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城市化鸟类群落变化及其与城市植被的关系

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摘要:持续而快速的城市化进程正在助长全球生物多样性的丧失,其中鸟类是城市生态系统的重要环节和城市生物多样性保护的重点目标,同时也是研究的热点内容。从城市环境变化压力下,鸟类群落组成与结构、空间分布和繁殖营巢方式的改变分析,重点介绍了支持城市地区鸟类多样性的植物环境因素与影响机制的最新研究成果。结果表明:1)城市中的植被和绿色空间为城市鸟类提供生存空间和食物资源,是城市鸟类最主要的栖息地。2)保留原生乡土植物和大型树木的地区能支持更丰富的鸟类物种。3)植被的结构和盖度对鸟类群落有显著影响。林冠覆盖率增加,复杂的垂直空间和多样的植物种类的组合产生各种不同类型的植物空间和栖息地类型,吸引不同的鸟类物种,相应地也会导致更丰富的鸟类群落。总之,保持和加强城市中植物环境良好和稳定是保护城市生物多样性的有效手段。据此,提出城市环境与鸟类群落关系研究的未来发展方向,指出了其在鸟类多样性保护和城市可持续发展等领域的应用前景。

关键词:城市化;城市环境;植被特征;鸟类群落;生物多样性;可持续发展

Changes of bird community under urbanization and its relationship with urban vegetation

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Abstract: There are more than half of the world's human population living in cities. The vast amount of predicted rapid urbanization in the coming years consuming habitats and reducing the possibilities for wildlife to thrive in cities, and is contributing to the loss of global biodiversity. Among them, birds are the most important part of urban ecosystem and a key target for urban biodiversity protection. Besides, it is also a research hotspot. The last 20 years of urban bird ecology research have experienced exponential growth and now enables literature analyses and reviews. Here, we try to roundup these present findings on urban bird communities research from all over the world, overviewing patterns and variation processes on urban bird community, especially the changes in composition and structure, spatial distribution, living habits and the way of breeding and nesting under this continuous and rapid urbanization. To further assess the importance of and contributions provided by urban green space and vegetation to the urban bird community, exploring its affecting mechanisms that support bird diversity in urban areas, we reviewed the published literature for such studies. The results showed that: 1) Provision of greenery can ameliorate the hostility of the urban environment for wildlife, as well as provide suitable living space and food resources for urban birds. Green spaces provide the most important habitats for urban birds. 2) Not all forms

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of greening benefit bird communities to the same extent. Compared to those areas that do not pay much attention to native plant protection, areas that retain natural or semi-natural cover and large trees can support richer bird species. 3) Structure and coverage of vegetation have significant impacts on bird communities. The increasing canopy coverage, complex vertical structures and many kinds of plant species can produce various types of plant spaces and heterogenetic habitats. The increased plant spaces and habitats can cause changes in bird community composition, a correspondingly increase in species richness and diversity. In conclusion, maintaining and strengthening the healthy and stable of vegetation communities in cities is an effective strategy to conserve urban biodiversity. Collectively, protecting existing and planting new greenery has great potential to restraint urban biodiversity loss. Based on these, we propose the future research development direction of the relationship between the urban environment and bird communities. Further, the application prospects of this research in bird diversity protection to provide a more resilient, stable, and sustainable urban system are also pointed out.

Key Words: urbanization; urban environment; vegetation feature; bird communities; biodiversity; sustainable development

城市野生动物保护是体现现代城市发展水平,衡量城市生态系统健康状况的重要指标[1]。鸟类群落是城市化过程中最受干扰的物种之一,它们对栖息地和环境变化异常敏感[2-3]。城市化过程中,森林、湿地以及农田等相对自然的土地不断向城市建设用地转化[4]。目前全世界城市地区占地球陆地面积的近 3%,且这个比例还在不断升高[5]。这极大地改变了生物群落的组成和多样性[6-8],是野生动植物灭绝的重要原因之一[9]。世界城市人口平均每年以近 1%的速度增长,到 2050 年,预计有 70%人口居住在城市[10],而城市的地理扩张速度更高于人口增长速度[11]。随着城市的不断建设与蔓延导致了野生动物栖息地不可阻挡的损失,目前全球本土鸟类物种栖息地丧失的速度为 1.1%年[12-13],且还在持续增加。因此,了解城市鸟类群落在城市化压力下的变化及其重点驱动因素对于建设富有生机活力、健康稳定城市生态系统,维持城市可持续发展至关重要,也一直是全球研究的热点内容[14]。

20 世纪 80 年代后,以城市栖息地鸟类群落为主要研究内容的城市鸟类生态学成为一个独立的研究领域[15-16],特别是在过去 20 年,城市化和鸟类群落的相关书籍和论文呈现指数增长(图 1)。随着研究的不断深入,城市绿色空间,即城市中被草、树、灌木或其他植被部分或完全覆盖的土地,包括城市公园、社区花园等[17],是城市中鸟类最主要的栖息地;植被对支持城市生物多样性的重要潜力与价值等问题[18],被更广泛地探讨与证实(图 1)。

本文拟从群落尺度,系统性阐述城市化下鸟类变化以及城市栖息地植被特征与鸟类群落关系,以促进从可持续角度设计和管理城市绿色空间,从而缓解城市快速发展带来的生物多样性下降,最大限度地保护城市生态系统完整性。

全球文章变化使用 Web of Science (All Databases) 检索从 2000 年到 2020 年发表的所有关于城市化与鸟类群落的文章,搜索主题词“urbanization”、“bird * ”,并按照对重点研究主题进行区分。中文文章发表数量变化汇总基于中国期刊全文数据库,搜索主题词“城市化”、“鸟类”。

1 鸟类群落随城市化变化特征

城市的快速发展以惊人的速度使自然生态系统转变为碎片化的城市景观[19-21]。持续的城市化中,建筑高度增加[22-24],绿色斑块减少[16, 20, 25],大气[26]、噪声[27]、光污染加剧[28],水域面积缩小[20, 29],水体污染加重等问题日益凸显[29]。这些变化的条件极大地改变了敏感物种,例如部分专性栖息在森林生境的鸟类。它们经历了栖息地的退化甚至丧失,导致了数量的减少,甚至局部灭绝[30]。对鸟类来说,城市栖息地完全不同于自然栖息地[9],具有多边界、高异质性以及岛屿化或破碎化的特征,且人为干扰频繁。这使城市鸟类群落在组成、结构、分布、繁殖及营巢方式等方面都发生了显著变化[31-33]

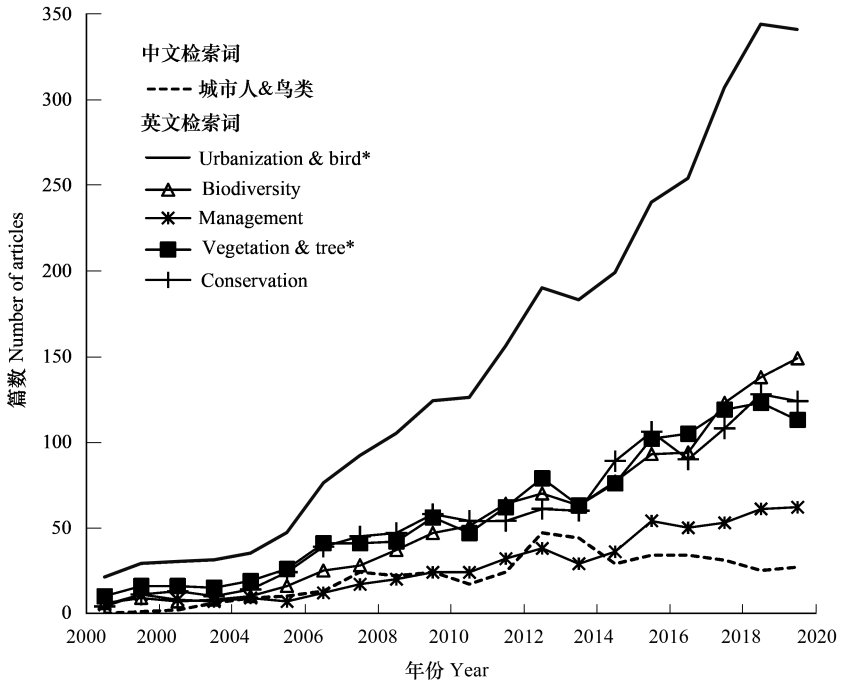

图 1　城市化与鸟类群落研究的中外文章发表增长趋势

Fig.1　The increasing trend of Chinese and foreign publications on urbanization and bird community research

1.1　鸟类群落组成结构变化

生物群落组成和结构很大程度上受到栖息地环境的影响,地形地貌、气候变化、水体与植物群落是关键因素[34]。城市的不断扩张使城市及其周边景观的人工化程度越来越高,导致城市鸟类群落向不良演替方向发展[32]。自然生态系统中常见的食虫鸟、地面巢鸟或洞筑巢鸟等,种类和数量在城市化过程中均呈减少趋势,尤其是面积敏感型鸟类,更难以适应城市化所带来的自然林地的消失及栖息地破碎化[35-36]。而某些优势鸟类(如杂食性鸟类集团)在城市环境中生活能力较高,甚至依赖于城市资源,如澳大利亚本地的黑额矿吸蜜鸟(*Manorina melanocephala*)和红垂蜜鸟(*Anthochaera carunculata*)是两种大型鸣禽,能够极好的适应城市化过程,并大量繁殖[35]。他们利用诸如建筑物、铺砌区域和草坪等人为构筑来觅食、栖息和筑巢[35-37],并成为城市主导物种。城市地区是引进外来物种和灭绝本地物种的焦点[38],城市发展中自然生态空间保留不足将导致外来鸟类入侵,虽然城市鸟类总生物量可能增加,但鸟类种群的不稳定性也随之增加[39]。一项对世界 54 个城市的研究显示,97%的城市出现了全球 31 种最具侵入性的鸟类[36]。

总体上,城市的生物多样性仍在持续减少[39-41],随着城市化对城市及周边景观的改变,鸟类物种密度和丰富度急剧下降[42-43],因为栖息于人造绿地的物种远比栖息于原生性林地中的物种少[44],受益也更少。

1.2　鸟类群落空间分布变化

全球城市化进程将影响全球生物分布[11]。由于人类活动、城市发展而导致物理环境均质化,敏感物种的局部灭绝和城市适应物种的扩散进一步促进全球生物均质化[45-47]。阿根廷一项研究显示,在 1400 km 范围内,任意距离的城市间鸟类群落比相邻的半自然区域间的相似度高。同样,世界各地多项研究支持了城市化已导致不同城市间鸟类群落逐渐趋向同质[48],且在城市化程度更高的区域,鸟类物种多样性降低[49-51],群落间的功能相似性更高[46]。群落间的相似性反映了鸟类物种组成及 β 多样性的空间变化[48]。

此外,城市化对环境的影响造成了部分鸟类种群迁徙行为改变[52]。由于繁殖季节的食物资源过剩降低了迁移的趋势[53],且迁徙行为具有数量遗传基础,这可能导致鸟类居留类型的变化[15]。例如,丝光椋鸟(*Sturnus sericeus*)[54]和乌鸫(*Turdus merula*)[55]由于城市热岛效应而停止迁徙,这是由于冬季城市中具有丰富

的食物来源以及能够避免迁徙过程中个体的死亡[15, 56]。

1.3 鸟类群落繁殖变化

城市繁殖鸟类群落的变化受到一系列环境因素的影响,其中包括建筑物高度[37]、密度水平[57]、城市绿化情况[58],绿地斑块大小[40]、碎片化状况[40, 59],以及栖息地中树木数量、规模以及多样性等[22, 60]。由于城市化导致建筑密度的增加,相较于自然林地,城市栖息地中鸟类密度更大,激烈的个体间竞争使单个栖息地斑块中捕食压力较大[61],导致整体的食物供应不足(尤其是食虫鸟类),巢捕食发生概率也大大增加[62]。除不稳定的食物供应外[57, 63],空气污染[26, 64]、人造光[28]、噪声[65]等城市效应可能造成雏鸟身体质量下降、死亡率增加,成鸟交配、筑巢与繁殖成功率的下降[66]。暴露在噪音下的灰喉鹩(*Myiarchus cinerascens*)的巢繁殖成功率比安静环境低,城市噪音导致的荷尔蒙失调造成了成鸟在孵化阶段放弃率升高[65]。然而,其他研究显示,相比于农村,凤头鹰(*Accipiter trivirgatus*)和游隼(*Falco peregrinus*)在城市生境有更高的筑巢成功率[66]。而北海道大学研究表明,城市栖息地中建筑面积和电线密度对几种常见山雀的杂交概率没有明显的影响[49]。另一项关于鸮形目鸟类(*Strigiformes*)的研究显示,其沿着城市梯度的筑巢没有变化[67]。总体来看鸟类繁殖变化对于城市化的反应仍不明确,不同研究显示,物种之间,小型鸟类和大型猛禽以及不同的食性间存在相当大的差异[50],有些通过利用原本相对较空的生态位而受益,而有些则因生态陷阱(Ecological Traps)而受到负面影响[68-69]。

2 城市植被对鸟类群落的影响

鸟类组成与植被关系的研究大部分是在自然环境中开展的,但是随着城市快速发展与蔓延,在城市中开展此项研究越来越重要[18]。城市植物群落间可能存在很大差异,从密集的灌丛栖息地到树木繁茂的林地,或是公园中的开阔草地和道路两侧绿化隔离带,都能为各种鸟类提供栖息地。城市植被的复杂性是生物多样性研究的最重要影响和预测因子[70],植被因子被证明比其他环境因子更能够解释鸟类群落多样性的变异[71-72]。改变植被的结构可以改变鸟类组成,增加植被结构复杂性和种类多样性可以增加鸟类的多样性[34, 58, 73],城市森林被证明可以在保护生物多样性方面发挥关键作用[47],特别是在许多主要城市处于密集化过程的情况下[74-75]。

维持城市中较高的生物多样性水平是一项艰巨的任务,研究鸟类与城市植被的依存关系使人们能够制定有效的保护战略以减少城市对自然的生态足迹与生态债务[47],并通过科学规划城市森林、湿地等生态空间的数量、类型、结构和布局,建设生物多样性、健康稳定的城市自然生态系统。

2.1 植被斑块面积对鸟类的影响

不同的鸟类对于环境资源的需求不同,栖息地植被斑块面积是影响斑块中鸟类物种多样性的主要因素[76]。通常来说,面积较大的绿色斑块中,植物组成和结构都更加丰富,因此生境异质性更高并且微环境的多样性更高,可满足更多物种对于栖息环境的不同需求[77]。大面积的城市森林对于不适应城市环境的鸟类非常重要[78-79],较小的绿色空间由于能够提供的资源有限,可能无法满足大部分鸟类种群[80],而其中一部分甚至不能达到一些大中型鸟类的最低生存要求。因此,保留和增加城市绿地斑块,减少隔离程度可能会促进城市环境中物种丰富度的提高。但有时在现有城市地区可能较难实现[34]。因此,最大程度的利用小型绿色斑块保护鸟类群落也至关重要。通过廊道将绿色斑块与其邻近的绿地连接起来,以促进鸟类的移动和与其他绿地物种互动[81]。这有助于维持平衡的鸟类种群,或通过种植本地物种和保持结构多样性将绿地栖息地扩展到廊道,进一步促进城市环境中的鸟类移动[13, 80]。

总体来看,城市中大块绿色空间可有效维持区域的植物和鸟类多样性[80]。因此,植树造林建设成片的城市森林绿地将是促进城市景观中鸟类群落流动的有效途径。

2.2 植被类型对鸟类的影响

城市森林中鸟类群落与植被类型之间的关系长期以来一直引起研究者的关注[82],其不仅会影响栖息地

的选择[82],还会影响鸟类的群落结构[54]。与自然或半自然植被相比,栽培绿化在植物物种组成和物理结构上趋于简单,这种较低的环境异质性只能由少数物种利用,这可能导致城市景观中物种同质化[30]。相比于人工种植林,天然林地为各种鸟类提供了更丰富的栖息空间[82]。由于鸟类的全部食物资源都来自于栖息地内的植被,因此他们的生存状况与其中植物种类密切相关[55]。一项在印度城市森林的研究显示,在不同的植被类型间,落叶阔叶林由于树木密度高,树冠开阔,具有广泛的微生境,其中的鸟类密度和物种丰富度都较高。针叶林和浆果灌木也由于能够提供丰富的栖息空间和食物资源而对鸟类具有非常积极的影响,而针阔混交林能够支持最高的鸟类多样性[56]。

2.3　城市植物群落组成对鸟类影响

2.3.1　植物群落数量及多样性特征与鸟类关系

城市森林绿地生境内植物组成、盖度、林冠层特征等对鸟类群落影响显著。植物群落物种组成的变化影响鸟类对栖息地的选择[54]及鸟类群落结构[83]。城市栖息地中树种丰富度可以对筑巢的鸟类物种产生积极影响,也可以对鸟类的整体多样性产生积极影响[84-85]。城市中植物群落中乔木林树冠层盖度与自然环境相比有所减少,乔木覆盖率的减少对鸟类群落具有负向影响,例如使日本三种雀类的杂交率降低[86]。随着绿地面积、灌木多样性和灌木密度的增加,喜欢森林的鸟类种类增加,但植物环境对于不同鸟类产生的影响具有差异[87]。在一项研究中,生境中草坪面积对红胸鸲(*Erithacus rubecula melophilus*)多样性影响较大,而对于北美红雀(*Cardinalis cardinalis*)则灌木盖度是最大影响因素[88]。

2.3.2　乡土植物对鸟类的重要价值

植被为鸟类提供了最多甚至是所有生存需求[3, 30, 82]。Cook 和 Howes 将城市观赏植物分为三大类:乡土植物、自然植物和外来植物[89]。原生乡土植物为本地鸟类提供的益处比外来植物多 10—50 倍[90]。长期以来,人们为了重建城市中的鸟类栖息环境,进行了诸多尝试,包括通过引入温室和外来植被来丰富本地植物物种多样性以及创造美学价值[3]。然而,外来植物对本地原生环境可能造成巨大危害,改变原有植物群落组成与结构,危及鸟类和其他野生动物生存。不适当引入外来物种是鸟类种群衰退的最主要因素,导致鸟类筑巢地和食物资源的丧失。群落中的本地鸟类物种数量和丰富度与本地植被比例正相关,而外来鸟种则与外来植被的比例相关[91]。保留自然营养特征的城市地区的自然物种比不保留原生植被的城市区域多,当原有植物被清除,人工绿化导致了同质的鸟类和蝴蝶群落的产生[90]。研究者们在不同的地域进行实验,也得到了相似的结果——外来植物经常由于无法提供本地鸟类所需的食物源(包括果实和节肢动物)和栖息需求而导致本地鸟类物种多样性下降[92-95]。城市地区的管理需要最大限度地利用自然或半自然保护区,适度改善人类主导景观,在建设野生动物栖息地时增加能够提供果实或支持本地节肢动物的乡土植物,可有效支持当地鸟种,尤其是食虫鸟类的生活需求。

2.4　植物群落结构对鸟类的影响

城市植物群落结构,尤其是乔木结构、垂直异质性与鸟类物种丰富度和筑巢密度之间存在显著的相关性[82],叶片的垂直分布常常用来衡量植物群落垂直结构的丰富程度,经证实,该指标与鸟类密切相关[3, 90, 96]。随着植被垂直异质性的降低,鸟类数量减少[97],乔木冠层的发育在很大程度上影响了鸟类的物种丰富度,并在较小程度上影响了它们的总体密度。植被结构通过影响食物的可探测性和可及性而影响鸟类觅食效率[18],在城市生态系统和环境变化压力下,鸟类在树冠层取食、树皮探食的机会减少,地面取食的种类会增加[91]。发育良好的草坪与灌丛可以为这些鸟类提供丰富的栖息环境与食物资源[3, 98]。陈水华等对杭州鸟类群落的研究显示,鸟类在城市中的空间分布主要由于鸟类群落受生境内植物结构影响[9]。植被分层结构、相对复杂的生境和多元化的乔木种类能够为鸟类提供丰富的空间结构,能最大程度的支持鸟类群落[55]。

同时,也有研究显示,在某些地区,城市公园中鸟类物种丰富度与多样性只随公园规模的增加而增加[99-101],而植被结构及其他因素对鸟类种群分布没有影响[90]。这可能因为大多数鸟类是城市适应者[102],在特定公园内,环境容量和种间、种内竞争成为制约其生存的主要因素[103-105]。

总体来看,相对多样的植被结构有利于为不同鸟类物种提供多种类型的栖息环境。过度人工设计导致城市森林绿地的结构趋向于简单化,地被和灌木盖度的减少,反复的更换草坪和修剪干扰可能是影响城市鸟类群落,甚至导致敏感物种消失的一个重要因素[78]。

2.5 城市中大树对鸟类的意义

树木是决定城市生物多样性的重要因素[106],植物群落中大型树木具有更加重要的价值。关于大树的价值已经在森林[107]或农业景观中被证实,相比之下,城市大树对生物多样性价值贡献的研究仍远远不够。随着树木规格的增大,它们对鸟类多样性的正面影响增加[96]。大型城市树木是为野生动物提供重要栖息地资源的基石结构[107]。在城市建设中,保留更多数量的大树,是增加城市中鸟类物种数量的有效手段[108]。大树提供了小树不具有的结构复杂性。例如,Mazurek 和 Zielinksi 在加利福尼亚州的研究发现,相比于较老的红杉(*Sequoia sempervirens*),年轻的红杉缺乏大的水平枝干、基部凹陷或空洞,这降低了对野生动物的吸引力[109]。更大的树冠和侧枝等物理属性可能使大树在景观视觉上更为突出,更容易吸引鸟类栖息[110]。此外,大树能提供更多花、花粉、花蜜、种子、悬挂树皮等小树所缺乏的食物和微生境资源[107]。因此在城市中对大型树木的管理至关重要,大树的砍伐或过度修剪常常限制了其对野生动物的生态价值。

此外,也有印度的研究显示,鸟类密度与中等大小的树木的密度也显著相关。可能的解释是,与大树和小树相比,中等大小的成熟树木生长旺盛,能够为鸟类提供更多的食物资源[80]。关于这两者研究结果相异的原因,或许与研究地域、植物种类、鸟类种群的不同有关,但更加详细的原因,还需进一步研究。

3 研究趋势与展望

在快速的城市化过程中,城市鸟类群落受到了很大的冲击,研究城市鸟类群落的变化已经成为评价城市生态系统健康状况的重要指标。以城市森林为主的绿色植被对于城市鸟类多样性保护具有重要的作用,是城市生态系统健康的重要保障。从上述研究来看,城市植被与鸟类群落关系的研究不仅关系到鸟类群落本身的生物多样性维持,也直接影响城市生态系统健康,未来的研究主要趋势是:

(1)基于长期定位观测,研究城市扩张中鸟类群落变化的全球格局研究。

基于各城市鸟类长期监测计划,建立统一标准与监测方法,健全城市鸟类群落监测与保护战略。通过长期数据集进行城市生物多样性的全球格局研究,探讨全球土地密集型转变和人类影响下生物多样性变化在全球范围内产生的生态后果;在世界各地的城市中比较物种及群落信息,研究地理范围间变化模式并评估现有研究成果在世界范围内的共性与差异性。

(2)进一步揭示城市植被特征与鸟类群落的关系。

针对城市植被环境,包括城市植被的植物组成、层次结构、空间营造等,深入挖掘其结构与功能对城市鸟类群落的影响与作用机制。充分利用现有的成熟食物网参数资料,从生态网络视角出发进行城市乡土植物和地带性植被与鸟类群落的深入研究;明确并量化植物特征对城市鸟类群落的影响与程度,探究如何适度引种并驯化外来植物能够最大程度减少对城市鸟类生存的影响及相关复合植物群落的优化配置策略;城市指示性鸟类的生境特征及其维持研究等。

(3)从景观生态学的角度深入研究城市绿色空间格局对鸟类群落作用机制。

在宏观、长期地时空尺度上探究城市绿色生态空间与鸟类的关系。基于更有针对性的城市鸟类监测与跟踪,深入解决城市空间架构对鸟类生存的影响,服务于城市的可持续发展和良好人居环境的建立。包括研究城市生态系统与鸟类群落关系与相互作用机制;城市绿色斑块大小、密度、分布格局等景观特征对鸟类群落的影响研究;城市绿色廊道与城市鸟类生物廊道关系与影响探究以及实践探索等。

(4)城市居民行为对城市鸟类群落的影响

随着城市居民与自然互动越来越普遍,对鸟类与人类之间相互作用的更全面的了解也应受到研究者的关注。人为活动、饲养宠物、喂食行为对城市鸟类群落组成、结构、分布,甚至基因流的影响,及其可能导致的依

赖性、疾病传播或生态陷阱可能是未来的研究重点。

(5)城市鸟类生物多样性调查方法的创新与探索。

在大多数情况下,鸟类的采样方法是缓慢且涉及现场的观察和收集,对采样者具有较高的物种识别的专业要求。探究创新性低干扰鸟类调查方法,包括声学监测技术的应用以及民众科学的借助,由于其成本较低、易于操作,有利于研究者开展城市鸟类的长期系统性研究,包括城市鸟类物种、群落分布、栖息地等长期定位观测;开发城市鸟类群落变化预测模型;区域生物多样性水平及生态系统健康状况快速评估体系的建立。

(6)注重学科交叉及研究结果落地。

生态学、生物学、社会学、景观规划学、风景园林学等多学科的交叉合作,使研究结果能够真正应用于城市可持续发展与建设实践,从规划、设计、建设、管理、使用维护等多环节,用更综合的科学视角探究改善城市鸟类生境的有效举措,指导政府管理者、城市规划者和景观设计师开展基于保护鸟类多样性的栖息地规划设计建设,以更好地平衡城市地区野生动物,特别是鸟类的生存与城市化和生态人居之间的关系。

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