

**Hidden Biodiversity of Urban Ecosystems: An Integrated Assessment of
Arthropod Diversity, Community Structure and Ecological Functions in
Parbhani, Maharashtra, India**

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Abstract

Urbanization is one of the most important drivers of contemporary environmental change, yet urban landscapes continue to contain a substantial and often overlooked diversity of arthropods. The ecological significance of these organisms extends beyond species richness because arthropods participate in pollination, biological control, decomposition, herbivory and nutrient cycling. The present study was designed to assess the diversity, community structure and ecological functions of arthropod assemblages across an urbanization gradient in Parbhani, Maharashtra, India. Twelve representative urban habitats were categorized into highly built-up areas, managed green spaces and semi-natural urban green spaces. A six-month standardized sampling framework combining pitfall trapping, sweep-net sampling, yellow-pan trapping and visual observations was developed. Environmental variables including vegetation complexity, flowering-plant richness, litter depth, canopy cover and impervious-surface percentage were incorporated into the analysis.

For methodological demonstration, a simulated dataset comprising 4,862 arthropod individuals representing 186 morphospecies was generated. Hymenoptera was the most abundant major taxonomic group, followed by Coleoptera and Diptera. Mean species richness increased from 31.25 species site⁻¹ in highly built-up habitats to 44.25 in managed green spaces and 55.50 in semi-natural green spaces. Mean Shannon diversity increased from 2.58 to 3.12 and 3.51, respectively. Functional-group composition also changed substantially along the urbanization gradient. Pollinators and predators contributed proportionally more to structurally complex habitats, whereas herbivores and disturbance-tolerant generalists were relatively more prominent in highly built-up environments. Vegetation complexity, flowering-plant richness and litter depth showed positive relationships with species richness and functional-group richness, whereas impervious-surface cover showed a strong negative association. Pollinator visitation was strongly associated with flowering-resource richness, while predator abundance was positively associated with vegetation complexity and litter depth.

The results indicate that urban biodiversity cannot be evaluated adequately using species counts alone. The ecological quality of urban habitats depends on habitat structure, resource availability, landscape permeability and management intensity. The study proposes an integrated framework combining taxonomic, structural and functional indicators for urban arthropod monitoring. The framework has particular relevance for rapidly changing cities of peninsular India, where small green spaces, institutional campuses, gardens, vacant vegetated plots and peri-urban habitats may collectively contribute to biodiversity conservation.

Keywords: Arthropoda; urban biodiversity; insects; community ecology; functional diversity; pollination; biological control; decomposition; urban green spaces; Parbhani; Maharashtra.

1. Introduction

Urbanization has transformed large areas of the Earth's surface and is continuing to accelerate, particularly in developing regions. Urban expansion is generally associated with increasing impervious surfaces, habitat fragmentation, vegetation simplification, artificial lighting, altered temperature and moisture regimes, and intensive management of remaining green spaces. These changes can influence the occurrence, abundance and interactions of organisms at multiple spatial scales.

Arthropods are particularly informative organisms for investigating such changes because they are exceptionally diverse, occupy almost every terrestrial habitat, respond rapidly to environmental conditions and perform a wide range of ecological functions. Urban arthropod communities include pollinators, predators, parasitoids, herbivores, decomposers and omnivores, making them important components of urban food webs.

Urban environments should therefore not be regarded simply as biologically impoverished systems. Rather, they constitute heterogeneous mosaics in which buildings, roads and other impervious structures are interspersed with gardens, parks, institutional campuses, roadside vegetation, vacant plots, plantations and semi-natural patches. The ecological value of these habitats can vary considerably according to vegetation complexity, patch size, connectivity and management.

Research in urban parks has demonstrated that habitat structure and landscape configuration can strongly influence arthropod communities. Vegetation structure and litter can provide shelter, foraging resources, oviposition sites and overwintering habitat, while landscape fragmentation and edge effects can restrict movement of some taxa.

Impervious surface is another important component of urbanization. Research on urban green spaces has shown that impervious cover and local abiotic conditions such as temperature and humidity can influence arthropod abundance, diversity and community composition. In one urban-green-space study, community composition was associated with impervious surface, floral resources and humidity.

Importantly, responses to urbanization are not necessarily uniform across taxonomic groups. Recent research has demonstrated considerable heterogeneity in the response of different arthropod groups to temperature, impervious surface and other anthropogenic variables. This means that total abundance alone may conceal substantial changes in community composition. The ecological functions provided by urban arthropods deserve equal attention. Bees, butterflies, syrphid flies and other insects contribute to pollination. Spiders, ladybird beetles, predatory bugs, mantises and parasitoid wasps can contribute to natural pest regulation. Detritivorous arthropods participate in litter fragmentation and decomposition. Consequently, loss of arthropod diversity may have implications extending beyond biodiversity itself.

Pollinator conservation is particularly relevant in urban landscapes. Recent synthesis has emphasized that the design of pollinator-friendly urban green spaces should consider not only

flower abundance but also functional matching between plant and pollinator traits, phenology and habitat conditions.

Similarly, urban green-space studies increasingly demonstrate that habitat quality, rather than green-space area alone, is critical for sustaining arthropod communities. Recent research has also shown that invertebrate diversity can decline when impervious surfaces dominate the surrounding landscape.

Despite growing international interest in urban arthropod ecology, substantial geographical gaps remain. Urban biodiversity studies are disproportionately represented by cities in Europe, North America and selected East Asian regions. Indian cities, especially medium-sized cities in the Deccan and semi-arid regions, remain comparatively underrepresented.

Parbhani provides a suitable setting for investigating urban arthropod biodiversity because the city encompasses a heterogeneous mosaic of densely built-up areas, residential gardens, institutional campuses, public green spaces, roadside vegetation, vacant plots, and peri-urban habitats. This spatial variation in habitat structure provides an opportunity to assess the extent to which small and fragmented urban green spaces can support diverse arthropod assemblages and contribute to important ecological functions. Accordingly, the present study follows an integrated approach that considers taxonomic diversity, community structure, functional-group composition, habitat characteristics, and selected indicators of ecological function. This combined framework enables a broader assessment of urban arthropod communities and helps explain how variation in habitat conditions influences their diversity, distribution, and ecological roles across the urban–peri-urban landscape of Parbhani.

2. Research Objectives

The study was designed to:

1. document the major arthropod groups occurring across contrasting urban habitats;
2. estimate species/morphospecies richness and abundance;
3. compare Shannon, Simpson and Pielou diversity among habitat categories;
4. characterize pollinator, predator, parasitoid, herbivore and decomposer groups;
5. evaluate the relationship between arthropod diversity and vegetation complexity;
6. assess the influence of flowering-plant richness on pollinator activity;
7. determine the relationship between impervious surface and arthropod diversity;
8. identify habitat characteristics associated with higher ecological functionality; and
9. develop recommendations for biodiversity-sensitive urban management.

3. Materials and Methods

3.1 Study area

The proposed study was conducted in Parbhani city and its immediate urban–peri-urban interface in Maharashtra, India. The sampling framework was designed to represent an urbanization gradient rather than making a simple comparison between urban and rural habitats. For this purpose, twelve sampling units were classified into three major habitat categories based on building density, vegetation cover, degree of habitat management, availability of flowering resources, and the extent of impervious surfaces.

Category I, Highly Built-up Urban Habitat, comprised sites characterized by high building density, extensive impervious surfaces, limited vegetation, intensive maintenance, relatively low accumulation of leaf litter and organic debris, and restricted availability of flowering resources. These locations represented the most intensively urbanized environments within the study area.

Category II, Managed Urban Green Habitat, included municipal gardens, institutional campuses, college and university green spaces, public parks, and other landscaped areas that receive regular management. Such habitats generally provide comparatively greater vegetation cover and floral resources than highly built-up areas, while still being influenced by routine maintenance and human activities.

Category III, Semi-natural Urban Green Habitat, consisted of vegetated vacant plots, scrub patches, urban woodland margins, areas with relatively low-intensity vegetation management, and green interfaces connecting the urban landscape with peri-urban environments. These habitats were expected to provide greater structural complexity, litter accumulation, and natural vegetation, thereby offering potentially suitable conditions for a wider range of arthropod taxa.

4. Sampling Design

Twelve sites were sampled conceptually:

Code	Habitat category	Sampling-site description
S1	Highly built-up	Residential-core habitat
S2	Highly built-up	Railway/station-influenced built-up habitat
S3	Highly built-up	Commercial-residential habitat
S4	Highly built-up	Peripheral built-up habitat
S5	Managed green	Municipal garden
S6	Managed green	Institutional green space
S7	Managed green	College/campus green space
S8	Managed green	Urban park edge
S9	Semi-natural	Vegetated vacant plot
S10	Semi-natural	Green patch influenced by seasonal drainage/riverine conditions
S11	Semi-natural	Semi-natural scrub habitat
S12	Semi-natural	Peri-urban green edge

5. Arthropod Sampling

A multi-method sampling protocol was adopted because no single collection technique can adequately capture the full range of arthropod communities occurring in urban habitats. Pitfall traps were used primarily to sample ground-active arthropods, including Formicidae, Carabidae, Staphylinidae, other Coleoptera, Araneae, and ground-associated detritivores. Pitfall trapping is a widely applied method for assessing ground-dwelling arthropods; however, trap design, placement, and sampling effort were standardized across sampling sites to ensure meaningful comparisons. Sweep-net sampling was conducted along standardized vegetation transects to collect arthropods associated with herbaceous and shrub vegetation. This method targeted major groups such as Hemiptera, Orthoptera, Coleoptera, Diptera, Hymenoptera, and Lepidoptera. Yellow-pan traps were additionally employed to improve the detection of small

flying insects, particularly Hymenoptera and Diptera, which may be underrepresented in other sampling methods. In addition, visual pollinator observations were carried out during standardized observation periods around flowering plants to document flower-visiting insects and assess pollinator activity. The principal groups recorded during these observations included bees, butterflies, hoverflies, wasps, beetles, and other flower-visiting insects. The combined use of these complementary methods increased the likelihood of detecting arthropods occupying different ecological niches and activity zones within the urban ecosystem.

6. Environmental Variables

For each sampling site, a set of environmental variables was recorded or simulated to characterize habitat conditions and assess their potential influence on urban arthropod diversity and community structure. The variables included the percentage of impervious surface, vegetation complexity score, flowering-plant richness, litter depth, canopy cover, percentage of bare ground, pesticide-management intensity, habitat connectivity, local temperature, and relative humidity. Together, these parameters provided a quantitative characterization of the physical structure, vegetation composition, degree of habitat modification, and microclimatic conditions of each sampling site. These environmental variables were also used to examine relationships between habitat characteristics and patterns of arthropod abundance, species richness, taxonomic diversity, functional-group composition, and ecological activity along the urban–peri-urban gradient of Parbhani.

Vegetation complexity was scored from 1 to 5:

Score	Description
1	Very low; predominantly bare/managed surface
2	Low; simple herbaceous vegetation
3	Moderate; herbs and shrubs
4	High; multilayered vegetation
5	Very high; trees, shrubs, herbs and litter layer

7. Functional Classification

Arthropods were assigned to broad functional groups.

Functional group	Representative taxa	Principal function
Pollinators	Apoidea, Syrphidae, Lepidoptera	Pollination
Predators	Araneae, Coccinellidae, Carabidae, Mantodea, Odonata	Biological control
Parasitoids	Braconidae, Ichneumonidae, Tachinidae	Natural pest regulation
Herbivores	Aphididae, Cicadellidae, Acrididae, Curculionidae	Herbivory
Decomposers/detritivores	Isopoda, Diplopoda, saprophagous Diptera/Coleoptera	Decomposition
Generalists/omnivores	Formicidae and selected generalists	Food-web interactions

Functional classification was used as an ecological interpretation framework rather than as a replacement for taxonomic identification.

8. Diversity Indices

8.1 Shannon–Wiener Index

$$H' = - \sum_{i=1}^S p_i \ln p_i$$

where H' is the Shannon–Wiener diversity index, S is the total number of species (or morphospecies), and p_i is the proportional abundance of species i , calculated as the abundance of species i divided by the total abundance of all species.

8.2 Simpson Diversity

$$1 - D = 1 - \sum p_i^2$$

8.3 Pielou Evenness

$$J = \frac{H'}{\ln S}$$

8.4 Relative abundance

$$RA = \frac{n_i}{N} \times 100$$

9. Simulated Dataset

Critical data statement: The following values are simulated for manuscript development and statistical demonstration. They are not field observations.

Table 1. Site-level environmental and biodiversity variables

Sit e	Habita t	Impervio us surface (%)	Vegetati on complexi ty	Floweri ng richness	Litte r dept h (cm)	Abundan ce	Richne ss	Shanno n H'
S1	Built-up	82	1.4	4	0.8	220	28	2.45
S2	Built-up	78	1.6	5	1.0	238	30	2.53
S3	Built-up	72	1.8	6	1.2	255	32	2.62
S4	Built-up	67	2.1	7	1.5	281	35	2.71
S5	Manag ed green	41	3.0	12	2.4	348	40	3.01
S6	Manag ed green	36	3.3	14	2.7	372	43	3.08

S7	Managed green	30	3.7	16	3.0	402	46	3.17
S8	Managed green	26	4.0	18	3.3	454	48	3.22
S9	Semi-natural	22	4.1	19	4.0	516	51	3.38
S10	Semi-natural	18	4.4	22	4.5	548	55	3.49
S11	Semi-natural	14	4.7	25	5.0	596	57	3.55
S12	Semi-natural	10	4.9	27	5.4	629	59	3.62

The constructed dataset comprised a total of 4,862 individual arthropods, representing 186 morphospecies distributed across the major arthropod groups recorded during the study. The observed assemblage reflected considerable variation in abundance and taxonomic composition among the different sampling sites and habitat categories. This overall dataset provided the basis for subsequent analyses of species richness, abundance, community structure, functional-group composition, and the relationship between arthropod assemblages and environmental characteristics across the urban–peri-urban gradient of Parbhani..

Table 2. Taxonomic composition

Taxonomic group	Individuals	Relative abundance (%)	Morphospecies
Hymenoptera	1,082	22.25	39
Coleoptera	821	16.89	34
Diptera	746	15.34	29
Hemiptera	623	12.81	24
Araneae	512	10.53	22
Lepidoptera	421	8.66	18
Orthoptera	267	5.49	9
Blattodea	138	2.84	4
Odonata	103	2.12	3
Mantodea	61	1.25	2
Dermoptera	48	0.99	1
Other detritivores	39	0.80	1
Total	4,862	100.00	186

Hymenoptera was the most abundant group, representing 22.25% of all individuals. Coleoptera contributed 16.89%, while Diptera accounted for 15.34%.

11. Diversity Along the Urbanization Gradient

Table 3. Habitat-level biodiversity

Biodiversity metric	Highly built-up	Managed green	Semi-natural green
Mean abundance/site	248.50	394.00	572.25
Mean richness/site	31.25	44.25	55.50
Shannon H'	2.58	3.12	3.51
Simpson diversity	0.87	0.93	0.96
Pielou evenness	0.76	0.83	0.88
Functional-group richness	4.1	5.2	5.8

A pronounced gradient in arthropod diversity and abundance was observed across the different habitat categories. Mean species richness in semi-natural habitats was approximately 77.6% higher than that recorded in highly built-up urban habitats, indicating the greater capacity of structurally complex and comparatively less disturbed green spaces to support diverse arthropod assemblages. Similarly, mean arthropod abundance in semi-natural sites was approximately 2.3 times higher than in highly built-up sites. These patterns suggest that increasing vegetation complexity, resource availability, and habitat quality may provide more favorable conditions for the establishment and persistence of diverse arthropod communities. However, as these values are derived from the simulated dataset, they should be interpreted as illustrative patterns and require confirmation through systematic field-based sampling.

12. Functional-Group Structure

Table 4. Relative functional composition

Functional group	Built-up	Managed green	Semi-natural
Pollinators	12.4%	21.7%	27.9%
Predators	15.1%	19.6%	23.8%
Parasitoids	4.3%	7.8%	10.6%
Herbivores	31.8%	27.1%	22.4%
Decomposers/detritivores	9.6%	11.8%	15.2%
Generalists/omnivores	26.8%	12.0%	0.1%*

The functional-group assignments used in the present simulated dataset are illustrative and should be recalculated using species-level identifications and verified ecological information obtained from field observations. Nevertheless, the overall pattern suggests a gradual shift from disturbance-tolerant and relatively herbivore-dominated arthropod assemblages in highly modified habitats toward more functionally diversified communities in structurally complex green spaces. This pattern indicates that habitats with greater vegetation complexity, resource availability, and ecological heterogeneity may provide suitable conditions for a wider range of trophic and functional groups, including predators, pollinators, parasitoids, and decomposers. Further field-based studies are required to validate these patterns and determine the contribution of different functional groups to ecological processes within Parbhani's urban landscape.

13. Pollinator Activity

Table 5. Pollinator visitation

Habitat	Mean visits/30 min	Pollinator morphospecies
Highly built-up	8.6 ± 2.1	11
Managed green	16.9 ± 3.4	19
Semi-natural	23.7 ± 4.1	25

Pollinator visitation was approximately 2.75 times higher in semi-natural sites than in highly built-up urban habitats, indicating a substantial difference in pollinator activity along the urbanization gradient. The strong positive relationship observed between flowering-plant richness and pollinator visitation further highlights the importance of floral resources in supporting urban pollinator communities. Habitats containing a greater variety of flowering plants can provide nectar and pollen resources across different periods, potentially supporting a wider range of pollinating insects. These findings emphasize the importance of incorporating diverse and seasonally continuous flowering vegetation into urban green-space planning. Contemporary approaches to urban pollinator conservation increasingly recognize the importance of both resource availability and the matching of plant characteristics with pollinator requirements when designing and managing pollinator-friendly habitats. However, because the values in the present analysis are derived from a simulated dataset, these relationships should be considered indicative and require validation through field-based observations.

14. Predatory Arthropods

Table 6. Predator assemblage

Habitat	Predator individuals	Predator richness
Highly built-up	182	18
Managed green	314	27
Semi-natural	463	35

Predator abundance increased progressively with increasing habitat complexity, with higher representation of spiders, predatory beetles, ladybird beetles, mantises, predatory bugs, and parasitoid Hymenoptera in structurally complex habitats. This pattern is ecologically significant because diverse urban vegetation can provide suitable shelter, hunting sites, and foraging resources for natural-enemy communities that contribute to the regulation of herbivorous insect populations. Greater vegetation complexity and litter accumulation may create additional microhabitats and refuge opportunities, thereby supporting a wider range of predatory arthropods. Urban parks and other green spaces can therefore function as important habitats for natural enemies when vegetation is maintained with sufficient structural diversity. The presence of these predators may contribute to natural biological pest regulation and potentially reduce dependence on chemical pest-control measures. However, as the present dataset is simulated, the observed pattern should be regarded as an indicative ecological relationship requiring confirmation through field-based observations.

15. Decomposition Indicator

A standardized litter-bag experiment was incorporated as an indicator of decomposition.

Table 7. Simulated litter decomposition

Habitat	Initial mass (g)	Remaining mass after 30 days (g)	Mass loss (%)
Highly built-up	50.0	43.7	12.6
Managed green	50.0	38.4	23.2
Semi-natural	50.0	32.6	34.8

Semi-natural habitats exhibited the highest simulated litter mass loss, suggesting greater detrital decomposition activity in these relatively less disturbed and structurally complex environments. The pattern indicates that retaining leaf litter and organic matter within urban green spaces may provide both habitat and food resources for detritivorous arthropods and other decomposer organisms. Accumulated litter can create suitable microhabitats with moisture, shelter, and organic substrates that support detritivore communities and associated decomposers. Thus, allowing a proportion of naturally fallen leaves and organic material to remain in semi-natural or low-management areas may contribute to nutrient cycling and other important ecosystem processes. Nevertheless, because the litter mass-loss values are based on the simulated dataset, this interpretation should be considered preliminary and requires validation through standardized field-based decomposition experiments.

16. Correlation Analysis

Table 8. Relationship between environmental variables and biodiversity indicators

Environmental variable	Richness	Shannon H'	Pollinator activity	Predator abundance
Vegetation complexity	0.86	0.89	0.91	0.87
Flowering richness	0.82	0.84	0.94	0.72
Litter depth	0.74	0.78	0.42	0.81
Impervious surface	-0.88	-0.86	-0.83	-0.79
Canopy cover	0.71	0.76	0.62	0.73

All correlation coefficients reported in this analysis are simulated values generated for the constructed dataset and should therefore be interpreted as illustrative rather than as measurements obtained from actual field observations. The strongest positive association was observed between flowering-plant richness and pollinator activity ($r = 0.94$), indicating a strong simulated relationship in which sites containing a greater diversity of flowering plants also showed higher levels of pollinator activity. In contrast, impervious-surface cover showed strong negative relationships with both species richness and Shannon diversity, suggesting that increasing levels of built-up and impervious surfaces were associated with reduced arthropod diversity in the simulated dataset. These patterns are consistent with the ecological expectation that greater floral-resource availability and habitat complexity can support arthropod communities, whereas extensive urbanization may reduce available habitat and resources. However, because the coefficients are simulated, these relationships should not be presented as statistically demonstrated field findings until they are validated using empirical data.

17. Simulated ANOVA

Table 9. Comparison among habitat categories

Response variable	F	p-value	Interpretation
Species richness	32.74	<0.001	Significant
Shannon diversity	27.61	<0.001	Significant
Simpson diversity	18.42	<0.001	Significant
Functional-group richness	21.83	<0.001	Significant
Pollinator visitation	29.47	<0.001	Significant
Predator abundance	25.19	<0.001	Significant

The simulated analysis supports significant differences among habitat categories. For the final field dataset, Tukey HSD or an appropriate generalized model should be used to identify pairwise differences.

18. Regression Framework

A multiple regression model was specified as:

$$SR = \beta_0 + \beta_1 VC + \beta_2 FR + \beta_3 LD + \beta_4 IS + \epsilon$$

where:

- SR = species richness;
- VC = vegetation complexity;
- FR = flowering richness;
- LD = litter depth;
- IS = impervious surface.

A simulated model produced:

$$R^2 = 0.86$$

indicating that approximately 86% of the variation in simulated site-level richness was explained by the environmental predictors.

Vegetation complexity and impervious surface were the strongest predictors.

This model should be treated as a demonstration rather than a final inferential result.

19. Results

The simulated six-month assessment comprised 4,862 individual arthropods representing 186 morphospecies. Among the major taxonomic groups, Hymenoptera was the most dominant, followed by Coleoptera and Diptera, indicating substantial variation in the abundance and representation of different arthropod groups across the study area. A clear gradient in species richness was observed among the three habitat categories, with highly built-up urban habitats supporting an average of 31.25 morphospecies per site, compared with 44.25 morphospecies in managed urban green habitats and 55.50 morphospecies in semi-natural urban green habitats. A similar pattern was observed for Shannon diversity, which increased from 2.58 in highly built-up habitats to 3.51 in semi-natural habitats, suggesting greater community diversity under conditions of comparatively higher vegetation complexity and lower habitat disturbance. Functional-group composition also varied across the urbanization gradient. The proportion of pollinators increased from 12.4% in highly built-up habitats to 27.9% in semi-natural habitats, while predator representation increased from 15.1% to 23.8%. Conversely, herbivores

constituted a comparatively larger proportion of the arthropod assemblage in highly built-up habitats. Pollinator visitation showed a marked positive association with flowering-plant richness, whereas predator abundance increased with vegetation complexity and litter depth. In contrast, impervious-surface cover exhibited negative relationships with species richness, Shannon diversity, pollinator visitation, and predator abundance. Because these results are based on a simulated dataset, the observed patterns should be treated as illustrative and must be validated using actual field observations before being presented as empirical findings.

20. Discussion

20.1 Urban biodiversity is spatially heterogeneous

The results indicate that the term “urban habitat” should not be regarded as ecologically homogeneous, as different types of urban environments can support substantially different arthropod communities. Within the same city, a densely constructed residential area and a semi-natural green patch may differ considerably in vegetation structure, resource availability, microclimatic conditions, and levels of human disturbance, resulting in pronounced differences in arthropod assemblage composition and diversity. This distinction has important implications for urban planning and biodiversity conservation, as the ecological value of urban areas depends not only on the overall quantity of green space but also on its spatial distribution, habitat structure, plant diversity, management intensity, connectivity, and availability of food and shelter resources. Consequently, small but structurally complex and well-connected green spaces may provide important habitats for urban arthropods even when the overall extent of vegetation is limited. Previous research on urban arthropod communities has similarly emphasized the importance of local habitat characteristics and landscape configuration in influencing patterns of species occurrence, abundance, and community structure.

21. Predators and Biological Control

The observed increase in predator abundance within structurally complex habitats suggests that urban green spaces may contribute to natural pest-regulation functions. Predatory arthropods are particularly valuable in urban gardens and agricultural areas because they can prey upon a range of herbivorous insects, including aphids, caterpillars, leafhoppers, and other potential plant pests. Spiders may function as generalist predators, while ladybird beetles and predatory hemipterans may target particular groups of herbivorous prey. Parasitoid insects can further contribute to biological control by regulating populations of their host organisms. These ecological relationships highlight the importance of avoiding a generalized perception of all insects as pests in urban environments. Instead, biodiversity management should distinguish among pest organisms, beneficial predators, pollinators, decomposers, and neutral or generalist taxa. Such an ecologically informed approach can help conserve beneficial arthropods, maintain natural biological-control processes, and potentially reduce unnecessary reliance on insecticides in urban green spaces.

22. A Proposed Urban Arthropod Functional Index

To make the study more innovative, an Urban Arthropod Functional Index (UAFI) can be proposed.

The index may combine standardized scores for:

$$AFI = \frac{P + Pr + D + F}{4}$$

where:

- P = pollinator score;
- Pr = predator score;
- D = decomposer score;
- F = functional-group richness.

The index could be scaled from 0 to 1.

Proposed interpretation

UAFI	Ecological condition
0.00–0.20	Very low functional potential
0.21–0.40	Low
0.41–0.60	Moderate
0.61–0.80	High
0.81–1.00	Very high

23. Urban Habitat Quality Classification

Based on the combined ecological indicators, the study proposes a five-level classification system for assessing the ecological quality of urban habitats.

Class I: Ecologically Poor represents habitats characterized by high impervious-surface cover, low vegetation complexity, and limited functional diversity.

Class II: Low Quality includes small and fragmented green patches with restricted floral and structural resources and consequently limited capacity to support diverse arthropod communities. Class III: Moderate Quality comprises managed urban green spaces that provide comparatively better vegetation cover and resources and support moderate levels of arthropod diversity.

Class IV: High Quality represents structurally complex green spaces with diverse vegetation, greater litter accumulation, and improved availability of shelter and food resources for different arthropod groups.

Class V: Biodiversity Hotspot denotes semi-natural and relatively well-connected habitats characterized by high taxonomic and functional diversity and greater ecological complexity. This proposed classification provides a conceptual framework for evaluating urban habitat quality and could be further tested and refined through systematic field-based studies across Parbhani and other cities of Maharashtra.

24. Implications for Urban Planning in Parbhani

The findings highlight the need for biodiversity-sensitive urban planning in Parbhani. Urban gardens should incorporate native and locally adapted flowering plants, while green spaces should maintain multilayered vegetation comprising trees, shrubs, herbs and ground cover rather than uniformly managed lawns. Small unmanaged vegetation patches and selected leaf-litter areas should be retained as refuges and breeding habitats for pollinators, predators and

decomposers. Unnecessary broad-spectrum pesticide use should be minimized through integrated pest-management practices. Green corridors connecting parks, institutional campuses and other vegetated areas should be developed to improve habitat connectivity, while vacant green plots should be recognized as potential biodiversity reservoirs. Educational institutions can further contribute by establishing butterfly and pollinator gardens, maintaining native vegetation, composting and leaf-litter zones, and adopting pesticide-reduction programmes, thereby transforming urban campuses into important refuges for arthropod biodiversity and ecological functions.

25. Conclusion

The present study provides an integrated framework for examining hidden arthropod biodiversity within urban landscapes and highlights the ecological importance of habitat heterogeneity in rapidly developing urban environments. The simulated dataset indicates a clear ecological gradient across the hypothetical urban habitat categories of Parbhani, with highly built-up environments supporting comparatively lower species richness and diversity, while managed and semi-natural green spaces supported progressively richer and more functionally diverse arthropod assemblages. Among the environmental attributes considered, vegetation complexity, flowering-plant richness, and litter depth emerged as important positive habitat characteristics, whereas impervious-surface cover was consistently associated with reduced biodiversity and ecological activity.

The findings further emphasize that urban biodiversity conservation should not depend exclusively on the creation of large conventional parks. Small, structurally complex, and strategically distributed green spaces can collectively provide valuable habitat and resources for pollinators, predators, parasitoids, and decomposers, particularly when these spaces are connected across the urban landscape. Consequently, urban planning should gradually shift from a simple “green-space quantity” approach toward a “green-space quality and connectivity” approach. In the context of Parbhani, municipal gardens, institutional campuses, roadside vegetation, vegetated vacant plots, and peri-urban green patches should therefore be considered potential components of a broader interconnected urban ecological network. Such an approach could strengthen habitat continuity and improve opportunities for the persistence of diverse arthropod communities within the city.

Overall, the proposed integrated framework offers a useful foundation for future field-based investigations of urban arthropod biodiversity in Parbhani and other rapidly developing cities of Maharashtra. However, the present patterns are derived from a simulated dataset and should be regarded as a conceptual and methodological framework rather than evidence of measured ecological relationships. Systematic field sampling, verified species identification, GPS-based site characterization, and statistical validation will be necessary to determine the extent to which these predicted patterns occur under actual environmental conditions. Future research can consequently build upon this framework to evaluate how arthropod diversity and functional groups contribute to the resilience, ecological stability, and functioning of urban ecosystems.

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