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Urban bird nest building on man-made structures: A review

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ABSTRACT

The behavioral responses of birds to urban environments are crucial for their ability to thrive within city landscapes. Various urban birds have demonstrated the capacity to exploit artificial structures as nesting sites due to the limited availability of natural options. This review examines the current state of urban bird nesting behaviors on man-made structures and highlights directions for future research. Nest types frequently observed on these structures include woven, cavity, ground, and mud nests. These adaptive behaviors increase nesting opportunities and improve reproductive success, although they may heighten vulnerability to ecological traps. Proximity to human habitats can promote conservation awareness but also presents potential economic and health-related challenges. Therefore, applying diverse strategies is essential for effectively managing and protecting nests on man-made structures across various circumstances. There is also a need for thorough, long-term studies on the ecological and evolutionary impacts of nest building on artificial structures and the mechanisms influencing nest-site selection. Furthermore, exploring innovative approaches that combine policy implementation and citizen science will be vital for advancing human-bird coexistence.

Keywords: Birds; Urbanization; Man-made structures; Nesting ecology; Nest-site selection

INTRODUCTION

Urbanization is a significant anthropogenic driver of global biodiversity loss (Aronson et al., 2014). Consequently, understanding the responses of species to human-induced disturbances and mitigating the negative impacts of urbanization on wildlife have become key priorities in contemporary conservation initiatives. With the continued acceleration and expansion of urban landscapes, the study and preservation of urban bird populations have gained increasing attention (Jokimäki et al., 2018). A pivotal constraint on avian population growth is the availability of suitable nesting sites, which directly influences reproductive success and population dynamics (Cockle et al., 2010). Birds must invest considerable time and energy in nest-site selection, construction, and maintenance to mitigate environmental risks and enhance their fitness (Mainwaring & Hartley, 2013). Furthermore, nest quality is equally crucial for the successful incubation of eggs and subsequent survival of fledglings.

Man-made structures, such as urban buildings, present both challenges and opportunities for avian breeding. On the one hand, buildings can disrupt flight paths, leading to increased mortality from collisions (Loss et al., 2014), and can indirectly affect breeding success in proximate fragmented natural habitats (Hedblom & Söderström, 2012). On the other hand, these human-altered landscapes offer novel nesting opportunities for many bird species, supporting a range of nesting behaviors (Figure 1) (Mainwaring, 2015). Recent research has indicated that specific behavioral and life-history traits are strongly associated with avian responses to urban environments, with species that nest in artificial structures showing greater resilience to urbanization (Leveau & Ibáñez, 2022). This adaptive behavior has contributed to population increases in certain species, resulting in shifts in bird community composition across urban gradients (Li et al., 2009). Understanding the selection of nest sites and associated energy expenditure during breeding on man-made structures not only deepens insight into the reproductive strategies of urban birds but also supports the development of sustainable urban ecosystems, guiding city management towards more biodiversity-conscious practices (Reynolds et al., 2019).

In the current review, we focus on three principal areas: (1) the prevailing patterns of avian use of man-made structures with diverse nesting characteristics; (2) the complex impacts of nesting in these structures on both avian and human well-being; and (3) the range of management approaches for bird nests on artificial structures. Lastly, we explore prospective avenues for future research on urban bird nesting across man-made structures.

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METHODS

We conducted a comprehensive literature search spanning publications from 1984 to 2024 using Web of Science (http://www.webofscience.com) and China National Knowledge Infrastructure (CNKI; https://www.cnki.net). The search was performed with the following terms: TS (topic)= (urban*OR city) AND (bird*OR avian) AND (artificial structure*OR man-made structure*OR building*OR bridge*OR pipe*OR pylon*) AND (nest*OR nest site OR nest composition). This search yielded 951 articles, of which 290 were selected for further analysis after screening and eligibility confirmation.

CURRENT STATUS OF URBAN BIRD NESTING ON MAN-MADE STRUCTURES

Urban birds frequently utilize artificial structures for nesting, primarily due to their stability and proximity to food sources. These structures, commonly composed of concrete or metal, offer protection from predators and harsh environmental conditions. Their locations, typically near areas of human activity, also influence nesting site selection.

Urban birds commonly build four types of nests on man-made structures, including woven, cavity, ground, and mud nests (Table 1) (Zheng, 2012). Different bird species exhibit distinct preferences for specific structures (Table 2). Overall, large species, such as storks (Ciconiidae), eagles (Accipitridae), falcons (Falconidae), and crows (Corvidae), tend to utilize taller structures, including high-rise buildings, towers, and pylons, while smaller species, such as doves (Columbidae) and thrushes (Turdidae), often utilize structural elements of houses for nesting, such as windowsills. Cavity nesters, including sparrows (Passeridae), chickadees (Paridae), starlings (Sturnidae), and parrots (Psittacidae), exhibit a preference for sheltered spaces within buildings and poles. Ground-nesting species, such as gulls (Laridae) and nightjars (Caprimulgidae), nest on rooftops, while mud-nesters, like swifts (Apodidae) and swallows (Hirundinidae), construct their nests on walls and beneath eaves.

Woven nests

Woven nests represent the most prevalent nest type observed on artificial structures within urban environments. In natural environments, species constructing woven nests typically select the elevated branches of tall trees or dense vegetation. However, the scarcity of suitable nesting trees in urban areas necessitates alternative strategies (Wang et al., 2015). Consequently, artificial structures that provide adequate height and structural stability have become functional surrogates, enabling these species to establish nests on or beneath such structures. These adaptations offer additional nesting opportunities for avian species from diverse ecological niches.

Urban environments have supported the presence of birds of prey since the Middle Ages, with a notable increase in their population densities in recent years (Mak et al., 2021). Following the prohibition of DDT and the implementation of stringent conservation measures, many predatory species have experienced population recoveries, frequently selecting man-made platforms as nesting sites (Goulet et al., 2021). Historical structures, in particular, provide substantial nesting opportunities for urban raptors, such as the common kestrel (*Falco tinnunculus*) (Sumasgutner et al., 2014). Studies comparing nest productivity in urban settings with those in rural areas have shown comparable reproductive outcomes (Gahbauer et al., 2015; Petersen et al., 2020). While various factors influence nest-site selection among urban-dwelling raptors, structural elevation consistently emerges as the primary consideration (Anushiravani et al., 2016).

White storks (*Ciconia ciconia*) and certain medium-sized corvids have demonstrated the ability to exploit urban pylons and high-rise buildings for nesting. While white storks possess

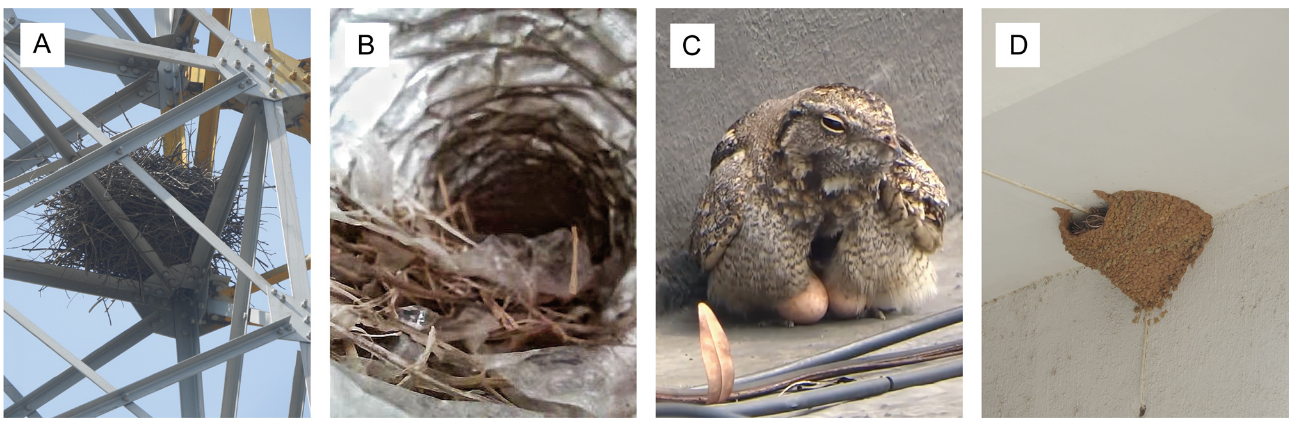

Figure 1 Various bird nest constructions on man-made structures

A: Woven nest of oriental magpie (*Pica serica*) on a transmission tower (photo by Xiaoru Liu). B: Cavity nest of white-cheeked starling (*Spodiopsar cineraceus*) within a vent pipe (photo by Xiaoru Liu). C: Ground nest of grey nightjar (*Caprimulgus jotaka*) on a rooftop (photo by Senxibage). D: Mud nest of barn swallow (*Hirundo rustica*) under a roof (photo by Xiaoru Liu).

Table 1 Descriptions of nest types built on man-made structures

Type	Definition
Woven	Nests made of twigs, leaves, grass stems, and hair woven into disks, cups, spheres, or bottles.
Cavity	Nests constructed in natural tree holes, caves, or other cavities. Some species do not use nesting materials or only insulate the bottom of the cave with materials such as grass, feathers, and moss, while other species build woven nests in caves.
Ground	Nests built directly on the ground without any nesting materials or with simple nesting materials such as hay and feathers, loosely lined inside a pit.
Mud	Nests made of mud adhered to cliffs or cavities.

Table 2 Representative bird species and their utilization of man-made structures for nesting

Nest type	Representative species			Man-made structures	Sources
Woven nest	Ciconiiformes	Ciconiidae	White stork (*Ciconia ciconia*)	Rooftops, pylons, and poles	Burdett et al., 2022
	Falconiformes	Falconidae	Peregrine falcon (*Falco peregrinus*)	Rooftops, pylons, and poles	Gahbauer et al., 2015
	Accipitriformes	Accipitridae	Bald eagle (*Haliaeetus leucocephalus*)	Pylons and poles	Goulet et al., 2021
		Pandionidae	Osprey (*Pandion haliaetus*)	Pylons and poles	Murphy et al., 2024
	Columbiformes	Columbidae	Spotted dove (*Spilopelia chinensis*)	Windowsills, brackets	Gao et al., 2018
	Passeriformes	Corvidae	Eurasian magpie (*Pica pica*)	Windowsills, pylons and poles	Nakahara et al., 2015
		Turdidae	Common blackbird (*Turdus merula*)	Window ills, brackets	Wang et al., 2015
Cavity nest	Anseriformes	Anatidae	Mandarin duck (*Aix galericulata*)	Cavities in buildings	Jiang & Cai, 2009
	Passeriformes	Passeridae	Eurasian tree sparrow (*Passer montanus*)	Cavities in buildings	Lee et al., 2023
		Muscicapidae	Daurian redstart (*Phoenicurus auroreus*)	Cavities in buildings	Zhang et al., 2023
		Paridae	Great tit (*Parus major*)	Cavities in poles	Rong et al., 2023
		Sturnidae	Common starling (*Sturnus vulgaris*)	Cavities in buildings	Stuart et al., 2023
		Hirundinidae	Purple martin (*Progne subis*)	Cavities in buildings and bridges	Airola & Grantham, 2003
	Psittaciformes	Psittacidae	Burrowing parrot (*Cyanoliseus patagonus*)	Cavities in buildings	Lera et al., 2023
Ground nest	Anseriformes	Anatidae	Canada goose (*Branta canadensis*)	Rooftops	Shearer et al., 2022
	Charadriiformes	Laridae	Slaty-backed gull (*Larus schistisagus*)	Rooftops	Zelenskaya, 2019
			Glaucous-winged gull (*Larus glaucescens*)	Rooftops	Blight et al., 2019
			European herring gull (*Larus argentatus*)	Rooftops	Perlut et al., 2016
		Haematopodidae	Eurasian oystercatcher (*Haematopus ostralegus*)	Rooftops	Löffler et al., 2024
	Caprimulgiformes	Caprimulgidae	Grey nightjar (*Caprimulgus jotaka*)	Rooftops, windowsills	Shi et al., 2012
Mud nest	Apodiformes	Apodidae	Common swift (*Apus apus*)	Cavities in buildings and eaves	Antonov & Atanasova, 2002
			Pallid swift (*Apus pallidus*)	Cavities in buildings and eaves	Antonov & Atanasova, 2002
	Passeriformes	Hirundinidae	Barn swallow (*Hirundo rustica*)	Walls, beams, and eaves	Qin et al., 2023
			Western house martin (*Delichon urbicum*)	Walls, beams, and eaves	Murgui, 2002

a limited tolerance for urban environments (Hmamouchi et al., 2020), their growing reliance on anthropogenic waste and man-made structures has become more pronounced as their populations expand (Burdett et al., 2022). In contrast, urban crows, such as the Eurasian magpie (*Pica pica*), display notable adaptability in nest-site selection, favoring elevated and structurally robust artificial platforms. This preference is particularly prominent in areas with limited tree availability or high levels of human activity, as nesting on these structures reduces the likelihood of anthropogenic disturbances (Nakahara et al., 2015).

Small to medium-sized avian species that construct woven nests on man-made structures are frequently found within residential structures and display a high tolerance for human presence. For example, the rock dove (*Columba livia*), whose native cliffside habitats closely resemble urban architecture, is commonly observed nesting on rooftops and within the recesses of bridges. Its urban populations have increased substantially in cities with sufficient food sources and appropriate habitats (Stukenholt et al., 2019). Other dove and thrush species also utilize windowsills and metallic components of buildings as alternative nesting sites in the absence of natural locations (Gao et al., 2018; Wang et al., 2015). In their native habitats, woven nest building birds customarily seek elevated nesting locations with concealment. In contrast, many urban-adapted species establish nests on prominent, exposed man-made structures, which may serve as a compensatory behavior in response to reduced concealment options. These elevated sites provide enhanced visibility, allowing for panoramic surveillance and increased vigilance against potential predators.

Cavity nests

Secondary cavity-nesting birds, which are unable to excavate their own nests, rely heavily on the availability of pre-existing cavities for reproductive success (Cockle et al., 2010). In urban environments, the paucity of mature trees with natural hollows has driven many of these species to utilize cavities in anthropogenic structures as alternatives to less abundant natural nesting sites (Sandoval et al., 2021).

Certain small-to-medium secondary cavity nesters, such as the house sparrow (*Passer domesticus*) and Eurasian tree sparrow (*Passer montanus*), are particularly well-adapted to urbanized environments (Nath et al., 2022). These species frequently nest in the crevices of buildings and other structures, with nest-site selection influenced by factors such as entrance size, proximity to foraging areas, and availability of structures, as well as a complex interplay of environmental variables (Choudhary et al., 2020; Lee et al., 2023). Research has indicated that great tits (*Parus major*) and starlings frequently use cavities in vertical structures, such as lampposts, flues, vents, and pipes, for nesting (Rong et al., 2023). The proficiency of common mynas (*Acridotheres tristis*) and common starlings (*Sturnus vulgaris*) in exploiting diverse anthropogenic structures for nesting has contributed to their rapid population growth, leading to their classification as invasive species in several countries (Lowe et al., 2011; Stuart et al., 2023).

An increasing number of cavity-nesting species now occupy previously unused anthropogenic substrates. For instance, burrowing parrots (*Cyanoliseus patagonus*), known for excavating holes in rocky and sandy terrains, have been observed nesting in roadside ravines and cavities within buildings (Lera et al., 2023). In rare cases, species such as mandarin ducks (*Aix galericulata*) have also been documented using man-made structures for nesting (Jiang & Cai, 2009). These adaptive behaviors emphasize the importance of flexibility in nest-site selection, which plays a critical role in the reproductive success of urban cavity nesters and highlights the potential benefits for the conservation of these populations in urban settings.

Ground nests

Ground-nesting avian species typically construct comparatively rudimentary nests, rendering them more vulnerable to predation by urban terrestrial predators (Evans et al., 2011). To mitigate this risk, many ground-nesting birds in urban areas have adapted by selecting elevated artificial platforms for nesting. In many coastal cities where natural beach habitats have been replaced by artificial landscapes, flat, open man-made substrates, such as rooftops, have become essential and relatively secure nesting sites for many shorebirds (Charadriiformes) (Löffler et al., 2024; Rock, 2005). Additionally, several ground-nesting nightjars and geese have been observed breeding on rooftops and balconies due to the decline in available natural nesting sites in open grasslands (Shearer et al., 2022; Shi et al., 2012).

Urban rooftop nesting by gulls is a well-established phenomenon (Soldatini et al., 2008), with populations experiencing notable growth due to the abundance of available nesting sites and urban food sources (Blight et al., 2019). Contrary to the earlier assumption that rooftop nesting emerged due to overcrowding in traditional nesting areas, recent comparative analyses of urban and natural habitats have suggested that this behavior may represent a deliberate adaptive strategy (Perlut et al., 2016). Additional research has also indicated that gulls nesting on rooftops achieve reproductive success rates comparable to, or even exceeding, those observed in natural habitats (Bellout et al., 2022). Unlike their centralized nesting patterns in natural environments, urban-dwelling gulls often exhibit a preference for occupying distinct rooftops, possibly capitalizing on the expansive visibility these locations offer (Zelenskaya, 2019). The factors influencing nest-site selection for ground-nesting species on man-made structures are multifaceted, including physical, behavioral, and even social factors. Consequently, a detailed assessment tailored to the specific population is crucial for understanding these nesting behaviors (Dalla Pria et al., 2022).

Mud nests

Mud nests, primarily constructed by swifts and swallows, are commonly observed on the exterior walls of low-rise buildings, particularly in rural areas. However, due to the distinct architectural features in urban areas, some swallows have adapted to nesting within residential buildings (Zhi et al., 2018). These species, capable of utilizing anthropogenic resources, are expected to exhibit more favorable population trajectories in human-populated areas (Hasegawa & Arai, 2022).

In general, urban environments are suboptimal for the breeding of swallows and swifts compared to the richer food resources available in agricultural landscapes (Osawa, 2015). Nevertheless, breeding success is often unaffected due to adaptive behavioral modifications in nest-site selection, which enable certain species to mitigate the potential negative impacts of urban settings (Zhao et al., 2022). For instance, barn swallows (*Hirundo rustica*) have been observed to alter nest positioning relative to the ground in response to varying levels of urbanization (Qin et al., 2023). In addition, urban swallows and martins frequently use complex support structures to enhance nest attachment and stability (Murgui, 2002; Wu et al., 2019). In urban areas where suitable breeding sites are limited, swallows and swifts exhibit flexibility in selecting nesting locations based on factors such as height and structure variety to help mitigate interspecific competition (Antonov & Atanasova, 2002). This behavioral plasticity highlights the importance of further research into niche differentiation and competitive dynamics among species that nest on man-made structures in urban areas.

TWO-SIDED IMPACTS OF MAN-MADE STRUCTURES AS NESTING SITES ON URBAN BIRDS AND HUMANS

This section explores the dual effects of man-made structures as nesting sites on both the reproductive fitness and well-being of urban-residing birds (Table 3). While avian species may derive benefits from artificial structures, they are also exposed to hazards not present in natural habitats. This phenomenon can lead to positive outcomes alongside a range of potential challenges.

Benefits to birds

Additional nesting sites: The most direct positive impact of man-made structures on avian species is the provision of suitable and substantial nesting sites, particularly in urban areas where natural nesting options are scarce (Mainwaring, 2015). These supplementary resources can be pivotal in the maintenance and proliferation of bird populations in cities. For example, a study in Warsaw estimated that approximately 80% of the local great tit population nests in vertical pipes on fences (Lesiński, 2000). In some cases, nests within buildings have provided additional nesting sites for species with similar ecological niches, suggesting that these structures may aid in the recovery of endangered bird populations (Guo et al., 2022). To clarify the importance of man-made structures for urban bird populations, further research is needed to examine

Table 3 Main benefits and drawbacks of avian nesting on man-made structures for urban birds and human communities

Object	Advantage	Disadvantage
Birds	Provision of available nest sites where they are otherwise limited	May be ecological traps due to unsuitable environments
	Energy saving for nest defense	May become unavailable due to human activities
	Increased accessibility to food resources and higher nest temperature, potentially improving brooding efficiency	May lead to unexpected predator-prey and competition relationships
Humans	Access to ecosystem services	May cause annoyance to residents
	Stimulation of public interest in urban biodiversity, likely promoting conservation awareness	May bring risk of environmental pollution and infectious disease
		May damage urban infrastructures (e.g., buildings and transmission system)

the relationship between nest prevalence in artificial environments and population dynamics, as well as to compare reproductive success rates between anthropogenic and natural nesting habitats.

Energy savings during reproduction: Man-made structures can also enhance reproductive efficiency in urban birds due to various factors inherent in the urban environment, such as reduced predators, increased food resources, and favorable microclimatic conditions (Møller & Díaz, 2018).

First, birds nesting on artificial structures expend less energy on nest defense and vigilance, as these locations often reduce the risk of predation. Human activity, combined with the structural features of buildings, tends to deter predators from accessing nests (Møller, 2010). Additionally, nesting closer to buildings can reduce the risk of nest parasitism by lowering the spatial distance between nests (Zhang et al., 2023). Furthermore, urban birds typically display a weaker defense response to human presence (Møller et al., 2015), allowing them to allocate more energy toward reproduction.

Urban environments also offer advantages in terms of foraging efficiency. The abundance of anthropogenic food sources near nesting sites reduces the foraging time required by birds (Risi et al., 2021). Second, artificial nocturnal lighting in cities can extend feeding hours, enabling birds to provide their chicks with more food and thereby enhancing fledging success (Wang et al., 2021). Another benefit is the elevated temperatures maintained by buildings compared to natural habitats, which reduce the energy required for incubating eggs (McCafferty et al., 2001). This thermal advantage decreases the need for nest attentiveness, potentially enabling adults to allocate energy towards other fitness-enhancing activities, such as foraging and predator avoidance (Batisteli et al., 2021).

Costs to birds

Ecological traps: While many birds successfully utilize man-made structures for nesting, these structures may also pose significant risks to their reproductive processes. Artificial structures can create ecological traps, where birds are attracted to sites that appear to be suitable for nesting but are ultimately harmful (Schlaepfer et al., 2002). One of the most prominent dangers is the physical threat posed by the structures themselves. For example, birds nesting on pylons face risks of electrocution or collisions with transmission lines, which can result in fatalities (Loss et al., 2015). Similarly, nests built near highways or bridges expose birds to high rates of roadkill (Brown & Bomberger Brown, 2013). In addition to the physical hazards, the microenvironments created by man-made structures can have detrimental effects on avian reproductive success. Elevated temperatures, common in urban settings, may cause increased thermal stress, potentially compromising chick health and development (Newberry & Swanson, 2018). These effects may not be immediately apparent in the breeding season but can result in low reproductive success long-term (Imlay et al., 2019). Furthermore, urban habitat quality may be overestimated. For example, the absence of voles, a primary prey for raptors such as common kestrels, in urban environments has necessitated a dietary shift towards avian prey, negatively affecting reproductive outcomes (Sumasgutner et al., 2014).

A further complication arises from the temporary nature of many urban nesting sites. The modernization of buildings often involves sealing and altering structures in ways that reduce potential nesting sites. Nests on artificial structures can be easily removed or destroyed, and renovations of older buildings frequently eliminate cavities that are essential for cavity-nesting species (Rosin et al., 2020). Birds reliant on these cavities for nesting may experience rapid population declines or local extinctions in areas undergoing extensive modernization (Moudrá et al., 2018).

Emerging interspecific interactions: As an increasing number of species adapt to urban environments, novel interspecific interactions can arise, particularly among birds nesting on man-made structures. Although urban areas generally have fewer traditional nest predators, new predators have increasingly colonized cities, posing novel threats to urban bird populations. For example, predation of barn swallow nests by the invasive Taiwan purple whistling thrush (*Myophonus insularis*) has been documented, significantly impacting the reproductive success of local swallows (Wang & Hung, 2019). Moreover, the expansion of invasive species in urban areas inevitably intensifies competition for nesting resources with early settlers (Rogers et al., 2020). If invasive species establish themselves in man-made structures before native birds, it can lead to a reduction in the availability of nesting sites for native avian populations (Airola & Grantham, 2003).

Physiological and psychological benefits to humans

A growing body of evidence has highlighted the positive effects of human-bird interactions (Gray et al., 2024). Birds residing near human populations provide a range of ecosystem services, such as pest and weed management within inhabited areas (Whelan et al., 2008). On a cultural and emotional level, individuals tend to show a higher level of concern for species that adapt to urban environments and utilize human-provisioned food sources (Takaya & Tomojiri, 2023). In some regions, scientists have integrated advanced technologies, such as camera systems and real-time digital streaming, with traditional tracking methods to facilitate access to information about urban birds to the general public, enabling non-specialists to interactively engage with urban wildlife (Searle et al., 2023). Birds that nest on artificial structures enhance the opportunities for close interactions between wildlife and humans, fostering a deeper connection with nature and evoking positive emotional responses to avian species. Consequently, these phenomena bolster support for conservation initiatives focused on urban biodiversity.

Negative effects on humans

Conversely, the use of man-made structures for nesting can also lead to a range of issues that impact both public health and the economy. In addition to creating disruptive noise (Rock, 2005), droppings from birds can carry various pathogens, such as *Chlamydophila psittaci*, posing potential health risks to the public and contributing to environmental contamination (Haag-Wackernagel & Moch, 2004). From a safety perspective, birds that nest near airports, such as gulls and raptors, can create a significant collision hazard for aircraft (Pfeiffer et al., 2023). Similarly, birds that nest on overhead transmission lines pose a threat to power infrastructure. Nesting materials, droppings, and bird activity, such as pecking at composite insulators, can trigger short circuits, flashovers, and other electrical malfunctions, compromising the security and stability of power systems (Yi et al., 2008). These bird-related faults not only disrupt essential services but also impose significant maintenance and repair costs on businesses (Maricato et al., 2016). Given these challenges, it is essential for researchers and urban planners to develop effective preventative strategies to mitigate various practical issues associated with bird nesting on artificial structures.

MANAGEMENT OF NESTS BUILT ON MAN-MADE STRUCTURES

While artificial structures cannot fully replicate the natural functions of vegetation for nesting and perching, they can serve as viable conservation tools when managed appropriately (Mainwaring, 2015). The proper management of nests on man-made structures is crucial for sustaining urban bird populations and minimizing conflicts with human activities and infrastructure.

The first step in nest management involves assessing the necessity for intervention by closely monitoring breeding activities. In some cases, species may face the threat of local extinction, particularly when the modernization of buildings eliminates essential cavities and surfaces for nesting (Biswal, 2021). In other circumstances, nests that negatively impact human life or interfere with the function of a structure may require removal. A strategic, top-down approach can be employed to identify structures at high risk for bird nesting and to prioritize management measures (Murphy et al., 2024). However, it is worth noting that many countries lack clear policies for determining the criteria for nest removal from man-made structures.

The use of artificial nests presents a viable solution, both as a supplementary habitat and a means to redirect nesting away from areas where their presence may be detrimental. Installing artificial nest boxes and nest cups on buildings is commonly used to support cavity-nesting (Dulisz et al., 2022) and mud-nesting species (Teglhøj, 2018). For species nesting on pylons, artificial supports and platforms beneath power lines can provide safer nesting sites while reducing damage to the power system (Cheng et al., 2020). However, prior to large-scale implementation, the placement of artificial nests should be carefully assessed. Factors such as landscape composition, nest density, orientation, and height must be considered to optimize occupation rates. Long-term monitoring of reproductive performance is also crucial to evaluate the effectiveness of artificial nests as substitutes for man-made structures (Schaub et al., 2016). In terms of preventive measures, several non-lethal techniques exist to deter birds from nesting on artificial structures without resorting to nest destruction and removal. Perching guards, bird repellents, and other physical or chemical deterrents have been applied to discourage nest building on residential buildings and pylon structures (Gagliardo et al., 2020; Sundararajan et al., 2004). Regulating the availability of anthropogenic food sources, such as urban waste, is another effective strategy in reducing the occupancy of man-made structures, given the strong correlation between nest-site selection and foraging areas (Coccon & Fano, 2020). By combining these measures with the installation of artificial nests, an integrated management strategy can be developed to foster a more harmonious coexistence between humans and birds. However, further research on bird responses to deterrents is necessary to avoid unintended negative consequences.

CONCLUSIONS AND IMPLICATIONS FOR FUTURE RESEARCH

Under the increasing scarcity of natural nesting sites, man-made structures provide crucial nesting opportunities for a wide spectrum of avian species and inevitably intensify human-bird interactions. The utilization of man-made structures demonstrates the exceptional behavioral plasticity of urban birds, offering key insights into their survival strategies in cities. However, while the occurrence of birds nesting on man-made structures has been widely documented, most studies have primarily focused on basic breeding behaviors, leaving comprehensive research into the broader ecological implications relatively lacking. As urbanization continues to shape avian behavior, future research should be directed toward the following areas (Figure 2).

Conducting multidimensional studies of the effects of nesting on man-made structures

The implications of nesting on man-made structures extend beyond simple reproductive ecology. It is essential to explore the long-term effects of this adaptive behavior on population dynamics, genetic diversity, and the potential emergence of new ecological challenges, such as the spread of diseases and increased interspecific competition. Given the role of urbanization in filtering specific ecological attributes, research should also explore how this nesting behavior influences shifts in the composition of urban bird communities. Comprehensive research that integrates perspectives from ecology, ethology, and genetics is necessary to fully understand the interactions between birds and their environment in the context of urbanization.

Elucidating the drivers of man-made structure use

One of the primary concerns in this field is understanding the multi-scale decision-making processes that birds employ when selecting man-made structures for nesting. The choice of these structures is influenced by a complex combination of physical factors —such as substrate, height, and stability —environmental conditions like food availability and human activity, and social cues, including previous reproductive success. Cognitive abilities, such as innovative problem-solving, associative learning, and social learning also play a significant role in bird nest building behavior (Lehtonen et al., 2023). Controlled experiments are needed to assess these cognitive traits in birds that utilize artificial structures for nesting, and to determine how these abilities influence their adaptability to multiple man-made structures. By comparing nest-site selection between natural and anthropogenic habitats, researchers can better understand whether birds actively choose artificial structures through experience and imitation or passively settle for suboptimal nesting sites due to the lack of natural nesting habitats. Clarifying the determinants of nest-site selection will help predict the occupancy of specific man-made structures, laying the groundwork for future conservation and management efforts.

Emphasizing the importance of man-made structures as nesting sites

Maintaining a sufficient supply of accessible nesting sites in urban environments is essential for preserving urban bird diversity. However, while previous studies have primarily focused on urban green spaces and vegetation, future work should also evaluate the contribution of man-made structures to urban avian nesting opportunities. Recognizing the importance of these structures will allow for prioritized and targeted conservation measures.

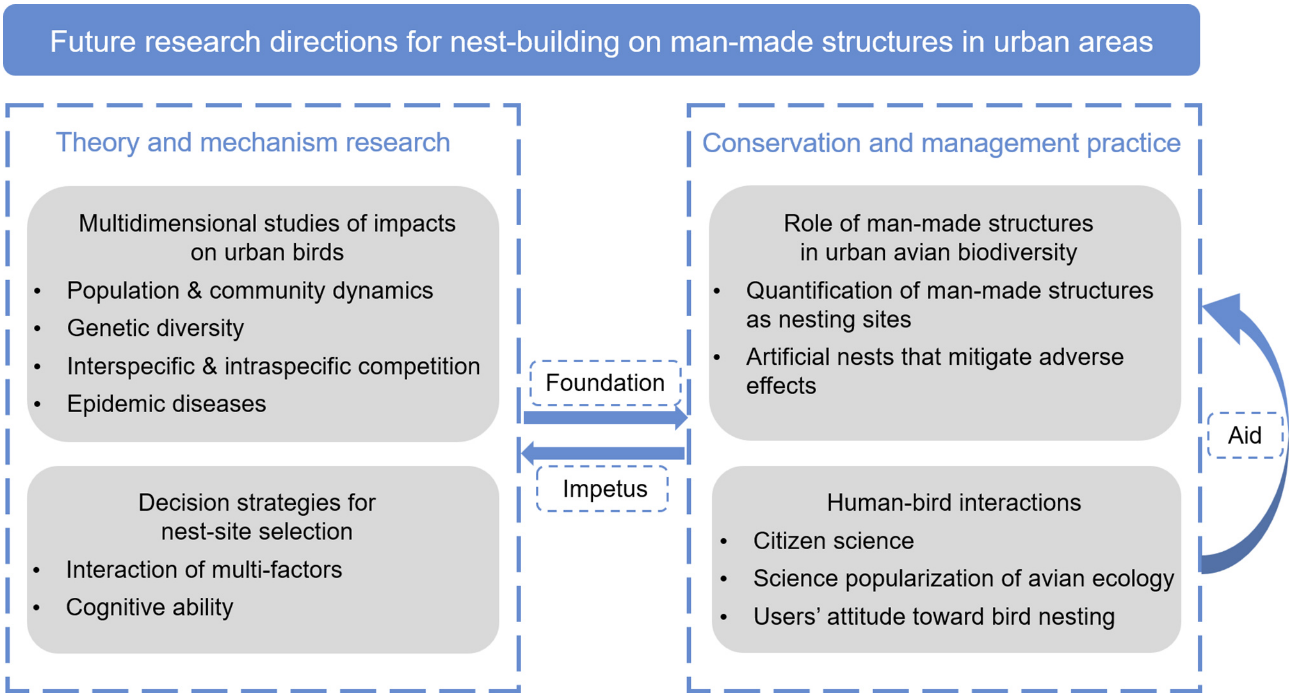

Figure 2 Conceptual framework of future research directions

In regions such as Asia, where artificial nesting boxes are not widely implemented, addressing the scarcity of breeding sites is particularly important. This can be achieved by supplying artificial nests or designing bird-friendly architectures in key urban habitats. The effectiveness of such measures should be evaluated through ongoing surveillance of population trends, reproductive success, and behavioral patterns. In addition to the efforts of wildlife professionals, engaging the general public in citizen science aimed at studying and monitoring the use of man-made structures and other artificial nests by birds is worth consideration. These initiatives, successfully applied in many bird monitoring projects (Tulloch et al., 2013), can assist researchers in gathering more comprehensive data while simultaneously enhancing public awareness of urban biodiversity conservation.

At the same time, the growing trend of birds utilizing urban structures raises concerns about potential human-bird conflicts. While damage to infrastructure and human property is more common in less urbanized areas, urban nesting introduces new challenges, particularly as bird populations continue to grow in cities (Araneda et al., 2022). Establishing clear guidelines to prevent conflicts caused by bird nesting on man-made structures is crucial. However, many existing methods only offer temporary solutions. The underlying causes of conflicts between humans and birds around man-made structures often stem from a lack of public understanding. We recommend that relevant organizations implement nature education programs in schools and communities to improve public awareness of urban bird behavior. Moreover, resident attitudes must be considered when evaluating nesting behaviors on artificial structures, as this is essential for formulating urban management policies that balance the needs of both humans and birds.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

X.R.L. wrote and edited the manuscript. Z.Q.L. discussed the study and provided suggestions for manuscript revision. All authors read and approved the final version of the manuscript.

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