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Original Research Article

The Influence of Anthropogenic Pollutant on Avian Species Richness in Kanpur: Assessment and Remedial Actions

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***Abstract**:* In parts of India that are experiencing fast urbanization, industrialization is a major factor in the deterioration of the environment. Air pollution is particularly bad in Kanpur, an industrial metropolis in Uttar Pradesh, because of all the tanneries, textile facilities, chemical companies, and thermal emissions that are concentrated there. Birds can be relied upon as bioindicators of environmental health due to their extreme sensitivity to weather and habitat quality. By analyzing species richness, abundance, community composition, and behavioral responses across industrial, urban, and peri-urban zones, this research seeks to evaluate the impact of industrial air pollutants on bird diversity in Kanpur. Field surveys, diversity indices, and analysis of pollution data were used to determine that there is a significant decrease in bird variety in areas with high levels of pollution. Species that are able to withstand pollution are more numerous, whereas those that are susceptible to it are extinct. In addition to proposing remedial and conservation measures tailored to individual sites, the article delves into the physiological, ecological, and reproductive effects of air pollution on birds. The results highlight the critical need of restoring habitats, implementing integrated pollution control measures, and designing for urban areas that are inclusive of biodiversity if industrial towns like Kanpur are to preserve their bird variety.

Keywords: Avian diversity, Industrial air pollution, Bioindicators, Kanpur, Conservation strategies, Urban ecology.

INTRODUCTION

An integral feature of India's economic progress has been its rapid industrialization; yet, this expansion has also brought about serious environmental problems, most notably air pollution. The industrial operations generate large amounts of air pollution, including particulate matter ($PM_{2.5}$ and PM_{10}), sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOCs), and heavy metals. These pollutants have far-reaching effects on animals and ecosystems, in addition to having a negative impact on human health. Birds are a key component of ecological networks. They help with pollination, spreading seeds, controlling pests, and cycling nutrients. They are particularly susceptible to air pollution because of their high metabolic rates, respiratory efficiency, and reliance on habitat quality. Birds are good monitors of ecosystem health because changes in their behavior and variety frequently reflect underlying environmental stress.

One of northern India's most industrialized towns, Kanpur is situated on the Ganga River's banks. The city is a major polluter due to its many businesses, including leather tanneries, textiles, fertilizer units, and heavily populated roadways. While there have been a number of studies looking at the effects of water contamination on humans in Kanpur, very few have investigated the link between industrial air pollution and bird diversity. By offering an overall ecological evaluation and proposing realistic corrective steps, this research aims to fill this vacuum.

Objectives of the Study

- To document avian species diversity and abundance across industrial, urban, and peri-urban zones of Kanpur.
- To analyze the relationship between industrial air contaminants and avian community structure.

- To assess the ecological and physiological impacts of air pollution on birds.
- To identify pollution-tolerant and pollution-sensitive bird species.
- To propose remedial and conservation strategies for sustaining avian diversity in industrial regions.

LITRETURE REVIEW

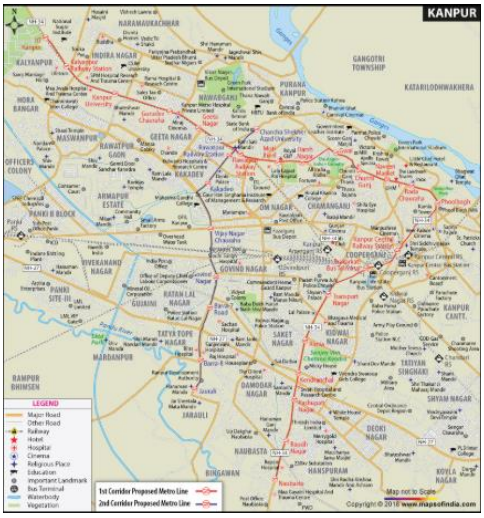
"The contributions of ecosystems to the benefits that are used in economic and other human activity" (UN 2024) is how ecosystem services are defined, and they typically fall into one of four categories. Some examples of ecological services include those that are provisional, cultural, regulatory, and sustaining (Hassan et al., 2005). Provisioning is the process of distributing foodstuffs, water, and other consumables to individuals (IPBES 2019). Ensuring ecological harmony and human safety is crucial for controlling processes such as water purification, pollination, carbon sequestration, and flood prevention (MEA 2005). In order for other services to work efficiently, supporting services must be in place to maintain the Earth's critical processes that are necessary for life (UN 2024). A venue for relaxation, reflection, and the appreciation of creative endeavors is one of the intangible benefits of cultural organizations. Because ecosystems are essential to human survival and prosperity, their protection and correct maintenance are of the utmost importance. This article will provide a comprehensive analysis of the effects and services provided by urban green structures (UGS) as an illustration of a subject that is applicable to both urban and industrial environments. By absorbing sunlight, casting shadows, and adding humidity, UGS helps regulate local climate and air and ground temperatures (Jenerette et al., 2011). The habitat that UGS provides for plants, animals, and pollinators is an example of a regulatory or provisional ecosystem function that helps with food production. According to Chen et al. 2021, urban green spaces (UGS) have the potential to control stormwater runoff and aid in water retention, two issues that frequently arise in urban environments because of the harsh surfaces there. Because natural variation is so complicated, measuring and mapping biodiversity is no easy task. This is especially true when multiple natural values are evaluated and analyzed simultaneously (Ecogain, 2024). Biodiversity refers to the variation in nature that enables ecosystems to be resilient, adaptable, and productive; nature is defined as the components and sites that locate biodiversity. Although they are synonymous, you cannot use them interchangeably (Dasgupta 2021). Although it may be more challenging to uncover results in a meta-analysis, this might suggest potential incompatibilities that could adversely affect pollination since it depends on the precise interaction between plants and their pollinators. Like incompatibility, urbanization disrupts pollination in certain ways. Wenzel et al. (2020) notes that a large number of alien plant species are responsible for the extinction of specialized pollinators.

Ozone pollution, for instance, alters the properties of light and is one of several types of pollution that humans produce simultaneously. Some of these effects may even work together to create others. Consequently, analyzing the cumulative impact of several pollution sources is both more challenging and more crucial than analyzing the impact of a single source of pollution.

STUDY AREA: KANPUR CITY

The subtropical climate of Kanpur, which is located between 26°28′N latitude and 80°24′E longitude, is characterized by scorching summers, cold winters, and monsoon rains. Urban residential neighborhoods, peri-urban or semi-natural landscapes, and industrial zones (Jajmau, Panki, Dada Nagar) are the main divisions of the city.

Diffuse emissions, less forest cover, and changed microclimate are the hallmarks of industrial regions. Although peri-urban areas still contain agricultural fields, marshes, and trees, which make them excellent habitats for birds, pollution levels in metropolitan areas are relatively low. Kanpur is a great place to study pollution-related gradients in bird diversity because of its geographical variability.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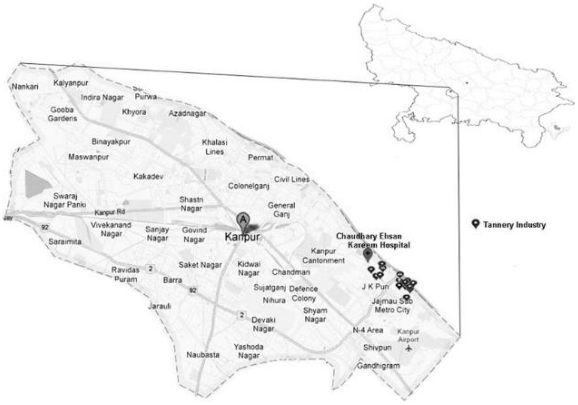
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Sanjay Nagar
Govind Nagar
Kanpur
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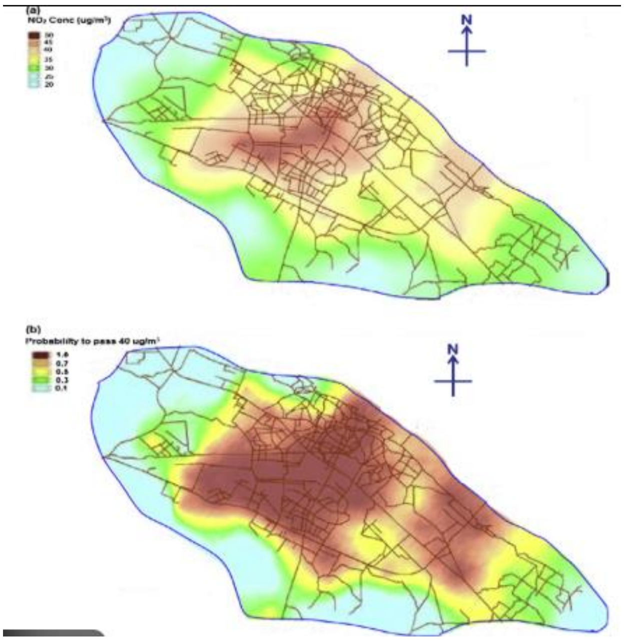
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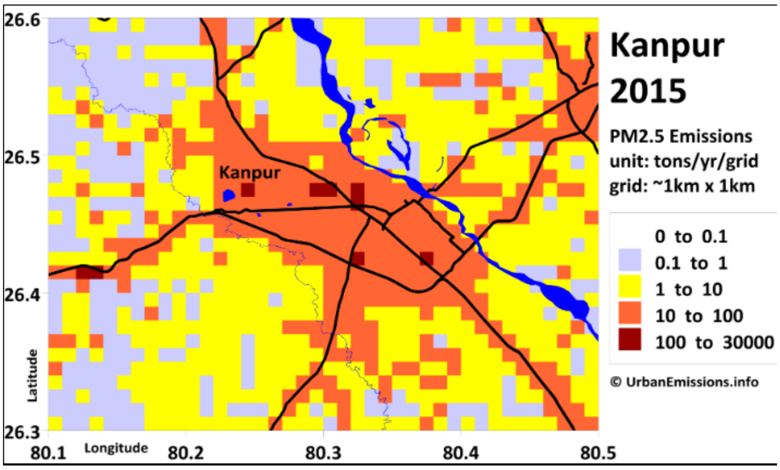

FIGURE 1. Study Area Map of Kanpur City

Anthropogenic Air Pollutants

Air pollutants may be harmful to human health and can come from both natural and man-made sources. Two examples of naturally occurring sources of pollution include dust from windblown volcanic eruptions and other similar events. The burning of fossil fuels in vehicles and other industrial machinery, the production of heat and electricity, the use of polluting fuels in residential heating and cooking, and the incineration of municipal and agricultural trash are all examples of human-caused processes and activities that contribute to the production of anthropogenic air pollutants. Particulate matter (PM), ozone (O3), sulfur dioxide (SO2), nitrogen dioxide (NO2), and metals are the most prevalent air pollutants. Pesticides in the air are another concern; for more information, see the section on pesticide pollution. One measure of air pollution is parts per million (ppm), while another, particulate matter (PM), describes the size of individual particles.

There may be population shifts in birds if they breathe in heavy metals. Certain species are particularly vulnerable in locations close to factories or cities. The impacts of heavy metal contamination on avian diversity are covered in the section on this topic.

MATERIALS AND METHODS

Avian Survey

Field surveys that used point count and line transect methods to increase detection performed best in the early morning and late evening. We made our observations with binoculars and referred to well-established field guides for species identification. Both migratory and resident species were surveyed numerous times to account for seasonality.

Air Pollution Data

Secondary data on air pollutants like PM2 were provided by government organizations' pollution monitoring stations. $_5$, PM_{10}, SO_2, and NO_x. The research locations were categorized into zones of high, medium, and low pollution based on these statistics.

Data Analysis

Avian diversity was evaluated using species richness, Simpson's dominance index, Shannon-Wiener diversity index, and evenness metrics. Comparative studies across pollution gradients were used to identify patterns in the composition of communities..

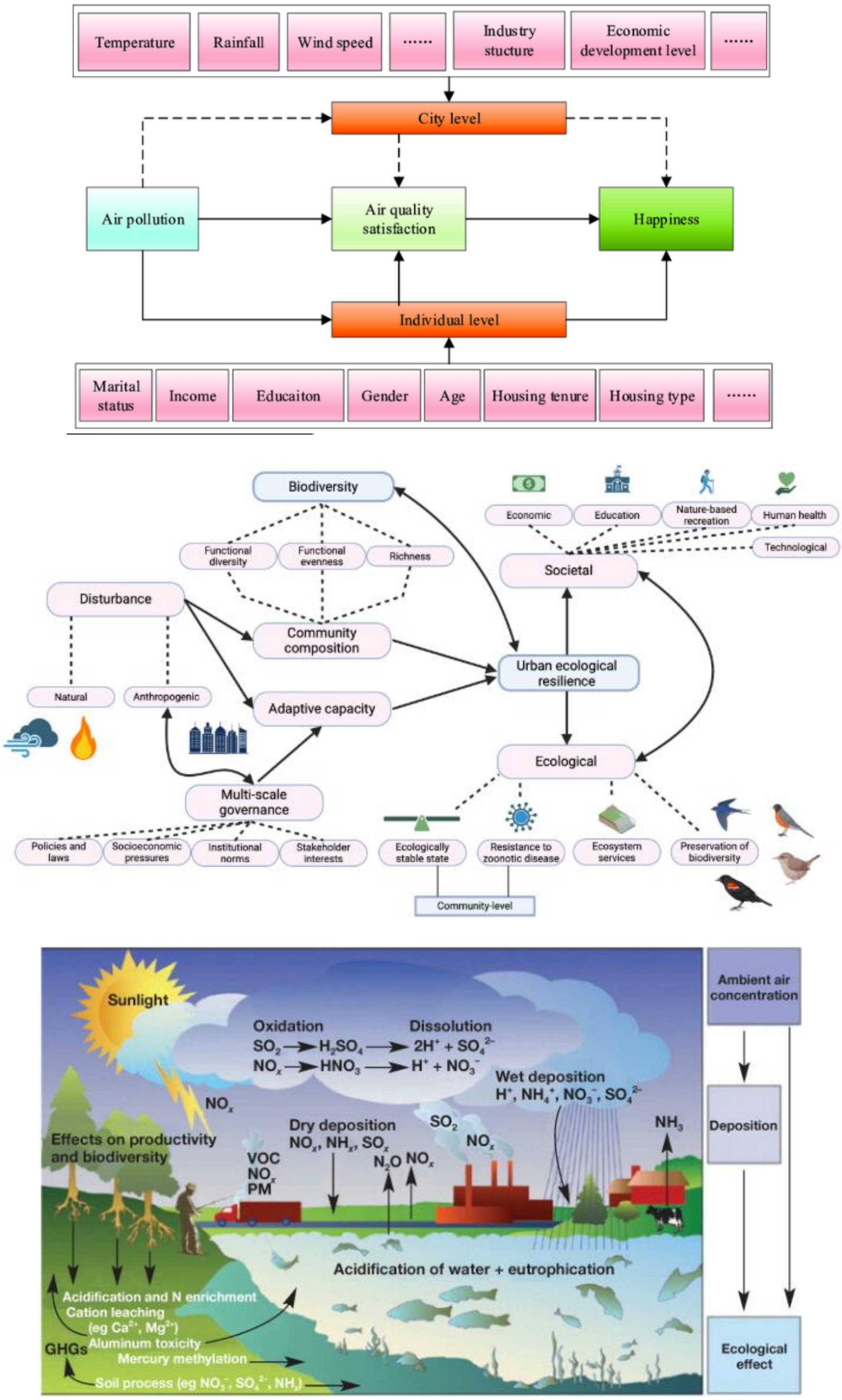

FIGURE 2. Conceptual Framework: Impact of Industrial Air Pollution on Avian Diversity

RESULTS

The research area contained a wide variety of bird species, but the locations they examined varied significantly. The species richness and diversity values were lowest in industrial zones. House Crows, Rock Pigeons, and Common Mynas were the most common generalist and pollution-tolerant species in these communities.

There was a reasonable amount of variety in urban regions, but a greater number of species, especially migratory and insectivorous ones, were found in peri-urban zones. In highly polluted regions, delicate wildlife like woodpeckers, warblers, and certain raptors were either not seen at all or were found in very low numbers.

Birds' behavior changed in close proximity to industrial areas as well, as evidenced by altered foraging patterns, increased vocalization stress, and decreased nesting success. These findings point to sub-lethal consequences of air pollutants.

TABLE 1. Avian Species Recorded Across Pollution Zones of Kanpur

S. No.	Common Name	Scientific Name	Feeding Guild	Industrial Zone	Urban Zone	Peri-urban Zone
1	House Crow	Corvus splendens	Omnivore	✓✓✓	✓✓	✓
2	Rock Pigeon	Columba livia	Granivore	✓✓✓	✓✓	✓
3	Common Myna	Acridotheres tristis	Omnivore	✓✓	✓✓✓	✓✓
4	House Sparrow	Passer domesticus	Granivore	✓	✓✓	✓✓✓
5	Red-vented Bulbul	Pycnonotus cafer	Frugivore	–	✓	✓✓
6	Indian Robin	Copsychus fulicatus	Insectivore	–	✓	✓✓
7	Black Drongo	Dicrurus macrocercus	Insectivore	–	✓	✓✓✓
8	Spotted Dove	Spilopelia chinensis	Granivore	–	✓	✓✓
9	White-throated Kingfisher	Halcyon smyrnensis	Carnivore	–	–	✓✓
10	Coppersmith Barbet	Psilopogon haemacephalus	Frugivore	–	–	✓✓
11	Indian Peafowl	Pavo cristatus	Omnivore	–	–	✓
12	Oriental Magpie-Robin	Copsychus saularis	Insectivore	–	✓	✓✓

Legend: *– = Absent ✓ = Low ✓✓ = Moderate ✓✓✓ = High abundance*

TABLE 2. Average Concentration of Major Industrial Air Pollutants in Kanpur

Pollutant	Industrial Zone	Urban Zone	Peri-urban Zone	National Ambient Air Quality Standards
$PM_{2.5}$ (µg/m³)	78–110	55–75	30–45	60
PM_{10} (µg/m³)	160–240	120–160	80–110	100
SO_2 (µg/m³)	18–26	12–18	6–10	80
NO_2 (µg/m³)	42–58	30–42	18–25	80
CO (mg/m³)	1.8–2.6	1.2–1.8	0.6–1.0	4

Source: *CPCB / UPPCB monitoring stations (secondary data)*

TABLE 3. Avian Diversity Indices Across Pollution Gradient

Zone	Species Richness (S)	Shannon Index (H′)	Simpson Dominance (D)	Evenness (E)
Industrial Zone	7–10	1.12–1.38	0.46–0.52	0.48
Urban Zone	12–15	1.85–2.10	0.30–0.36	0.62
Peri-urban Zone	18–22	2.45–2.78	0.18–0.24	0.76

Interpretation: *Lower Shannon values and higher dominance in industrial zones indicate community simplification due to pollution stress.*

DISCUSSION

Impact of Air Pollutants on Avian Physiology

Pesticide use can also contribute to unintentional air pollution in both urban and rural areas. For example, in urban places, you could see a lot of aerosolized pesticides floating about since they are released straight into the air to control mosquito populations. Many pesticides that are released into the air in gaseous or particle form eventually fall to the ground because they are only partially volatile. Seasonality, patterns of agricultural use, weather, and wind all have an impact on pesticide concentrations in the air. The peak seasons for concentrations are, unsurprisingly, spring and summer. Previous studies have shown that 33% of pesticides in polluted air are insecticides, 26% are fungicides, and 40% are herbicides. Next, birds may be exposed to pesticides even after local applications due to the wind spreading contaminated air over long distances (Sanderfoot and Holloway, 2017). Despite the lack of conclusive evidence, this exposure route may impact birds' health and vulnerability to airborne pesticides.

Ecological Consequences

Insects and plants suffer from habitat degradation as a result of pollution, which in turn affects the availability of food. Birds that eat both plants and insects may feel the effects of acidic pollution on plants in a roundabout way. As a result of ecological imbalance, bird populations in contaminated zones tend to be simpler.

Birds as Bioindicators

Many have speculated that air pollution is to blame for the dwindling bird populations, but no one knows for sure (Lehikoinen, et al., 2019). Air pollutants that harm birds include sulphur dioxide (SO2), heavy metals, smoking, carbon monoxide (CO), and mixes of these and other emissions, as shown in a substantial amount of controlled and in situ study (Sicard et al, 2016). Birds undergo oxidative stress and refocus their efforts on detoxification and reactive chemical species scavenging when they are subjected to harmful air pollution (Sanderfoot, and Holloway, 2017). According to Sanderfoot and Holloway (2017), birds with high levels of stress were more likely to experience respiratory distress, illness, immunosuppression, behavioral changes, and possibly decreased reproductive success. "Recent epidemiological studies in the United States and Central Europe have shown substantial drops in bird populations, lending credence to the idea that air pollution has real-world effects on bird populations and lending credence to predictions made in the stress biology and toxicology literatures" (Sanderfoot and Holloway, 2017). The detrimental effects of persistent O3 pollution on both human and plant health are well recognized. "O3 exposure considerably decreased the population growth rates of upland bird species in the alpine zone above treeline," according to a research that looked at 25 years of data from the Giant Mountains in the Czech Republic. The effects of the weather were also taken into account in the research. The risk of O3 exposure increases with elevation, although the impact was not statistically significant for all species. According to the findings of a recent study that was based on data from the United States, improvements in air quality over the past forty years could have prevented the extinction of nearly 20%, or 1.5 billion, of the world's bird populations. Preventing the loss of alpha diversity, destruction of biodiversity and conservation efforts, and subsequent mass bird death due to emissions of major pollutants that promote O3 production is of the utmost importance.

Particularly troublesome in high-elevation places, where O3 is already present at harmfully high quantities, making long-term exposure difficult for birds, is the continuous decline of bird populations; reducing exposure to the gas could help halt this trend. Limiting emissions of O3 precursors in urban areas may lead to a reduction in the transmission of O3 and its precursors to high-elevation sites and a weakening of O3 exposures. The local O3 production is controlled by the VOCs-toNOx ratio, hence this countermeasure may not be sufficient on its own. Finally, although legislation aimed at decreasing emissions of major air pollutants may bring down NOx levels, volatile organic compound (VOC) emissions are mostly biogenic and are expected to rise in response to climate change. Moreover, in a perfect world, lowering emissions of anthropogenic precursors might lead to higher exposures to ozone. The exposure to O3 is increased in high-elevation places due to the significant contribution of stratospheric O3. Therefore, lowering O3 exposures is challenging, air pollution laws are often ineffective, and lowering precursor emissions of O3 may have no impact at all if atmospheric chemistry processes are ignored. Reducing emissions of pollutants is not enough; other measures are needed.

Remedial and Conservation Strategies

There has to be a multi-pronged strategy for bird variety protection in industrial cities. Promoting cleaner industrial technology and enforcing stricter emission control regulations are crucial. Planting verdant belts around developed areas may reduce noise and air pollution and provide birds a place to call their own.

Protecting peri-urban areas, restoring wetlands, and planting native trees are all examples of biodiversity-friendly infrastructure that should be a part of urban development. Bird conservation efforts may be boosted by public awareness campaigns and citizen science projects. Environmental impact evaluations should include regular ecological monitoring..

Urban environments

One of the most significant forms of urban pollution, according to Sanderson and Holloway (2017), is air pollution, which has a negative effect on the overall health and well-being of bird species. Birds are particularly susceptible to air pollution due to the efficiency with which their respiratory systems absorb airborne pollutants (Brown et al., 1997). When birds breathe in polluted air, Sanderson and Holloway (2017) say that they may experience a variety of symptoms like illness, difficulty breathing, increased stress and detoxification efforts, immunosuppression, behavioral abnormalities, and lower reproductive success. Because it increases oxidative stress and decreases thyroid function, urban air pollution is bad for bird populations. In a controlled inhalation experiment involving common urban pollutants (benzene, toluene, NO2, and SO2), American kestrels demonstrated considerably reduced thyroid function and increased hepatic EROD (ethoxy resorufin O-demethylase) levels in response to exposure to polycyclic aromatic hydrocarbons (PAHs). Exposure to urban nitrogen oxide (NOx) has a significant impact on the plasma antioxidant capacity of four common passerine species in southern Sweden (Salmon et al 2019). For tree sparrows (P. montanus), oxidation damage was also higher in these urban areas. Birds such as the common house sparrow (P. domesticus) are great bioindicators for harmful airborne pollutants due to their worldwide distribution and capacity to detect oxidative stress in both urban and rural locations. When compared to their rural counterparts, house sparrows (P. domesticus) living in cities have lower total antioxidant capacity and levels of hemoglobin.

Industrial areas

Local biodiversity may be in jeopardy due to the persistent discharge of pollutants into the environment from certain industrial processes. For instance, ferri et al. (2018) cites research out of Canada's Athabasca oil sand region that found some bird species were more susceptible to mining-related air pollution. Tree swallows consumed polycyclic aromatic compounds (PACs) after being exposed to them in the air (Fernier, et al. 2018a).

"Thyroid function was altered in 14-day-old nestlings exposed to mining sites compared to non-mining sites" (Fernie et al., 2019). Additionally, this exposure was linked to poorer body condition, stunted growth, and reproductive success (Fernie, et al., 2018b)." The effects of polycyclic aromatic hydrocarbon (PAH) exposure in adult birds are extensive and include embryonic abnormalities and mortality, reduced egg production and hatching, increased desertion of clutches or broods, stunted development, increased organ weight, and a multitude of biochemical responses.

The effects of high amounts of perfluoroalkyl acids (PFAAs) at various distances from a fluorochemical factory in Belgium were examined in another study. In eggs deposited by wild birds, scientists discovered the greatest amounts of PFAAs ever observed near the plant site. When the quantity of perfluoro decanoic acids (PFDAs) is high, it has been shown that overall breeding success drops, egg laying starts earlier, and the thickness of the eggshell is affected by certain perfluorinated carboxylates (PFCAs) and perfluorinated sulfonates (PFSAs). Nevertheless, more investigation is necessary due to the discovery of some reproductive harm.

CONCLUSION

According to the findings of the research, industrial air pollutants have a major impact on the biological variety of birds in Kanpur. This has resulted in a decrease in the number of species, a change in the composition of the community, and the predominance of pollution-tolerant species in areas that are heavily contaminated. Birds are sensitive to pollution in the atmosphere, which makes them good indicators of the health of the urban environment. Not only is it vital for the protection of birds, but it is also essential for the maintenance of healthy urban ecosystems to address the issue of air pollution via the implementation of integrated policies, technological innovation, and habitat restoration.

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