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IMPACT OF ANTHROPOGENIC HABITAT ALTERATION ON BIRD–INSECT TROPHIC INTERACTIONS: A COMPARATIVE STUDY OF NATURAL AND HUMAN-MODIFIED LANDSCAPES

K. Shailaja [1], Dr. Mohd Babu Khan [2], Dr. Sanjay Kumar [3]

[1] Research Scholar (Zoology) Glocal School of Life and Allied health Sciences The Glocal University Saharanpur, Uttar Pradesh, India
[2] Assistant Professor, Research Supervisor, Glocal School of Life and Allied health Sciences The Glocal University Saharanpur, Uttar Pradesh, India
[3] Professor, Principal, Glocal College of Paramedical Science & Research Centre, Glocal University, Mirzapur Pole, Saharanpur (247121), Uttar Pradesh, India, India

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ABSTRACT

Anthropogenic habitat modification is the main reason of the ecological instability and loss of biodiversity in the world. The present study focuses on the effects of habitat changes that humans impose on the natural landscapes on the structure of the insect communities, the avian diversity, and the trophic interactions between these organisms. The research methodology was a field-based cross-sectional study and data collection was conducted under traditional methods such as sweep nets, pitfalls, light traps to collect the bugs, point count and line transect surveys to collect birds. Some of the biodiversity indices that were calculated were species richness, Shannon-Wiener and Simpson indices and statistical methods such as multiple regression and correlation were used to evaluate ecological interactions. In the comparison of the natural surroundings with the landscape that had been transformed by the human beings, it was revealed that the diversity of birds and insects was significantly higher. The natural ecosystems had higher indices of species richness, species abundance and diversity, which implied that the ecosystems were ecologically stable and structured with a balanced community composition. The number of birds and insects had strong positive interdependence in the natural environment, but in the disturbed landscapes, it was lower, which suggested that it interfered with trophic relationships. Feeding guild analysis revealed that species that were omnivorous were overrepresented in locations that were altered by humans, which suggested that they adapted to disturbance in the environment, and insectivorous birds were overrepresented in the natural environment. The regression study showed that habitat fragmentation, urbanization, and agricultural intensity negatively affect ecosystem stability, and vegetation cover has a positive effect on biodiversity.

Keywords: Anthropogenic Disturbance, Bird Diversity, Insect Community Structure, Trophic Interactions, Habitat Fragmentation

1. INTRODUCTION

Anthropogenic habitat modification has been among the primary factors contributing to ecological dysfunctioning and the loss of biodiversity in the twenty-first century. Globalisation is characterized by the accelerated urbanisation, accelerated agriculture, deforestation, infrastructural construction and increased industry activities have transformed natural ecosystems into man dominated

landscapes. Land-use change is one of the primary factors in species diversity loss and disruption of ecological interactions as the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) believes. Anthropogenic changes in troic interactions, in particular between birds and insects, have received comparatively minor focus, compared to the numerous studies that have documented the changes in species richness and abundance in altered ecosystems.

In the land settings, birds and insects have a biological association with each other. Insects provide the primary food source to many bird species, especially during breeding periods when large quantities of protein in the diet are required to nourish the chicks. The insectivorous birds in their turn stabilize the insect population in the ecosystem and help in the natural pest control. These interactions influence the transfer of energy, nutrient cycles and food web stability, which are critical to ecosystem functions. Fewer ecosystem resilient, more insect outbreaks, altered predator-prey interactions are only some of the cascading ecological effects that may be caused by the disconnection of these trophic interactions.

Anthropogenic landscape modification typically leads to habitat fragmentation, vegetation homogenization, microclimatic alteration, and chemical pollution (e.g. use of pesticides). Besides influencing avian feeding behavior, nesting success, and the population dynamics indirectly, the changes can have a direct negative effect on the insect diversity and biomass. As an example, intensive monoculturals and pesticides systems of agriculture might benefit the reduced insect populations in comparison with structurally complex natural environments such as woodlands or grasslands. Similarly to this, metropolitan areas can decrease the number of specialized insects that depend on the diverse population of arthropods in favor of generalist birds.

The significance of understanding the ecological processes that could drive these changes is emphasized by recent surveys carried out all over the world including the one by the International Union of Conservation of Nature which reported significant losses in both insect and bird species. However, instead of examining their functional associations across the differences in habitats, most studies have examined birds and insects in isolation. In order to explain the gradients of anthropogenic disturbance on troic interactions, natural and anthropogenic-modified landscapes should be compared.

2. OBJECTIVES OF THE STUDY

- To assess and compare bird species diversity, abundance, and feeding guild composition in natural habitats and human-modified landscapes.
- To evaluate insect diversity, abundance, and community structure across natural and anthropogenically altered ecosystems.
- To analyze the relationship between bird diversity and insect fauna in both habitat types in order to understand changes in trophic interactions resulting from habitat alteration.
- To determine the influence of anthropogenic factors such as land-use change, urbanization, agricultural practices, and habitat fragmentation on bird–insect predator–prey dynamics and overall ecosystem stability.

3. LITERATURE REVIEW

Barros et al. (2019) examined the diverse ecological fluxes of ecosystem services around forest-matrix boundaries mediated by birds in human altered landscapes. Their study revealed that, depending on the composition of the matrix and the landscape organization, the provision of ecosystem services by the birds such as seed dispersion and insect predation vary significantly across habitat boundaries. Context-dependent spillover of bird functional groups to adjacent human-altered matrices in fragmented tropical forest occurred only under the support of structurally complex matrices. This paper emphasized that human-made change of habitats does not only decrease species richness, but also transforms ecological processes involving birds such as insect trophic interactions.

Bregman et al. (2016) built upon this study by assessing the consequences of manipulating land cover on the stability of tropical forest ecosystems by using bird functional attributes. The article published in the Proceedings of the Royal Society B revealed that following distortion of the habitat, functional diversity declines more rapidly than taxonomic diversity. Traits related to mobility, specialization in diets and foraging behavior were particularly susceptible to alterations in land cover. This has far reaching implications on the trophic interactions between birds and insects since the loss of functionally distinct insectivores can change the predator-prey interactions, thus reducing the stability of the ecosystem.

Faeth et al. (2005) studied trophic relationships in the city and demonstrated how urbanization could alter nutrient cycling, primary productivity, and predator-prey interactions. Based on their study, the top-down control systems are often altered and food web simplified in urban settings. Urban bird assemblage shifts towards an omnivorous and generalist species might disrupt insect predation affecting the ecosystem services and trophic balance.

Williams-Guillén et al. (2015) stated the challenges and opportunities of maintaining environmental services in agricultural settings, and the role of bats in anthropogenic matrices. Although the study contained some Chiroptera concentration, the analogies made to the bird insectivores were helpful. It emphasized the point that trophic services such as insect suppression can be maintained through the conservation of heterogeneity of habitat in an agricultural matrix, which is important in general since it simply states that anthropogenic landscapes can still be ecologically functioning under biodiversity consideration.

Tscharntke et al. (2012) present eight hypotheses explaining the effect of landscape structure and landscape composition on biological process and biodiversity patterns. Their theoretical framework emphasized much on the connectedness between habitats, and spillover consequences among habitats, and cross-scale interactions. This landscape moderation perspective is highly relevant when studying bird-insect trophic relationships in natural and artificially modified ecosystems.

4. METHODOLOGY

4.1. STUDY AREA

The study will be conducted using two different types of habitat; human-altered landscapes (including farmlands, city green cover, and peri-urban settlements) and natural habitats (including forest reserves, preserves, or virgin forest patches). In order to ensure that there will be perfect comparison, the locations selected will be of similar size and similar climates. To eliminate site-specific bias, a number of sampling sites will be selected in each type of habitat.

4.2. RESEARCH DESIGN

The investigation will be done using a comparative cross-sectional field-based research design. The data of insect and bird diversity will be obtained simultaneously in the natural habitats and artificial ones. This design will be able to provide assessments of species abundance, composition, and trophic relationships in different categories of land use.

4.3. BIRD DIVERSITY ASSESSMENT

Bird diversity and abundance will be assessed by the use of standard field survey techniques such as line transect surveys and point count method. To maximize the chances of observation, the early morning and late afternoons will be observed. Both the visual and auditory identification of birds will be done by the use of field guides. The metrics to be calculated to each habitat type will be species richness, abundance, Shannon-Wiener diversity index and feeding guild classification (insectivores, omnivores, carnivores, etc.).

4.4. INSECT DIVERSITY ASSESSMENT

The samples of insect fauna will be collected by means of sweep nets, pitfall traps and light traps depending on the ecosystem. Sampling will be conducted systematically at a number of study sites to capture insects that fly as well as those that live in the soil. The identified collected specimens will be identified using the lowest level of taxonomy (i.e. order, family, or species). To evaluate the organization of insect communities in the two types of habitats, there will be the calculation of diversity indices and abundance metrics.

4.5. ASSESSMENT OF TROPHIC INTERACTIONS

The relationship between the abundance of bugs and the avian diversity will be investigated using regression analysis and correlation. Comparative statistics tests will be applied to determine the differences between natural and man-made landscape. In order to understand the changes in the predator-prey relationships and trophic interactions produced by anthropogenic disturbances, feeding guild analysis is going to be used.

4.6. ASSESSMENT OF ANTHROPOGENIC FACTORS

The data on land-use pattern, vegetation cover, habitat fragmentation, and human disturbance will be collected through field observation and secondary sources, such as satellite imagery and the local land-use records. These factors will be reviewed in terms of their influence on relations between birds and insects and on the stability of the ecosystem in general.

5. RESULTS AND DISCUSSIONS

Table 1

Table 1 Comparison of Bird Diversity between Natural and Human-Modified Landscapes

Parameter	Natural Habitat	Human-Modified Landscape
Species Richness (S)	48	29

Total Individuals (N)	620	410
Shannon-Wiener Index (H')	3.45	2.61
Simpson's Index (1-D)	0.92	0.81
Dominant Feeding Guild	Insectivores (52%)	Omnivores (46%)

Figure 1

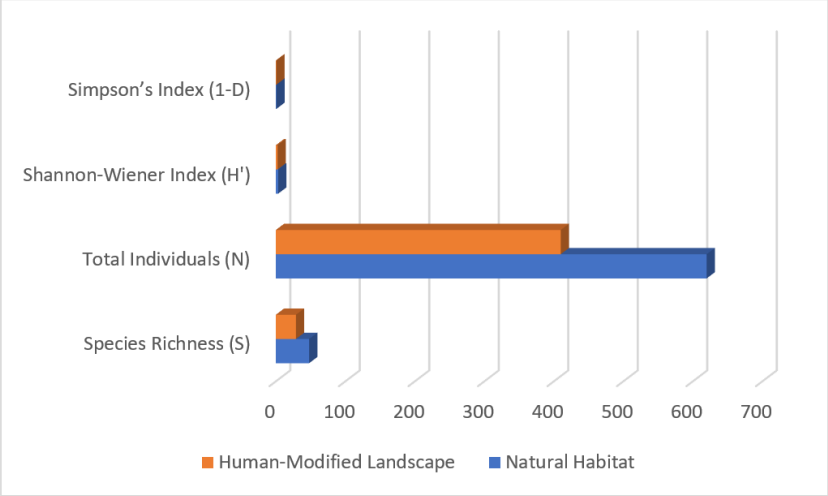

Figure 1 Comparison of Bird Diversity between Natural and Human-Modified Landscapes

The results of Table 1 demonstrate clearly that compared to landscapes modified by the anthropogenic factor, the natural ecosystems sustain a much larger number of species of birds. Due to better quality of the habitat and ecological stability, there are more species in the natural area (48 species) compared to the altered areas (29 species). Similarly, natural ecosystems (620) have a larger number of individuals as compared to landscapes that have been modified by people (410), which implies that they have a greater availability of resources and superior environmental conditions.

This observation is also already supported by the diversity indices. Natural environments recorded higher evenness of species and reduced dominance by few species in terms of higher Simpson Index (1-D = 0.92) and ShannonWiener Index (H 2 = 3.45). Conversely, the smaller index values in the landscapes that have been changed by human beings (H' = 2.61; 1-D = 0.81) presuppose the reduced variety and possible ecological disturbance.

Moreover, the fact that omnivores are the most common predators (46%) when human areas are altered implies the change of diet and the use of adaptation strategies because of changing the habitat whereas the dominance of insectivorous birds (52) in the natural environments supports strong animal-insect predator relationships. All in all, the results indicate that the trophic organization and biodiversity of the birds suffer through the anthropogenic change of habitat.

Table 2

Table 2 Insect Community Structure in Different Habitat Types

Parameter	Natural Habitat	Human-Modified Landscape
Total Orders Recorded	12	8
Total Individuals	1,480	920
Shannon-Wiener Index (H')	3.78	2.89
Most Abundant Order	Lepidoptera (28%)	Diptera (35%)

Unlike the landscapes which have been modified by people, the natural environments sustain more diverse and abundant insects as it is illustrated in Table 2. Insect natural environments (12) had more insect orders than changed areas (8), an indication that has a greater ecological complexity and increased taxa. Moreover, people in the natural ecosystems (1,480) are generally excessive in numbers compared to those in the human-modified landscapes (920) suggesting the sites are more resourceful and in favorable conditions.

Increased evenness and species richness can be demonstrated by the higher ShannonWiener Index of natural environments (H' = 3.78) than in the disturbed environments (H' = 2.89).

Also, the adaptation to disturbed or urban conditions is supported by the preponderance of Diptera (35% in altered landscapes) and the absence of vegetation-rich and less disturbed conditions is supported by the prevalence of Lepidoptera (28% in natural habitats). On the whole, the findings indicate that the alteration of human-made habitats modifies the community structure and reduces the abundance of insect species.

Table 3

Table 3 Correlation Between Bird and Insect Abundance

Habitat Type	Correlation Coefficient (r)	p-value	Significance
Natural Habitat	0.82	0.001	Highly Significant
Human-Modified Landscape	0.46	0.048	Moderately Significant

Correlation analysis of Table 3 indicates that the abundance of birds and insects in their natural habitat has a strong positive relationship that is statistically significant ($r = 0.82$, $p = 0.001$). This is an indication that increased insect abundance has a strong support on stable troic interactions and larger populations of birds. Instead, the relationship is weak ($r = 0.46$, $p = 0.048$), but statistically significant in the human altered landscapes, which means that whereas insect abundance influences the levels of birds, the connection did not turn out to be as strong due to the habitat disruption and altered ecological properties. The findings, in general, indicate that the changes in the anthropogenic habitat undermine the biological connections between birds and insects, whereas the wild ecosystems maintain the stronger connections in the trophic food relations.

Table 4

Table 4 Feeding Guild Composition of Birds in Different Habitats

Feeding Guild	Natural Habitat (n=620)	Percentage (%)	Human-Modified Landscape (n=410)	Percentage (%)
Insectivores	322	52%	148	36%
Omnivores	155	25%	189	46%
Granivores	68	11%	49	12%
Carnivores	45	7%	16	4%
Frugivores	30	5%	8	2%

Figure 2

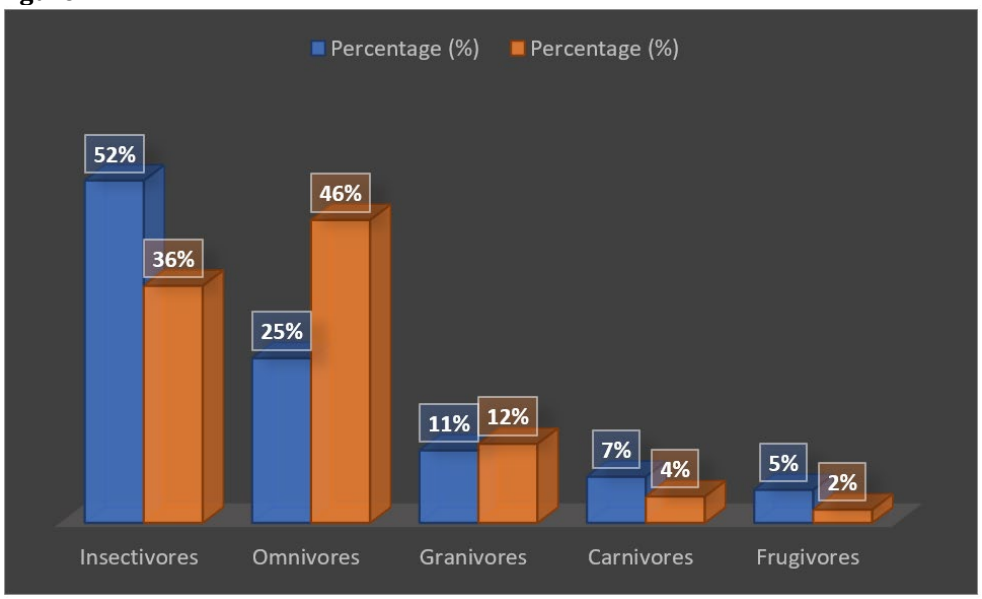

Figure 2 Feeding Guild Composition of Birds

The feeding guild composition depicted by Table 4 reveals that the troic structure of natural and human altered ecosystems is significantly different. The insectivorous population constitutes the largest part of the population in natural surroundings (52%), and this proves how highly the bird communities depend on single ecological conditions and abundance of the insect food. Instead, the increased proportion of omnivores in landscapes altered by humans is 46%. The latter indicates that the feeding methods of birds living in disturbed environments are more diversified in order to cope with the reduced or unpredictable insect availability. Though carnivore and frugivore proportions are much less in areas that are altered by humans, implying a decrease in the complexity of the habitats and the variety of resources, the proportions of the granivores are relatively comparable in both habitats. Everything said and done, the evidence demonstrates that the anthropogenic habitat alteration instigates the shift of the bird groups out of the troublesome insectivorous dominance into the more accommodative omnivorous species, which indicates the changes in the ecosystem structure and trophic interrelations.

Table 5

Table 5 Multiple Regression Analysis

Predictor Variable	Beta Coefficient (β)	Standard Error	t-value	p-value
Vegetation Cover (%)	0.68	0.12	5.67	0.001
Habitat Fragmentation Index	-0.54	0.15	-3.60	0.004
Urbanization Level	-0.47	0.18	-2.61	0.021
Agricultural Intensity	-0.32	0.14	-2.28	0.039

The multiple regression analysis in Table 5 illustrates that anthropogenic factors have significant effects on trophic interactions between birds and insects and biodiversity patterns on a broad basis. The positive impact of plant cover is significant (0.68, p = 0.001) since increased vegetation has a great positive effect on avian and insect diversity by providing habitat structure and food sources. Intensity

of agriculture (7 = -0.32, 0.039), the degree of urbanization (7 = -0.47, 0.021), and habitat fragmentation (7 = -0.54, 0.004), in their turn, exhibit significant negative impacts, which implies that the greater the degree of disturbance the weaker the ecological correlation and the lower the biodiversity. The statistically significant p-values and relatively large t-values confirm the significant effect of these predictors on trophic patterns. All in all, the findings indicate that human activities such as urbanization and fragmentation seriously disrupt bird-insect relationships albeit vegetation assists in stabilizing an ecosystem.

6. CONCLUSION

The present research paper highlights the significant impact of anthropogenic habitat alteration on insect communities and their structure, on avian species richness, and on their trophic interactions. A comparison of the natural and altered landscapes has found that the natural ecosystems can provide greater levels of species diversity, abundance and ecological stability to birds and insects. In the natural ecosystems, the greater Shannon-Wiener and Simpson diversity indices indicate lesser dominance and improved species evenness that demonstrates unbalanced ecological conditions. The research also indicates that landscapes that are altered by humans lack a large percentage of insect life and this undermines the trophic relationship between insects and birds. The abundance of insects to the population of birds is a key factor, as observed by the high positive correlation observed in the natural environments. The average relationship in disturbed topography, however, indicates a modification of predator-prey relationships due to an alteration in the habitat. An analysis of food flexibility and ecological adaptation during disturbance demonstrates the food guild analysis whereby an insectivore dominated group in the natural environment becomes an omnivore dominated group in human altered regions. Regression analysis also illustrates how habitat fragmentation, urbanization, and agricultural intensity affect the ecosystem stability negatively, but the vegetation cover affects the biodiversity positively.

CONFLICT OF INTERESTS

None.

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