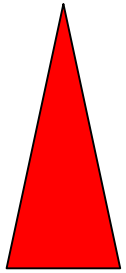
Environmental effects of electric, magnetic and electromagnetic fields: Flora and Fauna

Results of an International Workshop organized by the German Federal Office for Radiation Protection (BfS) Munich, 5 – 7 November 2019

Dr. Gunde Ziegelberger

Key question: Do changes of the environment affect/harm

- single individuals,
- the population,
- the species,
- the ecosystem?



Workshop program:

Session 1:	Exposure Assessment and Dosimetry
Session 2:	Interaction mechanisms
Session 3:	Low frequency electric and magnetic fields: Overhead powerlines and cables
Session 4:	Radiofrequency electromagnetic fields: Mobile communications including 5G

A) Radical Pair Mechanism

Daniel Kattnig, University of Exeter, Living Systems Institute and Department of Physics

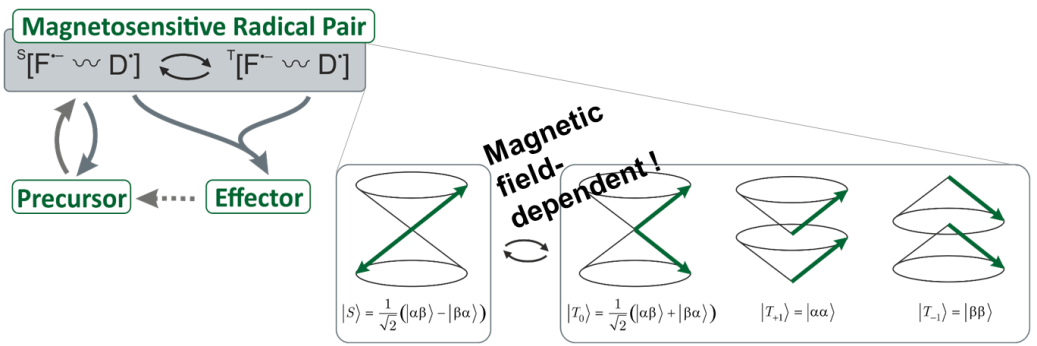
— Photo-induced redox processes lead to production of free radical pairs

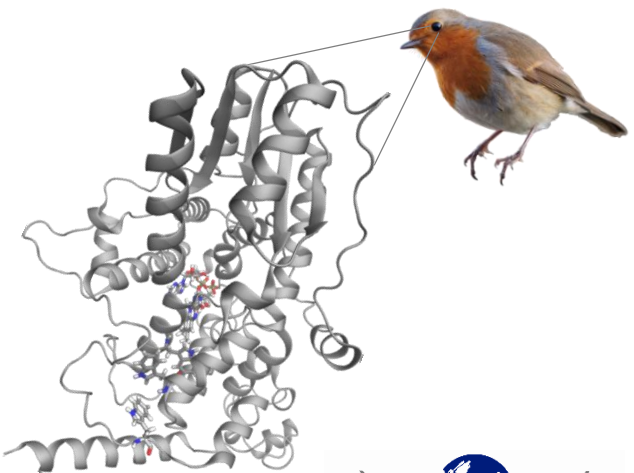
— Radical pairs characterized by their spin state (singlet or triplet state)

- Singlet and triplet states no stationary events → S-T mixing
- S/T states recombine into different reaction products

— External magnetic fields can influence reaction product ratio

— Candidate molecule for radical pair formation: Cryptochrome in the retina





K. Schulten et al. *Z Phys Chem.* (1978)
T. Ritz et al. *Biophys.* (2000)

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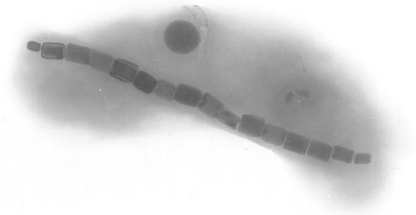
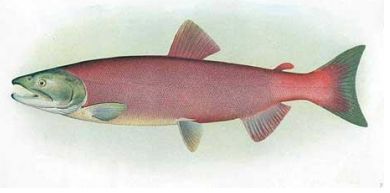
B) Magnetite

Michael Winklhofer, University of Oldenburg, Germany

— Of all natural iron-oxides, magnetite has highest spontaneous magnetization and therefore greatest *potential* for primary interaction with magnetic fields

— Species with magnetite deposits:
  - Beak of migratory birds
  - Some fish species
  - Subterranean mammals (mole rat)
  - On specialized structures of bacteria (magnetosome)





In animals and plants no known structure that is coupled to the nervous system and contains magnetite

Chew & Brown *Can J Zool.* (1989)
S. Marhold et al. *Naturwissenschaften* (1997)

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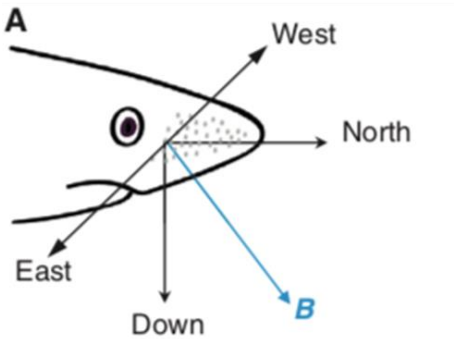
C) Induced electric fields

Michael Winklhofer, University of Oldenburg, Germany

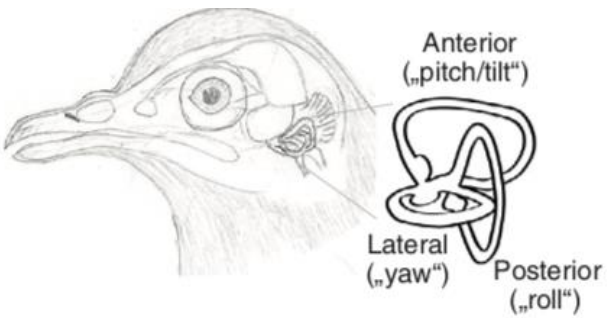
Conductive structures coupled with electroreceptors:

— Ampullae of Lorenzini in sharks
  - Perception of electric fields of their prey
  - Electric field sensitivity is 10 nV/cm



Ampullae of Lorenzini

— Ion channels in the inner ear of pigeons
  - Perception of magnetic fields via induced electric fields



M. Winklhofer et al. *Current Biology* (2019)

Environmental effects on birds

Henrik Mouritsen, University of Oldenburg, Germany

European robins (night-migratory songbird) are sensitive to anthropogenic EMF in the range 400 kHz – 10 MHz **under laboratory conditions**

- Circannual clock
- Inherited directions
- Sun compass
- Star compass
- **Magnetic compass**
- Multisensory maps

Follow-up studies:

Heiko Schmaljohann, Institute of Avian Research, Ornithological Station Helgoland, Germany

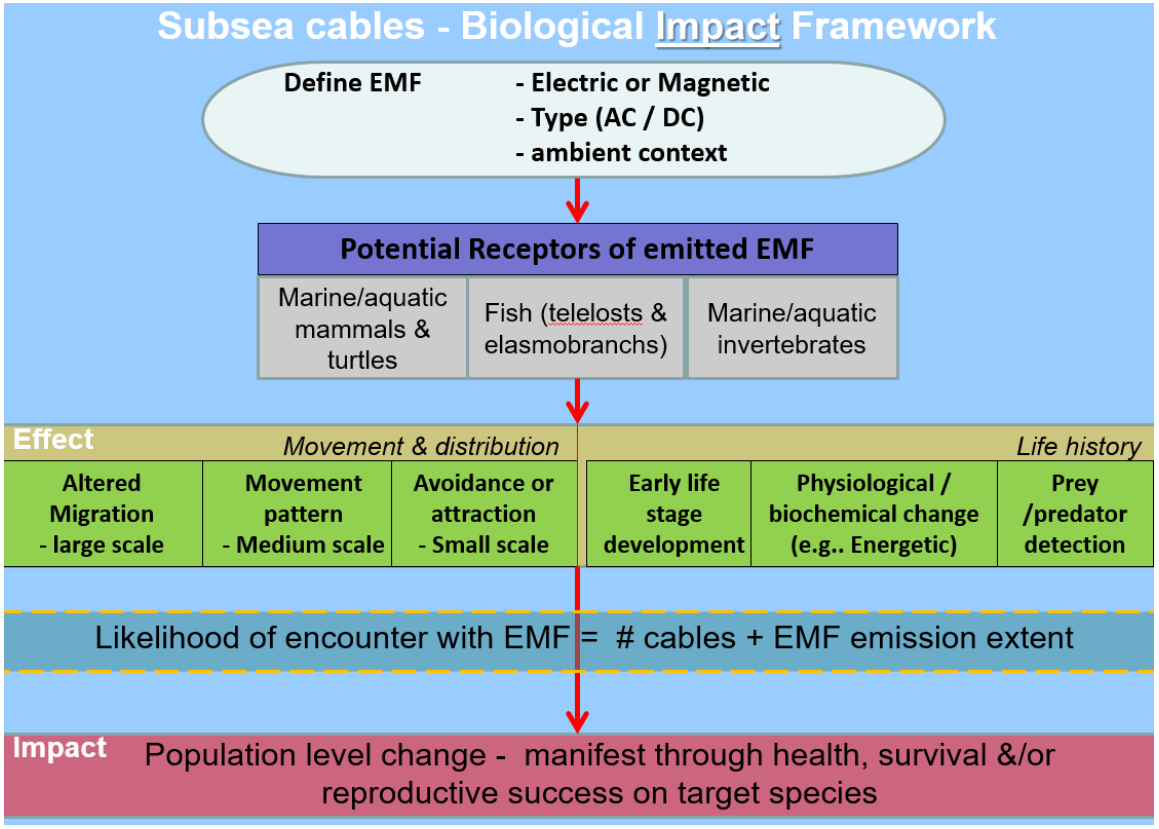
Effects of electromagnetic noise **on free-flying bird migrants**?

Northern wheatear

S. Engels et al. *Nature* (2014)
H. Mouritsen *Nature* (2018)
Eikenaar et al. *Proc Biol Sci* (2017)
H. Schmaljohann *Move Ecol* (2019)

Environmental effects on marine animals

Andrew Gill, Centre for Environment, Fisheries and Aquaculture Science, Lowestoft Laboratory, U.K.

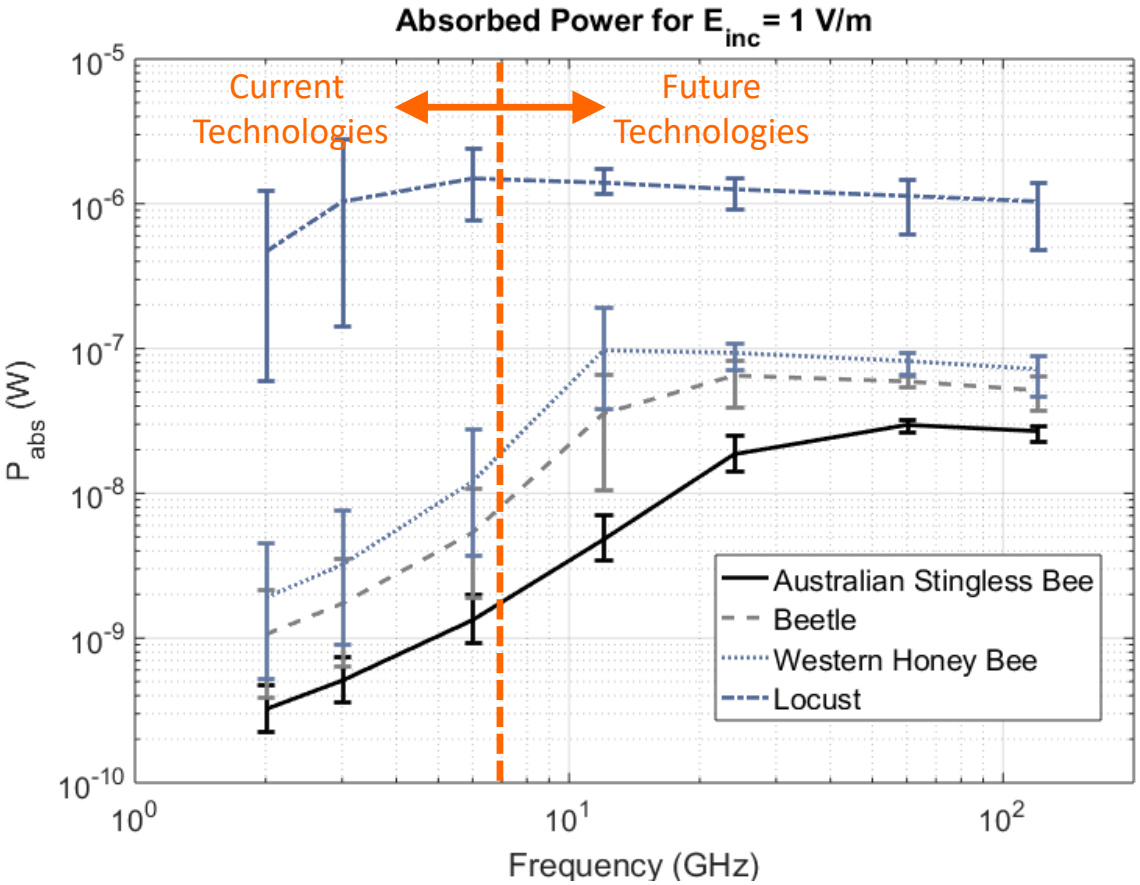


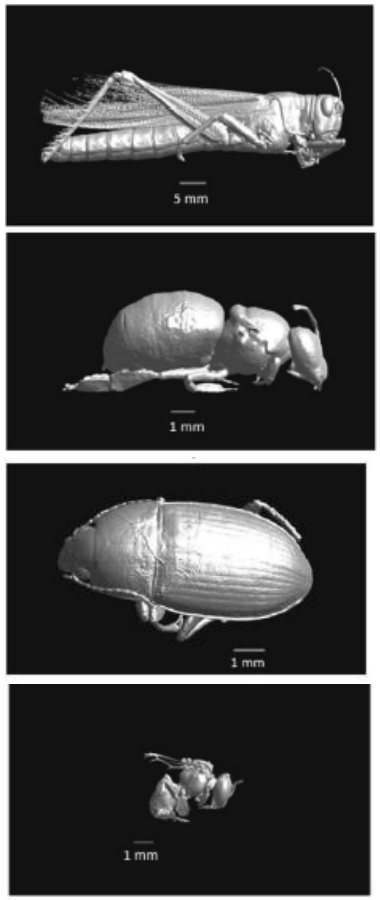
- single HV AC or DC cable no impact expected
- BUT this cannot be transferred into the future expansion plans for arrays (lack of knowledge)
- As main source of EMF is cable, seabed species, closer to the source, are considered most likely to encounter higher intensities

Exposure of insects to environmental RF EMF

Arno Thielens, University of Berkeley, USA / Department of Information Technology, Belgium

Numerical simulation of RF-EMF absorption in real models of insects:





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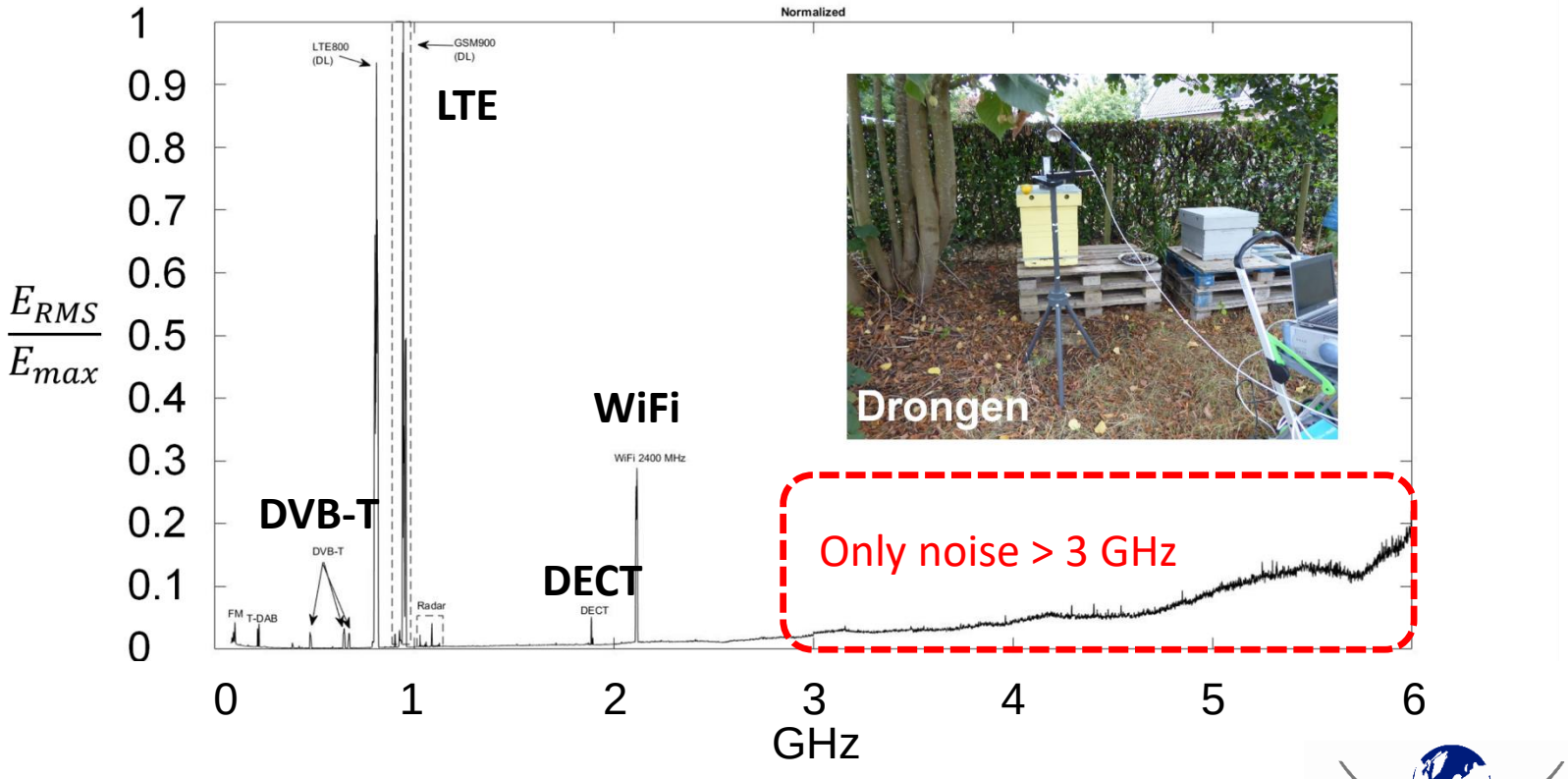
A. Thielens et al. *Sci Rep* (2018)

Exposure of insects to environmental RF EMF

Arno Thielens, University of Berkeley, USA / Department of Information Technology, Belgium

— The average E_{RMS} over 10 studied measurement sites was 0.06 V/m

— Rural, private areas → no uplink measured



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A. Thielens et al. *Sci Rep* (2020)

Exposure of insects to environmental RF EMF

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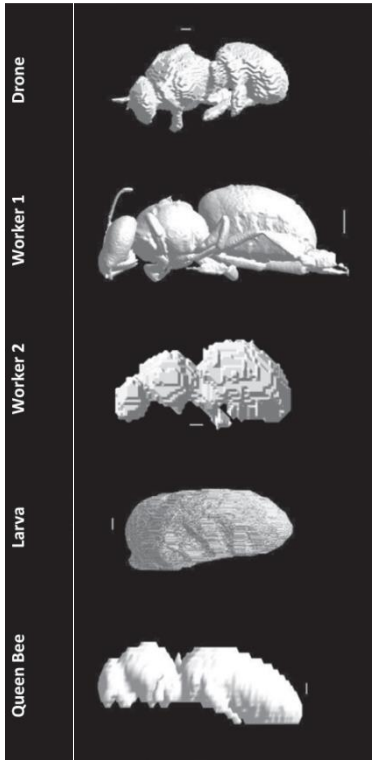
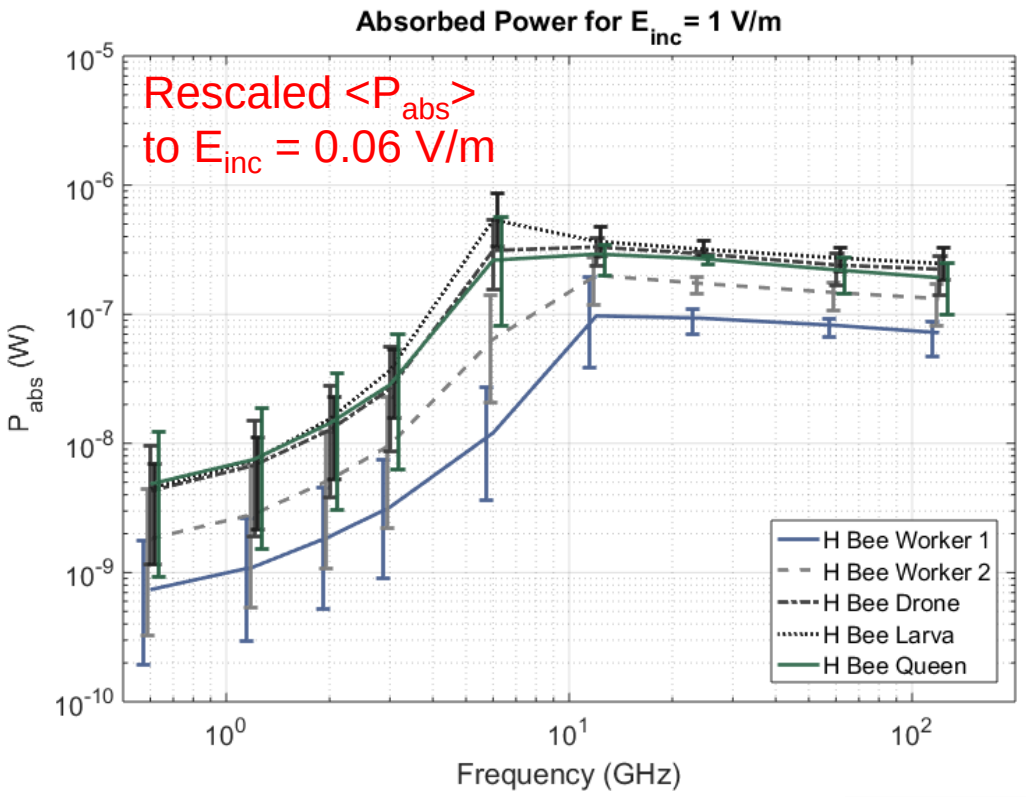
Closer look on Western Honey Bees: Total absorbed power





A. Thielens et al. *Sci Rep* (2020)

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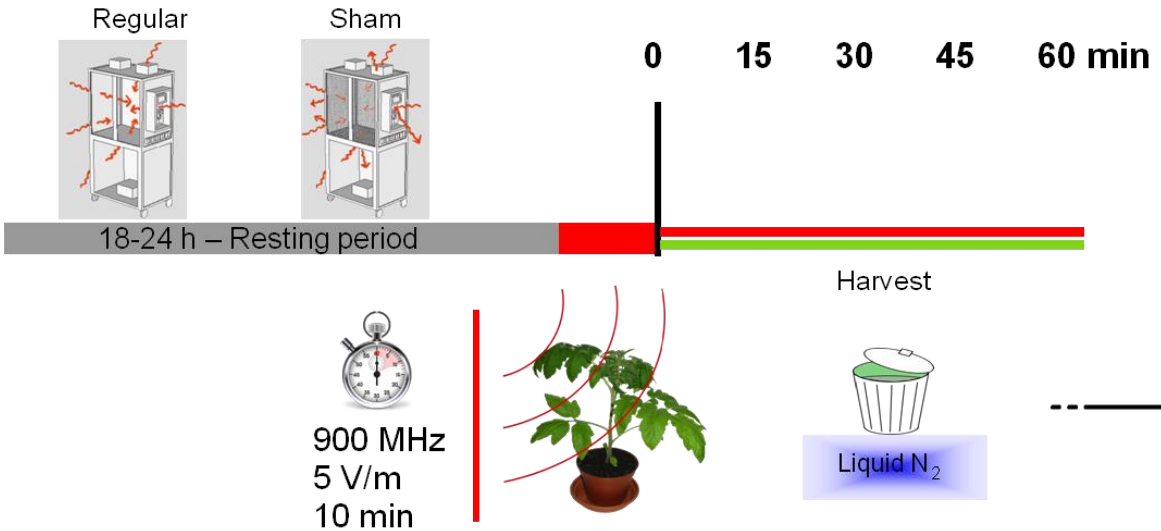
Effects on plants

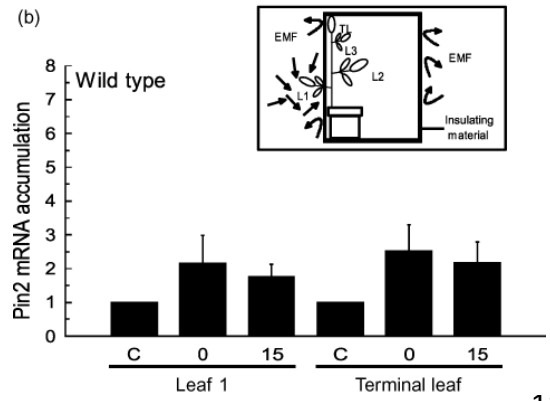
Alan Vian, University of Angers, France



Tomato
(Solanum lycopersicon)

Results:

1. Rapid (15 min) and transient (1 h) increase of RNA levels of stress-related genes (calcium dependent)
2. Systemic effect (localized exposure leads to reaction in the whole plant)

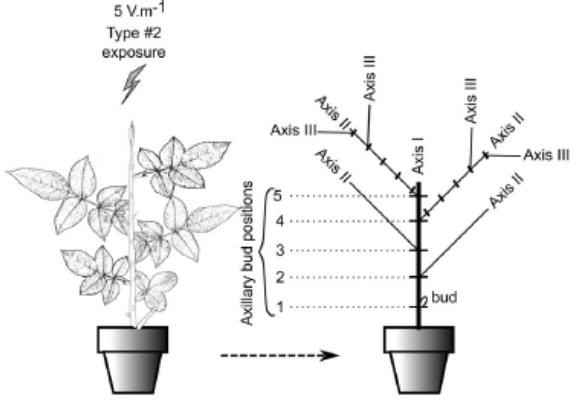


D. Roux et al. *Planta* (2008)
E. Beaubois et al. *Plant Cell Environ.* (2007)
A. Vian et al. *Biomed Res Int.* (2016)

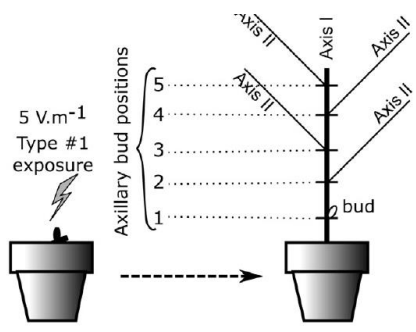
Effects on plants

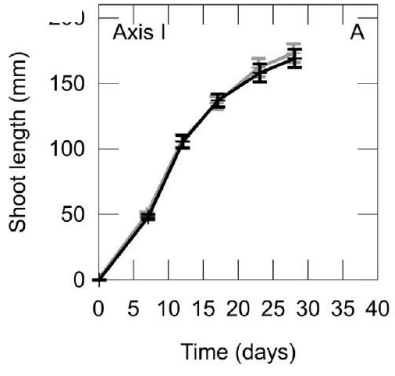
Alan Vian, University of Angers, France

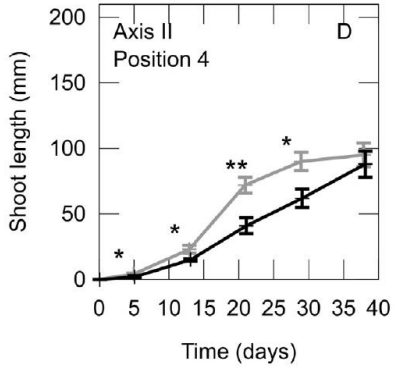
- 900 MHz, 5 V/m, 3x30 min (SAR: 720 nW/kg)
- No induced changes in the ramification or length of the newly-produced axes when exposing **a whole rosebush**
- Exposure of **rooted cuttings** bearing an axillary bud :
  - No change in axis I (that was preformed in the bud)
  - a significant reduction (up to 50 %) of newly-formed axis elongation, mainly at the upper positions

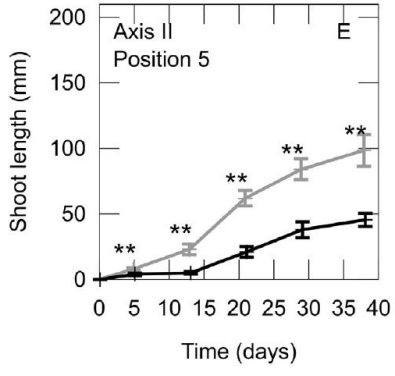


Rosa hybrida









Black: exposed
Gray: control

A. Grémiaux et al. *J Plant Physiol* (2016)

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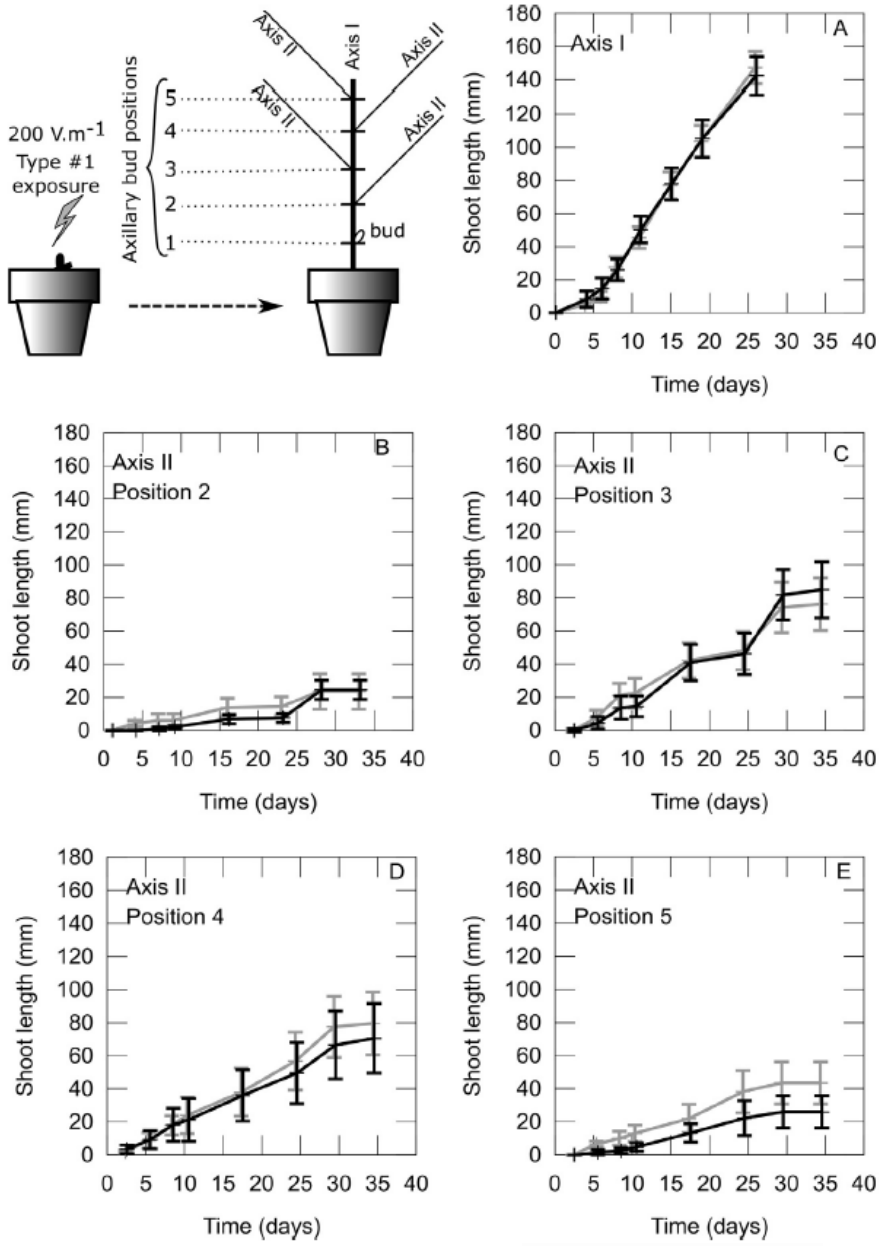
Effects on plants

Alan Vian, University of Angers, France

- 900 MHz, 200 V/m, 1x30 min (SAR: 1.15 W/kg)
- Temperature increase of 0.1°C after 16 min
- Exposure of rooted cuttings bearing an axillary bud :
  - No change in axis I (that was preformed in the bud)
  - No significant differences in axis elongation at upper positions



Black: exposed; Gray: control

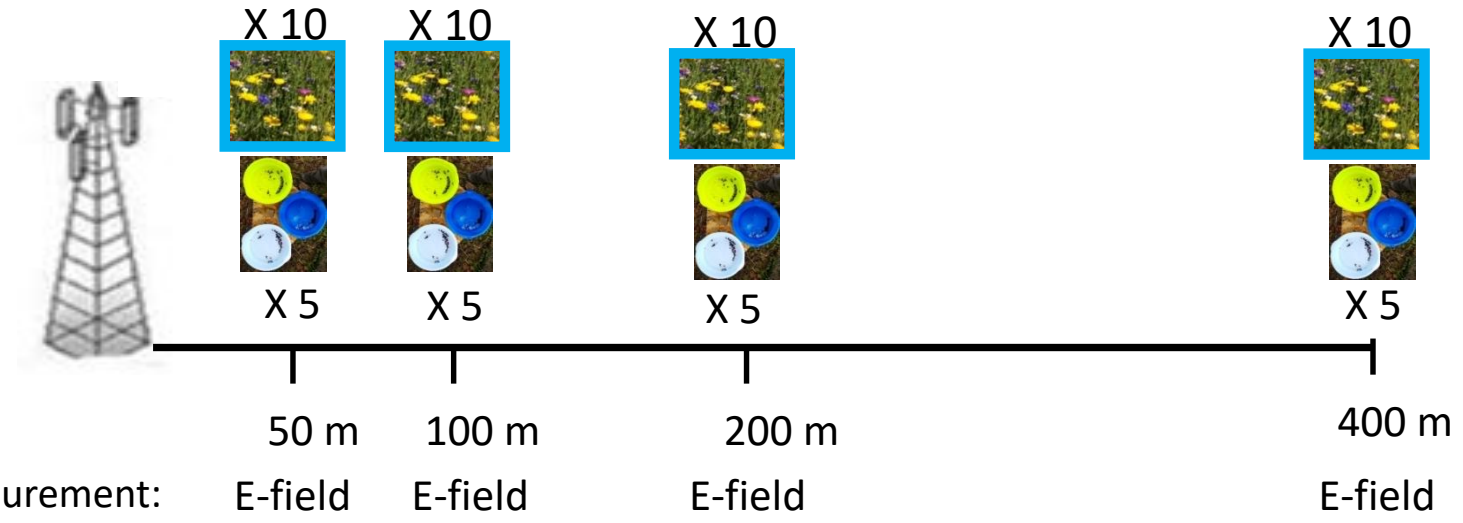
A. Grémiaux et al. *J Plant Physiol* (2016)

Effects on invertebrates

Amparo Lázaro, Mediterranean Institute for Advanced Studies, Spain

Field study on two islands (Limnos and Lesvos) with 5 mobile telecommunication antennas per island:

— Effects on biodiversity of pollinating insects depending on distance to antenna?



No significant differences of the measured fields between the 2 islands and distance to antenna

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A. Lázaro et al. *J Insect Conservation* (2016)

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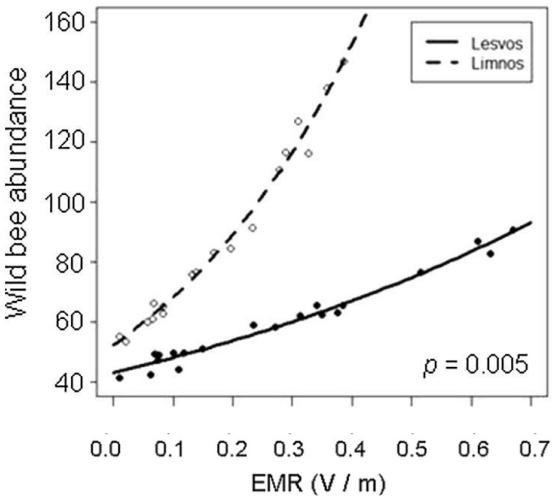

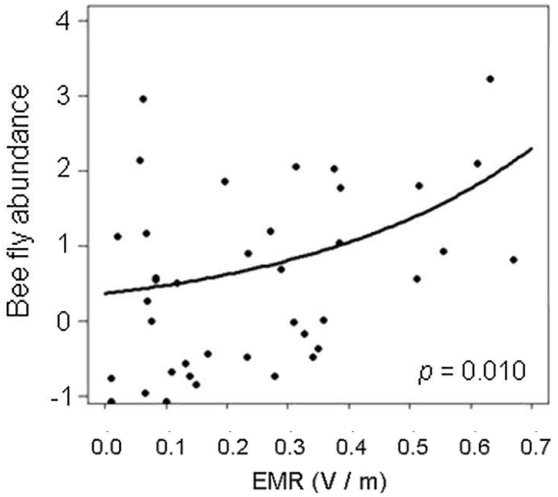

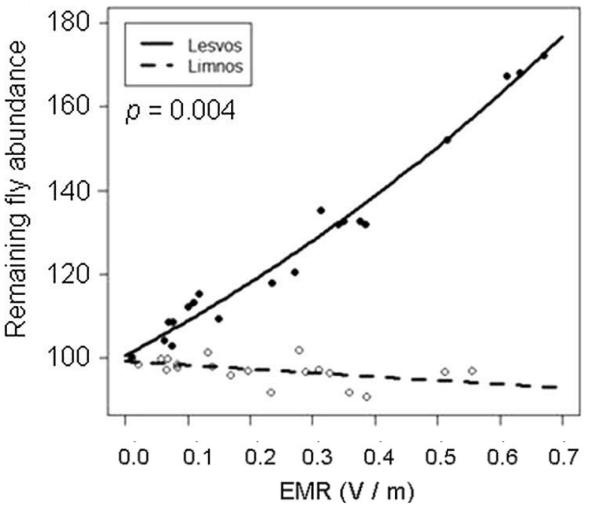

Positive relationships between EMR and abundance!

A. Lázaro et al. *J Insect Conservation* (2016)

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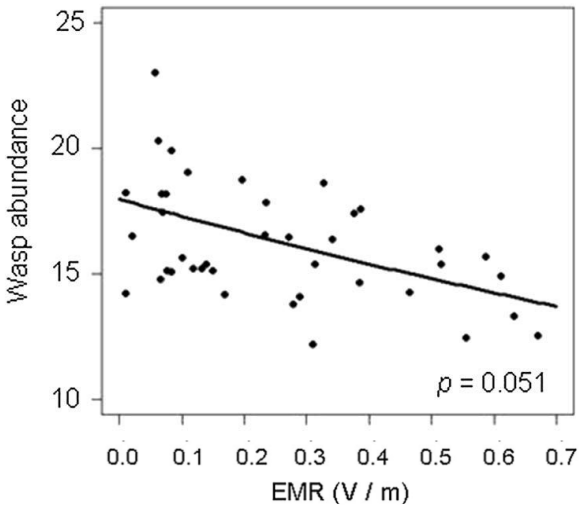
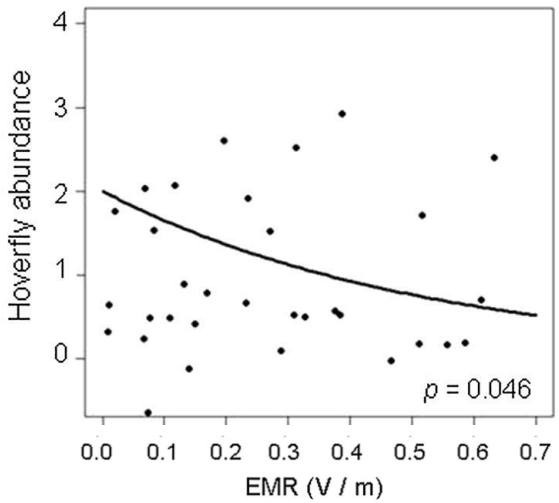
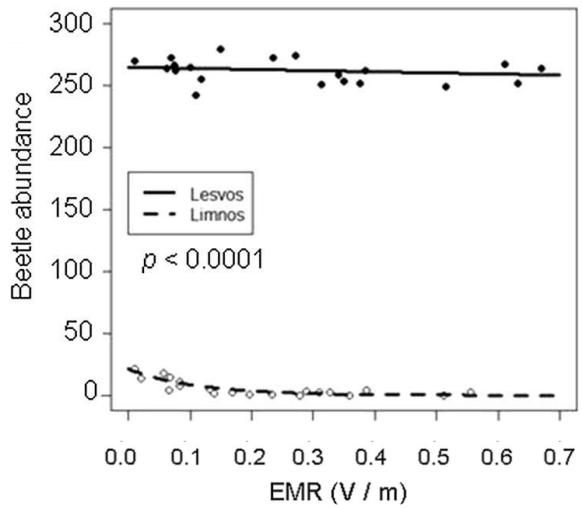
Effects on invertebrates

Amparo Lázaro, Mediterranean Institute for Advanced Studies, Spain







Negative relationships between EMR and abundance!

A. Lázaro et al. *J Insect Conservation* (2016)

Effects on pollinators

Adam Vanbergen, UMR Agroécologie, National Institute for Agricultural Research (INRA), France

Risk to pollinators from:

— Artificial Light at Night (ALAN)

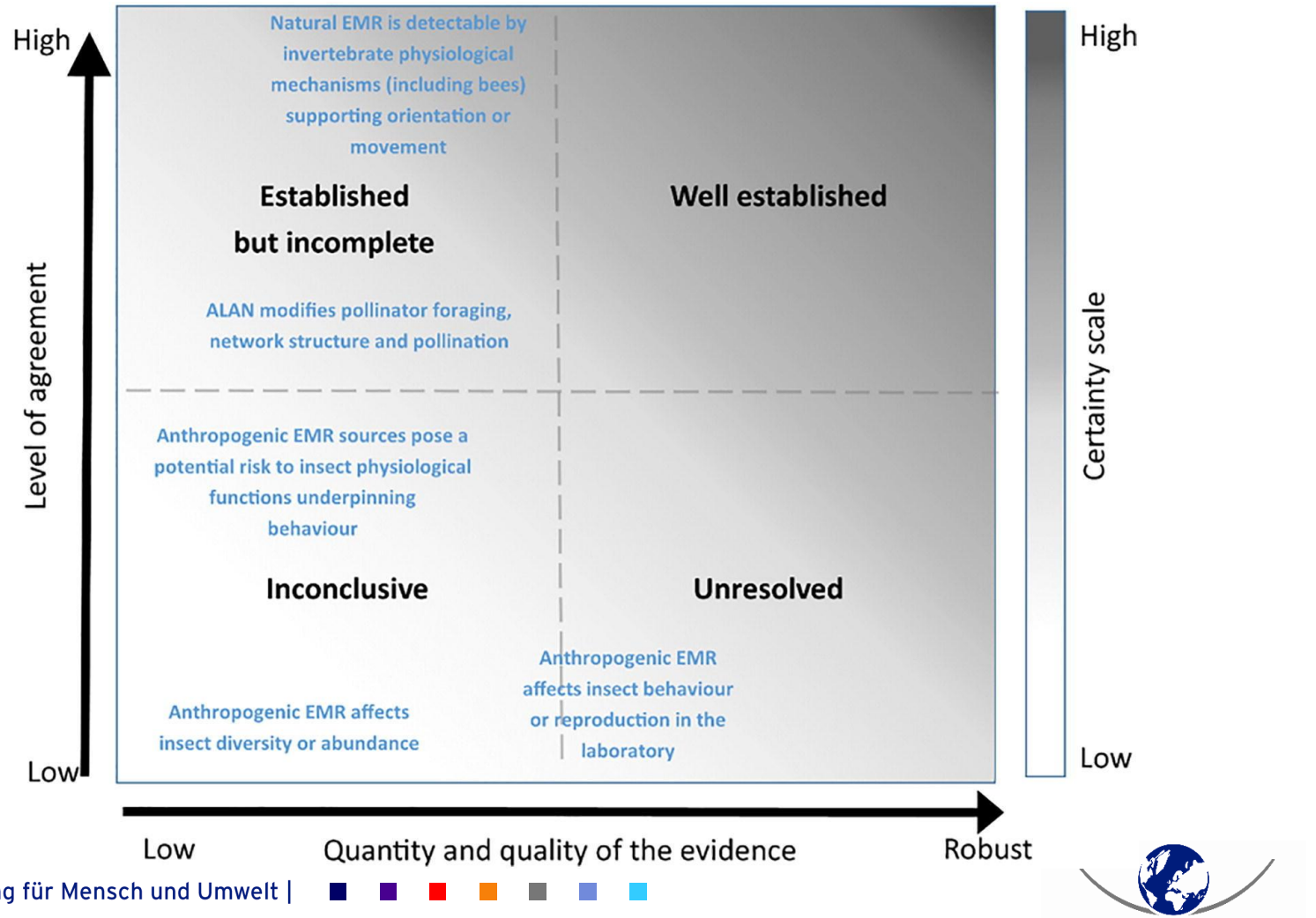
— Anthropogenic radiofrequency electromagnetic radiation (AREMR)

„The impacts of artificial electromagnetic radiation on wildlife (flora and fauna). Current knowledge overview“ P. Malkemper et al.
A Report of the EKLIPSE Project (2018) www.eklipse-mechanism.eu

“Risk to pollinators from anthropogenic electromagnetic radiation (EMR): Evidence and knowledge gaps” A. Vanbergen et al.
Science of the Total Environment (2019)

Effects on pollinators

Adam Vanbergen, UMR Agroécologie, National Institute for Agricultural Research (INRA), France



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A. Vanbergen et al. *Science of the Total Environment* (2019)

Conclusions of the International Workshop

- Some animal and plant species can sense electric or magnetic fields at low field intensities, but mechanisms of perception are not well understood
- Anthropogenic sources modified behavior of migrating birds in laboratory studies – relevance unclear; field studies are on the way
- Some studies observed (negative?) effects, but results are in part inconsistent or even contradictory
- Significant differences in study quality exist
- So far, there is no validated scientific evidence for negative effects on animals and plants (on an individual and population level)
- Single results of high quality papers should be reproduced

→ **Scientific report is on the way**

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