THE SCIENCE WORLD
A Monthly e Magazine
ISSN:2583-2212
October, 2025 Vol.5(10), 9476-9482

Popular Article

Silent Signals, Loud Impacts: Insects in the Age of Electromagnetic Radiation

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DOI:10.5281/ScienceWorld.17498875

Abstract

Insects, the most diverse and ecologically vital group of organisms, play a fundamental role in ecosystem functioning through pollination, decomposition and nutrient cycling. However, global reports indicate a rapid decline in insect abundance and diversity due to multiple anthropogenic stressors, including habitat loss, pesticide use and more recently, electromagnetic radiation (EMR). The proliferation of artificial electromagnetic sources from mobile phones, Wi-Fi routers and telecommunication towers to high-frequency 5G systems has added a new dimension to environmental stress. Electromagnetic and artificial light radiations can disrupt insect physiology, behaviour and population dynamics. Studies have reported reduced oviposition, extended developmental periods and decreased longevity under radiofrequency exposure, along with species-specific shifts in pollinator abundance linked to EMR intensity. In honeybees (*Apis mellifera*), EMR exposure impairs navigation, reduces foraging activity, queen fecundity, brood area and egg production. Additional effects include reduced hatching success, altered pupal development, metabolic disturbances and behavioural disorientation. Artificial light at night (ALAN) further intensifies these problems by disrupting nocturnal activity, feeding and pollination. Collectively, these findings suggest that EMR and ALAN are emerging threats to insect biodiversity, potentially contributing to pollinator decline and ecological imbalance. Further field-based research and regulation of EMR exposure are urgently needed to mitigate its impacts and sustain ecosystem stability.

Keywords: EMR, Insect decline, Artificial light at night (ALAN), Pollinator, Honey bee

Introduction

Insects are most diverse and abundant group in animal kingdom. These minute creatures play a key role in every ecosystem. Some of the most important ecosystem services they provide are climate regulation, crop pollination, pest control, decomposition, nutrient recycling, soil aeration and seed dispersal. Insects form the structural and functional base of numerous of the world's ecosystems.

However numerous studies have reported the serious decline in insects that has occurred in recent decades. According to some study about 41 % of total global insect saw decline from past decade. Research conducted in Germany's protected natural areas revealed a decline of 76-82% in the total population of flying insects from 1989 to 2016. Different pressure like agricultural intensification, with increased use of pesticide and fertilizers, may have provoked the reduction in insect abundance over the last decades.

In current condition there is a new addition to these factors called Electromagnetic radiations (EMR). From mid-20th century, there has been tremendous increase in the emission of Electromagnetic radiations (radio waves, microwaves, infrared, visible light, ultraviolet, X and γ radiation) in the environment. The urbanization and use of wireless technologies, including mobile in 21st century proliferated anthropogenic electromagnetic radiations (EMR) compared to last century. Anthropogenic radiofrequency electromagnetic radiation and artificial light at night emitted from power lines and used in wireless technologies were reported as an additional growing threat to insect population.

Nowadays, Android phones have also joined this category with advanced cellular systems such as 5G, which operate at frequencies up to 120 GHz. The adverse effects of such electromagnetic radiation have already been observed in vertebrates (humans, mice and birds) and to a limited extent in arthropods especially bees. A continued decline in insect populations could disrupt food chains, creating ecological gaps that humans currently have no means to fill. These facts strongly emphasize the need to develop strategies aimed at reducing electromagnetic radiation to preserve and maintain not only insect populations but the entire biodiversity, ensuring a healthy coexistence for all living beings.

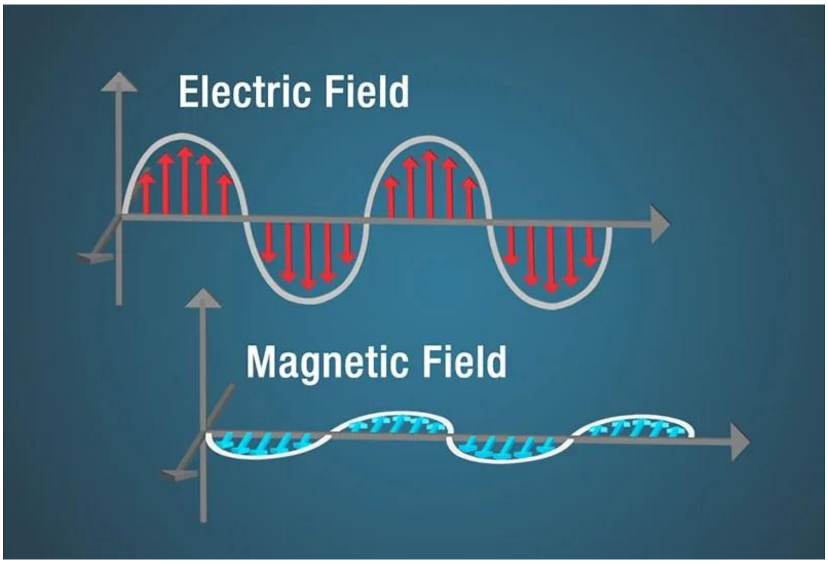
Electromagnetic Radiation (EMR)

Radiation can be defined as energy that is radiated or transmitted in the form of rays or waves or particles. Electromagnetic radiations are the radiations that travel through space by carrying electromagnetic radiant energy.

According to webster dictionary “It is waves of electric and magnetic energy moving through space”. A varying magnetic field generates a corresponding electric field, and conversely, a changing electric field produces a magnetic field — the two are inherently interconnected. These changing fields form electromagnetic waves. According to physicist James Clerk & Maxwell “Electrical fields and magnetic fields can couple together to form electromagnetic waves’’

EMR is produced by electrically charged particles undergoing periodic changes in their electric or magnetic fields. Depending on their source of emission and interaction with matter, these radiations are classified under different names. Regardless of type, electromagnetic (EM) waves carry energy, momentum and angular momentum away from their source particles and can transfer these quantities to the matter they interact with.

The primary source of EMR is sun. Optical solar radiation includes different radiation (visible, UV, infra-red etc.). However, various gadgets *i.e.* mobile phones, television sets, Wi-Fi routers, microwave ovens and computers, as well as telecommunication antennas, both produce and operate using EMR. In addition, artificial sources are employed to generate high-intensity EMR, typically found in medical devices such as Magnetic Resonance Imaging (MRI) scanners, laser lithotripsy systems, X-ray Computed Tomography (CT) machines and radiation therapy equipment.



Role of EMR in Insects

EMR plays diverse roles in insects, primarily via their ability to perceive and respond to different wavelengths of light. Insects have evolved specialized visual systems distinct from human vision, enabling them to detect and exploit various properties of EMR.

1. **Vision and Perception:** Insects' compound eyes, composed of ommatidia each containing photoreceptor cells tuned to specific wavelengths, allow them to discern colours, shapes and motion.

2. **Navigation and Orientation:** Many insects use polarized skylight as a compass cue. Species such as bees and ants can detect linear polarization patterns to maintain orientation and navigate efficiently (Heinloth, 2018).

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Published 25/10/2025

3. **Communication:** Some insects use light or polarization patterns for signalling. For example, scarab beetles can reflect circularly polarized light, which influences mate choice and gene expression (Li *et al.*, 2023).

4. **Thermoregulation:** Insects exploit EMR particularly sunlight for body temperature regulation, through behaviours like basking or seeking shade (Lahondere, 2023).

Beyond these functions, insects also use EMR in other essential ecological behaviours like locating food, defence and camouflage. The integration of EMR perception into their physiology and behaviour underscores its critical role in insect ecology and their interactions within ecosystems.

Effects of EMR

EMR can potentially affect insects in various ways, although the exact impact can depend on factors such as the frequency and intensity of the radiation, the type of insect and the specific circumstances.

These insects are very sensitive to EMR due to primarily two reasons

- **i.** Small size
- **ii.** Short life cycle

When insects are exposed to EM fields, it is partially absorbed by their body based on their frequency. As the insect body size is small it has a low biomass, so EMR can easily penetrate insect body system. Due to their short life cycle insect completes more generation in certain period, this implies a greater number of generations exposed to radiations.

Negative effects are seen either directly in insect or altering their behaviour. These EMR shifts ultimately could bring the changes in, physiology and morphology over time due to increased body temperatures, from dielectric heating. Insect abundance is also affected by these EMR.

Insect behaviour is the outcome of various actions in response to a stimulus or to its environment. It covers a wide range of activities like movement, feeding, learning, reproduction etc. EMR may hamper insect normal circadian rhythm and their navigational skills. For this different activity like foraging, communication is severely affected as for honey bee.

Artificial light at night (ALAN)

Localized illumination of nocturnal landscapes by anthropogenic sources of light such as street lamps, path lights and vehicle head- lights can be collectively referred to as artificial

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light at night (ALAN). It disrupts populations of crepuscular and nocturnal animal species present in affected habitats. The ecological consequences of ALAN vary according to its intensity and wavelength spectrum.

According to IPBES ALAN is "a driver clearly affecting nocturnal species and growing in importance due to urbanization". This ALAN are scarcely studied compared to another EMR components.

Effects of ALAN on nocturnal insects are as following

- **A.** Insect mortality
- **B.** Temporal disorientation
- **C.** Spatial disorientation
- **D.** Attraction
- **E.** Desensitization
- **F.** Alter foraging activity and species interactions

ALAN not only increases insect mortality but also induces sublethal effects. Moths exposed to artificial night lighting spend less time feeding, especially under short-wavelength (blue or green) light. Normally larger moths are more adversely affected than smaller ones, though both sexes show similar negative responses to ALAN (Van Langevelde *et al*., 2017). ALAN has been shown to reduce pollinator visitation rates to plants by 62%, resulting in a 13% decline in fruit set of plant species *Cirsium oleraceum* plant species (Knop et al., 2017). Low levels of nocturnal illumination can significantly disrupt the life-history traits of moths, particularly by suppressing or delaying the initiation of pupal diapause. Sex-specific effects of ALAN also seen where male caterpillars under green and white light shows reduced mass, early pupation and lower pupal mass (Van Geffen *et al.,* 2014).

Anthropogenic radiofrequency electromagnetic radiation (AREMR)

AREMR are the most widely used form of EMR. This AREMR include different type of radiation like ELF, VLF, LF, Radio waves and Micro waves. So maximum studies conducted on effects of AREMR on insects.

First study was conducted on pupae of *Tenebrio molitor* by Carpenter and Livstone, 1971. They irradiated the pupa with 10 GHz microwaves at 80 mW for 20–30 min and 20 mW for 20 minutes. There are rise in the proportion of insects with abnormalities or dead as a result. Since then, many studies had conducted on effect of EMR on Insects.

However maximum studies of EMR have been conducted on two insects i.e. the fruit fly (*Drosophila melanogaster*) and honey bees (*Apis mellifera*) (Balmori, 2021). In fruit fly, EMR shows developmental delay and reproductive failure.

Studies have shown the honey bee (*Apis mellifera*) is able to detect magnetic fields physiologically and potentially use this capacity for orientation, navigation and foraging Furthermore, bees use electric fields of the same magnitude as commonly encountered EMR for intraspecific (within hive) and interspecific (plant-pollinator) communication, in the context of foraging on floral resources. Therefore, there is the high possibility that AREMR could disrupt these physiological functions, ultimately affecting bee health and survival.

AREMR has significant biological and behavioural influences on insects, affecting their reproduction, development, physiology and orientation. In *Maruca vitrata*, exposure to low radiofrequencies (5-30 kHz) led to a notable reduction in oviposition, an extended developmental period and a decrease in adult lifespan, with negative effects becoming more pronounced over successive generations (Maharajan *et al.,* 2019). In *Blattella germanica*, exposure to weak radiofrequency and magnetic fields resulted in an extended free-running period of the circadian rhythm, indicating that EMR disrupts biological clocks (Bartos *et al*., 2019).

Honeybees (*Apis mellifera*), which are particularly sensitive to magnetic fields for navigation, showed several stress responses when exposed to EMR, including reduced foraging behaviour, impaired brood development, diminished queen fertility and disorientation. Queens exposed to cell phone radiation laid significantly fewer eggs per day compared to controls. Additional reported effects include reduced hatching success, altered pupal development, elevated haemolymph concentrations of carbohydrates, proteins and lipids, induction of worker piping behaviour leading to increased swarming and disruption of cognitive, learning, and communication abilities. Collectively, these findings indicate that EMR can impair insect reproduction, development and behaviour, potentially contributing to pollinator decline and colony collapse disorder (Sharma and Kumar, 2010).

Conclusion

EMR offers numerous advantages, making it impossible for us to completely cease its usage. However, it's essential to acknowledge the potential adverse effects it can have on invertebrate organisms like insects. These EMR could potentially disrupt their abundance, physiological functions, behavioral patterns and ultimately threaten their survival. Presently, there are relatively few studies focused on investigating the impact of EMR on insects, which makes it challenging to draw any definitive conclusions. Measures that can be implemented include the use of red light instead of white or green light, utilizing lower frequencies that are less harmful to insects, establishing proper guidelines and setting exposure limits. Further research is needed on insects in the context of ALAN/AREMR, using field-realistic models combined with factors like pesticides, pathogens and nutritional deficits, to comprehensively understand adverse effects and develop effective management strategies.

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