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The Impacts of Landscape Pattern and Human Activities on Urban Bird Diversity

Pengkai Tang

College of Bioscience and Biotechnology, Hunan Agricultural University, Changsha, China
T3044513652@outlook.com

Abstract. The rapid advancement of global urbanization processes leads to severe fragmentation and degradation of natural habitats, and urban biodiversity conservation faces severe challenges. Birds, as an important indicator group of urban ecosystems, their diversity changes profoundly reflect the changes of the ecological environment under human domination. This paper systematically reviews the impact mechanisms and integration pathways of urban landscape patterns and human activities on bird diversity. Research indicates that landscape patterns lay the resource foundation for diversity through the quantity and quality of habitats, and jointly shape the dispersal, settlement, and community assembly processes of birds through multi-level spatial configurations such as patch connectivity, patch area, and urbanization gradient. Human activities, through three levels of direct mortality, resource regulation, and environmental perception interference, form selective pressure. Further analysis shows that the two are not independent but present a mutually nested and interactively modulated relationship — good landscape patterns can buffer the negative impacts of human activities, while unreasonable spatial configuration may amplify disturbance risks and even form an "ecological trap". Future research needs to place landscape patterns and human activities under a unified framework for examination, which is the scientific prerequisite for revealing the maintenance mechanisms of urban bird diversity and supporting precise ecological planning and management.

Keywords: Urban bird diversity, Landscape pattern, Human activities, Ecological conservation

1. Introduction

The 21st century is the century of global urbanization. "According to the United Nations, two-thirds of global population growth through 2050 is expected to occur in cities" [1]. This unprecedented land use change causes natural habitats to be rapidly replaced by roads, buildings, and impervious surfaces, and ecosystems face crises such as fragmentation, degradation, and biotic homogenization. Biodiversity loss has been listed as one of the most urgent ecological problems of the Anthropocene. Birds, as the most observable and monitorable indicator group in urban ecosystems, the changes in their community structure and diversity profoundly reflect the changes in the ecological environment under human domination [2]. Therefore, analyzing the driving mechanisms of urban

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bird diversity is not only a natural experimental field for testing ecological theories, but also the scientific cornerstone supporting urban biodiversity conservation.

There are many factors influencing urban bird diversity, but they can be mainly summarized into two macro dimensions: urban landscape pattern and human activities. The former covers the area, connectivity, heterogeneity, and spatial configuration of habitat patches, determining whether birds "have a place to go" [3]. The latter includes resource regulation, physical disturbance, noise and light pollution, etc., which determines whether birds can "settle down and work in peace" [4]. The two do not operate in isolation, but are nested and mutually modulated with each other across multiple scales. However, current research mostly focuses on the independent effects of single factors, and the discussion on how the two synergize, offset, or couple with each other remains insufficient.

In view of this, this paper systematically reviews the research progress on the impacts of landscape patterns and human activities on urban bird diversity, aiming to: 1) clarify the respective action pathways and mechanisms of the two major factors; 2) construct an integrated understanding framework to elucidate how they synergistically affect urban bird diversity; 3) look ahead to the future development directions of urban bird diversity research.

2. The shaping role of urban landscape pattern

2.1. Quantity and quality of habitat

Landscape pattern focuses on the spatial morphology, size, quantity, and spatial arrangement and combination of habitat patches. In cities, it determines the distribution framework and accessibility of bird resources.

The quantity of habitat (e.g., total green space area) and its intrinsic quality are the foundation of diversity. Research shows that larger natural or semi-natural vegetation patches in cities (e.g., urban forests, large parks) generally support higher bird species richness. Area is a direct representation of habitat resources, the larger the area, the richer the available habitat space and food resources for birds, especially for large wading birds and raptors, their activity range and predation needs are more dependent on broad habitats, for waterfowl, a larger area may mean larger water bodies or wetlands, which can better meet their habitat and foraging need [5]. However, "quality" is more decisive than mere "area". High-quality habitats usually have complex vertical structure (abundant tree, shrub, and herb layers). Morphologically complex habitats can provide more habitat space and ecological niches, increasing species and functional diversity, especially among raptors that require diverse habitat resources and the most species-rich passerines. Complex habitat morphology may support more types of prey or food sources, meet the ecological needs of different bird species, thereby enhancing functional diversity [5].

Thus, the quantity and quality of habitat jointly affect urban bird diversity, under the premise of ensuring quantity, more complex habitat morphology can meet the ecological needs of different bird species and enhance their diversity.

2.2. Habitat spatial configuration

Spatial configuration determines whether and to what extent birds can utilize dispersed resources, and its impacts can be understood from three interrelated levels: connectivity between patches, geometric properties of patches themselves, and landscape changes along the urbanization gradient.

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Patch connectivity is one of the core concepts of spatial configuration. Through green corridors, river corridors, or small green space "stepping stones" connecting isolated habitat patches can significantly promote bird individual dispersal and gene flow, enhance habitat quality, and thereby support urban biodiversity conservation [6]. A highly connected landscape network can alleviate the negative effects of habitat fragmentation and maintain regional population health.

Patch area is another key dimension of spatial configuration. Island biogeography theory predicts that larger patches support higher species richness. However, research indicates that the relationship between patch area and bird diversity is not simply a linear positive correlation Liqing Peng conducted a 4-year study (with a total of 540 surveys) on 30 fragmented forest patches in Wuhan, and found that the responses of different dimensions of diversity to urban forest fragmentation varied: In taxonomic diversity, the richness of all birds and generalist birds increased with habitat complexity, but showed a non-monotonic relationship with patch area——medium-sized patches instead had higher diversity; whereas specialist birds exhibited a "small-island effect", meaning that their taxonomic diversity rapidly increased only when patch area exceeded a critical threshold (approximately 80 hm^2) [7].

The urbanization gradient is a macro-framework for understanding the effects of spatial configuration. From urban core areas to suburban rural areas, land use intensity, vegetation coverage, and the level of human disturbance show continuous changes, and bird communities undergo systematic succession accordingly. The study by Wang Xue et al. at Qinhu National Wetland Park in Taizhou City, Jiangsu Province, shows that the composition and configuration of urban-rural land use landscapes significantly affect the spatiotemporal distribution of bird diversity. Bird Shannon-Wiener diversity index shows seasonal variation of summer > spring > winter > autumn; although there is no significant difference in bird abundance between breeding season and non-breeding season, the species richness difference is obvious. More importantly, the abundance and richness of habitat specialists and urban generalists show differentiation along the urbanization gradient—in suburban and exurban areas with moderate human disturbance, bird species richness reaches a peak [8].

In summary, the three levels of habitat spatial configuration are not a coordinate relationship but are progressively layered: connectivity concerns the "passage" between patches, addressing the issue of dispersal; patch area concerns the "capacity" within patches, addressing the issue of settlement; the urbanization gradient concerns the "change" at the landscape scale, addressing the issue of community assembly. From "passage" to "capacity" to "change", the three levels respectively act on different stages of the bird life cycle, jointly shaping urban bird diversity.

3. Human activities

The impacts of human activities on urban birds can be divided into three levels: direct mortality, resource regulation, and environmental perception interference. These three levels, from explicit to implicit, from acute to chronic, together constitute the selective pressure of human activities on birds.

3.1. Direct mortality

The most direct impact of human activities is the death of individual birds. This type of impact often has the characteristics of being acute and having a high mortality rate, and is the most urgent threat faced by urban birds.

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Building collision is one of the most important direct mortality factors for urban birds. Glass curtain walls reflect vegetation and sky during the day, causing birds to mistakenly think it is a space they can fly through; at night, due to attraction by lights, it leads to migratory birds colliding with buildings and dying.Loss et al., based on a systematic analysis of 23 studies, for the first time quantified the scale of bird mortality due to building collisions in the United States, with an estimated 365 million to 988 million birds (mAt the same time, it points out that the proportions of bird collision deaths caused by different building types vary greatly: low-rise buildings (1-4 floors): the highest proportion, accounting for about 56% of total deaths (approximately 339 million); residential buildings (e.g., single-family houses): accounting for about 44% (approximately 253 million); high-rise buildings: accounting for less than 1% (approximately 508,000) [9]. This distribution pattern indicates that, although the individual mortality rate of high-rise buildings may be very high, due to their limited quantity, the resulting death scale is instead smaller; while widely distributed low-rise buildings and residences are the main sources of bird collision deaths.

Domestic cat predation is another major mortality factor.Free-roaming domestic cats (including pet cats, stray cats, feral cats) pose a serious threat to ground and shrub-nesting birdsGlobally, the number of bird deaths caused by cats annually is in the hundreds of millions, and in the United States in 2013 it was estimated to be 1.3 to 4 billion birds [10]. This figure far exceeds that of building collisions, making domestic cat predation the leading anthropogenic cause of bird mortality.And from from the perspective of ecological impact mechanisms, the impact of cats on birds is far more than direct killing—it also includes fear effects (changing birds' habitat selection and behavioral patterns), disease transmission (such as toxoplasmosis), and competitive exclusion [11].

3.2. Resource regulation

The impact of resource regulation is not direct mortality, but rather indirectly affects the survival and reproduction of birds by altering the resource base on which birds depend for survival. This type of impact often has cumulative and long-term characteristics.

Artificial feeding is the most common human resource supplementation behavior in citiesIn winter or periods of resource scarcity, artificial feeding can provide critical energy supplements for birds, increasing local survival rates and overwintering ability.However, artificial feeding also has negative effects.For example, the study by Wu Zhaolu and others on wintering black-headed gulls in Kunming showed that black-headed gulls developed adaptation to and dependence on artificial feeding, leading to partial loss of wildness, or following dense crowds to shift foraging grounds, or no longer returning to breeding grounds and becoming "resident birds." This led to human-bird conflict, and the severe pathogenic organisms carried by black-headed gulls negatively impacted humans, causing people to often choose to avoid or drive them away, or even capture and kill the black-headed gulls [12].

Water body design also affects the resources available to birds.The surrounding area of the Balishao Forest Farm site within the Hani Nature Reserve was originally a marsh wetland formed by river alluviation, historically an important habitat for waterbirds, with the nationally protected first-class key bird species, the Oriental Stork, having recorded stopovers in this area, and multiple species of migratory waterbirds and resident birds breeding here.In the early 1980s, some areas drained wetland water, built a forestry timber guesthouse (the building has now been demolished, leaving only a concrete floor), vegetation severely damaged, wetland function completely lost, no longer suitable for waterbird habitat [13]. South Dongting Lake International Important Wetland, as an important ecosystem of Hunan Province, has historically been affected by factors such as tree

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planting, reed harvesting, poaching, grazing, illegal fishing in agricultural, forestry, fishery and animal husbandry activities, and tourism activities in development and construction, the wetland ecological environment has also suffered degradation and fragmentation threats [14].

3.3. Environmental perception interference

The impact of this factor is the most subtle—it does not directly cause death, nor does it directly change the amount of resources, but rather, by interfering with the way birds perceive the world, it affects their behavioral decisions, intraspecific communication, and physiological rhythms.

Noise pollution is the earliest environmental perception interference that has been paid attention to.Noise from traffic, industry, drones, etc. will mask the singing signals used by birds for courtship, alarm, and territory defense. This is due to severe auditory frequency overlap in anthropogenic noise, called acoustic masking.Birds cannot hear significant acoustic signals in the environment, such as predators, competitors, or mates, causing them to lose important information about environmental quality, safety, and competition. Noise may also lead to reduced species richness, because noise-sensitive species (such as certain songbirds) are forced to avoid noise sources, making urban bird communities tilt towards a few noise-tolerant species [15].

The impact of light pollution has received much attention in recent years. The systematic review by Yadav et al. points out that the impacts of artificial light at night on migratory birds cover multiple levels: orientation and navigation interference, urban attraction effect, altered predator-prey dynamics, disrupted foraging behavior, and hormonal rhythm interference [16]. The study particularly emphasizes that there are still significant knowledge gaps in the current understanding of the mechanisms of light pollution, and the long-term health effects and population-level consequences still await in-depth investigation [16]. From the perspective of spatial scale, the impact of light pollution on birds has multi-scale characteristics . At the macro scale, global light pollution is increasing at an annual rate of 2. 2%, and light pollution is most severe above migration corridors, which may alter migration timing, leading to mismatch with food resources [17]. From the regional scale perspective, urban "light islands" can attract migratory birds from tens to hundreds of kilometers away to deviate from established routes, altering stopover site selection during migration [17]. Light pollution can also interfere with the physiological rhythms of birds—lengthening perceived day length, causing urban birds to sing at dawn earlier than their rural counterparts, consuming additional energy; and superimposing with the urban heat island effect, resulting in an earlier breeding season, leading to a mismatch with the peak of food resources.

4. Interaction between pattern and activity: integrated perspective and future challenges

Separating landscape patterns and human activities for study can no longer fully understand the complexity of urban bird diversity, and the interaction between the two is becoming a frontier focus.

The previous sections respectively discussed the independent effects of landscape patterns and human activities on urban bird diversity, but in real urban ecosystems, the two do not operate in parallel; they are continuously intertwined and mutually modulated.

The most intuitive manifestation of this interaction is: good landscape patterns can buffer the negative impacts of human activities, but unreasonable spatial configuration may also amplify disturbance risks. For example, the study by Planillo et al. on the functional diversity of 95 breeding bird species in Berlin found that complex vegetation structure can significantly buffer the impacts of population density and noise on bird functional diversity, providing a "refuge" for sensitive species [18]. This means that, even in high-intensity human activity areas, as long as sufficiently complex

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vegetation structure is retained, it can still support the survival of some birds. Conversely, the study by Le Magoarou et al. on great tits and blue tits in Dijon, France, showed the phenomenon of an "ecological trap": artificial nest boxes in urban areas attracted birds to settle, but food scarcity and human disturbance led to their reproductive failure—the resource supplementation (pattern) originally intended to support birds, instead produced negative consequences due to superposition with urbanization effects (activities) [19].

Understanding the interaction between landscape patterns and human activities is not only a need for deepening ecological theory, but also an urgent demand for urban management practice. Future research needs to deepen mechanistic studies, promote multi-scale integration, and strengthen dynamic process tracking. Only by placing the two under the same framework for examination can we avoid the "green space trap" of "having pattern without function" — a park with sufficient area and high connectivity, if it allows high-intensity recreation and free pet activities inside, its actual conservation benefits for sensitive species will be greatly reduced.

5. Conclusion

Urban bird diversity is an important yardstick of urban ecosystem health. This review indicates that its change is the result of the combined action of "spatial opportunities" provided by urban landscape patterns and "environmental filters" imposed by human activities. Landscape patterns, through habitat quantity, quality, and spatial configuration, set the geographical template and upper limit of diversity; Human activities, through the three levels of direct mortality, resource regulation, and environmental perception interference, determine the actual realization degree of diversity under that template. The relationship between the two is not a simple additive relationship, but rather there are non-linear, scale-dependent interactions and trade-offs — good landscape patterns can buffer the negative impacts of human activities, while inappropriate spatial configuration may also amplify disturbance risks.

Future urban biodiversity conservation must adopt a systematic collaborative management approach: it requires both planning an ecologically functional green infrastructure network at the regional scale, and precisely regulating the type and intensity of human activities at the local scale; it requires paying attention to both "whether birds have a place to go" and "whether birds can settle down and work in peace." Only by doing so can we preserve sustainable living space for birds and other wildlife in rapidly developing human settlements, and achieve harmonious coexistence between humans and nature.

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