birds

Communication

Electromagnetic Pollution as a Possible Explanation for the Decline of House Sparrows in Interaction with Other Factors

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Simple Summary: In recent decades, there has been a decline of the house sparrow (*Passer domesticus*), mainly in European cities, and several hypotheses have been proposed. The objective of this article is to delve into the reasons why an increase in electromagnetic radiation especially in cities, may be intervening in some way. Previous studies indicated that house sparrows were significantly negatively associated with increasing electromagnetic radiation and sparrows disappeared from areas most polluted. Electromagnetic radiation is the most plausible factor and is the only one that affects the other hypotheses proposed so far. Additionally, the recent sparrow decline matches the deployment of mobile telephony networks. For these reasons, electromagnetic radiation is not only a plausible but a probable hypothesis that must be seriously considered, probably in synergy with the other factors previously proposed.

Abstract: In recent decades, there has been a decline of the House Sparrow (*Passer domesticus*), mainly in European cities, and several hypotheses have been proposed that attempt to determine the causes of this rapid decline. Previous studies indicated that house sparrows were significantly negatively associated with increasing electromagnetic radiation and sparrows disappeared from areas most polluted. In addition, there are many studies on the impact of radiation on other bird and non-bird species, as well as numerous laboratory studies that demonstrated detrimental effects at electric field strength levels that can be found in cities today. Electromagnetic radiation is the most plausible factor for multiple reasons, including that this is the only one that affects the other hypotheses proposed so far. It is a type of pollution that affects productivity, fertility, decreases insects (chicken feed), causes loss of habitat, decreases immunity and can promote disease. Additionally, the recent sparrow decline matches the deployment of mobile telephony networks. Further, there are known mechanisms of action for non-thermal effects of electromagnetic radiation that may affect sparrows causing their decline. Thus, electromagnetic radiation must be seriously considered as a factor for house sparrows' decline, probably in synergy with the other factors previously proposed.

Keywords: immunity; food; *Passer domesticus*; phone masts; productivity

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1. Introduction

The House Sparrow (*Passer domesticus*) is a bird species that lives in urban or suburban habitats and has spread from its original areas in Eurasia to a large number of cities around the world [1]. In recent decades, there has been a decline of house sparrows in several European cities [2–4]. In the United Kingdom, a 71% decline from 1994–2002 occurred in London [5], and urban bird populations in southeast England appear to be declining more rapidly than suburban or rural populations [6]. The house sparrow has been added to the Red List of UK endangered species [7].

Outside of the United Kingdom, the decline of house sparrow populations appears as a global and widespread phenomenon throughout its native range in Europe [4]. In several European cities, such as Brussels, Ghent and Antwerp, many populations of sparrows have disappeared [7,8]; similar declines have been reported in Dublin [9]. A study on the abundance of house sparrows between September 1998 and November 2008, shows that the species has experienced a steep decline of about 70% in urban parks in Valencia (Spain), reflecting a declining population trend at the whole city scale [10]. In Hungary, the population of house sparrows has suffered a moderate declining trend for ten years [11]. Jokimäki et al. [12] studied population trends of the house sparrow and the Eurasian Tree Sparrow in Europe, and in more detail in Finland. The decrease of the house sparrow was quite clear in many European countries. The wintering populations of the house sparrow have decreased, whereas the Eurasian Tree Sparrows have both expanded their wintering range and increased their population size in Finland. The house sparrow has suffered from decreased winter feeding activities and increased human population size within human settlements in Finland.

The most complete and recent field study was conducted covering the urban diversity of Paris, analysing fine-scale habitat characteristics of house sparrow population sizes and trends, using a fifteen-year census (2003–2017) in nearly 200 census sites [4]. This study documented a dramatic decline (−89%) of the species over the study period, which was sharpest at sites with the highest numbers of house sparrows at the beginning of the study period. However, a study a few years previously mentioned that Paris was one of the few cities where house sparrow populations were preserved [3].

The decline of sparrows is also occurring outside of Europe. In India, the number of house sparrows has decreased dramatically in several parts of the country [13,14]. These worldwide declines are worrying, as house sparrows usually live in cities and suburban areas and are an important bioindicator of the health status of urban ecosystems, as an urban sentinel species [4].

Despite having carried out many studies to explain this, there is no solid theory concerning the underlying causes to solve the enigma, but several hypotheses have been proposed so far [3,7,15,16]. The objective of this article is to delve into the reasons why we consider there are strong arguments that the increase in electromagnetic radiation around the world and especially in cities may be intervening in some way, in combination with other proposed factors, in this house sparrow decline.

2. Hypotheses Raised to Explain the House Sparrow Decline

The most important explanatory hypotheses that have been raised so far are the following: lack of food in urban areas affecting both nestlings and adults, particularly insects, which adults feed to nestlings; cleaner streets resulting in reduced foraging opportunities; competition for food from other urban species; increased predation by domestic cats; an increase in predator pressure due to a possible recovery of urban Eurasian Sparrowhawk (*Accipiter nisus*) populations; loss of nesting sites as newly built houses often lack suitable nesting cavities; increased use of pesticides in parks and gardens, pollution, disease transmission, and reduction of colony size below some critical value, resulting in the disappearance of the colony as a breeding unit (the Allee effect) [6,7,11,17]. For many authors, this decline may be attributed to several interactive and cumulative effects [2].

Interestingly, in the most recent, broad and in-depth study carried out in Paris [4], house sparrows do not actually lack nesting sites in the urban areas. Furthermore, house sparrows declined at all sites and the local temporal trends in abundance were independent of habitat characteristics; even areas with extended green spaces did not provide sufficient quality to secure the maintenance of large populations. On the other hand, in Paris, Eurasian Sparrowhawk first bred in 2008, when house sparrows were already declining, and this cannot explain the decline of the species. The authors studied the evolution of 18 air pollutants in Paris over the study period and related these to house sparrow abundances and found that the highest numbers were counted at the beginning of the period, when air pollution was maximal, and air quality did not deteriorate during the fifteen-year study. They concluded that air pollution was not responsible for the observed decline, neither were weather fluctuations. Finally, the authors explained that their study did not assess the potential influence of other urban-specific disturbances that were proposed as proximate causes of the decline of urban house sparrows, such as the potential role of increasing noise, light and/or electromagnetic pollution, not assessing the influence of increasing domestic cat abundance (the other major predator of sparrows), neither the increasing inter-specific competition with other urban exploiters, nor the existence of diseases and parasites [4].

Another recent study showed that avian malaria (*Plasmodium relictum*) infection is found at a higher prevalence in sparrows in London and may be a factor contributing to the declining trend of this species [17]. On the other hand, pollution (air quality) may cause negative physiological effects, such as increased oxidative stress, and negatively affect the reproductive output through decreased chick body mass [2].

3. Electromagnetic Radiation as a Likely Factor

Four studies have been published on the possible effects of electromagnetic radiation on sparrows, two in Europe and two in India. The main characteristics, alternative hypotheses and results of these studies are shown in the Table 1.

A possible effect of long-term exposure to low-intensity electromagnetic radiation from mobile phone (GSM) base stations, on the number of house sparrows during the breeding season, was investigated in Flanders, Belgium [18]. The study was carried out by sampling 150-point locations within six areas to examine small-scale geographic variation in the number of house sparrow males, and the strength of electromagnetic radiation from base stations. Spatial variation in the number of house sparrow males was negative and highly significantly related to the strength of the electric fields from both the 900 and 1800 MHz frequency bands and the sum of both. The negative relationship was highly similar within each of the six study areas, despite the differences among the areas in both the number of birds and radiation levels. Thus, this study showed that the number of sparrows correlated with the electromagnetic pollution levels and supported the notion that long-term exposure to higher levels of radiation negatively affected the abundance or behaviour of house sparrows in the wild [18].

Another study was performed with 30-point transect sampling, visited every month for more than three years ($n = 40$) in Valladolid (Spain), counting the sparrows and measuring the mean electric field strength (radiofrequencies and microwaves between 1 MHz and 3 GHz range). A significantly low bird density was observed in areas with high electric field strength and a general population decline in bird density over time was detected [19].

Studies performed in India, showed that sparrows were disappearing from areas where mobile towers were installed and the electromagnetic contamination was highest [13,14]. A study performed by monthly monitoring of urban and rural areas, found that the population of house sparrows was declining in urban areas, where cellphone towers were more common compared to the rural areas, and sparrow populations were disappearing rapidly from areas contaminated with electromagnetic radiation [14]. Another study investigating the impact of electromagnetic radiation (mobile towers) was conducted over a period of two years. Rural sites with plentiful availability of nesting sites, food, water and roosting sites, and with minor competition for nesting sites, food and risk of predation were selected. In such places, the population should increase, however, the author found that the population decreased. Since the maximum decrease in nests was found in sites where the maximum number of mobile towers were operational, the author proposed that electromagnetic radiation from mobile towers could be the cause [13].

A lack of invertebrate prey during the reproductive period, used to feed chicks in the nest, has also been suggested as a possible explanation for the population decline of house sparrows in urban centres [7], since the availability of key insect prey such as Aphidoidea, Curculionidae, Orthoptera and Lepidoptera is very important for the growth and development of nestlings [6]. Numerous studies have shown that electromagnetic pollution might affect the number of insects that house sparrows feed to their chicks [20].

Table 1. House sparrows vs. radiation studies.

Ref	Study	City	Country	Habitat	Years	Study Type	Method	Number of Replicates	Main Results	Alternative Hypotheses
[18]	Everaert and Bauwens, 2007	Six residential areas in the region of Gent–Sint-Niklaas (East Flanders	Belgium	Urban areas	Spring of 2006	Descriptive	Point counts	No	Spatial variation in the number of house sparrow males was negatively and highly significantly related to the strength of the electric fields from both the 900 and 1800 MHz frequency bands. This negative relationship was highly similar within each of the six study areas	Not considered
[19]	Balmori and Hallberg, 2007	Valladolid	Spain	Urban areas	October 2002 to May 2006	Descriptive	Line Transect and Point Counts	40	Significantly low bird density was observed in areas with high electric field strength	-Air pollution -Food availability Electromagnetic pollution may be responsible, either by itself or in combination with other factors for the observed decline of the species in European cities during recent years
[13]	Singh et al., 2013	Jammu region	India	Urban and suburban areas	March 2009 to March 2013	Descriptive	Line Transect and Point Counts	2	In urban areas, the major cause of decline is the lack of nesting sites. In rural sites, the maximum decrease in nests found in Motorshed (30%) where maximum number of mobile towers were operational.	- Lack of nesting sites in modern houses - Increasing competition for nesting sites - Lack of roosting sites - Effect of mobile towers - Increase of predation - Shortage of food - Lack of water sites To study the impact of electromagnetic radiation (mobile towers), rural sites were selected where the availability of nesting sites, food, roosting sites, water is available in plenty. The competition for nesting sites, food and risk of predation is also less. So, in such places, the population should increase. But the population was found to decrease where maximum number of mobile towers were operational
[14]	Shende and Patil, 2015	Kalmeshwar region	India	urban suburban and rural areas	from July 2011 to June 2012	Descriptive	Line Transects Method	12	The correlation between population of Passer domesticus and number of RF towers shows that, the population of Passer domesticus is decreases with increase in number of RF towers. The authors found a relationship between dispersal of Population of Passer domesticus with distance (in Meter) from towers. The electromagnetic signals are directly or indirectly associated with the decline in the house sparrow population in Kalmeshwar and nearby areas	Decline in their number over the last decade because of: - Loss of nesting sites, - Food sources, - Pollution, - Diseases and - Increase in predators

The studies reviewed and discussed show that electromagnetic radiation is not only a plausible but a probable factor for multiple reasons, including that this is the only factor that interferes with all other hypothesised factors proposed so far. Electromagnetic radiation is a type of pollution that affects productivity [21–23], fertility [22], decreases insect chicken feed [24], causes habitat loss [25,26] and decreases immunity [27–29]. It is well known that a stressed immune system may increase the susceptibility of a bird to infectious diseases, bacteria, viruses and parasites [30].

4. Electromagnetic Radiation Effects on Other Species

There are interesting studies investigating the response of city birds according to the distance to phone masts, since the electric field strength is marked by that distance [31]. A study carried out in Spain showed that phone masts interfere with White Stork (*Ciconia ciconia*) reproduction. The total productivity in nests located farther than 300 m of antennae was practically double, compared with those located within 200 m. Furthermore, 40% of nests located within 200 m of antennae never had chicks, while only one (3.3%) located further than 300 m had no chicks. In sites located within 100 m of one or several phone masts with the main beam of radiation impacting directly on the nest, many young died from unknown causes [23].

A study in India noted the occurrence of changes for different bird species near cellphone towers. The occurrences were inversely linked with the power density and most birds were found at the lowest radiation areas. Avian nests were not detected near but were found at $\geq$80 m away from the towers, in the area with low radiation impacts. At different distances from the two different cellphone towers and for the four directions of space, the study clearly indicated that the occurrence of birds was closely negatively related to the electric field strength [32]. In another Indian study, the occurrence of birds in exposed and unexposed zones were 28.08% and 71.91%, respectively [33].

In another study, the number of individuals (birds) recorded within a 200 m radius of a mobile tower was comparatively less than that found outside the 200 m radius. Birds were highly affected by electromagnetic radiation produced from mobile towers and the electromagnetic radiation emitted from cellphone towers affected their physiology and behaviour [34].

A review highlighted the potential impact of electromagnetic field radiation on avian populations. An uncertainty exists on the effects of electromagnetic radiation exposure on birds due to the scarcity of studies on this matter, but most studies indicate the possibility of changes in behaviour and effects on physiology, breeding success and mortality [35]. A study on the airport radar effects on birds provided evidence that birds detected the radar presence, and slight differences in power density and pulse properties could potentially alter avian behaviour [36].

In addition, there are many other studies on the impact of radiation on non-bird animals [26,31,37–39]. Bat activity was significantly reduced in habitats exposed to an electromagnetic radiation (from a radar) that can exert an aversive behavioural response [40,41]. However, studies conducted in real field situations must be performed with a sufficient experimental exposure time, because results with a short exposure time are likely to be ambiguous (e.g., 48 h in [42]).

An experiment was conducted exposing the common frog (*Rana temporaria*) to electromagnetic radiation from several mobile (cell) phone antennae located at a distance of 140 m from the egg phase until an advanced tadpole phase prior to metamorphosis. The results indicated that radiation emitted by phone masts in a real situation may affect development and may cause an increase in mortality of exposed tadpoles [43].

A detailed long-term (2006–2015) field-monitoring study was performed in the cities of Bamberg and Hallstadt (Germany) [44]. Observations and photographic recordings of unusual or unexplainable tree damage were taken, alongside the measurement of electromagnetic radiation. Many trees showed damage patterns that were not attributable to harmful organisms, such as diseases (fungi, bacteria, viruses) and pests (insects, nematodes) or other environmental factors (water stress, heat, drought, frost, sun, compaction of the soil, air and soil pollutants). Statistical analysis demonstrated that electromagnetic radiation from mobile phone masts was harmful for trees [44].

In the laboratory setting, several authors have reported a significant increase of embryonic mortality of chickens exposed to radiation from mobile phones [25,45,46], that could affect wild birds living in areas polluted by electromagnetic radiation. Microwaves used in cellphones produce a non-thermal response in several types of neurons in birds [47]. Various outcomes of this radiation lead to neural damage, locomotory defects, threatening the reproductive capacities of birds [48]. For these reasons, electromagnetic radiation is not only a plausible but a probable hypothesis for the decline in sparrows.

5. Mechanisms by Which Non-Ionizing Electromagnetic Radiation Could Affect Birds

Some of the disruptive effects of radio frequency fields could be related to interference with voltage-gated calcium channels in cells [49–53]. It has been proposed that electromagnetic fields act similarly in animals and plants, with the probable activation of these calcium channels via their voltage sensor [54]. In their responses to low-intensity microwave electromagnetic fields, membrane calcium channel is activated, allowing calcium influx into the cell, and thus increasing the intracellular (Ca^{2+}) concentration. They undergo both oxidative stress and DNA strand breaks, with those strand breaks leading to the formation of micronuclei and to chromosomal rearrangements. Remote activation by electromagnetic fields significantly increases intracellular calcium concentrations in glass catfish (*Kryptopterus bicirrhis*), indicative of cellular excitability wireless control of cellular function by activation of a novel protein responsive to electromagnetic fields [55].

Current evidence indicates that exposure at levels found in the environment (in urban areas and near base stations) could particularly alter the receptor organs to orient in earth's magnetic field, although the species conservation implications are unknown. Radio frequency fields in the megahertz range disrupt the orientation of birds by interfering directly with the primary processes of magnetoreception and therefore disable the avian compass as long as they are present [56–58]; these authors, reported the sensitivity for orientation of European Robins (*Erithacus rubecula*) to radio frequency magnetic fields. The orientation of migratory birds is disrupted when very weak high-frequency fields (broadband field of 0.1–10 MHz of 85 nT or a 1.315 MHz field of 480 nT) are added to the static geomagnetic field of 46,000 nT [59]. Engels et al. [60] convincingly demonstrated that European Robins are unable to use their magnetic compass in the presence of urban electromagnetic radio frequency noise in the frequency range of 2 kHz to 5 MHz. Therefore, electrosmog scrambles a bird's magnetic sense.

6. Conclusions

The studies discussed above indicate that sparrows disappear from areas most contaminated by electromagnetic radiation. In addition, there are many other studies on the impact of radiation on other species of birds and non-bird animals, as well as laboratory studies that demonstrate its effects at electric field strength levels that can be found in cities. The results of all these studies considered jointly support the hypothesis that electromagnetic pollution may be responsible, by itself or in conjunction with other factors, for the reduced number of the sparrows in cities in recent years. Furthermore, the disappearance of sparrows and the introduction of phone mast towers are temporally correlated: sparrow decline matches chronologically with the deployment of mobile telephony networks, especially during recent decades. However, there are some weaknesses of this study; since it is based on only a few house sparrow's studies (n = 4), and low number of replicates. The correlation between electromagnetic radiation and sparrow abundance does not imply causality, although the possibility of this happening seems very likely considering the different number of places analysed. However, it is possible that other factors, such as habitat structure and vegetation, which may differ between the near surroundings of the towers (in addition to the radiation level) and areas further away could also interplay in house sparrow abundance. Interestingly, the study performed in Paris suggests that specific environmental changes have occurred in this city during the last 15 years and that the current conditions are unsuitable for the maintenance of dense local populations of house sparrows [4].

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