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Possible Effects of Electromagnetic Fields from Phone Masts on a Population of White Stork (*Ciconia ciconia*)

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Monitoring of a white stork population in Valladolid (Spain) in the vicinity of Cellular Phone Base Stations was carried out, with the objective of detecting possible effects. The total productivity, in the nests located within 200 meters of antennae, was 0.86 ± 0.16. *For those located further than 300 m, the result was practically doubled, with an average of* 1.6 ± 0.14. *Very significant differences among the total productivity were found (*$U = 240$; $p = 0.001$, *Mann-Whitney test). In partial productivity, an average of* 1.44 ± 0.16 *was obtained for the first group (within 200 m of antennae) and of* 1.65 ± 0.13 *for the second (further than 300 m of antennae), respectively. The difference between both groups of nests in this case were not statistically significant (*$U = 216$; $P = 0.26$, *Mann-Whitney Test U). Twelve nests (40%) located within than 200 m of antennae never had chicks, while only one (3.3%) located further than 300 m had no chicks. The electric field intensity was higher on nests within 200 m (*2.36 ± 0.82 *V/m) than on nests further than 300 m (*0.53 ± 0.82 *V/m). Interesting behavioral observations of the white stork nesting sites located within 100 m of one or several cellsite antennae were carried out. These results are compatible with the possibility that microwaves are interfering with the reproduction of white storks and would corroborate the results of laboratory research by other authors.*

Keywords Cellsites; Cellular phone masts; *Ciconia ciconia*; Electromagnetic fields; Microwaves; Nonthermal effects; Reproduction; White stork.

Introduction

Most of the attention on the possible biological effects of electromagnetic fields (EMF) has been focused on human health. People frequently use wildlife as biological indicators to detect the alterations in the ecosystems and in an urban

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habitat. The numeric tendency of the populations of birds is of particular interest in the conservation of nature [1].

The cellsite antennae emit a frequency of 900 or 1800 MHz, pulsed in very low frequencies, generally known as microwaves (300 MHz–300 GHz), similar to the radar spectrum. The cellsite ordinarily have 3 sectors, with 3 antennae that cover an angle of 120 degrees each [2–5]. Though they have many and varied outputs, at a distance of 50 m, the power density is about $10\,\mu W/cm^2$ [2], while at distances of 100 m at ground level it measures above $1\,\mu W/cm^2$ (personal observation). Between 150 and 200 m, the power density of the main lobe near the ground is typically of some tenth of $1\,\mu W/cm^2$ [3].

In real life, living organisms are exposed to variable levels of electromagnetic fields (radiofrequencies), according to the distance from the cellular bases stations, the presence of passive structures to either amplify the waves (e.g., the metallic structures) or to shield them (buildings or other obstacles), the number of transmission calls within the transmitters and their position with relationship to the orientation of the antenna [2].

Animals are very sensitive electrochemical complexes that communicate with their environment through electrical impulses. Ionic currents and electric potential differences exist through the cellular membranes and corporal fluids [6]. The intrinsic electromagnetic fields from the biological structures are characterized by certain specific frequencies that can be interfered with by the electromagnetic radiation, through induction and causing modification in their biological responses [3]. Animals exposed to the EMF can suffer a deterioration of health, changes in behavior [7, 8], and changes in reproductive success [9, 10].

The low intensity pulsed microwave radiation from cellsites produces subtle athermal influences in the living organisms, because this radiation is able to produce biological responses by the microwave carrier and by the low frequency of pulses from GSM system. "Windows" exist in whereby EMFs produce biological effects at specific frequencies (window effect) [11]. Some effects are manifested exclusively with a certain power density [12], while others are manifested after a certain duration of the irradiation, which indicates long-term cumulative effects [13]. During lingering exposure, the effects can change from stimulant to inhibition, depending on the pulse shape [14, 15], the duration, development, and differentiation and the physiologic condition or health of the receiving organism [16], and their genetic predisposition [17]. These waves seem to cause different, and even contrary effects, depending on their frequency, intensity, modulation, pulses or time of exposure [12, 16, 18]. The pulsed waves (in bursts) and certain low frequency modulations, produce great biological activity [14, 15, 18]. The dose-response relationships (athermal) are nonlinear [19].

Research has shown such effects on the living organisms at molecular [12] and cellular levels [20] on immune processes [21], in DNA [22], on the nervous, cardiac, endocrine, immune, and reproductive systems [16, 23–28], modification of sleep and alteration of the cerebral electric response (EEG) [29], increase of the arterial pressure and changes in the heart rhythm [30], and an increase in the permeability of the blood brain barrier [31].

The objective of this study was to investigate if the phone mast cellsites caused effects in wild birds similar to the laboratory studies, and studies carried out on people exposed to this radiation [3, 5, 32–35].

Materials and Methods

For monitoring the breeding success of the white stork population, nests ($n = 60$) were selected and visited from May to June of 2003. The difficulty of the investigation in the field, (and when studying wild species) does not allow one to control all variables as in the laboratory; however, the selected nests had similar characteristics. They were located in the roof of churches and buildings inside urban nuclei in Valladolid (Spain). (The nests on trees and other natural supports or outside the urban nuclei were never studied.) Since the cellsite radiations are omnipresent, very few places exist with an intensity of 0 V/m near inhabited nuclei. For that reason, nests were chosen that were exposed at very high or very low levels of electromagnetic radiation, depending on the distance from the nests to the antennas.

The nests were selected and separated in two categories:

a) Nests ($n = 30$) located within 200 m of one or several cellsite antennae (GSM-900 MHz and DCS-1800 MHz), placed in masts and in the roof of the buildings at 15–30 m high.
b) Nests ($n = 30$) located further than 300 m of any cellsites.

The nest were observed using a prismatic Zeiss 8×30 and a "Leika" 20-60 X telescope. The number of young were counted.

For the analysis of the results of the reproduction, two indexes were used:

1) the total productivity (number of young flown by each couple, including nests with zero chicks).
2) the partial productivity (number of young flown by couples with some chicks, excluding nests with zero chicks).

To compare the breeding success of both groups of nests a nonparametric test was applied (Mann-Whitney test U).

Also, we measured the electric field intensity (radiofrequencies and microwaves) in V/m, using a "Nuova Elettronica" device Model LX 1435 with 10% sensitivity, from a unidirectional antenna (range: 1 MHz–3 GHz). Keeping in mind the inaccessibility of the nests, the measurements were made in their vacinity under similar conditions, recording the reproducible values obtained when directing the antenna of the device toward the cellsite antenna in line of sight.

Between February 2003 and June 2004, we carried out 15 and 10 visits, respectively, to 20 nests located within 100 m of one or several cellsite antennae to observe the behavior of the species. The visits covered all the phases of breeding, from construction of the nest, until the appearance of young storks exercising their wings and practicing flight.

Results

Table 1 presents the number of young and electric field intensity (V/m) of each studied nest.

The total productivity, in the nests located within 200 m of antennae was 0.86 ± 0.16. For those located further than 300 m, the result was practically doubled, with an average of 1.6 ± 0.14 (Table 1). Both groups showed very significant differences in the breeding success ($U = 240$; $P = 0.001$, Mann-Whitney Test U).

Table 1
Intensity of electric field, total and partial productivity in the nests within 200 m and further than 300 m to the phone mast

Nests within 200 m			Nests further than 300 m		
Nest	Number of young	EMF (V/m)	Nest	Number of young	EMF (V/m)
1	2	0.8	1	1	0.4
2	2	0.6	2	2	0.7
3	0	0.8	3	1	1.3
4	3	1.5	4	1	1.1
5	1	1.7	5	1	0.6
6	2	2.9	6	3	0.4
7	1	3.1	7	2	0.6
8	1	1.3	8	2	0.7
9	1	1.3	9	3	0.6
10	1	2.8	10	1	0.7
11	1	1.8	11	2	0.8
12	3	3.2	12	2	0.3
13	1	1.6	13	3	0.1
14	0	2.7	14	1	0.6
15	0	2.3	15	2	0.5
16	0	2.7	16	3	0
17	0	2.5	17	2	0.3
18	0	3.5	18	1	0.8
19	0	3.5	19	2	0.2
20	0	2.7	20	0	0.8
21	0	2.9	21	2	0.2
22	2	3.2	22	1	0.6
23	0	2.5	23	1	0.5
24	1	2.6	24	1	0.7
25	1	2.4	25	1	1.4
26	0	2.2	26	2	0.1
27	1	2.6	27	1	0.1
28	1	3.1	28	2	0.2
29	1	3.1	29	1	0
30	0	3.0	30	1	0.6
Mean EMF		2.36			0.53
Total productivity		0.86		1.6	
Partial productivity		1.44		1.65	
Nests without young		12 (40%)		1 (3.3%)	

In partial productivity in average of 1.44 ± 0.16 was obtained for the first group (within 200 m of antennae) and 1.65 ± 0.13 for the second (further than 300 m of antennae) respectively. The difference between both groups of nests in this case was not statistically significant ($U = 216$; $P = 0.26$, Mann-Whitney Test U).

Twelve nests (40%) located within 200 m of the antennae never had any chicks, while only one (3.3%), located further than 300 m, never had chicks.

The electric field intensity was higher on nests within 200 m (2.36 ± 0.82 V/m) that on nests further 300 m (0.53 ± 0.82 V/m) (Table 1).

The results of the findings and interesting behavioral observations of the white stork nesting sites located within 100 m of one or several cellsite antennae and on those that the main beam impacted directly (EFI > 2 V/m) included young that died from unknown causes. Also, within this distance, couples frequently fought over the nest construction sticks and failed to advance the construction of the nests. (Sticks fell to the ground while the couple tried to build the nest.) Some nests were never completed and the storks remained passively in front of cellsite antennae.

Discussion

The effects of athermal microwaves on birds have been well known for more than 35 years [36, 37]. Some authors obtained beneficial effects in the production of insect eggs and exposed birds, but found that the mortality was doubled [38]. In hen experiments, problems of health and a deterioration of the plumage arose, while in the autopsies, leucosis and tumors of the central nervous system appears [39]. Giarola and Krueger [40] obtained a large reduction of the rate of growth and also a reduction of the adrenal glands, in exposed chickens. Kondra et al. [41] obtained an increase in the frequency of ovulation of exposed birds, and a bigger production of eggs but with less weight, proposing that the pituitary gland was stimulated. Other authors also have obtained effects reducing the rate of growth in chickens and rats, reduction in the production of eggs in hens exposed to microwaves of different frequencies and intensities, increase of fertility, and a deterioration of the quality of the eggshell at certain frequencies [42]. An increase in the embryonic mortality of chickens also has been found [15, 17, 43, 44]. These microwave effects are athermal [45]. Recently, it also has been demonstrated that the microwaves used in cellphones produce an athermal response in several types of neurons of the nervous system in birds [46] and that they can affect the blood brain barrier as has been observed in rats [47].

Birds are especially sensitive to the magnetic fields [48]. The white stork (*Ciconia ciconia*) build their nests on pinnacles and other very high places with high electromagnetic contamination (exposed to the microwaves). Also, they usually live inside the urban environment, where the electromagnetic contamination is higher, and remain in the nest a lot of the time, for this reason the decrease on the brood can be a good biological indicator to detect the effects of these radiations.

The results indicate a difference in total productivity but not in partial productivity between the near nests and those far from the antennae. This indicate the existence of nests without chicks, or the death of young in their first stages in the nests near cellsites (40% of nest without young, compared to 3.3% in nests further 300 m). Also, in the monitoring of the nests near to cellsite antennae, some dead young were observed and several couples never built the nest.

In previous studies in Valladolid, the results of productivity were generally higher than those obtained in this study and less nests appeared without young (Table 2).

Consistent with these results, the microwaves could be affecting one or several reproductive stages: the construction of the nest, the number of eggs, the embryonic

Table 2
Results of censuses carried out in Valladolid (Spain).

Year	Number of visited nests	Total productivity	Partial productivity	Couples without young(%)	References
1984	113	1.69	2.13	7	[65]
1992	115		1.93	5.2	[62]
1994	24	1.84		7.6	[63]
2001	35		2.43		[64]
2003 (<200 m)	30	0.83	1.44	40	This study
2003 (>300 m)	30	1.6	1.65	3.3	This study

development, the hatching or the mortality of chicks in their first stages. The faithfulness of the white stork to nest sites can increase the effects of the microwaves. A Greek study [49] relates to a progressive drop in the number of births of rodents. The mice exposed to 0.168 μW/cm^2 become sterile after 5 generations, while those exposed to 1.053 μW/cm^2 became sterile after only 3 generations. The interaction seems to take place through the central nervous system more than on the reproductive gland directly. Other studies find a decrease of fertility, increase of deaths after the birth in rats and dystrophic changes in their reproductive organs [16]. A recent study shows a statistically significant high mortality rate of chicken embryos subjected to the radiation from a cellphone, compared to the control group [43]. EMF exposure affected the reproductive success of kestrels (*Falco sparverius*), increasing fertility, egg size, embryonic development and fledging success but reduced hatching success [10]. An increase in the mortality [50] and the appearance of morphological abnormalities, especially of the neural tube [14, 15, 17] has been recorded in chicken embryos exposed to pulsed magnetic fields, with different susceptibility among individuals probably for genetic reasons. It is probable that each species, even each individual, shows different susceptibility to the radiation, since the susceptibility depends on the genetic bias, and of the irradiated living organisms physiologic and neurological state [4, 51]. Different susceptibility of each species also has been proven in wild birds exposed to CEM from high-voltage powerlines [9]. When the experimental conditions (power density, frequency, duration, composition of the tissue irradiated, etc.) change, their biological effects also change [25, 52]. Microwaves have the potential to induce adverse reactions in the health of people [2–5, 34, 35, 47]. Although the power output differs per site and type of transmitter, at more than 300 m distance from the antennas, most of the symptoms recorded in people diminish or disappear [34, 35]. It also has been pointed out that below 0.6 V/m the effects on the people disappear (Salzburg resolution).

Since, we cannot see symptoms for white storks, it is necessary to use objective variables such as the Total and Partial Productivity, and other characteristics of behavior (nonconstruction of nest, sticks fall, etc.). We recommend electromagnetic contamination in the microwave range be considered a risk factor in the decline of some populations, especially urban birds, especially when exposed to higher radiation levels. Because of their thinner skull, their great mobility and the fact that they use areas with high levels of microwave electromagnetic radiation, birds are very good biological indicators. The freedom of movement of birds and their habit of settling in the proximity and even on the cellsites, makes them potentially susceptible to such effects. Small organisms (children, birds, small mammals, etc.) are especially vulnerable, as absorption of microwaves of the frequency used in mobile telephones is greater as a consequence of the thinner skull of a bird, the penetration of the radiation into the brain is greater [2, 49, 53, 54].

Several million birds of 230 species die annually from collisions with the masts of telecommunication facilities in United States during migration [55]. The cause of the accidents has yet to be proven, although one knows that they mainly take place during the night, in fog, or bad weather. The birds use several orientation systems: the stars, the sun, the site-specific recognition and the geomagnetic field [48]. The illumination of the towers probably attracts the birds in the darkness, but it is possible that the accidents take place in circumstances of little visibility, because at the time, other navigational tools are not available. The perception to the terrestrial magnetic field can be altered by the electromagnetic radiation from the antennae. The reports of carrier pigeons losing direction in the vicinity of cellsites are numerous, and more investigation is necessary.

In the United Kingdom, where the allowed radiation levels are 20 times higher than those of Spain, a decline of several species of urban birds has recently taken place [56], coinciding with the increasing installations of cellsites. Although this type of contamination is considered at the present time by some experts as the most serious [4], inspection systems and controls have never been developed to avoid their pernicious effects on living organisms. Some of the biological mechanisms of the effects of these waves are still ignored [12], although the athermal effects on organisms have been sufficiently documented. The telephone industry could be taking advantage of the complexity of the biological and physical processes implied, to create an innocuous atmosphere, repeatedly denying the existence of harmful effects in living organisms. For this reason the reports related to animals are of special value, since in this case it can never be alleged that the effects are psychosomatic [3].

Future investigation should be carried out with long-term monitoring of the breeding success, of the sleeping places and of the uses of the habitat for species more vulnerable to the microwaves. Of special interest should be investigations that try to make correlations with the radiofrequency electromagnetic field measurements. Field studies investigating populations of urban parks and territories surrounding cellsites should be a high-priority. A radius of 1 sq K and the layout of concentric lines at intermediate distances can be useful to investigate differential results among areas depending on their vicinity and the radiation levels. We consider that the birds most affected from the microwave electromagnetic contamination could be:

1) those bound to urban environments with more sedentary customs, in general those that spend more time in the vicinity of the base stations;
2) those that live or breed in high places, more exposed to the radiation and at higher power density levels;
3) those that breed on open structures where the radiation impacts directly on adults and chicks in the nest;
4) those that spend the night outside of holes or structures that attenuate the radiation.

In far away areas, where the radiation decreases progressively, the chronic exposure can also have long term effects [13, 49]. Effects from antennas on the habitat of birds are difficult to quantify, but they can cause a serious deterioration, generating silent areas without male singers or reproductive couples. The deterioration of the ecosystem can also take place from the impact of the radiation on the populations of invertebrate prey [54, 57, 58] and on the plants [59].

Bioelectromagnetics is historically a frontier discipline. Controversy is frequent when the scientists recognize serious effects on health and on the environment that cause high economic losses. Independent investigators state the necessity of a drastic reduction of the emmitted power levels on people and the ecosystems and that it is technically viable although more expensive for the industry [4, 22, 60]. Our opinion is that areas of continuous use should never exist at the height of the antennas either inside the beam or within a radius of several hundreds meters. The restriction to exposure to fauna presents special complexity; the main reason for the drastic reduction in the emission power of the antennae is presented as the only viable and effective solution to prevent these effects. Some authors have already propose that we are withessing a paradigm change in biology [61].

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