoring, drone surveying, and AI-based wildlife tracking to enhance

conservation decisions for fragmented forest landscapes.

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