

## Effects of Air and Noise Pollution on Urban Bird Populations: Implications for School-Level Environmental Studies in India

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### Abstract

The urban growth which has occurred throughout India has created two different ecological problems which remain mostly hidden because of two different problems which include deteriorating air quality and escalating outdoor noise levels. Birds which scientists use to assess environmental conditions face significant danger because of the combined pressures which affect their environments. The research studies how air pollutants which include fine particulate matter (PM<sub>2.5</sub>) and nitrogen dioxide and polycyclic aromatic hydrocarbons impact avian physiology and reproduction and immune function within urban environments. The investigation reveals how human-generated noise interferes with bird communication patterns while it modifies their singing behavior and diminishes their ability to reproduce. The research article presents its evidence through peer-reviewed studies and Indian regulatory agency data to show how Indian cities which exceed World Health Organization air quality standards face significant air pollution problems. The final section discusses practical implications for school-level environmental studies, arguing that bird monitoring and soundscape observation can serve as accessible, curriculum-linked tools for young learners. The implementation of urban bird studies into school science programs creates environmentally educated citizens who possess knowledge and observational skills which India needs to develop as its urban areas expand.

**Keywords:** air pollution, India, environmental education, avian ecology, urban birds, noise pollution

### I. Introduction

The pre-dawn soundscape from a few years ago contained sparrows, mynas, and parakeets which performed as a musical group. The present day shows a reduction of that earlier musical grouping. The birds remain present in their location but only a small number of species visit while some birds produce weak sounds in areas near active roadways. The statement does not function as artistic writing. The statement operates as an ecological indicator which scientists worldwide have studied for several decades.

Birds function as bioindicators because their physical presence provides evidence about the condition of their surrounding environment. Birds demonstrate population changes when air quality decreases or noise levels increase. Birds exhibit different behaviors, they change their vocalizations, they leave their nesting areas, or their population numbers drop. The rapid urbanization process in India, which has forced millions of people into heavily polluted urban centers, creates ecological problems that affect both bird populations and the ecosystems that depend on birds for seed dispersal and insect control and pollination.

Indian cities experience population growth which exceeds the rate of infrastructure development planning. The Central Pollution Control Board (CPCB) of India has reported that

multiple cities throughout the country surpass both national ambient air quality standards and the more stringent World Health Organization (WHO) guidelines in every consecutive year since its establishment. The chemical pollution problem arises from road traffic and industrial activity and construction dust and the open burning of waste materials. The Indian urban environment experiences continuous noise level increases which arise from vehicle honking and construction activities and loudspeaker sounds and industrial processes.

The article studies two things through which air and noise pollution impact bird life research and Indian cities and their impact on environmental education. The case for urban bird observation as a mandatory subject in Indian schools exists because it has both scientific backing and practical implementation.

### II. The Urban Environment as an Ecological Stage

Understanding the challenges faced by birds requires knowledge about the ecological variations between urban areas and unbuilt natural environments. Urban ecosystems develop through two main factors which include fragmented green spaces and transformed food webs along with street lighting and degraded acoustic and air quality

environments. Grimm et al. (2008) described cities as novel ecosystems which show extensive human-induced changes to ecological systems that result in new wildlife selection pressures which differ from pre-industrial times.

Birds in urban areas display lower diversity levels when compared to the bird populations found in adjacent forest and wetland ecosystems. Generalist species — pigeons, house crows, common mynas — thrive, while specialist insectivores, migratory warblers, and wetland-dependent birds disappear. The drivers of this simplification are multiple: habitat loss, food availability, and predation all play roles. The scientific community has started to recognize pollution which includes chemical and acoustic elements as an important environmental problem that has not received enough attention.

Research studies use urban birds as models because these birds establish links between two environmental issues which people typically study as separate problems. Air pollution research focuses primarily on human health outcomes. Noise pollution research tends to address annoyance and sleep disruption in people. Birds serve as optimal environmental assessment tools because they live between two environmental stress factors which they can detect through observable reactions to both stress factors. Environmental assessment for any monitoring system which ranges from national networks to school gardens can use birds as indicators for their programs.

### III. Air Pollution and Urban Birds

#### 3.1 Physiological Impacts on Avian Systems

Birds have a different breathing system than mammals. Their respiratory system includes a series of air sacs that create a continuous, unidirectional flow of air through the lungs — a design that makes gas exchange remarkably efficient but also means that pollutants penetrate deeper into lung tissue with less filtration than in mammals. Fine particulate matter, classified as PM<sub>2.5</sub> because the particles are smaller than 2.5 micrometers in diameter, can reach these air sacs directly, bypassing much of the body's filtering infrastructure.

Chronic exposure to PM<sub>2.5</sub> causes inflammation in avian lung tissue, impairs surfactant production, and in severe cases produces lesions similar to those documented in humans with long-term occupational dust exposure. Isaksson (2015) reviewed evidence that urban birds across multiple species show elevated oxidative stress markers — their cells sustain more molecular damage from reactive oxygen species generated as the body metabolizes pollutants. This is not a minor biochemical detail. Oxidative stress shortens

lifespan, reduces reproductive output, and weakens immune responses to infection.

Nitrogen dioxide (NO<sub>2</sub>) and sulfur dioxide (SO<sub>2</sub>) exist in Indian cities because of vehicle and industrial operations. These pollutants cause damage to bird mucus membranes while disrupting their immune systems just like they do to human beings. The combustion of fossil fuels and biomass creates polycyclic aromatic hydrocarbons (PAHs) which North India's stubble burning practice releases during winter months to create severe air pollution. Birds face endocrine disruption because of the hazardous substances that stem from fossil fuel and biomass combustion. Disrupted hormone cycles can delay breeding, nestling, and alter nestling defence reactions. Each of these effects is individually significant. The two effects together create a continuous physical attack that threatens the biological systems which birds need to stay alive and reproduce.

#### 3.2 Reproductive and Developmental Consequences

The most ecologically important pollution effects occur during the reproduction process. A compromised breeding season affects not just the individual adults but the trajectory of entire local populations. Urban birds face two challenges which include fragmented nesting areas and lower quality food sources but toxic air pollution makes their situation much worse.

Lead contamination which people have connected to urban soils near busy streets has been found in feathers and blood of urban birds including house sparrows that live in European and South Asian city environments. Lead exposure at sub-lethal levels leads to neurological damage in chicks which affects their ability to learn because the species needs to acquire songs and foraging routes and predator recognition through observing adult behavior. A chick that cannot learn well enough in its first year has sharply reduced survival odds.

The house sparrow (*Passer domesticus*) which once populated Indian cities throughout India has experienced a major population decline in urban areas during the past 20 years. Multiple studies attribute this problem to food scarcity and habitat loss but air pollution decreases the arthropod prey populations that sparrow chicks need during their first weeks of life which acts as an additional cause of the problem. Chace and Walsh (2006) discovered that trophic cascades which occur when pollution decreases bird prey through indirect methods represent one of the most hard-to-detect environmental impacts which leads to major ecological consequences.

#### IV. Noise Pollution and Avian Communication

##### 4.1 The Signal-to-Noise Problem

Birds use vocalizations for their vital ecological activities which include mate attraction and territory defense and offspring coordination and predator alarm signaling. Song is not decoration because it serves as the main method which birds utilize to control their social interactions. Rising ambient noises create a decrease in avian communication signal-to-noise ratio which produces effects that impact their behavior and reproduction and finally their population patterns.

Slabbekorn and Peet conducted a landmark study which appeared in Nature to study the acoustic patterns of great tits *Parus major* through their songs which they performed in both noisy urban areas and peaceful urban spaces throughout Europe. Urban birds produced their songs at higher minimum frequencies which remained above the levels found in less noisy environments. The logic is direct: low-frequency sounds get masked by traffic noise to a greater extent than high-frequency sounds. Birds that cannot make sounds will not be able to attract partners or win territorial battles because natural selection will

favor birds that produce higher-pitched sounds in loud environments according to the process of natural selection which functions over short time periods.

Researchers have proven this frequency modification through studies on more than twenty species from different regions around the world. Francis et al. discovered through a North American research project that noise pollution operates as a barrier which protects certain bird species from developing in noisy regions because their natural songs have low-frequency components which match with traffic noise. The Indian cities experience heavy acoustic pressure on their bird populations because traffic noise levels consistently reach 70 to 80 decibels during peak times which exceeds the World Health Organization's recommended 55-decibel outdoor limit for daytime hours.

As shown in Figure 1, the relationship between noise exposure and avian community composition follows a clear directional pattern: as noise levels increase, species richness declines and community composition shifts toward species with inherently higher-pitched or noise-tolerant vocalizations.

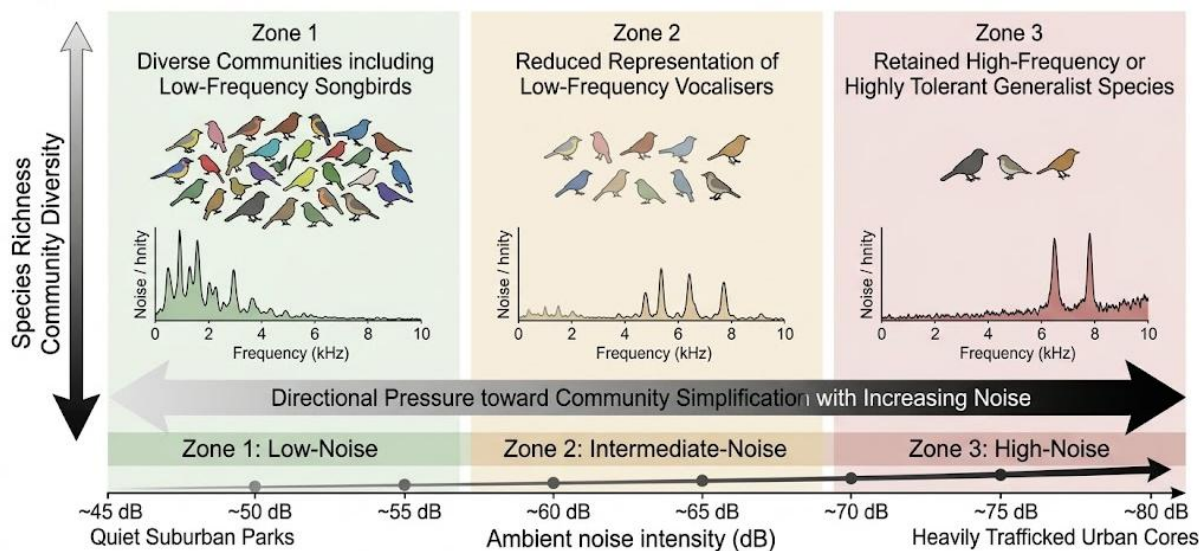


Figure 1: Conceptual Model of Noise Pollution Filtering on Urban Bird Communities

The figure shows a conceptual flowchart which demonstrates how rising noise levels between 15 decibels and 105 decibels eliminate different bird species from urban areas. The horizontal axis demonstrates how noise pollution levels increase from quiet suburban parks which produce sounds at approximately 45 dB to busy urban centers which reach 80 dB sound levels. The vertical axis shows

both species richness and community diversity. The three zones display their effects on animal species the first zone protects all types of animals the second zone protects most animals but loses some low-frequency vocalizing species while the third zone permits only high-frequency and generalist species to remain. The arrows show how increasing noise levels lead to a pattern which simplifies the

existing community structure. The model uses empirical data which Francis et al. (2011 PLOS ONE) and Slabbekoorn and Peet (2003 Nature) discovered.

#### 4.2 The Lombard Effect and Its Biological Costs

Birds demonstrate two responses to environmental noise, which include singing at higher frequencies and producing louder sounds. The Lombard effect represents an automatic response to environmental noise, which causes people to speak louder. The researchers showed that birds possess an automatic mechanism which lets them handle loud noises by releasing their normal vocal volume. The practice of singing at higher volumes comes with significant energy costs that musicians need to pay. Birds use their metabolic energy for singing which they should have used to search for food and protect their health and care for their young. Birds need to expend extra energy for communication purposes in areas with high noise levels which creates an ongoing biological cost that combines with the various stressors of urban living.

The researchers found that chronic noise exposure increases stress hormones in birds, which leads to reproductive and survival problems that resemble the results of air pollution studies. The study found that house sparrows which lived in areas with high traffic noise exposure showed higher levels of corticosterone, which is the main avian stress hormone. The body experiences multiple negative effects when corticosterone levels remain elevated for extended periods. A city filled with noise creates multiple obstacles that hinder birds from existing there because they must deal with the city sounds and air pollution. The combined effects of two stressors create a stronger impact which exceeds the effects made by either stressor.

## V. Indian Cities: A Specific and Pressing Crisis

### 5.1 Air Quality Realities on the Ground

The air quality problem in India currently exists as a well-recorded issue which presents serious environmental consequences. The WHO's 2021 Global Air Quality Guidelines set the recommended annual average PM<sub>2.5</sub> concentration at 5 µg/m<sup>3</sup>. The CPCB's National Ambient Air Quality Status report for 2019 found that virtually every monitored Indian city exceeded this figure by wide margins. The annual PM<sub>2.5</sub> concentration in Delhi reached approximately 98 µg/m<sup>3</sup> during 2019 which marks a level that exceeds the WHO guideline by nearly twenty times. Cities throughout the Indo-Gangetic Plain which includes Lucknow and Kanpur and Patna rank among the topmost polluted cities worldwide according to this measurement.

The following information represents actual data records. The birds that inhabit these airsheds throughout their entire life cycle which includes nesting and raising young and foraging through polluted air experience continuous particulate matter and NO<sub>2</sub> and SO<sub>2</sub> and PAHs exposure which their bodies lack the ability to handle. The WHO's 2021 guidelines document establishes that PM<sub>2.5</sub> levels which Indian cities maintain throughout their streets lead to serious health problems which affect all vertebrate species not just humans.

As illustrated in Figure 2, when PM<sub>2.5</sub> annual averages in major Indian cities are placed against the WHO 2021 guideline, the gap is stark. For birds that spend their entire lives breathing this air, the cumulative physiological burden across a breeding season or a lifetime is difficult to overstate.

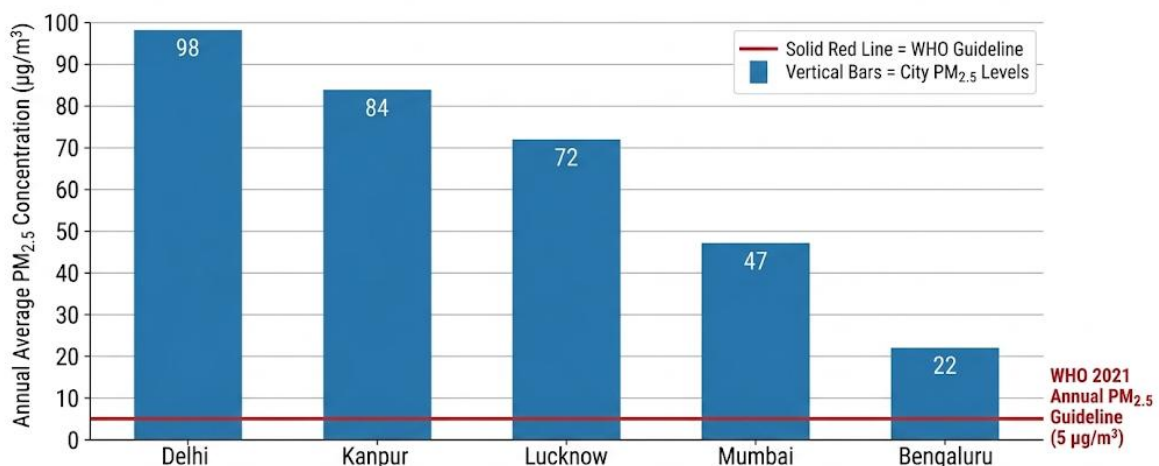


Figure 2: Annual Average PM<sub>2.5</sub> Concentrations in Selected Indian Cities Compared to WHO 2021 Guidelines

This bar chart compares annual average PM<sub>2.5</sub> concentrations ( $\mu\text{g}/\text{m}^3$ ) for five major Indian cities — Delhi (~98), Kanpur (~84), Lucknow (~72), Mumbai (~47), and Bengaluru (~22) — against the WHO 2021 annual average PM<sub>2.5</sub> guideline of  $5 \mu\text{g}/\text{m}^3$ , represented as a horizontal red reference line. The guideline is exceeded by all five cities because North Indian cities in the Indo-Gangetic Plain display pollutant levels which reach 15 to 20 times the permitted limit. The chart shows a distinct north-south air quality pattern which shows southern metros having lower air pollution levels than northern regions yet still experiencing major health risks from their existing pollution levels.

### 5.2 Bird Diversity Trends in Indian Cities

Bird population research through citizen science eBird and academic studies show existing patterns despite ongoing development of Indian city bird population studies. The study conducted by Kumar and Joseph (2019) discovered that Indian cities experience a strong correlation between bird species richness and three factors which include green cover and proximity to water bodies and distance from high-traffic roads. Urban areas that experience the highest pollution levels contain the fewest species which exist as a small group of adaptable generalists who can thrive in any city environment. The urban centers of cities which used to support diverse bird populations now exist as environments controlled by common mynas and rock pigeons. The process of homogenization leads to actual environmental damage. The disappearance of a species results in the disappearance of its essential activities because they include insect control and pollination and seed distribution. Birds that still inhabitate a city enable the evaluation of ecological health yet the city shows a basic ecological system that lacks diverse species which those birds had previously established. Narango, Tallamy, and Marra (2018) demonstrated this kind of functional impoverishment in urban systems — where apparent abundance of a few species masks the collapse of broader ecological guilds that underpin healthy ecosystems.

## VI. Implications for School-Level Environmental Studies in India

### 6.1 Why Birds Work So Well for Schools

The Indian educational system struggles to teach environmental studies because students cannot connect their theoretical textbook learning with their actual environmental observations. Students can read about climate change and biodiversity loss in their coursebooks but they rarely get to observe and measure environmental change in their own

neighborhoods. Urban birds close this gap more naturally than almost any other subject.

Birds can be seen and heard throughout the entire year. They need no special access to national parks or specialized laboratory facilities. A school garden, a roadside tree, or a patch of urban park will do. The way birds behave in different areas lets students observe their real-world results because students can see how different areas affect birds through their movements. The student uses ecological data when observing fewer sparrows this year compared to last year and when he hears different crow calls at the main road versus the back lane.

Rajagopalan (2011) presents his environmental studies textbook as a vital resource which defines Indian environmental literacy requirements through local ecological knowledge. Environmental science needs observable local environmental science entrance points which birds provide. They function as public resources which all people can access without incurring any costs.

### 6.2 Practical Activities for Classrooms and Schoolyards

A complete bird monitoring program at schools needs no special equipment for its operation. The point count method requires students to remain at a specific site for a defined duration to document all birds which they observe or hear. Chace and Walsh (2006) state that urban bird point counts enable researchers to track changes in bird communities over time when they conduct their studies at regular intervals which makes this method appropriate for extended school research projects that produce significant authentic results.

Schools situated close to busy roads can conduct a study that compares bird species and vocalization patterns between different locations which range from peaceful gardens to areas with heavy street traffic. The fundamental logic of this research method mirrors the work of Francis et al. (2011) who conducted their scientific research through published studies which demonstrated how classroom education connects with actual scientific research techniques. The students can use free smartphone decibel meter apps to assess noise levels at all survey locations which helps them establish a direct connection between their noise studies and their current acoustic masking educational content.

Schools can employ soundscape recording as an efficient assessment method which requires no expenses other than what a person spends for their smartphone. People can analyze recordings from school garden dawn sessions through a week by week and month by month and year by year comparison process. Students can observe which

bird species start calling first and which ones stop vocalizing after traffic congestion reaches its highest level and they can see how the bird chorus transforms throughout different times of the year. The research presented by Blickley and Patricelli (2010) demonstrated that urban acoustic monitoring at the community level generates scientific data which enhances scientific research and school-based acoustic monitoring can contribute data to create such databases.

### 6.3 Linking Bird Studies to the School Curriculum

The National Curriculum Framework of India promotes inquiry-based learning together with local environmental learning at upper primary and secondary educational levels. Bird monitoring exists as a fundamental part of Environmental Studies at primary school while it extends to Biology and Geography and Science subjects at higher educational levels. The organized bird observation program provides a teaching method that enables students to learn food webs population ecology biodiversity indices bioindicators and the scientific method through more effective educational experience than traditional textbook teaching methods.

The annual report of the Ministry of Environment Forest and Climate Change from 2022 recommends that schools should implement environmental monitoring programs to fulfill India's obligations under the Convention on Biological Diversity. Schools that establish regular bird monitoring programmes contribute, in a small but real way, to the national biodiversity knowledge base — particularly through platforms like eBird, which aggregates citizen observations into scientifically usable, spatially referenced datasets. The school network which performs regular point counts throughout the city will create data that professional monitoring programs cannot afford to gather through their own methods.

## VII. Conclusion

The urban environment provides birds with a message. The bird communities of Indian cities show two species loss and three song alterations and three hidden physiological costs which develop through breeding cycles and their entire lifespan. The changes which exist in this area remain so faint that most pedestrians will not be able to detect them. Environmental education needs to establish visibility for these solutions which now stay hidden because of their current state.

Birds experience two types of pollution through air pollution and noise pollution which scientists have found to produce harmful effects that

disrupt urban ecosystem health. Schools in India should provide students with knowledge about urban environments which will exist as future citizens who will control city planning and management.

Bird watching is not a hobby for the leisured few. Urban ecology requires students to use their curiosity and notebook skills to perform environmental monitoring through this activity. The most effective way for schools to promote environmental citizenship with young people requires schools to provide young people with tools which enable them to watch and measure and protect natural ecosystems. The first step to achieve this goal needs minimal financial resources.

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