

# Effects of artificial electromagnetic fields on insects

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In his book "The Amazing Senses of Animals", science journalist Ed Young devotes two chapters to describing the importance of electric and magnetic fields for communication, orientation and hunting in animal species such as fish, arthropods, bees and bumblebees.<sup>1</sup> They have highly developed sensory organs for this purpose. But how do they react to artificially generated electromagnetic fields (EMFs), which have irradiated the environment almost continuously through radar, radio and, since around 2000, mobile communications? Is there a potential for damage here? Research results show negative effects of non-ionising radiation (NIR) on arthropods, such as bees and bumblebees. The studies suggest that EMFs could play a role in insect mortality. However, the effects of EMFs on insect decline are complex, as there are many causes, including habitat loss, climate change, pesticide use and changes in land use. The interaction of the many toxins has not yet been sufficiently investigated. What role do artificial electromagnetic fields play in this?

## Early warnings as early as 25 years ago

In 1999, the ICNIRP (International Commission on Non-Ionising Radiation Protection) and the German Federal Office for Radiation Protection (BfS) organised a symposium entitled: "Effects of Electromagnetic Fields on the Living Environment". The background to this was that even then, there was already a great deal of knowledge about the effects of EMFs on insects. The symposium proceedings therefore called for studies on the effects of radiation on animals and insects:

"The specific issues that need to be addressed include

- EMF exposure of animals, plants and marine organisms,
- orientation and migration effects on birds and marine organisms,
- behavioural changes in insects (conference proceedings, p. 8)."<sup>2</sup>

However, this warning had no consequences. The research available at that time on the effects of the geomagnetic field, radar and other electromagnetic fields of various frequencies on animals since 1965, e.g. by Wiltschko (navigation)<sup>3</sup>, Semm (birds)<sup>4</sup> and Warnke (bees)<sup>5</sup>, was not systematically evaluated. Study results that appeared in the early 2000s were downplayed by the authorities, and no research projects of their own were commissioned.

## BUND recognised the risks of EMFs to insects early on

The relevance of research became increasingly important: the expansion of mobile phone infrastructure led to the first widespread exposure to artificially generated non-ionising radiation in the history of the Earth. The signal patterns are completely new in evolutionary terms, with radiation intensities billions of times higher than those emitted by lightning discharges, for example (see Fig. 1). Biology is therefore not adapted to this new radiation and at the same time is sensitive to it.

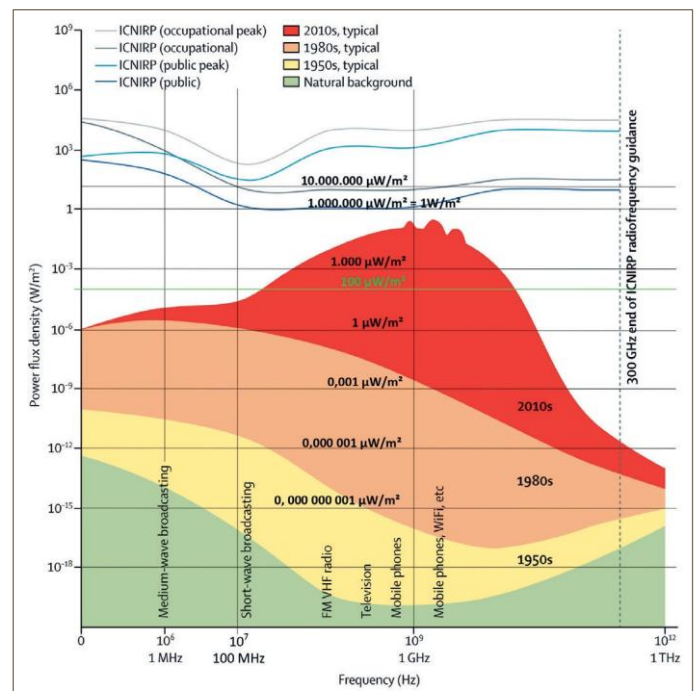


Fig. 1: Typical daily exposure to natural background radiation (green) and artificial electromagnetic fields in the 1950s (yellow) / 1980s (orange) / 2000s (red). The legal limits (occupational, population) based on the ICNIRP recommendations are shown as lines in the graph above. (Source: Priyanka/Carpenter (2018), doi.org/10.1016/S2542-5196(18)30221-3, supplemented by diagnose:funk).

In 2008, the German Environmental and Nature Conservation Association (BUND) pointed out possible negative consequences for animals in its position paper 46: "As early as the 1970s, it was found that bees exposed to low-frequency fields (10 to 20 KHz) showed stress reactions and a greatly reduced ability to find their way back. In 2005, a pilot study on the effects of electromagnetic radiation on bees found that their homing ability and honeycomb construction were severely disrupted."<sup>6</sup>

In his 2021 bestseller *Silent Spring*, leading British insect researcher Prof. Dave Goulson writes: "It seems plausible that such fields can trigger significant behavioural changes [in insects; author's note] [...] What concerns me most is the fact that so little research is being done in this area. We have introduced a series of global telecommunications networks in a huge, unreplicated experiment in which virtually every living creature on this planet is exposed to a rapidly increasing dose of high-frequency radiation, even though we are not yet fully aware of the consequences" (pp. 221/223).<sup>7</sup>

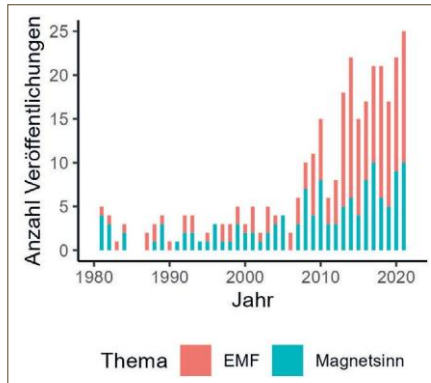


Fig. 2. Number of published insect studies on magnetoreception and electromagnetic fields (graphic: Thill et al. 2023)

This early warning from BUND and Goulson's concerns have since been confirmed and clarified by a steadily growing number of individual studies (Fig. 2). Some recent examples:

- The study by the Chilean working group Molina-Montenegro et al. (2023) reported declining pollination performance in the vicinity of high-voltage power lines. German beekeepers report restlessness and aggressive behaviour in bees, which disappears when the hives are moved away from high-voltage power lines.
- Nyirenda et al. (2022)<sup>9</sup> and Adelaja et al. (2021)<sup>10</sup> observed a decrease in insect density (abundance) in relation to proximity to an EMF source (mobile phone mast).
- Migdal et al. (2023, 2024) demonstrated impairments to the immune system, nutrient transport and oxidative cell stress in bees exposed to 900 MHz radiation (mobile phone radiation).<sup>11</sup>
- A study by the State Institute for Apiculture at the University of Hohenheim, which meets the highest scientific criteria, demonstrated in field trials that bees exhibited disturbed homing behaviour when exposed to Wi-Fi radiation throughout their 7-week lifespan (Treder et al. (2023), Figs. 3 and 4).<sup>12</sup>

The results of the University of Hohenheim study, which were also presented at the annual congress of the German Beekeepers' Association, should have led to a broad debate on the risks involved. The fact that this did not happen shows how the issue of mobile phone radiation is overshadowed by cognitive dissonance and a narrative of progress, because the findings call into question users' own behaviour. Does the love for one's own smartphone go so far that the scientifically proven damage is negated?

Radiation Treatment	Observations	Effects
2.4 GHz + 5.8 GHz	brood development 	no effect
	homing ability 	negative effect
	longevity 	no effect

Fig. 3: Results of the study by Treder et al. (2023): Long-term exposure to high-frequency, clocked and pulsed EMFs (here: Wi-Fi) had a significant negative impact on honey bees' ability to orient themselves when foraging. (Graphic: Treder 2023).

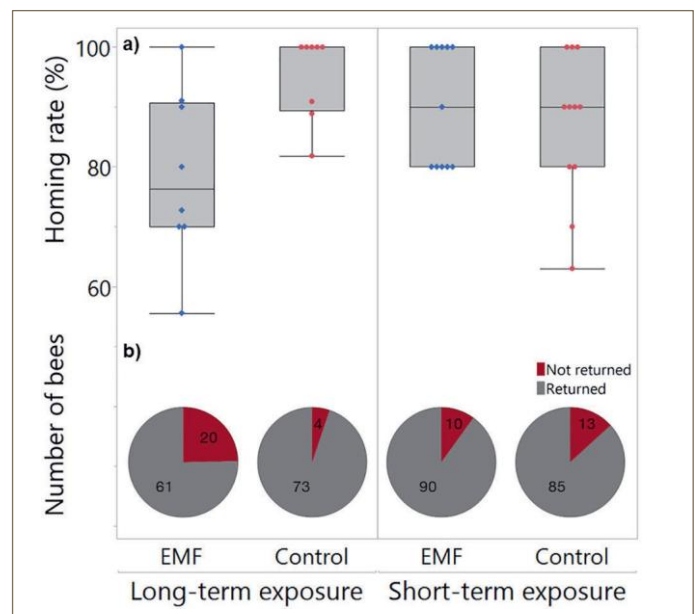


Fig. 4: The number of bees that successfully returned to their hives differed significantly: 95% of the bees in the un-exposed control group returned successfully, compared to only 75% of the bees in the EMF group that had been exposed to radiation for 7 weeks (graphic: Treder 2023).

### diagnose:funk promotes independent studies

Diagnose:funk also presented analyses. We commissioned environmental scientist Alain Thill and the editorial team of *ElektromogReport* to analyse the study situation for us. In 2020, Thill's first review, "Biological effects of electromagnetic fields on insects," was published as a supplement in *umwelt-medi-zin-gesellschaft*, and in 2021, his article "Disorientation caused by electromagnetic fields during bird migration" appeared on the diagnose:funk website. The Federal Office for Radiation Protection (BfS) responded to this development in the study situation by devaluing the available results with the astonishing argument: "The currently much-discussed insect decline began in the early 1990s, before the widespread expansion of mobile communications. Therefore, mobile communications cannot be considered a significant cause."<sup>14</sup> The fact that mobile communications could be a new factor whose contribution to the acceleration of insect decline needs to be investigated is obviously ignored here. The BfS justifies its inaction with a flimsy argument that is based neither on the idea of protection nor is characterised by the precautionary principles.

This corresponds to the illogical argument of climate change deniers that temperature fluctuations, ice ages and warm periods have always existed, and therefore there is no need for research or action.

### The European Economic and Social Committee vehemently calls for studies

The authorities are blocking scientific, open-ended knowledge acquisition according to the motto "Digital first. Concerns second." This is probably due to the government's promotion of mobile communications expansion as a key factor for economic growth. There is also reason to believe that, in return for €55 billion in UMTS/LTE licence fees paid by mobile operators since 2001, the authorities have refrained from regulatory intervention.<sup>15</sup> However, 24 years after the BfS symposium mentioned at the beginning, the European Economic and Social Committee (EESC) once again calls for studies in the Official Journal of the EU of 29 September 2023: "The EESC suggests that an EU study be conducted to collect accurate data on the effects of electromagnetic radiation from mobile phone masts on wild pollinators in their natural habitats and to identify the policy measures necessary for the effective protection of pollinators" (section 1.8).<sup>16</sup> These studies are now available, but were not commissioned by either the EU or the Federal Office for Radiation Protection.

### Swiss study speaks plainly

Two recent reviews clarify the overall results of previous individual studies. The findings on the threat to insects posed by electromagnetic fields are no longer uncertain, but are approaching the level of proof. This is the main conclusion of a review for the Swiss Federal Office for the Environment (FOEN), conducted at the University of Neuchâtel. This review by Mulot et al. (2022) provides an assessment of the potential risk:

"Anthropogenic NIR [non-ionising radiation; author's note] poses a potential threat to arthropod populations as it affects the selection value (fitness), reproduction and behaviour of individuals." The conclusion: "NIR clearly has a sublethal effect on arthropods, both at the cellular and organismal levels."<sup>17</sup> This study clearly shows that mobile communications are a new factor in insect mortality, contrary to the complacent position of the BfS.

### BEEFI study: most comprehensive evaluation of studies on EMFs and insects

The findings of Mulot et al. are confirmed by the most comprehensive review to date, the systematic meta-analysis by Thill, Cammaerts & Balmori (2023): "Biological Effects of Electromagnetic Fields on Insects: a Systematic Review and Meta-analysis" (in short: the BEEFI study).<sup>18</sup> For the study, 119 peer-reviewed scientific studies were evaluated. The results of 51 studies could even be used for a meta-analysis (= recalculation) due to the good data quality. The overall result of the BEEFI study:

"Non-thermal biological effects of EMFs have been proven in the laboratory" (p. 1). These effects impact the reproductive capacity, behaviour, DNA and health of insects. According to Thill et al., the laboratory results demonstrating damage cannot be transferred 1:1 to field effects, but: "It is very likely that the effects demonstrated in the laboratory also occur under real life conditions" (p. 8). The BEEFI study documents new field studies that confirm this. In the field, insects are not only exposed to

EMFs, but also to other harmful influences, so that even greater damage must be assumed due to combination effects. The current state of research requires the application of the precautionary principle in the expansion of mobile communications. The details presented by Thill et al. show the explosive nature of the findings. There are three main findings that must have immediate consequences for species protection:

#### Firstly, the actual radiation situation is harmful, and the ICNIRP limits do not provide sufficient protection.

Epidemiological and biological field studies show chronic negative effects on insects and birds in the vicinity of mobile phone towers at current power levels.<sup>19</sup> The limits based on the ICNIRP recommendations only protect humans from excessive heating. They are not designed to protect animals and plants, nor do they protect against non-thermal biological effects. Thill et al. conclude: "These findings on biological effects in insects at around 2 V/m [= 10,600 µW/m<sup>2</sup>; author's note] imply that existing standards need to be revised and tightened to take into account the interests of nature conservation and wildlife" (Thill, p. 10).

#### Secondly, studies show damaging effects on reproduction, DNA, behaviour and the development of oxidative stress, among other things.

The toxicity estimate derived from the meta-analysis "could, in the worst case, be interpreted as a 50% increase in DNA damage or a 33% reduction in reproductive capacity" (ibid. p. 6).<sup>20</sup> In terms of behaviour, the ability to find their way home is particularly impaired, and pollination performance declines.

#### Thirdly, the results of previous studies are highly significant despite weaknesses in the study design.

The fact that there are still major gaps in research is mainly due to the long-standing obstructionist attitude of the authorities, who did not invest in research projects and for years used these gaps to give the all-clear according to the motto: "What I don't know doesn't bother me". Thus, self-inflicted or alleged ignorance was passed off as knowledge. With this tactic, the Federal Office for Radiation Protection, for example, continues to prevent investigations from being carried out. Diagnose:funk analysed this policy in two focus areas.<sup>21</sup> Thill et al. reject this policy of downplaying the issue: "The vast majority of studies have found effects that are generally harmful. It is unlikely that these findings are the result of chance [...] Despite these shortcomings [mostly no randomised controlled studies; author's note], the consistent results of numerous studies conducted by different research groups using different protocols are an irrefutable argument for the harmful effects of low-power NF and HF EMF on insects" (ibid. p. 8).

#### Conclusion: The evidence and findings call for a precautionary protection policy

Based on this research, a responsible environmental policy should strive to minimise radiation exposure. Thill et al. argue:

"Based on an assessment of the overall situation of studies on insects, we must warn against the reckless expansion of further mobile phone infrastructure, as harmful effects on insect populations are to be expected, especially when interactions with other pollutants are taken into account (including high-voltage power lines and artificial lighting). This could lead to a further decline in already dwindling pollinator populations and would

thus entail costs for humanity" (ibid. p. 11).

The authors advocate the funding and implementation of field studies. Due to the many indications of potential damage, they call for the application of the precautionary principle. Further research and investigations are necessary, including to determine interactions with other factors.

### Federal policy demands for the protection of insects

The BEEFI and Mulot studies provide two current and comprehensive research overviews that prove that artificially generated electromagnetic fields have a negative effect on the organism of insects – even at low flux densities (radiation intensities) during normal operation of the transmitters and thus well below the legal limits. At the end of 2024, the traffic light coalition government wanted to use the Telecommunications Network Expansion Acceleration Act (TkNaBeG) to define the construction of mobile phone masts as being in the "overriding public interest" – and thus exempt them from environmental regulations. Environmental organisations protested against this.<sup>22</sup> The findings from the available studies call for the protection of insects from the effects of mobile phone radiation. Insects do not need radiation, they need rest. At least the further readings and the passing of the TkNaBeG went down with the traffic light coalition government. However, the new federal government's 2025 coalition agreement once again announces the passing of this law.

Based on the BEEFI study, diagnose:funk is running the "Silent Spring" campaign, with its own website [www.insekten-schuetzen.info](http://www.insekten-schuetzen.info). Based on scientific findings, diagnose:funk is calling on the federal government to take measures to minimise radiation exposure and to maintain and expand radio-free protection zones for insects. This means:

1. In order to protect insects, the federal government must limit **mobile phone coverage** to a maximum of 100  $\mu\text{Watt}/\text{m}^2$  (green line in Fig. 1). Reception will still be possible at full bandwidth.
2. No new mobile phone masts may be built or continue to operate in **nature reserves**. These include national parks, nature reserves, Natura 2000 areas and core zones of biosphere reserves.
3. The **interactions** between electromagnetic fields and other environmental pollutants must be scientifically investigated.
4. Further **field studies** must be financed and carried out to further clarify how insect populations are already being negatively affected by the current infrastructure.

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