G.J.B.B., VOL.5 (1) 2016: 09-17 ISSN 2278 – 9103

GLOBAL JOURNAL OF BIO-SCIENCE AND BIOTECHNOLOGY

www.scienceandnature.org

Review Article

TERRESTRIAL AMBIENT POLLUTION: CONSEQUENCES ON BIRDS AND OTHER WILDLIFE

(Terres Poll Wildl)

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ABSTRACT
The terrestrial ambient environment is damaged by three prime entities atmospheric pollutants, noise and light. The present review highlights the consequences of such pollution on wildlife which has not received much attention in this regard. But while doing so it emphasises more on birds because these are the most exposed to the problems. It compares the consequences on birds with other wild animals and in this way tries to depict a clear picture of impacts on wildlife as a whole. In addition, it also provides recommendations to mitigate the problem, which are however, not only confined to birds but generalised for wildlife as a whole. It thus deals with a significant issue much relevant to the subject of human environment.

KEYWORDS: Atmospheric pollution, Effects, Light, Noise, Wildlife.

INTRODUCTION

Atmospheric pollutants, noise and excessive artificial lighting are the three most common entities that have been exerting negative consequences on the terrestrial ambient environment. Human health has been the primary concern in most of the air monitoring research-work that has been carried out (Gupta and Bakre, 2013). However, air pollution also severely affects wildlife but this aspect has received much less attention (Holder, 2015). A similar kind of problem is noise which is a unique evolutional selection pressure; exerting affects at both individual and population levels in wildlife (Slabbekoorn and Ripmeester, 2008). Anthropogenic noise propagates through natural ecosystems throughout the world and imposes pressures in their processes (Tennessen *et al*., 2014; Barber *et al.*, 2010). Its consequences have generated much interest but little is known about the impacts of noise on wildlife (Tennessen *et al*., 2014). This is a problem is predicted to increase with increasing human population growth (Babisch *et al*., 2005). Another issue that is expected to intensify due to population expansion is the negative impact of artificial lighting (Wise, 2007). Light pollution has in fact been an ecological issue for long and the problem is likely to increase with development in lighting technologies (Gaston *et al*., 2013). All the three agents have impacts that extend beyond mankind into the animal world. This is true for birds; especially in urban areas which are continuously exposed to toxic atmospheric chemicals, loud anthropogenic sounds and excessive artificial lighting at nights. However, these perform important ecosystem functions. According to UN Millennium Ecosystem Assessment, birds provide four types of ecosystem services; *viz*: provisioning, regulating, cultural and supporting services. These in fact play important roles in predation, pollination, scavenging, seed dispersal, seed predation and ecosystem engineering (Whelan *et al*., 2008). However, apart from birds, a number of other types of wildlife are also affected by air pollutants, light and noise. These too have their own important ecosystem functions. But due attention has not been given to the effects of the three pollution types with respect to wildlife. Therefore the present review has been undertaken to reveal the same. However, while doing so, birds have been given emphasis as these are the most common victims of all the three kinds of disturbances. The consequences, where-ever possible, have been compared with other wildlife and in this way an overall picture of the problems across the terrestrial animal world has been depicted.

AIR POLLUTION & BIRDS

Direct effects

Atmospheric particulate matter is highly problematic for birds because of their narrower capillary lungs, which make them highly vulnerable. In addition, birds are more exposed to airborne particles than humans due to higher breathing rates and also because they spend more time in the open air. Hence, air pollution directly affects bird lungs in urban areas (Holder, 2015; Qin, 2015). In this regard, mention can be made of forest fires in Singapore that gave rise to large amounts of atmospheric particuate matter, causing the death of many birds in 2013 (Qin, 2015). Avian lings can also suffer direct and irreversible damage due to ground-level ozone and nitrogen oxides. Long-term exposure of these pollutants can cause inflammation and lung failure as well as rupture blood vessels (Qin, 2015). Another toxic air pollutant, polycyclic aromatic hydrocarbons, emitted from traffic, on long-term exposure, can cause growth inhibition, reduce production and hatching of eggs and increase clutch or brood abandonment (Qin, 2015). Air pollution impacts can also extend upto bird habitats and bring significant changes in landscape (Qin, 2015).

In passerine birds, atmospheric pollutants arising from coal-fired power plants causes alterations in the tracheal epithelium such as increase in mucus cover of the tracheal epithelium, shortening of the cilia, and increase in the number of secretory granules and vesicles (Llacuna *et al*., 1993). Long-term air pollution in such birds also leads to lower red blood cell counts and other changes in blood whereas in case of blackbirds it results in remarkably lower body weights (Qin 2015). The sparrows that live in highly-polluted urban areas tend to have remarkably reduced haemoglobin contents and anti-oxidant capacities. The level of this impact depends upon pollution levels in the birds' habitat (European Commission, 2013). Polycyclic aromatic hydrocarbons could cause DNA mutations which can be pass theorugh generations and this is evident in case of in Double-crested Cormorants in Canada. Such mutations can lead to carcinogenic effects (Qin, 2015). In Beijing and Manilla, air pollution has been found to give rise to black lungs and enlarged testes. In addition, lungs and livers of birds in Beijing were fond to contain three or four times more polycyclic aromatic hydrocarbons and common by-products of fossil-fuel burning, than those in better air quality (Lovett, 2012). The feeding activity of ruby-throated hummingbird (*Archilochus colub ris*) could be influenced by ground-level ozone and other atmospheric pollutants. In addition, as these birds breathe greater volumes of air with respect to their body weight, they are also likely to experience the adverse effects of ozone (Lewis, 2013).

Indirect effects

Ground-level ozone (O_3) directly damages the plant communities which provide food and shelter to birds. In fact, increased ozone levels can result in decreased species diversity, changes in water and nutrient cycles, and facilitate invasive plant species (Qin, 2015). Air pollution at times decreases carotenoid levels in plants which in turn reduces the availability of the same for phytophagous insects. As insects are the source of carotenoids for insectivorous passerine birds, lower accumulation of carotenoids in insects results lower levels of caroteinoids in birds. Consequently parents are not able to provide adequate caroteinoids to their nestlings. This is an important impact as these provide antioxidant protection and are essential for better body condition and immunocompetence and may thus enhancing overall fitness of nestlings. In addition, these are also required for the development of eggs for the same reasons. Development of both nestlings and eggs could thus be hampered (Sillanpää, 2010).

Sulphur dioxide and nitrogen oxides emitted as a result of fossil fuel combustion can lead to acidification of water bodies and thereby affect the quantity and quality food resources available for birds (Weblink 1). Several invertebrate species like molluscs and crustaceans that have high concentrations of calcium are sensitive to pH levels and tend to disappear rapidly due to acidification of wetlands (Weblink 1). In fact, reduction of pH of soil and water due to the accumulation these pollutants lowers calcium availability in the environment, leading to reduced clutch sizes (Qin, 2015). On the other hand, higher levels of aluminium arising due to acidification leads to thinning of egg-shells of some bird species, like the great tit and pied flycatcher (Dudley and Stolton, 1996). However, acidification can have different implications on different birds. For example ospreys could find fewer fish to consume in an acid lake because there are far fewer fish to be found. However, the same could be helpful for divers as clearer water in acid lakes makes hunting easier (Weblink 1). In addition, higher levels of atmospheric nitrogen oxides (NOx) facilitates eutrophication that negatively affects fish and invertebrates that birds depend on for food (Qin, 2015). Over time, nitrogen oxide accumulation can facilitate invasive nitrogen-loving plants that propagate at the expense of native plants such as lichens which provide forage and nesting material to birds (Qin, 2015). Atmospheric dioxins accumulate in the soils which are absorbed by earthworms. These organisms which are not affected by the pollutant, can up to five times the concentration found in the soil. Birds acquire this chemical by feeding on earthworms and this can exert severe carcinogenic, reproductive, and immunotoxic effects (Weblink 1).

NOISE POLLUTION & BIRDS

Impact of noise

Low-frequency songs by wild male birds are related to female fertility as well as sexual fidelity. The efficiency of the song signal is hampered by noise, which in turn impairs male-female communication. In addition, due to noise, males are bound to elevated the song frequency which is not favourable for reproductive success (Yirka, 2011). When low-frequency calls from male birds are interrupted by noise, song-based assessments in females are masked, leading to lower energy investment in egg production. This is exemplified by reduced clutch sizes in case of great tits nesting in noisy areas (Francis *et al*., 2011). The masking of low-frequency signals is also likely to hamper the capacity of female birds of differentiating quality males. This could lead to pairing with inferior males whose higher frequency signals are less interrupted by noise (Francis *et al*., 2011). In this way, by causing serious swings in the mating of males the females, noise pollution can alter the strength of a species (Heimbuch, 2011). In addition, noise can also affect developing nestlings which have less tolerance levels and being confined to nests, could not move away from stressful stimuli. This could cause immediate effects like suppression of growth and immune function (Crino *et al*., 2013). Long-term effects include physiological, morphological and behavioral consequences including lifelong and transgenerational effects on reproductive success and survival. In fact, exposure to even short periods of stress during development could translate to large-scale effects (Crino *et al*., 2013).This is evident in case of nestlings white-crowned sparrows that experience phenotypic effects due to elevated levels of traffic noise (Crino *et al*., 2013). High-noise events also cause birds to engage in escape or avoidance activities which cost energy. In addition, it can also cause birds to spend less time in necessary activities like feeding, preening and caring for their young (NoiseQuest, 2015). Birds and amphibian are likely to use other strategies to overcome the effect of noise. This can lead to evolutionary changes in signal characteristics or short-term adaptations (Herrera-Montes & Aide, 2010).

Consequences of impacts

Modification in singing of birds is an important consequence of noise. For instance, as traffic noise masks the song of the male blackbirds, these try to adjust their dawn song to times of lower noise levels, but for this, they have to become active several hours before humans (Helmholtz Centre for environmental research 2013). British robins have been found to avoid their dawn chorus at the peak of rush hour, and shift to night-time singing. German nightingales have taken to sing aloud at 95 decibels, which are intense enough to damage human hearing (Francis *et al*., 2009).

Noise also reduces the diversity of bird communities (Francis *et al*., 2009). This is espicially evident in case of secondary lowland forest sites (Herrera-Montes and Aide, 2010). However, although it negatively influences bird populations, a few bird species prefer noisy area to quiet ones due to vocalization pitches, a reduction in nest predators and less competition from other songbirds that prefer quiet environments (University of Colorado, 2009). In fact, at times noise proves beneficial for smaller birds as it is intolerable to egg-eating predators such as the western scrub jay which is a major cause of nest failure. But these have other important ecological consequences as scrup jays are important pollinators (Francis *et al*., 2009). The consequences of noise can also be generelised to the ecosystem level (both natural terrestrial and marine). Different groups of organisms like birds, insects etc. occupy their own respective sonic zones of specific bandwidth in their habitats so that the voice of every organism can be heard without any competition. This phenomenon, which reflects the health of a habitat and indicates its age and level of stress, is severely affected by noise and thus the entire ecosystem in affected (Acoustic Ecology Institute, 2001).

Impacts on birds versus other animal groups

Adjustment of vocal behaviour that occurs in birds in response to noisy environments is also evident in anurans (frogs and toads) which do so by ceasing to call, calling faster or modifying frequency or amplitude (Tennessen *et al*., 2014). This can be exemplified by the southern brown tree frog (*Litoria ewingii*) which emits calls at elevated pitch levels due to traffic noise (Parris *et al*., 2009; Marris 2009). Such elevated vocalizations increases amphibian aerobic metabolism up to 22 times, making it a highly energy consuming process. This results in physiological consequences and alters behaviours. Behavioural changes in turn affect breeding success. The overall collective impact affects population growth and persistence. Increasing vocal output triggered by noise may have consequences at both the individual- and the chorus-level (Kaiser *et al*., 2010). The impairment in reproduction and breeding that occurs in birds due to noise is also comparable to that in amphibians. Man-made noise interferes with anuran chorus by changing call rates as well as by suppressing calls of one set of species which in turn stimulates calling in other species (Sun and Narins, 2005). Noise pollution can also cause amphibian male choruses to end earlier than female arrival and in this way can reduce the synchronicity between male calling and female presence in the chorus. This ultimately reduces mating opportunities for both sexes (Kaiser *et al*., 2010). It has been found that female wood frogs (*Lithobates sylvaticus*) are unable to locate male calls in presence of noise. Their direction of movement could even be oriented towards roads which emit noise and thus are exposed to accidental mortality. Thus, in addition to impairing reproductive behaviour, noise can also lead to deaths in amphibians (Tennessen *et al*., 2014).However, amphibians have an additional consequence which is not relevant in birds. Many frogs vocalize simultaneously in their habitats. This vocal synchronization hampers prey-location by predators based on sound. In presence of noise, individual frogs momentarily elevate their pitch and hence the risk of predation rises (Acoustic Ecology Institute 2001). In addition, noise has been found to trigger increased levels of a stress-relevant glucocorticoid hormone (corticosterone) in female wood frogs (*Lithobates sylvaticus*) which can have substantial consequences even at the population-level (Tennessen *et al*., 2014). Such Glucocorticoid related stress levels due to noise have been observed in mammals like elk and wolves (Acoustic Ecology Institute, 2001). In addition, noise affects home ranges, foraging patterns and breeding behavior in some mammals (NoiseQuest, 2015). However, although large mammals are repelled by noise, effects are not very severe. Small mammals are also not adversely affected (US Department of Transportation and Federal Administration, 2004). In this regard, mention can be made of mouse-eared bats (*Myotis myotis*) which use acoustic cues to prey upon insects. Noise disrupts such cues and decreases the suitability of foraging grounds near its sources (Schaub *et al*., 2008). Noise also affects fishes in which it influences pattern of locomotion and growth and induces startle response (US Department of Transportation and Federal Administration, 2004). It also affects lizards; however, sensitivity of lizards to noise is influences by changes in temperature and is usually the highest in their ranges of activity (Campbell 1969).

Thus, it is understood that in addition to birds, noise affects several animals across different terrestrial habitats. However, its effects also extent to the aquatic ecosystems. Many marine mammals and fish, in particularly, dependent on sound for a wide variety of vital activities such as reproduction, feeding, predator avoidance, and navigation. In fact, in the underwater environment, sound is an important means of communication as vision is limited. Thus, noise can have severe impacts in such cases. Noise has been shown to be deadly for several species of whales. Noise has led to the death and deafening of marine animals, drove them away from important breeding and feeding areas, as well as resulted in declines in fisheries**.** In fact, fish catch has been observed to be reduced by 50-80% near seismic survey sites and such effects have lasted to five days after exposure and extend upto at distances beyond 30 km such sites (Weilgart, 2005). All these impacts are comparable to disruption of breeding and distribution in birds.

LIGHT POLLUTION & BIRDS

General effects of light

The impacts of light pollution are subtle but have not received the required attention (Cell press, 2010). Light not only limits the sense of orientation but also alters activity patterns in birds to a great extent (Iacurci, 2014). This is because the circadian rhythm of birds which determines the time of mating, breeding, foraging and migration, is dependent upon light. Therefore, when natural day and night rhythms are affected by artificial light, the natural behavioral patterns are likely to change (Iacurci, 2014). The effects artificial night lighting on natural seasonal rhythms is independent of other impacts of urbanization. However, the impacts on fitness of the observed changes in seasonal timing of behaviour due to light have not been fully understood (Da Silva *et al*., 2015). Many artificial lights prove to be fatal distraction for insects, resulting in their decline which in turn negatively impacts other organisms such as birds that rely on insects for food (International Dark Sky Association). In fact, attraction towards causes the deaths of billions of insects every year summer in Germany (Eisenbeis, 2006).

Effects on bird movement

Migratory birds depend on cues from properly timed seasonal schedules. Artificial lights can cause prepone or postpone their migration due to which they miss optimal conditions for nesting, foraging and other behaviors (International Dark Sky Association). Artificial night lighting can also cause disorientation in bird migration (Gauthreaux and Belser, 2006). It can bleach the visual pigments of migratory birds, resulting sight loss of the horizon and thus making them to circle within the cone of light. This can also lead to exhaustion or collision with the light source (Florida Fish and Wildlife Conservation Commission). Artificial light can deviate birds away from course towards the dangerous nighttime city landscapes. In fact, every year many birds die due to collision with illuminated structures (International Dark Sky Association). Death of migrating birds due to collisions with man-made structures across North America annually range from 98 million to close to a billion (Chepesiuk, 2009). It can also deviate seabirds their usual feeding grounds because these birds feed on bioluminescent sea animals and are cued in to low levels of light (Florida Fish and Wildlife Conservation Commission). In addition, night-time light can enable some shorebirds to use visual foraging during night hours instead of tactile foraging (Rojas *et al.,* 1999).

Effects on bird singing

Beyond a threshold, increased light intensity leads to earlier onset of dawn song in some birds (Helmholtz Centre for environmental research, 2013). In fact, a number of songbirds initiate singing earlier around dawn and later around dusk and even tend to become nocturnal singers under the influence of artificial night light (Da Silva *et al*., 2015). Earlier singing not only results in sleep loss in male birds but also increases predation risk (Cell press, 2010). Night-lights can extend the day-length of diurnal songbirds and make them more susceptible to predators as they sing beyond their location (Florida Fish and Wildlife Conservation Commission). It must be added that the presence of street lights, which induces earlier morning singing males in some bird species, also leads to earlier egg-laying in females (Cell press, 2010). Another dimension to the problem is the fact that the females of some birds are considered to engage in additional copulations with high-quality sires to increase the quality of their offspring. These could use early singing, due to light pollution as a cue to decide the quality of male. Light pollution could thus disrupt the link between the cue – early singing -- and male quality, so that females would end up having lower-quality males (Cell press, 2010).

Effects on reproductive behavior

Light pollution influences breeding behavior in birds and has led to consequences that have not been properly studied (Cell press, 2010). It can make birds to breed early as breeding is related to longer days (Florida Fish and Wildlife Conservation Commission). This is evident in case of urban common blackbirds *Turdus merula* in which light pollution can prepond breeding by alomost a month and moulting by three as compared to those in rural areas (Helm *et al*., 2013; Partecke *et al*., 2005). Artificial lighting also effects the reproductive behavior of blue tits (Iacurci, 2014). Nocturnal light also could influence affect avian strategies of choosing partners, as males and females in certain have their own preferences for light (Iacurci, 2014). In case of blue tits, males near lights at the forest edges have been found to be more successful in attracting additional mates. In other words, these often have offspring with females other than their primary social partners (Cell press, 2010). The effects of night lighting on breeding times may grow stronger as birds and other animals respond to warming spring temperatures as well (Cell press, 2010).

In additon, density of nests is also affected by road-lightings (Longcore and Rich, 2004). Similar effects have also been found in case of noise which leads to decline in bird abundance near roads. Certain species, however, tend to shift between periods and their absence (Boise State University, 2013). Moreover, traffic noise and night-light make birds active up to five hours earlier in morning compared to natural areas (Helmholtz Centre for Environmental Research, 2013). Their combined effect is reflected in the behavioral patterns and natural cycles of city blackbirds (Helmholtz Centre for environmental research, 2013). In addition, disruption of melatonin production may occur in birds due to night lights in birds, resulting severe physiological consequences (Gaston *et al*., 2013).

Impacts on birds versus other animal groups

Some effects of light on birds are comparable with those on hepetofauna *i.e*. amphibians and reptiles. For instance, disruption in mating due to interference by light that occurs in birds is also evident in case of amphibians. In fact, frogs have been found to inhibit their mating calls when they are exposed to excessive light at night, reducing their reproductive capacity (Chepesiuk, 2009). However, amphibians suffer from some additional consequences. In this regard, it can be mentioned that widespread distribution of amphibian declines have been also linked with increased ultra-violet radiation (NZFrog, 2006). This is a consequence of ozone depletion and another form of light pollution induced by anthropogenic activities. In fact, amphibians and reptiles, which together constitute herpetofauna have not evolved with artificial lighting at night and hence it has the potential to disrupt their physiology, behavior, and ecology (Perry *et al*., 2008). On the other hand, just as artificial night lighting can disorient movement in birds; it can also do the same to marine turtles during sea-finding (Tuxbury and Salmon, 2005). Sea turtles live in the ocean but hatch at night on the beach. Hatchlings find the sea by detecting the bright horizon over the ocean. Artificial lights draw them away from the ocean. In Florida alone, millions of hatchlings die this way every year (International Dark Sky Association). A similar example is the case with tadpoles of Bufo *bufo* which have been found to gather more under the light of artificial lights in course of their migration. A probable reason could be increased availability of insect food under brightness. However, this increases the risk of death due to accidents (Wise, 2007). Another impact of lighting found in birds which is also evident in herpetofauna is disruption in mating calls. In fact, male mating calls in frogs have been found to decrease and their movements have been found to increase under artificial illumination. This reduction in calls can affect mate selection by females, an impact which can influence population dynamics in a long-term (Wise, 2007). In addition, metamorphosis can also be greatly suppressed in some frogs due to artificial lights. This in turn could delay the escaping of such frogs from water bodies before these dry up; thereby resulting in heavy mortality (Wise, 2007).

Effects of light have not been much documented in case of mammals. However, it has been found that the impairment of melatonin production that could occur in birds due to lighting, could also take place in mammals and fish (Gaston *et al*., 2013). With regards to mammals, it must be mentioned that feeding behavior of bats could altered by artificial light, an effect not evident with regards to birds (Chepesiuk 2009). Certain bat species have also been found to exhibit increased foraging rates around street lights (Gaston *et al*., 2013). However, chronic exposure to artificial night lighting has been found to reduce foraging in salamanders and this can hamper growth and reproductive output as well as survival during winter hibernation, population size and distribution (Wise, 2007).

In addition to the above, light can also alter interactions among different species. In fact, species exhibit different activity patterns under different light conditions and hence alterations in lighting can increase or decrease competition among species. In this regard, mention can be made of a native gecko species in Hawaii which has been shown to get out-competed by another species during the presence of clustered insect distributions caused by lights (Petren and Case, 1996). Light facilitates predation by visually orienting predators and hence can increase their activity. Consequently activities of prey could be reduced due to higher risk of predation. Diurnal and crepuscular predators could become facultative nocturnal predators under suitable lighting (Gaston *et al*., 2013).

CONCLUSION & RECOMMENDATIONS

Atmospheric pollution, noise pollution and light pollution have significant impacts on wildlife. The effects of the first are more prominent in case of birds whereas the consequences of the second and the third impact not only birds but also other organisms. A probable reason could be the fact that animals other than birds have not been paid much attention to in the context of air pollution. In fact, even birds have also not received due attention in this regard. Studies in this respect have mostly been confined to humans and the same is true for light and noise pollution. But the rate at which these problems have intensified and likely to increase, due attention should be gives to their consequences on wildlife. However, in the light of existing literature, it can be stated that the consequences of air pollution in most of the cases is immediately on health, although it also entails some indirect consequences. On the other hand, the effects of noise and excessive light take place indirectly mainly through impacts in reproductive behaviour. The latter, however, also causes direct mortakity in migrating birds. Combined effects of more than one type of pollution can prevail in areas where these occur together. For example, air and noise pollution negatively affects the abundance and variability of birds in forests (Saha and Padhy, 2011). In the context of air pollution, it must be stated that mammalian fecal matter is a good bio-indicator for atmospheric metal exposure and provides a reasonable and reliable method for long term pollution assessments (Gupta and Bakre, 2013).

Physiological effects of noise on animals changes in endocrine, digestive, blood, immune and reproductive function (US Department of Transportation and Federal Administration 2004). However, much less is known about the impacts of noise on wildlife populations (Tennessen *et al*., 2014). In fact, sublethal consequences of noise like physiological stress and impaired reproduction have not been properly understood (Kight and Swaddle, 2011). Life history and communication traits are important determinants of adaptability of organisms to noise (Kaiser et al. 2010). With respect to noise it must be stated that even urban bird species adapted to a variety of environmental conditions could be sensitive to noise (Francis *et al*., 2011). Larger bird species that emit lower frequency signals are more venerable to noisy areas than the smaller ones which transmit of higher frequency signals. Body size, vocal amplitude and frequency are important factors that determine tolerance (Francis *et al*., 2011). Smaller species that rely upon high frequency transmissions could persist in noisy environments. In addition, these could also benefit from reduced predation risk in such areas. But this benefit entails costs to male-female communication, pairing success, and reproductive success in the absence of predation (Francis *et al*., 2011). There is a need to study this problem because the effect of anthropogenic noise, like traffic noise, on acoustically communicating animals has not been understood (Kaiser *et al*., 2010). Sufficient data is also lacking on amphibians and reptiles regarding this issue (Perry *et al*., 2008).

The various characteristics of light pollution has the potential to influence ecological and evolutionary processes (Navara and Nelson, 2007; van *Langevelde et al*., 2011).Light pollution triggers changes in diurnal patterns of behaviour and usually causes diurnal animals to extend their active period and also affect endogenous circadian rhythmicity (Dominoni *et al*., 2015). Some aspects like mortality of hatchling turtles and of birds arising disorientation of have received much attention (Gaston *et al*., 2013). However, there are a number of additional significant implications which need to be studied (Gaston *et al*., 2013). Thus, it concluded that atmospheric pollutants, light and noise are important entities which have severe impacts not only in humans but also birds and other wildlife. These have however, not yet been recognized as issues in the context of wildlife and hence has not receive requisite scientific attention. Based on literature, the following recommendation has been put forward:

1. Adequate information is lacking on the effects of the three pollution types on wildlife. Hence, more animals should be brought under research studies.
2. The three types of terrestrial environmental pollution often occur together at the same time and likely to have synergistic effect among themselves. Therefore, attempts should be made to study their combined effect on widlife and device mitigation measures accordingly.
3. Studies should also be done on the consequences of the three types of pollution with respect to other current environmental problems such as global warming, forest fragmentation, water pollution etc. Attempts should also be made to corelate their effects with these problems. This is because; the effect of these pollution types could be more severe in presence of such issues. For instance, as mentioned earlier lizrds are more susceptible to noise at higher temperatures. Hence, global warming could make them more intolerable. The outcome will help in understanding which of the other problems should be addressed to reduce the effects of the three problems.
4. Light and noise pollution do not involve toxic substances. Hence, if the effects of these agents on wildlife could be understood, these can be suitably used for beneficial purposes such as human-wildlife conflict management which is a major wildlife conservation problem. In fact, these could easily be used to drive away conflict animals without causing any harm under appropriate use. Therefore more studies should be done on the repulsive nature of light and noise on wildlife.
5. Urban areas should be planned so that the existing wildlife could be protected from the three agents. This is especially important in case of industries and roads which are the sources of all the three pollution types.
6. Trees could be effective against all the three types of pollution. They can reflect and decapitate noise, provide shade and also perform ecological functions beneficial to the ambient atmosphere. These can thus be suitably used to counteract the effect of air, noise and light pollution with adequate planning. But while doing so, slection of appropriate species is important because trees themselves could be affect by ambient pollution. For instance, elongated day-length due to artificial lighting alters flowering patterns; especially in angiosperms such as trees. As a result continued growth is promoted which prevents dormancy development in trees that enables them to survive rigors (Ecological Light Pollution, 2015). Young trees are more vulnerable to the effects of artificial illumination because of their greater vigor and tendency to grow compared to older nature trees. Hence, cold injury due to growth prolonged by light pollution is likely to impact young trees more significantly (Chaney, 2002). However, with respect to noise it must be mentioned that plants which depend upon pollen dispersal by smaller birds like hummingbirds indirectly benefit from noise as these are increased by noise (Science News Releases, 2012). In fact, trees can be used as a mitigation measure to noise pollution as sound is scattered by their body parts. In addition, mechanical vibrations caused in pant parts by sound waves converts' sound enery to heat (Tang *et al*., 1986; Nasiri *et al*., 2015). Species with a low ratio Height to DBH and wide crown are suitable to be used decreasing noise pollution used to decrease noise pollution. Evergreen trees are prferred for this purpose because they bear leaves throughout the year (Nasiri *et al*., 2015). Forest stands located at the edges of roads play an important role in controlling noise and hence the properties of such trees such trees have great significance in this aspect. In this regard, shape and the growth form are the main determinants (Spellerberg 1998; Demir *et al*., 2009; Maleki and Hosseini, 2011).
7. Awareness should be generated among the public so that they could recognize the importance of the three issues. This is because mitigation measures cannot be applied without the support of people. In fact, public awareness and regulations have addressed the challenge of light pollution effectively in some areas (Salmon, 2006).
8. Enforcement of proper regulations to control ambient terrestrial pollution. The methods of regulation have been highly discussed with regard to air pollution and sufficient literature exists in this aspect. However, regulation could also be temporal or seasonal in case of light and noise. For, example if in a species, mating which takes place in a particular season is hampered by noise, steps should be made to reduce noise in that season in areas where the species exists. The same is applicable to light pollution as well as in case of temporal regulation. With regard to light pollution, it must be added that ultraviolet light is should be avoided and longer wavelengths should be used for illumination (Longcore and Rich, 2010). Lighting should be avoided under circumstances which it is not necessarily required and should be focussed to only where it is needed at an optimal intensity. A proper duration of lighting should be maintained and should be turned off after a certain hour; a practice which has already been successfully regulated by the Dutch government does this with some of its street lights (Longcore and Rich, 2010). The introduction of broad spectrum street lamps can alter the balance of species interactions in the artificially lit environment (Davies *et al*., 2013).

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