International Journal of Global Science Research **ISSN: 2348-8344 (Online)**
Vol. 12, Issue. 1, April 2025, pp. 2598-2605 **DOI: https://doi.org/10.26540/ijgsr.v12.i1.2025.301**
Available Online* at *www.ijgsr.com

Review

Industrial air pollution and its consequences for Avian Biodiversity: A review of Ecological, Evolutionary, and Conservation perspectives

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Received: 08/03/2025
Revised: 15/03/2025
Accepted: 25/03/2025

Abstract: There is a fresh sense of urgency to determine the causes of population decline and possible remedies due to the enormous losses experienced by animals over the last half-century. Our findings give the first compelling evidence that air pollution is a major problem on a wide scale. We demonstrate that the conservation of birds has reaped significant advantages from an air pollution rule that limited emissions of ozone precursors. It is challenging to describe the effects of air pollution on organisms in the field because exposure levels vary across place and time, and species reactions are complex and hard to separate from other environmental stresses. Given air pollution's extensive effects on human and environmental health, it is reasonable to assume that it will have significant, direct or indirect, and multi-mechanism effects on species. Politicians, city planners, and farmers may all benefit from a greater understanding of the effects of pollution on birds if they were to work together to protect these species and the ecological services they provide. Conservation efforts for bird species should be prioritized because their function as bioindicators is conditional on the availability of resources for ecological assessment and the characteristics of interest. Regardless, there must be a greater emphasis on studying interactions between contaminants because their nature is still unclear. Mitigation strategies are of paramount importance for protecting bird species since human-caused pollution and threats to these animals are only worsening. For conservationists and decision-makers, this chapter is a good place to start when comprehending the many birds face.

Keywords: Anthropogenic, Environmental stress, Habitat fragmentation, Pollution, Birds

Introduction:

Modern biodiversity loss rates exceed those of natural extinction. This tremendous decline in biodiversity is commonly believed to represent the sixth global extinction (Barnoskay et al. 2011). In 2020, most of the world's insect, fish, reptile, and mammalian populations had disappeared (Hallmann,et al. 2017). These creatures are particularly vulnerable to the

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myriad threats they face due to human interference.

During the Industrial Revolution, pollution dramatically increased due to the proliferation of factories and cities. Today, pollution is widespread, even in inhospitable environments like Antarctica and it endangers the well-being of all living things.

Bird extinction has been on the rise for the last half-century. The root causes of decline must be addressed, and ways to prevent extinction must be discovered. It is well-known that birds suffer from the negative effects of contaminants and pollutants caused by humans. These include noise, air, oil, plastic, heavy metals, radioactive substances, pesticides, medications, etc. Scientists have shown a correlation between ozone layer depletion and bird populations declining worldwide, including in the US (Sanderfoot and Holloway, 2017). The papers assert that 1.5 billion birds have been lost globally due to declining bird populations induced by poor air quality over the last few decades.

Factors such as climate change, invasive species, diseases, habitat degradation, cat predation, and loss of habitat or fragmentation are among those that may lead to a drop in bird numbers. Agricultural intensification and other technological changes in the last half-century, including mechanized farming practices, landscape homogenization, and increased agrochemical input, have significantly reduced wildlife diversity and abundance (Bengtsson et al, 2005). This includes many bird species, especially those that live on insects and grains (Bowler et al, 2019). Among these dangers, a wide range of pollutants is known to reduce the fitness and survival rates of bird species.

Anthropogenic contaminants have worsened environmental health and have grown in popularity with human activity. Birds and other species are negatively impacted by the large amount of chemicals or agents that contribute to human activities on a global scale. Pesticides (including organochlorine), metals, industrial chemicals, and veterinary medications are usually included as substances that threaten bird populations, and their discharge into the environment is mostly caused by human activity. Further, air, light, noise, climate change, and oil spill pollution are all aspects of human activity that degrade environmental quality. In addition, plastics have been building up in aquatic ecosystems due to their widespread use and tenacity; this poses a serious threat to marine and terrestrial animals (Plaza et al, 2017). Birds play an important role in so many interconnected ecosystem processes, which helps ensure the health and stability of these systems. There are four categories of ecosystem services that birds help with: provisioning, regulation, culture, and support. The important contributions that birds play in maintaining ecosystem function are often overlooked. Indirectly, bird populations help humans in many ways, including by distributing seeds, adding to nutrient cycling, managing pests, serving as ecosystem engineers, and pollinating some plants (Wenny et al, 2011). Despite their lack of showmanship, certain bird species are important to ecosystems. It has been shown that infectious illness rates have increased in the Indian subcontinent due to the reduction of vultures. For human health and well-being, birds provide several important functions. They are edible, and their feathers have long been used as insulation and bedding. “The multibillion-dollar bird watching and hunting industries are testaments to the cultural significance of many bird species and a significant economic driver in many regions”. For

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example, in 2016, out % of 86 million Americans who went wildlife watching, 45.1% were birdwatchers. Bird watching was a major contributor to this sector, bringing in USD 75.9 billion.

Literature Review:

"The contributions of ecosystems to the benefits that are used in economic and other human activity" are what the United Nations calls ecosystem services (UN 2024), and there are typically four major ways to classify them. These ecological services include cultural, regulating, supporting, and provisioning (Hassan et al 2005). The distribution of consumable goods and services, including food, water, and raw materials, to people is known as provisioning (IPBES 2019). Maintaining ecological balance and human security are important for regulating functions like water purification, pollination, carbon sequestration, and flood mitigation (MEA 2005). The efficient functioning of other services depends on supporting services, which keep vital processes that sustain life on Earth running (UN 2024). Among the intangible advantages of cultural institutions are places for leisure, contemplation, and the enjoyment of artistic pursuits. The significance of protecting and properly maintaining ecosystems cannot be overstated since they jointly support human life and welfare. The impacts and services offered by urban green structures (UGS) are a prime example of a topic that is pertinent to both industrial and urban settings, and they will be thoroughly examined in this paper. As a regulating ecosystem function, UGS helps keep local climate and air and ground temperatures in check by mitigating heat via absorption, shading, and humidification (Jenerette et al, 2011). A regulating/provisional ecosystem service is the habitat that UGS offers to animals, plants, and pollinators who contribute to food production. As an example of a regulating ecosystem function, UGS may aid in water retention and manage stormwater, two problems that often arise in metropolitan areas with hardened surfaces (Chen, et al 2021).

Measuring and mapping biodiversity is a tough undertaking because of the complexity of nature's variance. This is especially true when analysing and mapping diverse natural values in one evaluation (Ecogain, 2024). "Nature is defined as the components and locations that locate biodiversity, in contrast, biodiversity are the variety in nature that allows nature to be productive in terms of ecosystems, resilience, and adaptability". The two phrases are closely connected but should not be used interchangeably (Dasgupta 2021).

Pollination relies on the exact interaction between plants and their pollinators; therefore, this might indicate possible mismatches that could negatively impact the process, even if it makes it harder to discover findings in a meta-analysis. When it comes to urbanization, similar incompatibilities disturb parts of the pollination system. For example, many alien plant species cause specialized pollinators to disappear (Wenzel, et al., 2020).

Several forms of human-caused pollution happen simultaneously, and some may even have mutually reinforcing impacts, such as how ozone pollution alters the characteristics of light. Therefore, it is more difficult and more important to analyse the multiplicative effect of several sources of pollution than the impact of a single source of pollution

Anthropogenic Air Pollutants:

Pollutants in the air may originate from naturally occurring or artificial sources and are known to cause health problems. Volcanic eruptions and dust carried by the

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wind are two examples of natural causes of pollution. Vehicle fuel combustion, industrial processes, heat and electricity generation, domestic use of polluting fuels for cooking and heating, incineration of waste from municipalities and farms, and other sources are the origins of anthropogenic air pollutants. "Metals, sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), and particle matter (PM) are the most common air contaminants. Airborne pesticides are another issue (for more on this, see the section on pesticide pollution)." While parts per million (ppm) indicate the concentration of the volume of air, particulate matter (PM) indicates the size of the particles.

Heavy metals inhaled by birds may affect their populations. Nearby urban or industrial regions provide a special threat to some species. The section on heavy metal pollution discusses the effects of these metals on birds' diversity.

Urban environments:

A major kind of urban pollution is air pollution, which has been shown to have detrimental effects on avian species' general health and well-being (Sanderfoot, Holloway., 2017).

Birds are particularly vulnerable to air pollution because their respiratory systems are so effective at absorbing chemicals that float in the air (Brown et. al., 1997). When birds breathe polluted air, it may cause various symptoms, including sickness and difficulty breathing, increased stress and detoxification efforts, immunosuppression, behavioural abnormalities, and decreased reproductive success (Sanderfoot and Holloway, 2017).

Air pollution in cities hurts bird populations by raising oxidative stress and decreasing thyroid function. "American kestrels showed markedly impaired thyroid function and doubled hepatic EROD (ethoxy resorufin O-demethylase) levels in response to exposure to polycyclic aromatic hydrocarbons (PAHs) in a controlled inhalation experiment that involved common urban pollutants (benzene, toluene, NO_2, and SO_2). The plasma antioxidant capacity of four common passerine species in southern Sweden was considerably affected by exposure to urban nitrogen oxide (NO_X) (Salmon et al 2019). In these city settings, tree sparrows (P. montanus) also showed more oxidation damage. Because of their global distribution and ability to monitor oxidative stress in urban and natural areas, birds like the common house sparrow (P. domesticus) are excellent bioindicators for dangerous airborne contaminants. The total antioxidant capacity and haemoglobin content were lower in urban house sparrows (P. domesticus) than in their rural counterparts.

Industrial areas:

The continued release of toxins into the surrounding environment by some industrial operations may threaten the local biodiversity. For example, several studies in Canada's Athabasca oil sand area have shown that some bird species are more vulnerable to air pollution caused by mining (Ferni et al, 2018). Polycyclic aromatic compounds (PACs) were ingested by tree swallows when they were exposed to them in the air (Fernier, et al 2018a). "Thyroid function changed in 14-day-old nestlings exposed to mining sites compared to non-mining sites (Fernie, et al., 2019), and worse body condition, growth, and reproductive success (Fernie, et al., 2018b) were also associated with this exposure." Embryonic abnormalities and mortality, decreased egg production and hatching, increased clutch or brood desertion, stunted growth, increased organ weight, and a myriad of biochemical

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reactions are all outcomes of PAH (polycyclic aromatic hydrocarbon) exposure in adult birds.

Another investigation checked the effects of perfluoroalkyl acids (PFAAs) in large quantities at different distances from a fluorochemical facility in Belgium. Near the plant site, they found the highest quantities of PFAAs ever seen in eggs laid by wild birds. There is a correlation between high concentrations of perfluoro decanoic acids (PFDAs) and a decrease in total breeding success, an earlier start to egg laying, and an effect on eggshell thickness caused by certain perfluorinated carboxylates (PFCAs) and perfluorinated sulfonates (PFSAs). However, more research is needed since some reproductive damage was found.

Pesticides in the air:

Another potential source of unintended air pollution is the widespread use of pesticides in urban and agricultural settings. To suppress mosquito populations, for instance, aerosolized insecticides are discharged directly into the environment and may be detected in high quantities in the air in metropolitan areas. Many pesticides' gaseous and particle forms are released into the atmosphere and eventually settle to the ground because of their semi volatility. Seasonality, patterns of agricultural usage, weather, and wind all have a role in the airborne pesticide concentration. Predictably, spring and summer tend to have the greatest concentrations. According to prior research, herbicides make up about 40% of pesticides in polluted air, followed by insecticides at 33%, and fungicides at 26%. Then, even with local pesticide applications, birds might still be exposed to these chemicals by the wind carrying polluted air at great distances (Sanderfoot and Holloway, 2017). Although no hard data shows that pesticides in the air affect birds, this exposure pathway might affect their well-being and susceptibility.

Ozone Pollution Threatens Birds Populations to Collapse:

Air pollution has long been considered a possible cause of the diminishing bird numbers, but the exact causes remain unknown (Lehikoinen, et al, 2019). O_3, carbon monoxide (CO), heavy metals, smoke, sulphur dioxide (SO_2), and mixtures of emissions are among the air pollutants that have negative effects on birds, according to a large body of controlled and in situ research (Sicard et al, 2016*)*. When exposed to dangerous air pollution, birds experience oxidative stress and redirect energy and resources towards detoxification and the scavenging of reactive chemical species (Sanderfoot, and Holloway, 2017). Elevated stress levels in birds are associated with respiratory discomfort, immunosuppression, disease, behavioural changes, and maybe reduced reproductive success (Sanderfoot and Holloway, 2017). "New studies using an epidemiological-like approach have shown significant declines in bird populations in the US and Central Europe, proving the real-world impacts of air pollution on avian populations and further supporting expectations from stress biology and toxicology literature (Sanderfoot and Holloway, 2017)". It is well-known that ongoing O_3 pollution adversely affects human health and vegetation. "One study examining 25 years of data from the Giant Mountains in the Czech Republic found that O_3 exposure significantly reduced the population growth rates of upland bird species in the alpine zone above treeline." The study also took weather conditions into account. The effect was not statistically significant across all species, and the dangers associated with O_3 increase with increasing altitude. Air quality improvements over the last 40

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years have prevented the extinction of almost 20%, or 1.5 billion birds, of the world's bird populations, according to a new study of US statistics. The depletion of alpha diversity, the undermining of biodiversity and conservation goals, and the resulting mass mortality of birds caused by emissions of main pollutants that increase O_3 production must be prevented.

Reducing exposure to O_3 might help slow the steady fall of bird populations, which is particularly problematic in high-elevation regions where the gas is already present at dangerously high concentrations, making long-term exposure to it impossible for birds. A decrease in the transmission of O_3 and its precursors to high-elevation locations and a weakening of O_3 exposures might result from limiting emissions of O_3 precursors in metropolitan areas. Since the VOCs-to-NOx ratio controls local O_3 generation, this countermeasure may not be enough on its own. In conclusion, main air pollutant emissions regulations may reduce NOx, but VOCs are mostly biogenic and grow with climate change; moreover, in an ideal world, reducing anthropogenic precursor emissions might increase O_3 exposures. Significantly, stratospheric O_3 contributes to high-elevation regions, increasing exposure to O_3. Consequently, reducing O_3 exposures is difficult, air pollution legislation tends to have little effect, and reducing precursor emissions of O_3 in general may not have any effect if atmospheric chemistry processes are not considered. Decreasing pollutant emissions is not enough; further actions are required.

Conclusion:

In this chapter, we looked at how pollutants and pollution affect bird populations. This chapter delves into pharmaceutical wastes, heavy metals, pesticides, air pollutants, plastics, and oil, as well as their prevalence and environmental emissions. There may be far-reaching consequences for ecosystem health and the ecological services birds provide if bird species go extinct. More and more pollutants and toxins are reaching birds due to habitat loss, urbanization, and human-caused pollution. It is important to note that while individual pollutants may not have a major impact on bird populations, the cumulative effect of several pollutants and the stress that results from exposure to them may have a significant impact. Their effects on bird populations could be short-lived (death) or long-lasting (alterations to reproductive capacity or quality of life). For example, since big plastics may entangle but are regularly broken down into smaller plastic sizes, the smallest particles may be able to pass past cell membranes or tissue barriers. Even though there are many unanswered questions in the scientific community, the evidence is strong enough to support taking precautions to save birds and other animals immediately. Pollution and changes in land use will worsen future biodiversity risks unless significant political and economic policy reforms are carried out. Consequently, developing alternatives to these pollutants and reducing their use are of the utmost importance for protecting biodiversity. Protecting birds and the ecosystem services they provide requires a heightened focus on finding ways to reduce human impact on the natural world. The cost of executing a mitigation strategy can be substantial and is likely to vary greatly for each pollutant. From an economic perspective, it can seem excessive in some cases, which might prevent mitigation strategies from being put into place.

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