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Influence of Radar Radiation on Breeding Biology of Tits (*Parus sp.*)

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*The aim of the present study is to observe the influence of long-term exposure to radar radiation on breeding biology of tits (*Parus sp.*), living and building nests around a military radar station, emitting pulse-modulated microwave radiation of 1,200–3,000 MHz. Two series of 36 nest-boxes each were located on the radar station area. Measurements of exposure were performed separately for each nest-box. Average power density (P_{av}, W/m^2) and dose of exposure (W/m^2 × h) were recorded for each nest-box during 45 days. Control nest-boxes ($N = 42$) were located in other part of the same forests, free from radar radiation. The assessment of effects of radar exposure on breeding biology of tits included number of inhabited nest-boxes, number of eggs, and nestlings in the nest (Why not chick mortality?). Experimental nest-boxes were either exposed to relatively high levels of radiation (2.0–5.0 W/m^2, mean 3.41 ± 1.38 W/m^2) or an intermediate level of radiation that ranged from 0.1–2.0 W/m^2 (mean 1.12 ± 0.84 W/m^2). For control nest-boxes the exposure ranged from 0.001–0.01 W/m^2 (mean 0.0062 ± 0.0007 W/m^2). Only blue or great tits occupied all nest-boxes, used in the experiment. The number of nesting blue tits was higher in nest-boxes located on the radar station area than in the control boxes. In contrast, control nest-boxes were inhabited mainly by great tits. On the radar station area, blue tits nested in high exposed nest-boxes (67,0%) and great tit occupied mainly these boxes, which were exposed to low-level radiation (62,5%), the difference being statistically significant ($p < 0.01$). No statistically significant differences in other parameters of breeding biology (number of eggs per box, number of nestling per box) were observed between tits occupying exposed and control nest boxes.*

Results of the present study show that radar radiation generally does not lead to decrease of number of nesting tits, but may cause shifts in tits species living around the radar station. (But is the microhabitat, apart from the radiation level, around each nest box more likely to attract one species of tit or another?)

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Introduction

Naturally occurring, non ionizing electromagnetic radiation (EMR) impacts living organisms throughout their lives. However, industrial development during the last decades, mainly in the form of modern radiocommunication systems, has resulted in significant increases of levels of EMR in the environment. The spectrum of environmental EMR consists of electromagnetic waves of numerous frequencies and modulations. High-frequency EMR (radiowaves: 0.1–300 MHz and microwaves: 300 MHz–300 GHz) are emitted mostly by various broadcasting systems (radio and TV stations), mobile phone systems, and radiolocation devices (radars). Military radar localizations (close to forest areas) and high peak power densities emitted from radar antennas (kW/m^2, MW/m^2) may have potential negative influences on the living environment, including birds.

Few studies have been published about the influence of high-frequency EMR on bird biology in their natural environment. Among the few results, some changes were found during monitoring of breeding of birds living near a powerful radar station located in Skrunda, Latvia, although detailed analysis was not made (Liepa and Bolodis, 1993). Fernie and Bird (1999, 2000) and Fernie et al. (2000) reported on the influence of EMR on body mass, food intake, reproductive success, and growth of nestlings of American kestrels. Recently, Balmori (2005) monitored population of a white stork living in the vicnicity of mobile phone base stations in Spain and found that in nesting sites located within 200 m from base station antennas survival of chicks was considerably lower than in nests located more than 300 m from the antennas. These studies suggest that relatively weak pulse-modulated microwave fields (far below those recommended as permissible exposure levels) may exert bioeffects in populations of wild birds and possibly influence their health status.

The aim of the present study was to experimentally document the influence of long-term exposure to radar radiation on breeding biology of tits (*Parus sp.*).

Materials and Methods

The present observation concerned two species of tits, the great tit (*Parus major*) and the blue tit (*Parus caeruleus*), living and building nests around military radar stations that emit pulse-modulated microwave radiation of 1,200–3,000 MHz, situated in Kampinos Forests near Warsaw, Poland.

On the radar station area, we placed two transects of 36 nest-boxes each. The nest-boxes were located on trees, about 3 m above ground level. We could determine no significant differences in the microhabitat surrounding each nest-box. Measurements of exposure were performed separately for each nest-box. For measurements, two types of meters were used: NARDA (USA) and MPEM-1 (MIHE, Poland). Average power density (P_{av}, W/m^2) and dose of exposure ($W/m^2 \times h$) were recorded for each nest-box during 45 days. Dose of exposure was calculated after analysis of working time for each device in the radar base.

Control nest-boxes were located in other part of the Kampinos forests, free from radar radiation.

The assessment of effects of radar exposure on breeding biology of tits included the number of inhabited nest-boxes, number of eggs, and nestlings in the nest. Observations lasted 45 days.

Results and Discussion

Our results showed that there were significant differences of radiation exposure among nest-boxes. Some nest-boxes were exposed to relatively high levels of radiation (2.0–5.0 W/m^2, mean 3.41 ± 1.38 W/m^2); other nest-boxes were exposed to radiation levels that ranged from 0.1–2.0 W/m^2 (mean 1.12 ± 0.84 W/m^2). For control nest-boxes the exposure ranged from 0.001–0.01 W/m^2 (mean 0.0062 ± 0.0007 W/m^2), a level consistent with natural emissions.

Only blue or great tits occupied all nest-boxes, used in the experiment. The number of nesting blue tits was significantly ($p < 0.05$) higher in nest-boxes located on the radar station area than in the control boxes (Table 1). In contrast, control nest-boxes were inhabited mainly by major tit. On the radar station area, blue tits nested in high exposed nest-boxes (67,0%) and great tit occupied mainly these boxes, which were exposed to low-level radiation (62,5%). The difference between number of nest-boxes occupied by blue tits and great tits in areas of high and low exposure to radiation was statistically significant ($p < 0.01$, Table 1). However, we found no other statistically significant differences in other parameters of breeding biology (number of eggs per box, number of nestling per box) between tits occupying exposed and control next boxes (Table 1).

Results of the present study indicate that radar radiation generally does not lead to a decrease of the number of nesting tits, but may cause shifts in tits species living around the radar station. Sites where radiation level is higher are inhabited mainly by blue tits. Previous behavioural studies (Tanner, 1966; Tanner and Romero-Sierra, 1974) show that the blue tit is often the loser in competitive interactions with the great tit. This ecological pattern could explain the higher number of nest-boxes occupied by blue tit in locations with exposure exceeding 2 W/m^2. On the other side, reproduction parameters (number of eggs per box, number of nestling per box) were not impaired either in low-exposed (0.1–2 W/m^2) or high-exposed (2.0–5.0 W/m^2) boxes and did not differ from the parameters in control boxes. This result contradicts the recent report of Balmori (2005), who found lower number of chicks

Table 1

Influence of chronic exposure to radar radiation on breeding biology of tits

Parameters of birds breeding biology		Exposed ($N = 72$) Low (0.1–2.0 W/m^2) $N = 36$	Exposed ($N = 72$) High (2.0–5.0 W/m^2) $N = 36$	Unexposed (<0.01 W/m^2) $N = 42$
Inhabited nestboxes	Great tit	62.5%	33.0%	65.2%
	Blue tit	37.5%	67.0%	34.8%
		$p < 0.01$		
Number of eggs per box		11.00 ± 1.76	10.67 ± 1.82	10.85 ± 1.94
Number of nestling per box		10.14 ± 1.58	10.25 ± 1.64	9.61 ± 1.36

in nests of a white stork exposed to very low levels of EMR (below $0.1\,W/m^2$). This contradiction could be explained by the different forms of radiation in the two studies. In the present study, nest-boxes were exposed to pulse-modulated 1,200–3,000 MHz microwaves with 5 ms pulses (radar radiation), while in the Balmori (2005) study, a 900 or 1,800 MHz with 217 Hz modulation (mobile phone radiation) was the source of exposure.

In general, the effects of low-level microwave exposure in birds were suspected for nearly 40 years (Tanner et al., 1967) with both harmful and beneficial effects being reported. Tanner and Romero-Sierra (1974, 1982) found that in wild and domestic birds exposed to low-level radar radiation number of eggs was slightly increased, but mortality of chicks was nearly doubled. An increase in the embryonic mortality of chicks exposed to low-level microwaves has been found also in other studies (Farrel et al., 1997; Grigoriev, 2003). In the present study, the number of eggs and survival of nestling did not differ between exposed and non exposed boxes. However, exposed boxes were occupied by a weaker species of tits (blue tit) what suggests that birds percieve high frequency electromagnetic fields as a stressful environmental factor and avoid living in exposed places.

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