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The Effects of Urbanization on Biodiversity

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ABSTRACT

Urbanization, characterized by the expansion of cities and human infrastructure, profoundly influences biodiversity at genetic, species, and ecosystem levels. While urban growth drives habitat loss, fragmentation, and biotic homogenization, it also creates novel environments that some species exploit. This paper reviews the multifaceted effects of urbanization on biodiversity, examining species adaptation, ecosystem processes, and the spatial and temporal variability of urban impacts. Despite urban areas generally supporting fewer species than rural landscapes, cities can serve as refuges and sources of evolutionary novelty, especially through the introduction of non-native taxa. Conservation strategies focusing on connectivity, habitat diversity, and sustainable urban planning are critical to mitigate biodiversity loss. The paper highlights the need for integrated research efforts and policy frameworks to reconcile urban development with biodiversity conservation, emphasizing the socio-political challenges inherent in managing urban ecosystems.

Keywords: Urbanization, Biodiversity loss, Habitat fragmentation, Biotic homogenization, Species adaptation, Urban ecology, Conservation strategies, Non-native species.

INTRODUCTION

Urbanization leads to the growth of cities and human-made structures, a trend expected to continue. Concepts such as urban ecology, ecosystem urbanity, and urban politics are increasingly prominent. This complex process significantly alters urban ecology, producing both positive and negative impacts. Historically, urbanization has affected biodiversity, increasing generalist species, including pests, and causing significant species and habitat loss. Species responses vary, and this variability can reflect biogeographical contexts, observing faster effects in less biodiverse regions. Generally, urbanization promotes biotic homogenization of flora and fauna, with urban areas expanding as rapidly changing land uses. Concerns about terrestrial biodiversity loss are rising, alongside growing interest in alternatives to traditional conservation methods. Biodiversity loss from human actions is a global issue, characterized by ongoing and rapid declines. Urban areas typically host fewer species compared to surrounding rural ecosystems. It's crucial to evaluate whether this trend holds across different taxa at various spatial scales. Understanding these patterns is essential for determining if urbanization has intensified homogenization or if some taxa still reflect traditional urbanization trends [1, 2].

Understanding Urbanization

Urbanization, a widespread global process, is often defined as the expansion of metropolitan areas at the expense of natural environments. This growth places a strain on infrastructure and influences social behaviors and attitudes. Scholars frequently study this extensive land transformation phenomenon to understand its subtle impacts on ecological systems. Many species find cities inhospitable, and those that can tolerate urban life often experience health declines. These trends vary based on species traits and urban contexts, with many factors remaining incompletely understood. Conversely, some species find urban resources valuable, leading to important habitats in cities. These dynamics prompt questions about urbanization's effects on broader evolutionary processes. Urbanization has been viewed as a promoter of biotic homogenization, while more recent perspectives suggest that cities can also be sources of evolutionary novelty. This secondary viewpoint remains underexplored in discussions of urban impacts on biodiversity. Cities create unique landscape combinations and offer new sampling opportunities for existing variants. It is hypothesized that urban areas boost local biodiversity by introducing non-native taxa, particularly non-native birds that adapt to urban environments. Unlike many native birds, these

non-natives occupy open habitats, avoiding direct competition. Even as ballast species, they may enhance dispersal and adaptation among resident passerine models. Research often treats urbanization in binary terms, comparing metropolitan and rural samples. However, the interaction between urbanization and historical biogeography remains an understudied area, warranting further exploration [3, 4].

Biodiversity: Concepts and Importance

Biodiversity includes the variety of life at the gene, species, community, and ecosystem levels. It is crucial for maintaining ecosystem processes necessary for human survival. High biodiversity features a range of organisms, including terrestrial plants, animals, and microbes, and influences landscape processes like climate and soil type. These elements provide essential ecosystem services, such as carbon capture and oxygen production. Human livelihoods depend on biodiversity's various forms, with greater diversity enhancing ecosystem service efficiency. Conversely, biological uniformity can lead to life-support failures and biosphere collapse. Current biodiversity is declining rapidly, with recovery taking decades or longer. Noteworthy wildlife commodities contributing to this decline include ivory, animal skins, and exotic pets. Habitat loss and climate change are significant drivers of this decrease. This crisis prompted the establishment of the Convention on Biological Diversity to prevent a potential sixth extinction. Numerous indicators highlight reduced richness, abundance, and genetic diversity, emphasizing the necessity for conservation efforts [5, 6].

Urbanization Patterns

As one of the most consequential global processes of the twenty-first century, it is essential to understand urbanization's impact on biodiversity and how to manage urban ecosystems for conservation. Urbanization is the rapid global sprawl of cities, with over half of all humans living in cities. It leads to worldwide intensification of land use: simultaneously loss, degradation and fragmentation of habitats, and alteration of natural geophysical and chemical processes. Meanwhile, a loss of many functional and taxonomic groups of species. Urbanization is the canopy over physiological, behavioral, functional, and biogeochemical processes that occur in ecosystems. This canopy covers a potentially large area of scale: from a patch to a city to a multitude of cities. This scale encompasses many of the most studied questions of ecological and environmental science. Urbanization is an extreme disturbance, and biodiversity loss in some taxa even exceeds that of deforestation. However, patterns and drivers of biodiversity loss remain poorly studied, particularly because urbanization of landscapes has historically happened more gradually and less uniformly than expected. Urbanization is a serial process from landscapes to cities, from dense, heterogeneous urban cores to diffuse, homogeneous suburbs. The contrast between urbanization levels may have changed over time: a greater loss of sensitive species in suburban woodlands because of considerably higher exploitation rates. This has important implications for how to assess the impact of landscape urbanization depending on habitat type and quality. For example, current suburban woodlands may lag behind urban woodlands in species loss, and how to reduce negative impacts of increasing urbanization on biodiversity in (semi-) natural habitats [7, 8].

Impacts of Urbanization on Ecosystems

Urbanization and habitat destruction have led to global biodiversity loss. While urbanization diminishes biodiversity across regions, the loss of habitat quality is a greater driver of this decline than disturbances alone. This suggests that urbanization creates inherently harmful conditions for wildlife, rather than merely causing regime shifts. Additionally, the effects of urbanization vary worldwide, underscoring the importance of historical factors in understanding the current biodiversity crisis. Urban growth is expected to further threaten terrestrial ecosystems, affecting primary productivity, herbivory, litter decomposition, soil carbon storage, and pollination services. Research has shown that cities generally host fewer species than nonurban areas, with urban-only and invader species being less common than urban-avoiders. Although cities can occasionally act as biodiversity hotspots, this is challenged by the "biological desert fallacy," which highlights the need for greater scale consideration due to the surrounding agricultural landscapes. Future studies should apply metacommunity theory and multi-scale modeling. Urbanization alters physical landscapes and climates, leading to significant differences between urban and surrounding areas. Urban locations tend to have more nonnative species compared to undeveloped lands, with synanthropic species often dominating. This invasion by new species can disrupt trophic structures and resource availability, making surrounding landscapes more variable, from intact ecosystems to those heavily impacted by agriculture [9, 10].

Species Adaptation and Resilience

Urbanization increases extinction risk for native species by reducing suitable habitats, yet cities often support diverse native and non-native species. In some instances, cities serve as refuges for species whose habitats lie outside urban areas, enabling recovery post-regional extinction. Urban green spaces help protect species against extreme temperatures and climate change by offering unique resource

combinations. The variation in these green spaces influences local biodiversity, ecosystem functioning, and resilience to change. A study of native bees across urban parks in Melbourne, Mexico City, and San Francisco showed significant differences in species composition between parks, while common native bee species were less found in less urbanized areas. Local land use and horticultural practices impact those species compositions. Concerns over declining native bee populations and fragmented green spaces due to urban development can be mitigated through improved management of urban landscapes. Understanding the interactions among species, resources, and environmental stressors is crucial for recognizing species' potential for urban adaptation and the conservation significance of cities amid ongoing urbanization. While urbanization threatens native biodiversity by reducing habitat and increasing fragmentation, cities also offer habitats that may be absent in surrounding landscapes. As urban areas expand, they may present opportunities for various species to thrive outside their native ranges, along with resources that could alleviate local resource shortages [11, 12].

Conservation Strategies

Efforts should focus on enhancing connectivity, habitat diversity, and the size of urban natural areas, while eliminating isolated, poorly connected remnants. Connectivity must be addressed locally and regionally. Intensively managed areas, such as parks, serve as a conservation base. These parks, along with urban greenery and less-managed public and private spaces, require proper management and connectivity to support species movement in urban settings. Daily strategies can enhance biodiversity persistence in urban areas, building on existing community management efforts aimed at conservation. For instance, the restoration of formerly industrial regions into 'brownfields' has prompted efforts to conserve 'pioneer' species that colonize these sites, with potential modifications to benefit other species or habitats. Small, healthy breeding colonies allow for more effective conservation intervention than established, larger ones. Urban breeding populations of gulls, for example, may grow due to abundant food, but can increase interspecific competition for resources. Encouraging conditions for non-resident species can boost their numbers, possibly leading to undesirable species, like pigeons or parakeets. Understanding daily or seasonal species movement is crucial for effective conservation, although gathering such data is challenging. This information can help explain population declines, assess human impacts on dynamics, and guide effective conservation strategies [13, 14].

Case Studies of Urban Biodiversity

The Biophilias Project presents essays and images from artists and writers across California and beyond, addressing significant ecological, socio-political, and economic changes in the Anthropocene. Works by Mindy Weisel, William H. McNeill, Kelly Gleason, and Kenneth Womack engage with these shifts. The California desert often feels foreign, even alien, to newcomers and reflects complex cultural and ecological layers for those familiar with it. The second half of the eighteenth century marked significant political upheaval, leading to the decline of large game in coevolved ecosystems in Euro-American regions. The national identities of the United States and Australia during the nineteenth century shared narratives of rural ideals and solitude. However, the California desert expresses a unique, unfulfilled cultural longing. Previous writings capture the shifting experiences of its climate and culture. Urbanization has drastically altered natural landscapes, particularly in Boston, where development has fragmented once expansive areas of natural land. While the overall size of Boston has remained stable, its land cover has transformed, with marshes, farmlands, and forests replaced by buildings and paved surfaces. This habitat loss has contributed to a significant decline in biodiversity within urban areas compared to nearby rural regions [15, 16].

Future Directions in Research

Research on urban biodiversity is growing rapidly, but is still considerably behind multi-scale vegetation ecology. In the decades to come, urban ecologists should broaden their research agenda to delve into the finer-scale and coarser-scale environmental and anthropogenic conditions that shape urban biodiversity. The planning and management impulses that call for the inclusion of more biodiversity in cities, such as "10,000 biodiversity effort," "city biodiversity index," "Urban Green Adaptation," etc., await responses from the urban ecology research community. In the past two decades, urbanization ecology has flourished, revealing the distribution patterns, influencing factors, functioning mechanisms, and fit-for-purpose planning of urban biodiversity. However, it is still in its infancy, far behind community ecology and landscape ecology. Kolkwitz bemoaned that in the early 20th century, there were only a few people studying the relationship between nature and urbanization. Similar to about 300 years ago, cities are still considered biological deserts. Under this condition, it is unsurprising that teamwork in the field is limited compared with the dozens of large-scale initiatives in multi-scale vegetation ecology. Yet cities have a long history of acting as "meeting points" for people to work on hypotheses that needed labor, land, or

other skills to tackle (retaliation against invasive learning goats, prospects of precinct-based community kitchens…). The future of urban ecology lies in the hands of those willing to investigate biodiversity in cities, both as scientific and societal challenges [17, 18].

Policy Implications

Policy makers are promising to enhance urban biodiversity through various strategies. The Edinburgh Biodiversity Action Plan aims to audit the city's biodiversity and green spaces, such as parks, while engaging the public. The City of Edinburgh Council promotes a "green city" vision, adopting strategies to improve park accessibility and integrate greenery into urban design. However, urbanization continues to undermine these efforts, raising doubts about the realization of promises. Previous biodiversity projects show little continuation, and public authorities may allow actions harmful to conservation despite their claims of protection. The contradiction of urban green improvement suggests that, while enhancing greenery is thought to aid biodiversity, such measures may hinder conservation and exacerbate urban expansion. A framework for investigating socio-political issues in urban biodiversity enhancement was proposed, highlighting the need to focus on feasible actions rather than simply identifying them. Studies addressing socio-political dimensions remain scarce. Civil society organizations view policy promises as poorly implemented, vague, and non-binding. While policies are intended to be action-oriented, underlying stakeholder-specific issues often guide policymaking. Many participants are skeptical about the execution of proposed policies, as urbanization expands the urban footprint, fragments habitats, and disrupts animal movement [19, 20].

Public Awareness and Education

To create well-connected urban ecosystems, challenges such as security, privacy, and technical limitations must be addressed. In the Global South, local community acceptance is crucial for promoting biodiversity and ecosystem connectivity amid rapid urbanization. Cultural perceptions of biodiversity enhancement, influenced by environmental justice contexts, necessitate diverse engagement strategies. Emerging technologies offer new tools for urban biodiversity mapping and monitoring, but low-tech approaches utilizing existing knowledge may be more immediately effective. A framework for assessing local biodiversity needs is essential, and successful actions require participation from governments and organizations. Engaging citizen scientists throughout projects has proven beneficial. Further research is needed to align professional and citizen efforts for better outcomes. Ongoing development of coordination tools, along with significant outreach and education to highlight benefits for health, urban aesthetics, and climate resilience, is equally important [21, 22].

CONCLUSION

Urbanization remains one of the most significant drivers of biodiversity change worldwide, often leading to habitat loss, species declines, and altered ecosystem functioning. However, the relationship between urban development and biodiversity is complex, with urban areas occasionally fostering unique ecological niches and facilitating the persistence of certain native and non-native species. Effective conservation within urban contexts requires a nuanced understanding of species-specific responses and spatial patterns, alongside proactive management to enhance habitat connectivity and diversity. Policymakers and urban planners must prioritize long-term, actionable strategies that integrate ecological, social, and political dimensions to preserve biodiversity amid growing urban footprints. Ultimately, the challenge lies in balancing urban growth with the protection of biodiversity, transforming cities from biological deserts into sustainable habitats that support diverse life forms and ecosystem services.

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