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IMPACT OF URBANIZATION ON BIRD MIGRATION: HOW URBAN SPRAWL AND LIGHT POLLUTION ARE ALTERING THE MIGRATORY PATTERNS OF BIRDS

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Abstract

Undoubtedly, urban sprawl and light pollution pose great threats to the migratory patterns of birds all over the world. This study aims to compile all the literature available on the effects of urbanization and light pollution on bird migration. A comprehensive search of several academic databases resulted in the identification of relevant studies, which were systematically reviewed. The outcomes of this study shows that urbanization causes habitat loss, fragmentation, and disruption of migratory corridors. In addition to light pollution, altered migratory routes, causing structural collisions with birds, and changing the times of migration. Changes in both urban sprawl and light pollution will alter migratory behaviors, change migratory routes, and increase collisions with buildings and other anthropogenic structures in birds. The current context submits that conservation strategies are greatly needed in mitigating urbanization and light pollution regarding bird migration patterns. Many studies focused only on avian ecology, but there are still only a few studies that examine both urban growth and light pollution together and how they disturb migratory birds. Future direction includes more research designs and practical implication of these research results to protect birds from the adverse effects of urban sprawl and light pollution. These designs include making bird-friendly conurbations, using smart lights, and making more strict international policies for the conservation of the bird species.

Introduction

Bird migration is defined as the "regular, seasonal, large-scale, long-distance movement of population to twice a year between fixed breeding and a fixed non-breeding area" (Lack 1968), and is a flexible, adaptive behavior that evolves as a function- on of environmental conditions (Lack 1954,1968, Sutherland 1998, Alerstam et al. 2003, Greenberg and Marra 2005).

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Scientists and birdwatchers are enchanted by the complex and interesting event of bird migration. The regular seasonal movement of a population over great distances twice a year between set breeding and non-breeding locations is known as migration (Alerstam et al., 2003; Lack, 1968). It can also be described as a behavior that contributes to the operation of an ecosystem and is flexibly adapting and changing against environmental conditions (Alerstam et al., 2003; Lack, 1954, 1968; Somveille, 2016; Sutherland, 1998). In addition to helping with seed dispersal, plant regeneration, and nutrient cycling, migratory birds are markers of the health of ecosystems in a variety of habitats and biomes (Bauer & Hoye, 2014; Gauthreaux, Belser, et al., 2006a; Sekercioglu, 2006; Wotton & Kelly, 2012; Zöckler, 2005).

Bird migration is becoming more and more threatened by human-caused environmental change, despite its ecological value. Due to habitat loss, fragmentation, and disruption of migratory routes, urbanization especially urban sprawl modifies landscapes (Evans et al., 2011). Simultaneously, artificial light at night (ALAN), a consequence of urban growth, increases mortality through collisions with illuminated structures, distorts direction, and changes the timing of migration (Longcore & Rich, 2004; Rodríguez et al., 2017). When it joined, these elements put migratory animals under synergistic pressure, altering their paths, raising their energy expenditures, and endangering their chances of survival.

Few studies have integrated the effects of light pollution and urbanization on migrating birds, despite the fact that both have been examined separately. This review aims to provide an integrated perspective on one of the most pressing challenges for avian species. The existing knowledge about the increase in light intensity due to modern facilities and extension in urban areas limit the rural lands and convert the useful agricultural lands to concrete forests by urban sprawl. It also adversely affect the overall climate, hence many avian populations are facing the habitat loss, food shortage, and breeding failure ultimately results to population decline of the certain avian species.

Effects of Urban Sprawl on Bird Migration

While analyzing how urbanization affects habitat composition and structure, birds constitute a superb model (Bregman et al., 2014; Reis et al., 2012). Urban sprawl strongly influences avian migration, such as the fragmentation of habitats that block migratory routes and alter food availability significantly (Marzluff, 2001b). As a result, the habitats become degraded and reduced in both quality and quantity of stopover sites, and compel migratory birds to somehow adjust themselves to these new surroundings, hence expending extra energy. Thus, this drains energy, results in reduced fitness, and decreases survival rates in migratory birds (Gauthreaux, Belser, et al., 2006a).

Urbanization, literally the most significant threat to bird populations, is the loss and fragmentation of habitats (González-Oreja, 2011). It may also cause subsequent events with far-reaching repercussions, such as reduced breeding success, limited dispersal, and resource acquisition failure for migrated species (Bregman et al., 2014). Additionally, habitat loss or fragmentation modifies the makeup, structure, and ecosystem functions of biodiversity, further heightening the threat to avifaunal assemblages (Scolozzi & Geneletti, 2012). Fig, 01 illustrate the impacts of urbanization and light pollution which alter the migratory routes of the birds. It also disrupt the biological rhythms and sleep behaviour, additionally it affects the population density by increasing the mortality rate of the birds.

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Fig 01. Impacts of urbanization and light pollution on Migratory routes of the birds

One of the most remarkable example areas is the Prairie Pothole Region (PPR), where the loss of wetlands and grasslands has brought a severe consequence to waterfowl migration, thus contributing to sever population decline as reported by Johnson in 2015. Wetlands in this region were also depleted by modernizing the agricultural economy and land-use changes, which decreased the accessibility of habitats' accessibility and changed the hydrological patterns of migratory birds (Donnelly et al., 2022; McLean et al., 2022). The remaining wetlands keep on homogenizing, lowering ecosystem function while rendering it harder for crucial waterfowl species to establish breeding colonies (Devries et al., 2023; McLean et al., 2022).

Urban sprawl has a serious effect on the migration of songbirds, including habitat loss and fragmentation, as well as changes in environmental conditions. Evidence shows that urbanization reduces migratory songbird populations, such as *Acadian flycatchers,* that have lower nesting attempts and increased brood parasitism associated with increased urban areas (Rodewald & Shustack, 2008). Finally, the change in the timing of migration culminates in a loss of biodiversity among songbirds and future research concerning the ecological impacts of urbanization (Isaksson, 2018; Larsen, 2008).

In addition, the distance between or within urban environments limits dispersal and connectivity. The spatial difference is population-dependent, leading to the loss of connectivity, and an example has been witnessed in the Song Sparrow (Unfried et al., 2013a). Changing the natural environment into an urban one alters the sources of nutrition for insectivore migratory birds but favors those that have more generalized diets (Larsen, 2008). Some studies say that the reduction in the proportion of migratory bird species is caused by urbanization, especially in cities where the green areas have become smaller (Leveau, 2019).

Additionally, urban environments, also defined as heat islands, might affect migratory patterns, with certain species arriving sooner in cities than in rural regions, showing the complicated relationship between urbanism and the accessibility of resources (Tryjanowski et al., 2013).

Significance of the complex nature of such a relationship between the avian species and

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climate change, altered environment, modernization, rapid conversion of rural to urban areas leads a dire need of conservation strategies, hence it should keep in mind that special problems are being faced by migrant birds in urban environments (Isaksson, 2018). For effective conservation and mitigation strategy for urban populations of birds, a healthy environment is needed where avian species can restore their population. For this eco-friendly urban planning, restoring lost habitats, comprehensive understanding of the complexities of the urban sprawl-migratory bird relationship, an increase intensity of light leading to light pollution, altered avian migratory routes should be kept in mind.

Table 1. Effects of Urban Sprawl on Migratory Birds

Impact Category	Examples	Consequences for Migratory Birds	References
Habitat loss & fragmentation	Wetland drainage, deforestation, and agricultural expansion	Reduced stopover sites, increased energy expenditure, and lower survival rates	(González-Oreja, 2011; Marzluff, 2001a; Scolozzi & Geneletti, 2012)
Case study: Prairie Pothole Region	Loss of >50% wetlands	Population cessation of waterfowl, altered hydrology	(Donnelly et al., 2022)
Songbirds	Acadian flycatcher decline in urban areas	Lower nesting attempts, brood parasitism	(Rodewald & Shustack, 2008)
Connectivity & dispersal	Fragmented urban patches	Loss of connectivity, Song Sparrow isolation	(Unfried et al., 2013b)
Urban heat islands	Higher city temperatures	Earlier arrivals, mismatched migration timing	(Tryjanowski et al., 2013)

Effects of Light Pollution on Bird Migration

With the extension urban areas, light intensity also increases by artificial lights from streetlamps, house, markets and tower lights, or floodlit structures disrupt the natural patterns of migratory behavior in birds. This light pollution is an ever-increasing problem across the globe that adversely affect the migratory routes and patterns of the birds. The nocturnal migrating birds like warblers or thrushes face tragic encounters with towers, buildings and flood lights, which ultimately consequences to millions of bird deaths per year (Horton et al., 2019). Ultimately these birds are excluded from their regular migratory routes, ultimately tend to decline the natural rhythm of following their natural route (Gauthreaux, & Belser, et al., 2006). Further this disorientation encompasses striking with different structures, such as wind turbines and constructions, which could result in mortalities or serious injuries (Kerlinger, 2000).

Moreover, light distortion is also capable of altering the timing of avian migrations, where certain species, like those of the European starling, would appear to migrate earlier by responding to artificial light sources (Miller, 2006). These slight differences can have cascading effects on ecosystems, which upset the delicate balance of species.

Light pollution additionally impacts migration behavior and the consumption of energy in birds. For instance, compared to European robins that traversed under natural light conditions, those exposed to artificial lights during their migration utilized more energy and had significantly distinct behavioral patterns (Schroeder, 2012). Furthermore, artificial light disturbs birds' circadian cycles, which may influence their hormone balance and fitness level as well as the timing and behavior of their journeys (Cabrera-Cruz et al., 2018; Falcón et al., 2020).

Short-distance migrants tend to encounter more extreme light pollution during migration

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seasons, which impacts habitat selections and drives birds to remain away from important stopover locations located near bright lights (Cabrera-Cruz et al., 2018; McLaren et al., 2018).

These issues highlight the importance of conservation methods for mitigating light pollution's negative effects on shorebird populations (La Sorte et al., 2022; McLaren et al., 2018). Almost all migratory bird species are negatively impacted by artificial night brightness, and these nearly irreversible effects continue to call for quick conservation measures to lessen the catastrophic consequences of avian reductions. Strategies for mitigating light pollution are essential corrective actions to sustain the ecosystem's health and long-term migratory bird populations. Together, scientists, those who make decisions, and the general public will tackle the problem of light pollution and how it affects migratory birds.

Table 2. Effects of Light Pollution on Migratory Birds

Impact Category	Examples	Consequences for Migratory Birds	References
Collisions	Streetlights, buildings, towers	Every year, hundreds of millions of people die	(Horton et al., 2019)
Disorientation	Glare, skyglow	Birds stray from their paths, which increases mortality.	(Gauthreaux, Belser, et al., 2006b; Kerlinger, 2000)
Altered timing	Early migration in European starlings	Mismatches within the ecosystem	(Miller, 2006)
Energy expenditure	European robins exposed to artificial light	Changes in habit and increased energy use	(Dominoni, 2015)
Circadian disruption	Nighttime artificial lighting	Reduced fitness and hormone imbalance	(Cabrera-Cruz et al., 2018; Falcón et al., 2020)

Interplay between Light Pollution and Urban Sprawl

Bird migration patterns are greatly impacted by two interrelated factors: urban development and light pollution. Birds find it difficult to migrate when natural habitats are destroyed and fragmented due to urban sprawl, which is defined by the fast growth of metropolitan areas (Marzluff, 2001b). Birds' natural migratory patterns are disrupted by light pollution, which is caused by the growing usage of artificial light sources in metropolitan areas. As a result, birds become confused and lose their path (Gauthreaux, & Belser, et al., 2006).

Due to concerns how light pollution and urban development work together to affect bird migration patterns, it is evident that climate change, urbanization and due to increased light intensity, avian species show stress marks. These stress behaviors work together to make a larger ecological effect that increases the risks to migratory species beyond the effects of each component alone (La Sorte et al. (2018. It is concerning how light pollution and urban development work together to affect bird migration patterns.

Light pollution and urban sprawl considerably decline the avian inhabitants and also altered the migratory routes. This demonstrates that migratory instabilities are universal urban-ecological issues rather than isolated occurrences (La Sorte et al., 2018).

Light pollution and urban development affect bird migration patterns. For instance, a study in New York shown that the airport's light pollution caused severe bird strikes and hindered with migratory patterns (Gauthreaux, & Belser, et al., 2006). While in Toronto, light

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pollution caused changes in migration routes by an increase in collisions with constructions (McLaren et al., 2018). Whereas, in Singapore, migration patterns were significantly disturbed by the light pollution (Horton et al., 2019). These studies show that the concurrent stresses of artificial light and habitat destruction are present globally, indicating a global conservation concern.

In conclusion, avian migratory routes and their behaviors are significantly obstructed by the interplay between urban sprawl and light pollution. These fundamentals compounds to produce rehabilitated migration, messy migratory behaviors, and increased collisions with structures. Combined conservation frameworks, mitigation strategies which can contemporarily address the factors altering migratory routes and pattern in birds is required (Evans et al., 2011).

Table 3. Global Combined Impacts of Urban Sprawl and Light Pollution on Migratory Birds

Location	Urban Sprawl Factor	Light Pollution Factor	Consequences for Migratory Birds	Reference
Chicago Metropolitan Area	Rapid urban expansion, habitat loss	Intense artificial night lighting	Significant decline in bird populations; altered migration patterns	(La Sorte et al., 2018)
John F. Kennedy International Airport, New York	Major transportation hub, urban land use	High-intensity airport lighting	Increased bird strikes; disrupted migratory behaviors	(Gauthreaux, Belser, et al., 2006b)
Toronto, Canada	Dense downtown urbanization	Bright city-center lighting	Altered migration routes; higher collision rates with buildings	(McLaren et al., 2018)
Singapore	Urbanized city-state, loss of natural stopover sites	Strong urban sky glow and illuminated structures	Significant disruption of migratory behaviors; altered patterns and increased collisions	(Horton et al., 2019)

Conservation and Mitigation Strategies

For a significant mitigation strategy and conservation of avian species, multidimensional and interconnected uniform approach is needed. To counter the effects of urbanization through the restoration of habitats and the creation of bird-friendly urban public spaces, some studies has shown that urban parks, such as gardens, are usable stopover sites for migratory birds (Aronson et al., 2014; Seewagen et al., 2010). Greening urban spaces with structures such as green roofs and walls can further reduce urban heat island effects as well as provide habitat for birds (Fernandez-Juricic & Jokimäki, 2001; Wang et al., 2022). In addition, promoting ecological connectivity through green corridors and preserving wetlands within urban matrices are essential for maintaining functional migratory pathways (Beninde et al., 2015).

Reducing light pollution through the application of smart lighting technologies is one possible strategy for reducing the impacts of light pollution on bird migration. For instance, studies have shown that smart technologies like motion sensor LED might cut light pollution in half (Longcore, 2023). Other examples include using amber LED for bird-friendly lighting

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options that lessen the attractiveness of artificial light sources to birds and mitigate collision situations (Longcore & Rich, 2004; McLaren et al., 2018). Such technological solutions, if combined with public awareness campaigns and local regulations, could reduce nocturnal collision-related mortality rates that currently affect millions of migratory birds annually (Horton et al., 2019).

Urban planning and policies are very important in making the migration patterns of birds free from the effects of urbanization and artificial light at night. It has been found that such impacts of urbanization on birds can be reduced by designing urban places specifically for birds and reducing light pollution levels (Evans et al., 2011). Policy measures such as bird-friendly lighting standards can also reduce the impacts of light pollution on bird migration patterns (Lysyk et al., 2025). Importantly, integrating these standards into building codes and environmental impact assessments could mainstream bird conservation into urban development agendas worldwide.

Conducting international research and developing conservation programs is the only way to lessen urbanization and light pollution interference in bird migratory patterns Urbanization's negative effects on bird populations have been found to be lessened by international collaboration and conservation initiatives that include the development of bird-friendly habitats and the mitigation of light pollution (across its range). Different types of bird conservation have taken place in countries like Pakistan and many others in the world to try to save birds from the adverse effects of urban sprawl and light pollution. These cooperative frameworks are especially critical given that migratory birds cross multiple national borders, and unilateral efforts by one country may be insufficient to ensure species survival (Runge et al., 2015).

In Pakistan, the government has initiated a lot of projects to solve the problems related to the environment, and the effect of urban sprawl and light pollution on the bird population. One such initiative is the Living Indus Initiative, which protects, conserves, and restores the natural ecosystem essential for the survival of the vast majority (90%) of the people in Pakistan in the Indus Basin (Homan & Burak, 2024; Tariq & Shahzad, 2024). The recently launched, 2014, Billion Tree Tsunami projects focus on the environmental restoration of afforested land and degraded land, contributing to the reduction of urbanization's impact on bird habitats (Khan et al., 2021). These initiatives highlight how large-scale afforestation and river-basin restoration can serve as models for integrating bird conservation into broader climate-resilience strategies.

Many international programs try to deal with light pollution and protect birds. The International Dark-Sky Association advocates for education and outreach to promote dark skies, reduce light pollution, and unite members and allies worldwide in support of this cause (Silver & Hickey, 2020). Again, the National Geographic Society has launched several projects to reduce light pollution and promote conservation work, including the Light Pollution Project, which raises awareness about the negative effects of light pollution on the environment (Pothukuchi, 2021). These global campaigns demonstrate the role of civil society organizations and non-governmental actors in complementing governmental and intergovernmental conservation frameworks.

Table 4. Conservation and Mitigation Strategies for Migratory Birds Affected by Urbanization and Light Pollution

Strategy	Description / Actions	Expected Benefits for Migratory Birds	References
Habitat restoration & urban greening	Creating bird-friendly urban spaces (parks, gardens), green roofs, and vertical walls	Provides stopover sites, reduces heat island effects, and increases urban habitat diversity	(Aronson et al., 2014; Fernandez-Juricic & Jokimäki, 2001; Seewagen et al., 2010; Wang et al., 2022)

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Smart & bird-friendly lighting	Use of motion sensor LEDs, amber lights, and downward-directed fixtures	Reduces light attraction, lowers disorientation risk, and prevents collisions with structures	(Longcore, 2023; Longcore & Rich, 2004; McLaren et al., 2018)
Urban planning & policy	Design cities with bird corridors, and enforce bird-friendly lighting standards	Minimizes fragmentation and mortality, integrates biodiversity into planning	(Evans et al., 2011; Lysyk et al., 2025)
National initiatives (Pakistan)	Living Indus Initiative; Billion Tree Tsunami	Restores ecosystems, enhances resilience against urbanization impacts	(Homan & Burak, 2024; Khan et al., 2021; Tariq & Shahzad, 2024)
International cooperation	Convention on Migratory Species; international conservation networks	Facilitates cross-border protection, coordinates habitat management	(Runge et al., 2015; Silver & Hickey, 2020)
Awareness & advocacy programs	International Dark-Sky Association campaigns; National Geographic Light Pollution Project	Promotes global awareness, fosters community engagement, strengthens conservation culture	(Pothukuchi, 2021; Silver & Hickey, 2020)

Conclusion

Two buzzwords can envelop the process of bird migration: annual migration and urbanization with light pollution. Urbanization will cause the fragmentation of habitats and the breakdown of migratory corridors. In other words, it has positive or negative effects on food availability for migratory birds; light pollution disorients the bird, colliding it with structures and migrating it at the wrong time. All these synergistic effects threaten the whole face of birds, and therefore, these demand conservation strategies to reduce. Effective countermeasures include bird-friendly urban planning, habitat restoration, and smart lighting technologies. These will prove essential in ecosystem stabilization and long-term capacity development for the migratory bird species. There is a research gap in how urban sprawl and light pollution affect bird migration patterns. The open areas in this gap seem to be four that require further investigation: assessing the degree of effects of urban sprawl and light pollution; identifying the possible mechanisms by which the urbanization and light pollution affect birds; evaluating the geographical ecosystems as well as across different sites; and exploring certain vital elements of effective conservation.

New methods and techniques should be employed to fill these voids in future research. The combination of remote sensing and GIS with observations carried out on the fields might probably give a complete picture of the effects of urban spreading and light pollution. Experimentation could be aimed at understanding mechanisms, particularly by developing and testing schemes for conservation, which provide practical solutions. Assessing impacts elsewhere in the world and different ecosystems will provide a more global perspective of the problem. It would close those research gaps and establish novel approaches with which an understanding can develop of the negative impacts of urban sprawl and light pollution on bird migration. The research would feed into workable conservation strategies to alleviate the damaging effects of urbanization on migratory populations of birds.

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REFERENCES

Alerstam, T., Hedenström, A., & Åkesson, S. (2003). Long-distance migration: evolution and determinants. Oikos, 103 (2): 247-260.

Aronson, M. F., La Sorte, F. A., Nilon, C. H., Katti, M., Goddard, M. A., Lepczyk, C. A., Warren, P. S., Williams, N. S., Cilliers, S., & Clarkson, B. (2014). A global analysis of the impacts of urbanization on bird and plant diversity reveals key anthropogenic drivers. Proceedings of the royal society B: biological sciences, 281 (1780): 20133330.

Bauer, S., & Hoye, B. J. (2014). Migratory animals couple biodiversity and ecosystem functioning worldwide. Science, 344 (6179): 1242552.

Beninde, J., Veith, M., & Hochkirch, A. (2015). Biodiversity in cities needs space: a meta-analysis of factors determining intra-urban biodiversity variation. Ecology letters, 18 (6): 581-592.

Bregman, T. P., Sekercioglu, C. H., & Tobias, J. A. (2014). Global patterns and predictors of bird species responses to forest fragmentation: implications for ecosystem function and conservation. Biological Conservation, 169 372-383.

Cabrera-Cruz, S. A., Smolinsky, J. A., & Buler, J. J. (2018). Light pollution is greatest within migration passage areas for nocturnally-migrating birds around the world. Scientific Reports, 8 (1): 3261.

Devries, J. H., Armstrong, L. M., Howerter, D. W., & Emery, R. B. (2023). Waterfowl distribution and productivity in the Prairie Pothole Region of Canada: tools for conservation planning. Wildlife Monographs, 211 (1): e1074.

Dominoni, D. M. (2015). The effects of light pollution on biological rhythms of birds: an integrated, mechanistic perspective. Journal of Ornithology, 156 (Suppl 1): 409-418.

Donnelly, J. P., Moore, J. N., Casazza, M. L., & Coons, S. P. (2022). Functional wetland loss drives emerging risks to waterbird migration networks. Frontiers in Ecology and Evolution, 10 844278.

Evans, K. L., Chamberlain, D. E., Hatchwell, B. J., Gregory, R. D., & Gaston, K. J. (2011). What makes an urban bird? Global Change Biology, 17 (1): 32-44.

Falcón, J., Torriglia, A., Attia, D., Viénot, F., Gronfier, C., Behar-Cohen, F., Martinsons, C., & Hicks, D. (2020). Exposure to artificial light at night and the consequences for flora, fauna, and ecosystems. Frontiers in Neuroscience, 14 602796.

Fernandez-Juricic, E., & Jokimäki, J. (2001). A habitat island approach to conserving birds in urban landscapes: case studies from southern and northern Europe. Biodiversity & Conservation, 10 (12): 2023-2043.

Gauthreaux, S., & Belser, C. G., Rich, C., & Longcore, T. (2006). Effects of artificial night lighting on migrating birds. Ecological consequences of artificial night lighting, 67-93.

Gauthreaux, S., Belser, C. G., Rich, C., & Longcore, T. (2006a). Effects of artificial night lighting on migrating birds. Ecological consequences of artificial night lighting, 67-93.

Gauthreaux, S., Belser, C. G., Rich, C., & Longcore, T. (2006b). *Effects of artificial night lighting on migrating birds* (Vol. 2006). Island Press Washington, DC, USA.

González-Oreja, J. A. (2011). Birds of different biogeographic origins respond in contrasting ways to urbanization. Biological Conservation, 144 (1): 234-242.

Homan, P., & Burak, T. (2024). India, Pakistan, and environmental security: a path to peace. In *International Security Studies and Technology* (pp. 47-65). Edward Elgar Publishing.

Horton, K. G., Nilsson, C., Van Doren, B. M., La Sorte, F. A., Dokter, A. M., & Farnsworth, A. (2019). Bright lights in the big cities: migratory birds' exposure to artificial light. Frontiers in Ecology and the Environment, 17 (4): 209-214.

Isaksson, C. (2018). Impact of urbanization on birds. Bird species, 235 257.

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

Kerlinger, P. (2000). Avian mortality at communication towers: a review of recent literature, research, and methodology.

Khan, M. B. A., Rahman, A.-u., & Shaw, R. (2021). Evaluation of ecosystem-based approaches for disaster and climate risk resilience and policy perspectives in Pakistan. In *Ecosystem-Based Disaster and Climate Resilience: Integration of Blue-Green Infrastructure in Sustainable Development* (pp. 53-84). Springer.

La Sorte, F. A., Aronson, M. F., Lepczyk, C. A., & Horton, K. G. (2022). Assessing the combined threats of artificial light at night and air pollution for the world's nocturnally migrating birds. Global Ecology and Biogeography, 31 (5): 912-924.

La Sorte, F. A., Lepczyk, C. A., Aronson, M. F., Goddard, M. A., Hedblom, M., Katti, M., MacGregor-Fors, I., Mörtberg, U., Nilon, C. H., & Warren, P. S. (2018). The phylogenetic and functional diversity of regional breeding bird assemblages is reduced and constricted through urbanization. Diversity and Distributions, 24 (7): 928-938.

Lack, D. (1954). The natural regulation of animal numbers.

Lack, D. (1968). Bird migration and natural selection. Oikos, 1-9.

Larsen, E. A. (2008). Effects of urban development on breeding bird diversity: the role of diet and migration.

Leveau, L. M. (2019). Large cities and the loss of green areas exclude migrant birds: a global analysis. bioRxiv, 709725.

Longcore, T. (2023). Effects of LED lighting on terrestrial wildlife.

Longcore, T., & Rich, C. (2004). Ecological light pollution. Frontiers in Ecology and the Environment, 2 (4): 191-198.

Lysyk, A., Khan, A. I., Conners, D., & Buxton, R. (2025). Barriers and opportunities to preventing residential bird-window collisions.

Marzluff, J. M. (2001a). Worldwide urbanization and its effects on birds. In *Avian ecology and conservation in an urbanizing world* (pp. 19-47). Springer.

Marzluff, J. M. (2001b). Worldwide urbanization and its effects on birds. Avian ecology and conservation in an urbanizing world, 19-47.

McLaren, J. D., Buler, J. J., Schreckengost, T., Smolinsky, J. A., Boone, M., Emiel van Loon, E., Dawson, D. K., & Walters, E. L. (2018). Artificial light at night confounds broad-scale habitat use by migrating birds. Ecology letters, 21 (3): 356-364.

McLean, K., Mushet, D., & Sweetman, J. (2022). Climate and land use driven ecosystem homogenization in the Prairie Pothole Region. Water, 14 (19): 3106.

Miller, M. W. (2006). Apparent effects of light pollution on singing behavior of American robins. The Condor, 108 (1): 130-139.

Pothukuchi, K. (2021). City light or star bright: a review of urban light pollution, impacts, and planning implications. Journal of Planning Literature, 36 (2): 155-169.

Reis, E., López-Iborra, G. M., & Pinheiro, R. T. (2012). Changes in bird species richness through different levels of urbanization: Implications for biodiversity conservation and garden design in Central Brazil. Landscape and urban planning, 107 (1): 31-42.

Rodewald, A. D., & Shustack, D. P. (2008). Urban flight: understanding individual and population-level responses of Nearctic–Neotropical migratory birds to urbanization. Journal of Animal Ecology, 77 (1): 83-91.

Rodríguez, A., Holmes, N. D., Ryan, P. G., Wilson, K. J., Faulquier, L., Murillo, Y., Raine, A. F., Penniman, J. F., Neves, V., & Rodríguez, B. (2017). Seabird mortality induced by land-based artificial lights. Conservation Biology, 31 (5): 986-1001.

Runge, C. A., Watson, J. E., Butchart, S. H., Hanson, J. O., Possingham, H. P., & Fuller, R. A. (2015). Protected areas and global conservation of migratory birds. Science, 350 (6265): 1255-1258.

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

Schroeder, J., et al. (2012). Artificial light at night alters nocturnal urban bird migration. . Journal of Ornithology, 153(2), 251-258.,

Scolozzi, R., & Geneletti, D. (2012). A multi-scale qualitative approach to assess the impact of urbanization on natural habitats and their connectivity. Environmental Impact Assessment Review, 36 9-22.

Seewagen, C. L., Slayton, E. J., & Guglielmo, C. G. (2010). Passerine migrant stopover duration and spatial behaviour at an urban stopover site. Acta Oecologica, 36 (5): 484-492.

Sekercioglu, C. H. (2006). Increasing awareness of avian ecological function. Trends in ecology & evolution, 21 (8): 464-471.

Silver, D. A., & Hickey, G. M. (2020). Managing light pollution through dark sky areas: learning from the world's first dark sky preserve. Journal of Environmental Planning and Management, 63 (14): 2627-2645.

Somveille, M. (2016). The global ecology of bird migration: patterns and processes. Frontiers of Biogeography, 8 (3):

Sutherland, W. J. (1998). Evidence for flexibility and constraint in migration systems. Journal of Avian biology, 441-446.

Tariq, R., & Shahzad, S. (2024). Sustainable Environment: The Intersection of Environmental and Political Communication in Pakistan to Overcome Environmental Challenges. In *Multi-Stakeholder Contribution in Asian Environmental Communication* (pp. 122-134). Routledge.

Tryjanowski, P., Sparks, T. H., Kuźniak, S., Czechowski, P., & Jerzak, L. (2013). Bird migration advances more strongly in urban environments. Plos one, 8 (5): e63482.

Unfried, T. M., Hauser, L., & Marzluff, J. M. (2013a). Effects of urbanization on Song Sparrow (Melospiza melodia) population connectivity. Conservation Genetics, 14 41-53.

Unfried, T. M., Hauser, L., & Marzluff, J. M. (2013b). Effects of urbanization on Song Sparrow (Melospiza melodia) population connectivity. Conservation Genetics, 14 (1): 41-53.

Wang, L., Wang, H., Wang, Y., Che, Y., Ge, Z., & Mao, L. (2022). The relationship between green roofs and urban biodiversity: a systematic review. Biodiversity and Conservation, 31 (7): 1771-1796.

Wotton, D. M., & Kelly, D. (2012). Do larger frugivores move seeds further? Body size, seed dispersal distance, and a case study of a large, sedentary pigeon. Journal of Biogeography, 39 (11): 1973-1983.

Zöckler, C. (2005). Migratory bird species as indicators for the state of the environment. Biodiversity, 6 (3): 7-13.