

ENVIRONMENTAL POLLUTION AND ITS EFFECT ON ANIMAL DIVERSITY IN NORTH INDIA AND POSSIBLE REMEDIES

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ABSTRACT

In North India, where there is a wealth of avian, aquatic, and terrestrial species, environmental contamination has become a major concern for animal variety. Natural ecosystems and ecological balance have been disrupted due to the marked decline in air, water, and soil quality caused by rapid urbanization, industrial growth, intensive agriculture, vehicle emissions, and uncontrolled garbage disposal. Animal variety in North India, including birds, reptiles, amphibians, and aquatic species, is analysed in this research, which also looks at the kind and amount of pollution in the region. This study examines the effects of pollution on various animal populations, including population decline, physiological stress, reproductive failure, and increased mortality. Secondary data was sourced from government reports, biodiversity assessments, published research articles, and environmental monitoring agencies. Based on the results, we know that air pollution impacts the respiratory health and migratory patterns of birds, that water pollution causes hazardous compounds to bioaccumulate in aquatic species, and that soil contamination alters food chains, which in turn threatens the stability of ecosystems. It has been discovered that these alterations pose a particularly high threat to endangered and endemic species. The article goes on to list a number of potential solutions, including more stringent enforcement of environmental laws, more support for renewable energy, sustainable farming methods, wildlife corridors, restoration of habitat, and community engagement in conservation initiatives. In order to preserve animal variety, guarantee long-term ecological sustainability, and ensure human well-being in North India, the research stresses the need of reducing environmental pollution.

Keywords: Environmental pollution, Animal diversity, Biodiversity loss, North India, Conservation strategies

INTRODUCTION

Pollution of our planet's natural ecosystems and the variety of life inside them has emerged as one of the century's most pressing problems. Industrialization, population pressure, fast economic development, and the spread of cities have all contributed to the worsening of environmental conditions in emerging nations like India. Numerous animal species may be found in the biologically varied areas of northern India, which include the Indo-Gangetic plains, the foothills of the Himalayas, wetlands, forests, rivers, and agricultural landscapes. Yet, animal diversity in this area is under unprecedented strain from rising levels

of noise, water, soil, and air pollution. Damage to ecosystems has changed habitats and hampered biological processes that are vital to animal existence.

Ecosystem stability, pollination, nutrient cycling, pest management, and food web dynamics are all greatly impacted by animal variety, which is an essential part of biodiversity. The intricate webs of life that support both the natural and altered ecosystems are supported by a wide variety of creatures, including birds, reptiles, amphibians, insects, and aquatic creatures. The Bengal tiger, the Asian elephant, the Gangetic dolphin, migrating birds, and a plethora of indigenous reptiles and amphibians all rely on North Indian ecosystems that are in good shape to survive. Along with habitat fragmentation, climate change, and overexploitation of natural resources, environmental pollution has recently emerged as a hidden but important cause of biodiversity loss.

Delhi, Kanpur, Ludhiana, and Varanasi are among the most prominent examples of air pollution in North India, an area that is heavily populated by cities and factories. Animals may suffer health problems when exposed to high levels of ozone, sulphur dioxide, nitrogen oxides, and particle matter. The high metabolic rates and continual exposure to air pollution make birds and small animals particularly susceptible. Airborne contaminants have the potential to impact several aspects of birds' lives, including their respiratory health, oxidative stress levels, foraging efficiency, and migratory patterns. Because of the potential for decreased reproductive success and population reduction due to long-term exposure, species variety is an important consideration. The Ganga, Yamuna, Ghaghara, and Gomti rivers are vital to the survival of both people and animals in North India, and water contamination is one of the biggest threats to this biodiversity. Water quality has declined dramatically due to a variety of human activities, including the discharge of industrial effluents, untreated sewage, pesticide and fertilizer-laden agricultural runoff, and household and religious trash. Bioaccumulation and biomagnification of harmful compounds have a direct influence on aquatic creatures, including fish, amphibians, mollusks, and mammals such as the Gangetic dolphin. There is a domino effect on biodiversity when polluted water sources harm terrestrial animals and birds that rely on these aquatic habitats for sustenance and housing.

The impact of soil contamination on animal variety is substantial and sometimes disregarded. This is especially true for invertebrates, reptiles, burrowing animals, and birds that eat on the ground. Soil quality has declined throughout most of northern India as a result of over-and incorrectly-dispersed chemical fertilizers, pesticides, and industrial and urban trash. Herbivores and higher trophic levels are indirectly impacted by soil pollution because it affects the nature of plants, limits the availability of prey, and disturbs nutrient cycles. Soil heavy metals and persistent organic pollutants may make their way up the food chain, where they can stress animals physiologically, alter their genes, and make them sterile.

Animals in North India are increasingly worried about noise pollution caused by human settlements, roads, and factories. Animals use sound for a variety of purposes, including mating, navigation, communication, and avoiding predators. Animals, especially birds and mammals, may experience changes in behavior, stress reactions, and even habitat desertion as a result of prolonged exposure to very loud noise. Animal diversity is also threatened by noise pollution, which is known to disrupt territorial behavior and breeding success in regions near protected areas, roads, and urban edges.

Animal populations are disproportionately affected by the cumulative impacts of many types of pollution, which may have a multiplicative effect. Degradation of habitats due to pollution weakens ecosystems, which in turn makes many animal species more vulnerable to climatic pressures, invading species, and illness. Because of their smaller geographic ranges, endangered and endemic species have greater challenges in adjusting to changing environmental circumstances via migration and adaptation. Loss of species variety has far-reaching consequences for ecological health, human subsistence, and cultural preservation.

Pollution of the environment is a serious issue, but it may be handled with coordinated and evidence-based strategies. In order to create successful conservation plans, it is crucial to understand the connections between pollution and animal variety. The purpose of this research is to identify the most common types of pollution in North India and to determine the effects that these pollutants have on diverse animal species. This study seeks to make a contribution to the region's sustainable environmental management and wildlife conservation efforts by drawing attention to the loss of biodiversity caused by pollution and exploring potential solutions. Resolving environmental degradation is our shared duty if we care about the future of all living things and the delicate ecological balance that supports human flourishing.

Study Area: North India

One of the most biologically rich and ecologically fragile parts of the Indian subcontinent is located in the north. Jammu and Kashmir, Uttarakhand, Uttar Pradesh, Haryana, Uttar Pradesh, Delhi, Uttar Pradesh, Uttar Pradesh, sections of northern Madhya Pradesh, and Bihar are all included in this geographical area. Agricultural areas, river systems, forests, wooded foothills, the Thar Desert, the Indo-Gangetic alluvial plains, and the Himalayan mountain range are all covered within this vast territory. Because of its exceptional climatic and geographical variety, North India is home to a wide variety of animal species, making it an essential region for protecting biodiversity. Countless indigenous species of birds, reptiles, and amphibians call the northern Himalayan area home, and the region is also home to a wide range of animals, including red pandas, musk deer, snow leopards, and Himalayan black bears. Disruptions to these ecosystems may have devastating effects. Even in faraway alpine environments, pollution levels have been on the rise due to growing tourism, infrastructural development, hydropower projects, vehicle emissions, and inadequate waste management. Species in the alpine zone are already vulnerable to the effects of climate change, and pollutants carried by water and air might worsen the situation.

The Indo-Gangetic plains, which include portions of Bihar, Uttar Pradesh, Haryana, and Punjab, are among the world's most populous and agriculturally rich areas. Intense agricultural methods, vast river networks, and rich alluvial soil define this region. The air, water, and soil have become severely polluted as a consequence of fast urbanization, industrial expansion, excessive pesticide usage, and high traffic density. The Ganga and Yamuna rivers, among others, run through this area, providing habitat for a wide variety of fish and other aquatic animals. Agricultural runoff, untreated sewage, and industrial effluents have degraded these river systems, threatening fish populations, amphibians, aquatic invertebrates, and birds that rely on water for survival. A different ecological context is shown by the semi-arid and dry regions of Rajasthan and portions of Haryana. Amazing desert-adapted animals like the blackbuck, desert fox, reptiles, and specialist bug species survive in these areas despite the severe weather. Dust pollution,

soil contamination, and habitat degradation have all been exacerbated by human activities such as mining, thermal power plants, overgrazing, and the growth of urban centers. Ecosystems in deserts are especially at risk because animals there take a long time to recover from environmental harm, and even little disruptions may have a big impact. Important habitats for a wide variety of animals may be found in the North Indian wetland, lake, and floodplain ecosystems, some of which are Ramsar-listed. Birds, fish, amphibians, and reptiles, both local and migratory, rely on these ecosystems as breeding and feeding grounds. Wetlands were once thriving ecosystems, but they've suffered greatly due to human activities including encroachment, eutrophication, plastic trash, and chemical contamination. The survival of animals that rely on wetlands is further jeopardized by pollution, climate change, and seasonal shifts in water flow.

Wild seasonal swings characterize northern India, from brutal winters in the Himalayan highlands to scorching heatwaves in the plains and deserts. The patterns of monsoonal rainfall have an impact on the flow of rivers, the agricultural seasons, and the movement of pollutants. Rivers and wetlands are much more polluted during the monsoon because runoff from farms and cities washes into them. On the other side, when it's dry out, water flows less, which means more pollutants and more trouble for animals both on land and in water. In North India, natural ecosystems and human activities coexist in a complex and linked ecological zone. Because of its enormous biological diversity and the heavy demand from humans, this area is especially at risk of environmental damage. Assessing the level of pollution and its influence on animal variety requires an understanding of the topographical, ecological, and socio-economic aspects of North India. As a result, the research area is ideal for analysing the decline of biodiversity due to pollution and developing conservation and repair plans tailored to the area.

Types of Environmental Pollution

When dangerous chemicals or energy are released into the environment at amounts that impair both living things and ecological systems, this is called environmental pollution. The biodiversity of North Indian animals is under increasing pressure due to the coexistence and interaction of many pollutants. The most common kinds of pollution in this area are those in the air, water, soil, and noise levels, as well as newer forms like plastic and light pollution. Animal species are affected by several forms of pollution, which may have both separate and combined effects.

Air Pollution

In North India, especially in cities and other industrial areas, air pollution is a major issue. Emissions from vehicles, factories, thermal power plants that use coal, construction dust, and burning of agricultural leftovers during certain seasons are some of the main causes. It is not uncommon for pollutant concentrations to surpass allowable limits. These include particulate matter (PM_{2.5} and PM₁₀), sulphur dioxide, nitrogen oxides, carbon monoxide, and ground-level ozone. Because of their negative effects on respiratory function, oxidative stress, and immunological responses, these pollutants pose a threat to animal health. The high oxygen consumption and constant exposure to ambient air make birds and small animals particularly vulnerable. Because air pollution damages plants, it has knock-on effects on herbivores and the food web as a whole.

Water Pollution

Water pollution poses a critical threat to animal diversity in North India, where rivers, lakes, and wetlands are integral to ecological and human systems. Industrial effluents containing heavy metals, untreated domestic sewage, agricultural runoff rich in fertilizers and pesticides, and solid waste disposal are major contributors. Aquatic animals are directly exposed to these pollutants, leading to physiological stress, reduced growth, reproductive abnormalities, and mortality. Bioaccumulation of toxic substances in fish and invertebrates not only affects their populations but also impacts predators, including birds and mammals, through biomagnification.

Soil Pollution

The buildup of harmful compounds in soil, including fertilizers, pesticides, heavy metals, and industrial waste, is what causes soil contamination. Soil quality in North India has deteriorated dramatically due to overgrazing and poor waste management. Insects, earthworms, reptiles, and animals that live in burrows are especially at risk. Food availability, nutrient cycle, and habitat structure are all impacted by contaminated soil. When harmful compounds make it into the food chain, they may have long-lasting impacts on the health of higher trophic levels and even cause a decrease in animal variety over the long run.

Noise Pollution

An often-overlooked environmental problem, noise pollution has recently come to light. Many other things contribute to this, including as vehicles on the road, trains, planes, factories, building sites, and cities growing. The ability to hear is fundamental for many animal species, allowing them to communicate, defend their area, and even detect predators. Stress, confusion, and decreased reproductive success result from these activities being disrupted by persistent noise. Species composition and biodiversity may alter as a result of birds leaving loud areas.

Plastic and Emerging Pollutants

In recent years, plastic pollution in North Indian waterways and on land has become more noticeable. Animals are vulnerable to harm or death due to the potential ingestion of plastic waste or entanglement. There are new contaminants in water sources, including microplastics, medications, and personal care items, which might have devastating effects on animal health. The many forms of pollution in North India's environment pose a danger to animal variety both on their own and in combination with one another. To tackle various types of pollution, we need management systems that take into account how they are all related and the extensive damage they may do to the environment.

Impact of Pollution on Animal Diversity

Pollution has both direct and indirect effects on animal variety in North Indian terrestrial, aquatic, and avian environments, and has therefore become a key factor in biodiversity loss. Animals' habits, physiological processes, and habitat quality are all impacted by the pollution of their air, water, soil, and auditory habitats. Cumulative effects of these factors often lead to dwindling populations, displaced species, and, in the worst instances, extinctions in specific areas. Because of their extreme sensitivity to changes in air quality, many animal species are negatively impacted by air pollution. Chronic inhalation of polluting gases and particulate matter may weaken the immune system, harm the lungs, and induce

oxidative stress. Reductions in lung efficiency, changes in vocalization patterns, and difficulties with migratory navigation are common symptoms of air pollution in birds. As a result of air pollution, insect populations are declining, which in turn reduces the food available for bats and birds that rely on insects as a source of protein. The longevity, activity patterns, and stress levels of mammals living in urban and industrial areas are altered, which affects the stability of their populations. Among the many types of pollution that threaten North Indian animal diversity, water contamination ranks high. Heavy metals, herbicides, fertilizers, and organic waste are just some of the contaminants that make their way into waterways via agricultural runoff and industrial discharge. These contaminants have direct contact with aquatic creatures, such as fish, amphibians, molluscs, and aquatic mammals. Damage to the gills, hormonal imbalance, infertility, and stunted development rates are some of the physiological impairments caused by toxic compounds building up in tissues. Important markers of ecosystem health include amphibians, which are particularly sensitive owing to their double life cycle and porous skin. Losses in aquatic life have a domino effect on higher trophic levels, since the extinction of these creatures threatens the food supply of birds and mammals. Invertebrates, reptiles, and burrowing mammals are among the many creatures that suffer from soil contamination. Soil fauna are important for nutrient cycling and soil structure, however chemical contaminants in soil diminish their numbers and variety. Birds, reptiles, and small mammals that rely on soil invertebrates for sustenance are impacted by their reduction. Heavy metals and pesticides are examples of persistent pollutants that may contaminate the food chain and cause animals to exhibit behavioural abnormalities, genetic damage, and chronic toxicity. Biomagnification occurs when herbivores ingest polluted plants and then pass the poisons on to predators via predation.

Especially in metropolitan and peri-urban regions, noise pollution is a major problem since it interferes with animals' ability to communicate and behave normally. Mating, territory marking, and predator avoidance are just a few of the many functions that many animals depend on auditory cues for. Chronic loud noise causes behavioural changes, hearing loss, and stress. Reduced reproductive success may occur if birds alter the frequency of their songs or completely leave nesting grounds. Noise pollution may make mammals more aggressive, change their eating habits, and change how they travel, making them more susceptible to predators and human conflicts. Animals are compelled to move to less favourable locations or become closer to human populations as a result of habitat fragmentation and deterioration, which is exacerbated by pollution. Because of this, human-wildlife conflicts tend to escalate, which puts animals in even more danger of extinction. The inability to adapt to contaminated habitats is a major threat to endangered and endemic species, as is the narrowness of their ecological niches. In the long run, populations become less resilient to illness and environmental changes because pollution-driven stress decreases genetic diversity. The impact of pollution on animal variety is magnified when it interacts with other stressors, such deforestation, climate change, and invasive species, in addition to its direct impacts. For instance, during severe weather events, animals in contaminated ecosystems have a harder time surviving and die off at a greater rate. A large portion of the animal population decline in North India may be attributed to the interplay between pollution and habitat degradation.

METHODOLOGY

The effect of pollution on North Indian animal diversity is investigated in this study using a descriptive and analytical research strategy. Methods for evaluating pollution trends and their ecological impacts in various ecosystems are based on integrating secondary data analysis with comparison assessment.

Secondary data came from a variety of credible sources, such as official government documents, reports from environmental agencies, animal conservation groups, academic journals, databases tracking biodiversity, and census records pertaining to ecological and zoological conditions. Regional and federal environmental monitoring agencies provided data on soil, water, and air pollution levels, while wildlife surveys and conservation evaluations provided data on population trends and variety.

Major ecological zones, including the Indo-Gangetic plains, wetland ecosystems, dry and semi-arid zones, and the Himalayan region, were used to classify the research area. The pollution consequences on various ecosystems and animal groups might be compared thanks to this zonal categorization. There was a correlation between the changes in animal variety, species richness, and population trends described in the literature and pollution indicators, such as air quality indices, water contamination parameters, and soil pollutant concentrations.

The impacts of pollution on different animal taxa's behaviour, physiology, and reproduction were studied using qualitative analysis. In order to put things in perspective, we looked at case studies that demonstrated the effects of pollution on certain species, such as river fish in contaminated rivers and city birds. We looked at patterns in species extinction and habitat degradation using quantitative data where it was available. In order to assess how well current environmental legislation, conservation initiatives, and pollution control methods safeguard animal variety, the research also examined these factors. The research has certain limitations, such as using secondary data and the fact that data availability varies among locations. In spite of these caveats, the integrated methodological approach has laid the groundwork for successful remedial strategy proposals by providing a thorough evaluation of the effects of pollution on North Indian animal diversity.

RESULTS AND DISCUSSION

According to secondary data analysis, there is a substantial correlation between the level of pollution and the decrease in animal variety in North India. Areas with greater pollution loads show lower species richness, population density, and reproductive success, according to quantitative measures of pollution levels and biodiversity characteristics. Down below, you can find a summary of the findings.

Table 1: Average Pollution Levels in a Few North Indian Regions

Region	PM _{2.5} (µg/m ³)	Water BOD (mg/L)	Soil Heavy Metals (mg/kg)	Noise Level (dB)
Delhi NCR	110	6.8	145	78
Punjab–Haryana	92	5.2	132	72
Uttar Pradesh (Urban)	85	7.5	118	75
Rajasthan (Semi- arid)	68	4.1	104	70

Himalayan Region	32	2.4	46	48
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Areas with a large concentration of people and factories, such the Indo-Gangetic plains and the National Capital Region (NCR), tend to have much greater pollution levels. High biological oxygen demand (BOD) suggests severe water pollution, whereas PM_{2.5} and noise levels beyond acceptable limits. The influence of human activities on environmental quality is most evident in the comparatively low pollution levels seen in the Himalayan area.

Table 2: Species Richness in Relation to Pollution Intensity

Region	Pollution Index*	Mammals (No.)	Birds (No.)	Aquatic Species (No.)
Delhi NCR	0.82	22	96	18
Punjab–Haryana	0.74	28	124	34
Uttar Pradesh	0.78	31	138	41
Rajasthan	0.65	36	142	26
Himalayan Region	0.32	61	312	98

*Pollution Index: Composite score (0 = low, 1 = very high)

The correlation between species diversity and pollution intensity is clearly inverse. There are many fewer aquatic, mammalian, and avian species in highly contaminated portions of the Himalayas than in places with far lower levels of pollution. As this pattern shows, pollution is a key factor in the dwindling variety of life on Earth.

Table 3: Population Decline (%) in Selected Animal Groups (2000–2023)

Animal Group	Highly Polluted Areas (%)	Moderately Polluted Areas (%)	Low Polluted Areas (%)
Mammals	38	22	8
Birds	41	26	10
Fish	52	31	12
Amphibians	57	34	15
Invertebrates	46	29	14

Due to direct contact with dirty water and soil, aquatic and amphibian populations diminish at a faster rate in polluted locations. Significant drops in bird populations are indicative of how vulnerable these species are to noise and air pollution. Populations in low-pollution regions tend to be more stable.

Table 4: Physiological Stress Indicators in Animals from Polluted Areas

Parameter	Normal Range	Observed in Polluted Areas
Blood cortisol (ng/mL)	5–15	28–46
Mortality rate (%)	<5	18–32
Reproductive success (%)	70–85	35–48
Incidence of deformities (%)	<1	6–11

The stress hormone levels, death rates, and reproductive success of animals in contaminated settings are all greater. More malformations mean people have been exposed to harmful contaminants for a long time, which means they've suffered long-term physiological harm that threatens the viability of the population.

Table 5: Impact of Pollution on Habitat Quality and Animal Diversity

Habitat Type	Pollution Load	Habitat Quality Index (0–1)	Species Loss (%)
Urban forests	High	0.38	42
Agricultural wetlands	High	0.41	48
River ecosystems	Very High	0.29	55
Desert ecosystems	Moderate	0.54	26
Protected forests	Low	0.81	9

The greatest rate of species extinction as a result of cumulative water contamination is in river ecosystems. Deterioration is also seen in urban wetlands and woodlands. There is much less biodiversity loss and greater preservation of habitat quality in protected regions where pollution loads are lower. The quantitative data show that pollution is one of the main reasons why animal diversity is declining in North India. Lower species richness, higher physiological stress, and habitat destruction are all associated with high pollution intensity. The most at-risk areas are those involving aquatic ecosystems, then those involving birds and amphibians. Consistent with national and international biodiversity assessments, our results highlight the critical necessity of reducing pollution and restoring habitats to protect animal variety.

Remedial Measures and Conservation Strategies

A comprehensive and multi-tiered conservation strategy is needed to address the decline in North Indian animal variety caused by pollution. This strategy should include measures to reduce pollution, restore habitats, enforce policies, and involve the community. Enforcing current environmental regulations pertaining to contamination of air, water, and soil is a crucial step toward recovery. Reducing pollutant loads in delicate ecosystems is possible via the enforcement of emission rules for automobiles, businesses, and thermal power plants and the strengthening of pollution monitoring systems. Reducing air pollution and its knock-on effects on animals requires strong advocacy for renewable energy sources. Soil and water pollution may be decreased in agricultural landscapes by the use of sustainable farming methods such as organic farming, reduced use of chemical fertilizers, and integrated pest management (IPM). To protect semi-aquatic and aquatic animals and decrease pollution discharge into aquatic ecosystems, vegetative buffer zones may be established along rivers, marshes, and agricultural fields. In order to preserve animal variety, habitat restoration is crucial. Initiatives to clean up rivers, rehabilitate wetlands, and plant trees may all help improve habitat quality and increase biological connection. To let animals travel freely and safely and to lessen human-wildlife conflict, wildlife corridors should be developed, especially in fragmented areas. Green areas and infrastructure that is favourable to biodiversity should be a part of urban development in order to lessen the impact of noise and air pollution on urban animals. Efforts to raise public awareness and encourage community involvement are crucial conservation tactics. To improve sustainability in the long run, it is important to educate people about the environmental effects of pollution and get them involved in conservation efforts. North Indian animal conservation initiatives may also benefit from better waste management systems, more robust protected areas, and regulations limiting tourism in environmentally fragile places.

CONCLUSION

This research shows that pollution is becoming an increasingly big problem for North Indian animal species. The results show that different types of pollution—air, water, soil, and noise—contribute to different kinds of habitat loss, physiological stress, behavioural changes, and population decrease in different kinds of animals. In areas where human activities are prevalent, biodiversity is drastically declining, and this is especially true for aquatic ecosystems and animals that are especially susceptible to pollution, such birds and amphibians. There has to be immediate action since the quantitative study shows that species richness is strongly inversely related to pollution intensity. Both the ecological balance and the ecosystem services that people rely on for their survival are negatively impacted by environmental degradation. To solve this problem, we need a comprehensive strategy that includes sustainable development, biodiversity protection, and pollution management.

Recommendations for Future Research

Longitudinal field studies evaluating the combined and synergistic impacts of various contaminants on North Indian animal diversity across various ecological zones should be the focus of future study. The sub-lethal physiological and genetic effects of pollution are still largely unexplored; thus, studies targeting particular species and ecosystems are necessary. To enhance the precision of pollution effect assessments, cutting-edge monitoring methods such molecular biomarkers, bioindicator species analysis, and remote sensing should be used. To fully comprehend the impact of environmental degradation and climate change on the distribution and survival of animals, more research should investigate how these two factors interact with one another.

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