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Urban Entomology: How Insects Are Adapting to Cities

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Cities are growing at a rapid pace, leading to the transformation of natural habitats into dense patches of buildings, roads and fragmented green areas. In the case of insects, the most diverse group of animals, this changeover is both a major source of danger and an unexpected opportunity. Global syntheses have revealed that urbanization leads to a reduction of 40–45% in the number of insects and a similar reduction in species richness compared to conserved areas, with a particularly strong effect on sensitive and specialist species. However, cities also provide the habitat for "urban exploiters," which are generalist, heat-tolerant and often mobile species that can exploit the warmer, drier and highly modified conditions of urban habitats to create local hotspots for certain groups of insects, such as bees and pollination services. Habitat destruction, the urban heat island effect, pollution, light pollution and habitat fragmentation, together with species characteristics, are the main drivers. Recent research highlights that the design and management of urban green infrastructure, especially native or drought-tolerant vegetation and habitat connectivity for freshwater habitats, can effectively counteract biodiversity loss and even allow cities to act as partial "bioarks" for certain species of insects.

Introduction

Urbanization has emerged as one of the major drivers of ecological change worldwide. As cities rapidly grow into megacities, natural and agricultural habitats are increasingly replaced by impervious surfaces, fragmented green areas and polluted air and water. Insects, which support essential ecosystem processes such as pollination, decomposition and biological control, are particularly vulnerable to these fast-paced environmental shifts (Collins *et al.*, 2024; Vaz *et al.*, 2023).Across regions, continents and climates, a consistent pattern is evident: rising urban intensity is generally linked to declines in insect species richness and abundance, along with a shift toward simpler and more homogenized communities (Collins *et al.*, 2024). A recent global meta-analysis estimated that urban-related stressors reduce insect abundance by an average of 42% and species richness by around 40% compared with conserved habitats (Vaz *et al.*, 2023). Comparable patterns are reported in reviews of both terrestrial and freshwater insects, although the magnitude of change varies considerably among taxa, regions and habitat types. Nevertheless, cities are not solely biodiversity sinks. Under certain conditions, urban environments can sustain unexpectedly diverse insect communities, particularly where high-quality green spaces and abundant floral resources are preserved. Local management practices can partly counterbalance broader urban pressures: for example, in a hot, arid city, sites planted with native or drought-tolerant vegetation supported more than 30% higher insect richness and abundance, regardless of the surrounding level of urbanization (Adams *et al.*, 2020).

This contrast has led to the idea of cities functioning as potential insect "bioarks" in the 21st century. Although urbanization and climate change together pose significant threats to insect biodiversity, well-planned nature-based solutions such as green roofs, connected parks, wetlands and insect-friendly plantings can provide refuges and movement corridors within the urban landscape. At the same time, research cautions that trade-offs exist: poorly designed infrastructure, excessive artificial lighting and intensive chemical management may exacerbate insect declines even in otherwise green cities (Diamond *et al*., 2023). The following discussion examines how urbanization reshapes insect diversity, traits and ecological interactions, identifies which species are most vulnerable or adaptable and explores how urban design can be strategically used to conserve insect biodiversity and maintain vital ecosystem services in an increasingly urbanized world.

Urban Change and Responses of Urban Insect Diversity

Key urban pressures and typical insect adaptations:

Urban change or pressure	Common insect response	Citations
Less habitat, more concrete	Fewer species overall; assemblages simplified, dominated by tolerant "cosmopolitan" insects	(Collins *et al*., 2024; Theodorou *et al*., 2020;)
Urban heat island (warmer, drier cities)	Heat-tolerant species gain; some butterflies and other insects show higher survival or extended flight seasons	(Kaiser *et al*., 2016; Diamond *et al*., 2015)
Fragmented green spaces, ponds, streams	Dispersal traits, flight morphology, and connectivity become critical for survival	(Liao and Lin, 2023;)
Pollution, pesticides, novel chemicals	Selection for detoxification, insecticide resistance, and stress-tolerant genotypes	(Fifer *et al*., 2025; Zhang *et al*., 2025)
Artificial light at night	Altered movement and behavior; massive attraction to city lights in some outbreaks	(Tielens *et al*., 2021)

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On a summer evening, cities can appear biologically barren dominated by concrete, glass and steel. Closer inspection, however, reveals a quiet but intense evolutionary process unfolding in sidewalk crevices, rooftop gardens, storm drains and street trees. Urban environments are far from insect-free; instead, they impose strong selective pressures that compel insects to alter their behavior, physiology and life cycles in order to persist in city landscapes.

Winners, losers, and the urban filter

Urbanization generally leads to declines in overall insect abundance and species richness, particularly as natural vegetation is replaced by buildings, roads, and other impervious surfaces. Many taxa including freshwater insects inhabiting streams and wetlands, as well as numerous herbivores and predators decline sharply or disappear altogether as pollution increases, habitats become fragmented and ecological interactions are disrupted (Mata *et al*., 2014). However, urbanization does not affect all insects uniformly. Certain generalist and heat-tolerant species, along with those capable of exploiting human structures or cultivated plants, often flourish in cities. As a result, urban insect communities are frequently dominated by a reduced set of so-called "urban exploiters" (Diamond *et al*., 2015; Diamond *et al*., 2023). Bees provide a notable example: in several European cities, bee species richness and pollination activity exceed those found in surrounding agricultural landscapes, effectively turning cities into unexpected centers of pollination services (Theodorou *et al*., 2020).

Adapting to heat, light and hard edges

Urban environments are typically warmer and often drier than surrounding rural landscapes due to the urban heat island effect. For some thermophilic (warm-adapted) butterflies, these elevated temperatures can enhance survival and even lead to larger adult body sizes within urban habitat patches, particularly at fine spatial scales (Kaiser *et al*., 2016). Across northern Europe, urban populations of two butterfly species have begun entering winter dormancy (diapause) later in the year and remain active further into autumn. These shifts reflect genetic changes in sensitivity to day length, enabling additional generations to be produced in warmer urban settings (Merckx *et al*., 2021).Other insects respond to urban pressures through morphological change. Aquatic beetles in Helsinki, for example, show systematic shifts in wing and body dimensions along urbanization gradients, suggesting species-specific strategies for dispersing among fragmented ponds and wetlands embedded within a highly built environment (Liao and Lin, 2023). Artificial light at night represents another powerful urban selective force. During a grasshopper outbreak near Las Vegas, remote-sensing data revealed that tens of millions of insects took flight at dusk and were drawn toward the city's brightest light sources. This massive attraction created a large-scale ecological trap, fundamentally altering nocturnal movement patterns across the region (Tielens *et al*., 2021).

Rethinking social life and behavior

Urbanization affects not only insect morphology and physiology but also social organization and behavior. In North America, the odorous house ant has repeatedly evolved distinct social structures in urban versus rural environments. Urban colonies commonly form expansive, multi-queen supercolonies that are genetically and chemically differentiated from their rural counterparts, demonstrating that cities can act as strong selective filters on social systems (Janda, 2022).Herbivorous insects face particular challenges in cities, where they must locate host plants, feed, reproduce and overwinter within a highly fragmented and intensively managed landscape. In response to practices such as mowing, mulching, lawn maintenance and soil modification, many species adjust behaviors related to host selection, oviposition and pupation. The high environmental variability characteristic of urban habitats may therefore favor behavioral flexibility and generalist strategies, enabling some species to persist where more specialized insects decline (Schmitt and Burghardt, 2021).

Mosquitoes, disease vectors and urban evolution

Among the most consequential urban adapters are mosquitoes. Although only a small proportion of the more than 3,500 mosquito species have successfully colonized cities, those that have become established now serve as major disease vectors within dense human populations. Urban mosquitoes either evolve or exploit traits well suited to city life, including preferences for human hosts, the ability to breed in artificial containers and resistance to insecticides. Some of these traits represent recent adaptations, while others are "exaptations" features that evolved in different ecological contexts but happen to confer advantages in urban environments. Traits that enhance survival in cities may simultaneously increase vectorial capacity, influencing how efficiently pathogens are transmitted (Fifer *et al*., 2025).

Comparable patterns are observed in triatomine bugs, vectors of Chagas disease. In one Neotropical species, urban populations exhibit convergent changes in thorax size and antennal sensory structures. This apparent morphological simplification likely reflects adaptation to relatively stable, human-dominated environments and occurs without obvious costs to reproductive output (Aguilar *et al*., 2022).

Cities as bioarks and battlegrounds

Urban insect biodiversity remains highly dynamic. Many populations have not yet reached equilibrium: some continue to decline, others are recovering from disturbance and many are still undergoing rapid adaptation to urban conditions. Importantly, responses to urbanization vary across climatic contexts; patterns observed in hot, dry cities may differ substantially from those in cooler, wetter regions (Diamond *et al*., 2015). Increasingly, research demonstrates that urban design and management decisions play a critical role in shaping insect outcomes. The use of native or drought-tolerant vegetation, the preservation and connectivity of green spaces and the careful management of ponds and streams can significantly enhance insect richness and abundance, even within highly urbanized neighborhoods (Diamond *et al*., 2023). Nature-based climate solutions such as green roofs, urban tree planting and wetland restoration can simultaneously support insect biodiversity, although potential trade-offs must be carefully evaluated (Diamond *et al*., 2023; Collins *et al*., 2024). Urban areas thus function both as battlegrounds for insect persistence and as potential bioarks for certain taxa, including pollinators, heat-tolerant butterflies and ants. How cities are planned and managed in the coming decades will play a decisive role in determining whether insects remain a diverse and functional component of urban ecosystems or decline into simplified communities with diminished ecological services.

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