The impacts of artificial Electromagnetic Radiation on wildlife (flora and fauna). Report of the web conference

A report of the EKLIPSE project

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Report of the EKLIPSE web conference “The impacts of artificial Electromagnetic Radiation on wildlife – fauna and flora”

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1. Executive Summary

EKLIPSE received in 2016 a request by Buglife to produce an overview of knowledge relating to the impacts of Electromagnetic Radiation (EMR) on wildlife and answered the request via an interactive web conference.

After evaluating and reformulating the question with the requester, EKLIPSE assembled the most recent literature on the topic and established a group of experts in the field to analyse the publications. They produced a preliminary document assessing the quality of the selected studies, pointing out the gaps, and describing the existing knowledge on the topic.

This document was used as the basis for discussions during the web conference that followed. The event included scientists and other stakeholders and was organised in sessions divided by taxonomic group (plants, vertebrates, invertebrates). The participants commented on the work done by the experts, discussed the findings, and developed a list of key research needs and policy recommendations for each taxonomic group.

Next to the specific knowledge gaps and research needs associated to each taxonomic group, several research needs that were common to the different groups were identified and ranked according to their importance, feasibility and contribution. EKLIPSE also extracted general policy recommendations based on the outputs of the participants.

The general message conveyed during the conference was that there is an urgent need to strengthen the scientific basis of the knowledge on EMR and their potential impacts on wildlife. In particular, there is a need to base future research on sound, high-quality, replicable experiments so that credible, transparent and easily accessible evidence can inform society and policy-makers to make decisions and frame their policies.

This report highlights the different steps leading to the organisation of the web conference, the details of the proceedings of the conference itself, as well as a summary of the main results.

2. Introduction and context

2.1 Organisers

EKLIPSE is an H2020 funded project that aims to develop an innovative and self-sustaining EU support mechanism for evidence-based and evidence-informed policy on biodiversity and ecosystem services. A major function covered by EKLIPSE is the identification of research needs and emerging issues. This is done by answering requests from policy, civil society and science. These requests then lead to an in-depth knowledge synthesis, a foresight activity (identification of research gaps and emerging issues), or a societal engagement activity – depending in the nature of the topic of the request.

Buglife is a non-profit organisation in Europe devoted to the conservation of all invertebrates.

Buglife's aim is to halt the extinction of invertebrate species and to achieve sustainable populations of invertebrates.

2.2 Context

Electromagnetic radiations or EMR are a combination of invisible electric and magnetic fields of force that can occur both naturally and due to human activity (anthropogenic EMR).

Anthropogenic EMR are used in a wide range of technologies (namely powerlines, TV/radio broadcasting, Wi-Fi, 2G/3G/4G communications), with their presence expanding in terms of the range of frequencies and the volume of transmissions. An important issue is to explore how current use of EMR is affecting biodiversity and ecosystem services (such as pollination and pest control). A better understanding and awareness of environmental risks from EMR can lead to the development, promotion and implementation of adequate and timely policy frameworks.

The increase of EMR and its potential effects on wildlife has already been identified by an international experts group led by Bill Sutherland as 1 of the 15 emerging issues that could affect global biodiversity but that are not yet well recognised by the scientific community, as reported by their 9th annual horizon scanning exercise for conservation and biodiversity (Sutherland, 2018).

However, the existing community of experts in this field is still very limited, and research tends to be focussed on only a few specific species or taxa, and certain types of radiations. The technical set up and conditions in which the studies are undertaken are often questionable, and there are no common standards or methodologies that can be used to compare and/or reproduce the experiments.

There are a number of policy documents and regulations published related to the risks and effects of EMR[1] but most of them refer to the impacts on human health, very rarely incorporating the effects on animals or plants.

In 2015, a group of international scientists released an appeal to the U.N. calling on them to better assess the risks and protect humans and wildlife from the effects of EMR (EMF, 2015). By 2017 this appeal had been signed by over 230 scientists.

2.3 Introduction to the request

EKLIPSE launched a first "Call for request" in September 2016, inviting decision-makers, practitioners and other stakeholders to submit a proposal with questions affecting biodiversity. The request submitted by Buglife on the impacts of anthropogenic EMR on invertebrates was selected to initiate a process for identifying key knowledge gaps and research needs, as well as to formulate recommendations. Because the corpus of research studies on the impacts of EMR on invertebrates specifically appeared limited, and because of the interest in comparing the effects on different types of organisms, the scope of the request was adjusted and extended to the impacts on vertebrates and plants too. However, it was decided to still exclude the impacts on human health, since humans are differently exposed to radiations and the literature – which is also more extensive - is part of the medical field of research.

[1] At European level, the latest one being the Directive 2013/35/EU of the European Parliament on minimum health and safety requirements regarding the exposure to electromagnetic fields (European Union, 2013). Other policy documents and reports found were mainly published by national agencies.

2.4 Scoping of the literature

A first search for relevant peer-reviewed literature was undertaken by EKLIPSE using ISI Web of Knowledge and Google Scholar using the following combinations of keywords:

- EMR; EMF; electrosmog; electromagnetic field; electromagnetic radiation; electromagnetic

AND

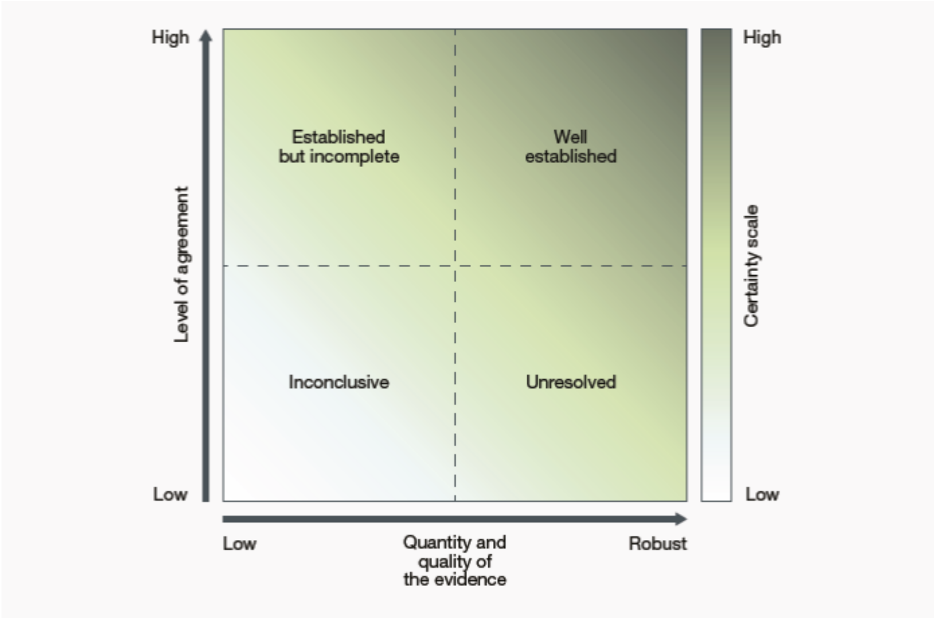
- wildlife; invertebrate(s); vertebrate(s); plant(s); animal(s); insect(s); arthropod(s); bee(s); *Drosophila*; mammal(s); fish; amphibian(s); bird(s); tree(s); flower(s); biodiversity.

Only recent papers (from 2000 onwards) were considered. The publications cited in the identified papers were also examined to complement the list and a further search was done with the names of recurring experts. The aim was not to compile a comprehensive list of references, but to gather a representative set of papers and studies to allow an overview of the current evidence and knowledge gaps. This evidence base was further complemented through a Call for Knowledge to the wider scientific community through the EKLIPSE KNOCK Forum.

2.5 Analyses by the Experts Steering Group

EKLIPSE then invited selected scientists to join the Experts Steering Group to analyse the publications and help prepare the organisation of a consultation through a web conference. The Experts Steering Group was multidisciplinary and was composed of four biologists/ecologists specialised in different taxonomic groups, as well as two physicists having worked with electromagnetic field (see Appendix I: Members of the Experts Steering Group).

In total, 97 of the 147 scientific papers or reviews initially identified were used in the analysis (see the Knowledge framework document, Malkemper et al, 2018). The Expert Steering Group conducted the assessment according to their expertise by dividing the work into three main taxonomic groups (Plants, Vertebrates, Invertebrates). They examined the scientific quality and technical set up of the studies and identified research gaps and needs for each taxonomic group. They also assessed the confidence level of the findings and messages reported in the studies through a qualitative “four-box model” (see Figure 1) , adopted from the IPBES (IPBES, 2016), to communicate the level of certainty in knowledge and show how each key message is based on the assessment of the quantity, quality and level of expert agreement in the evidence.



The summary terms to describe the evidence are:

- **Well established:** comprehensive meta-analysis[19] or other synthesis or multiple independent studies that agree.
- **Established but incomplete:** general agreement although only a limited number of studies exist but no comprehensive synthesis and, or the studies that exist imprecisely address the question.
- **Unresolved:** multiple independent studies exist but conclusions do not agree.
- **Inconclusive:** limited evidence, recognising major knowledge gaps

Confidence increases towards the top-right corner as suggested by the increasing strength of shading.
Source: modified from Moss and Schneider (2000).

Figure 1 Four-box model for the qualitative communication of confidence

The experts' findings were compiled into a document that has been used as the basis for discussions during the web conference (see Malkemper et al, 2018).

3. The web conference

3.1 Objectives

EKLIPSE organised its online, interactive web conference from Monday 22nd to Thursday 25th of January 2018. A wide range of experts from different disciplines was selected and invited to discuss the current knowledge on the effects of EMR on wildlife.

The aim was to highlight the current state-of-the-art in this field, to identify knowledge gaps related to the impacts on different taxonomic groups, to discuss the technical aspects and methodologies used in current studies, and to identify and prioritize key research needs and policy recommendations.

The specific objectives of the web conference were to discuss the scope of existing studies, weaknesses and gaps as well as major findings; to identify and prioritize key research needs potentially in relation to current policy needs; and to identify policy recommendations based on current knowledge.

3.2 Format and organisation

To achieve its objectives, EKLIPSE used an innovative, collaborative format where the presentations were kept to a minimum. This meant the focus could be on capturing what the participants thought about the topics - which they explored in 15-20 minute, small-group discussions throughout the conference.

What made this conference different from other virtual conferences was that the ideas and insights from the participants' discussions were able to be recorded and integrated, so they formed the key output of the conference. This outcome was enabled by leveraging two online tools together. Zoom was used as a virtual "plenary room" for the presentations and to split participants in virtual, small discussion groups (5-6 people per group). A collaborative group-work tool from Covision made it possible for the participants to compile, and send to the facilitator, the ideas and insights they had identified during their discussions. The whole group was then able to see the key ideas that were generated and they could prioritize them through the online polling system.

The conference was organised in five sessions spread over four days (see Appendix II: Agenda of the web conference), with daily sessions of 2 hours:

- Monday 22nd at 16:00 CET for the introduction, framing and opening discussions

Invited expert/presenter: Matt Shardlow, Buglife

- Tuesday 23rd at 13:30 CET for group discussion on Plants

Invited expert/presenter: Prof Alain Vian, University of Angers

- Tuesday 23rd at 16:00 CET for group discussion on Vertebrates

Invited expert/presenter: Dr Pascal Malkemper, Research Institute of Molecular Pathology, Vienna

- Wednesday 24th at 16:00 CET for group discussion on Invertebrates

Invited expert/presenter: Dr Thomas Tscheulin, University of the Aegean, and Dr Adam Vanbergen, Centre for Ecology and Hydrology, Edinburgh

- Thursday 25th at 16:00 CET for integration and final plenary recommendations

During the introduction session, a summary of the findings of the experts and the background document were presented, as well as an explanation on the use of the online tools.

The three sessions on each taxonomic group followed the same structure: the appointed expert of the Steering Group presented the findings related to its taxonomic group. The participants were invited to work in small groups three times per session to identify 1/ knowledge gaps (on the basis of the literature review), 2/ research needs, and 3/ policy recommendations. After a process of compiling the key ideas into themes done by EKLIPSE, using the Covision tool, the themes from those discussions were presented back to the participants, so they could vote on what they considered as the most important and relevant elements.

During the final session, a set of transversal research needs/priorities, as well as a set of transversal policy recommendations was compiled by EKLIPSE and presented to the participants who had the opportunity to rank the research needs/priorities according to a selected set of criteria.

3.3 Participants

EKLIPSE conducted a thorough analysis of relevant scientists with direct expertise in the impacts of EMR on wildlife. The scientific community appeared to be rather small and most of the identified researchers had expertise on a specific taxonomic group but did not specialise on EMR impacts. Nevertheless, EKLIPSE identified over 250 experts who were invited to participate in the web conference. Information about the event was also largely disseminated to the scientific and knowledge community through mailing lists, social media and other communication channels of EKLIPSE and its networks.

During the four days and five sessions of the web conference, a total of 55 participants attended (see Appendix III: List of participants to the web conference), supported by a technical and organisational team of 6 people (see Figure 2).

In total, 19 countries from across the world were represented (see Figure 3).

	TOTAL All sessions	Introduction session 22/1	Plants session 23/1	Vertebrates session 23/1	Invertebrates session 24/1	Closing session 25/1
Participants	61	36	31	35	27	34

Figure 2 Number of participants per session

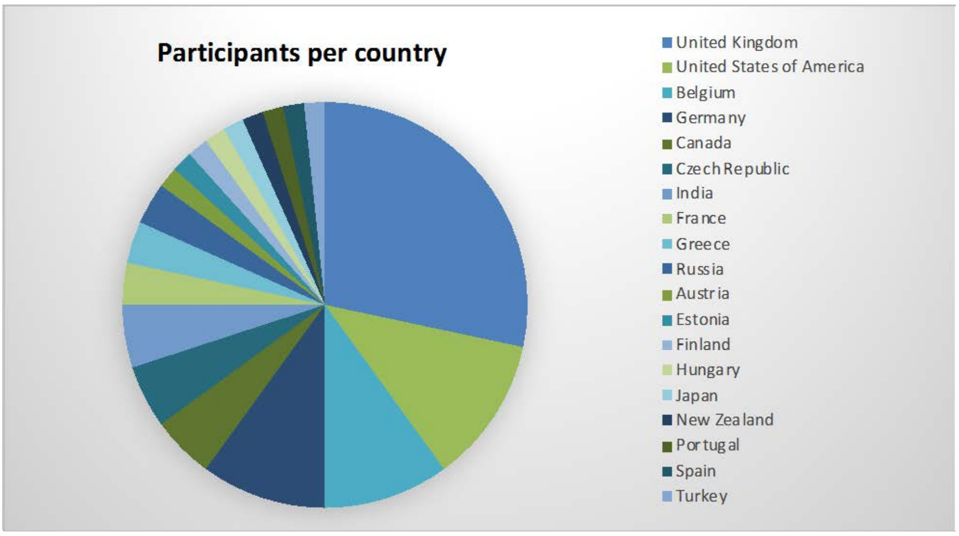


Figure 3 Number of participants per country

From the participants who shared information about themselves (see Figure 4), the large majority identified as scientists, but some also indicated that they work as policy-makers, practitioners, and/or[2] entrepreneurs on topics related to EMR. The great majority reported being active in the Natural Sciences, compared to only a few experts in Technology/Electrical Engineering, the others being professionals from other fields. A third of them had already at least some experience with studying the effects of EMR, even if mostly the case in the framework of research on specific species or ecosystems of their expertise.

2 Participants could indicate more than one field of activity or area of expertise.

Figure 4 Profile of the participants

Current activity		Area of expertise		Experience with EMR	
Scientist/academic	56%	Natural Sciences	69%	Very experienced	25%
Policy-maker	10%	Technology/Electrical engineering	8%	Somewhat experienced	42%
Practitioner	6%	Other	22%	Little experience	11%
Entrepreneur	13%			No experience but interested	22%
Other	15%				

4. Results

4.1 Introduction session

For this first session, the participants were asked to discuss and answer the following question:

"What do you think of the results presented in the background document? What stands out for you? Is there anything missing?"

In general, the participants agreed with the conclusions of the expert group.

The results were compiled into main themes:

- More research is needed on migrating species (e.g. like dragonflies)
- Consider knowledge from local, non-expert people too
- Need for a standardized model and/or standardised criteria for EMR radiation
- Identify the best organisation/people to gather data on EMR effects and agree on a platform to share the knowledge
- Find a way to prioritise the risks related to EMR
- Need for studies that can be replicated to ascertain which results are consistent
- Fill the temporal gap: important research from past decades should be included

4.2 Session on a specific taxonomic group: Plants

The participants were asked to discuss and answer the following question:

"In reviewing the key knowledge gaps in the background document, what stands out for you? Is anything missing?"

The results were compiled into main themes. As a result, the participants pointed out additional knowledge gaps that they perceived should have been included in the background document:

- Older research studies about radar and broadcast transmitters on ecological systems
- Research on the effects on biota of low frequency fields and EM static fields
- To investigate research on positive, stimulating effects of EMR
- Research on synergistic effects of different kinds of EMR in the environment
- Assessments of the effects of "new" frequencies on biodiversity
- More knowledge on the mechanisms of EMR effects on biota

- Overall, more field studies are needed (e.g. to answer questions such as: How do the lab results and EMR relate to the real world? What frequencies are commonly encountered at what power in the real world? How much of a risk?)

Next, participants were asked to discuss and answer the following question:

"Based on the identified knowledge gaps, what do you consider as the most important research needs/priorities?"

The results were compiled into main research needs. After being presented to them, participants were able to vote on the most important ones (up to 3 research needs per participant). The ranking of research needs is shown below with the percentages indicated at the end.

- Standardization and standard methodology for future study designs (21%)
- More and better cooperation between field and lab studies (14%)
- Need to account for confounding/interfering factors in analyses of EMR effects (14%)
- Research on the effects at different levels of biological organisation (ecosystem, population, species) (14%)
- Better understanding of the role of natural EMR as basis for plant growth (10%)
- Research on the impacts of 5G technology and LED lamps (10%)
- Research on the effects of EMR on evolution and co-evolution (7%)
- Research on the impact of EMR on water uptake by plants (5%)
- Study the effects of pulsed radiation (5%)

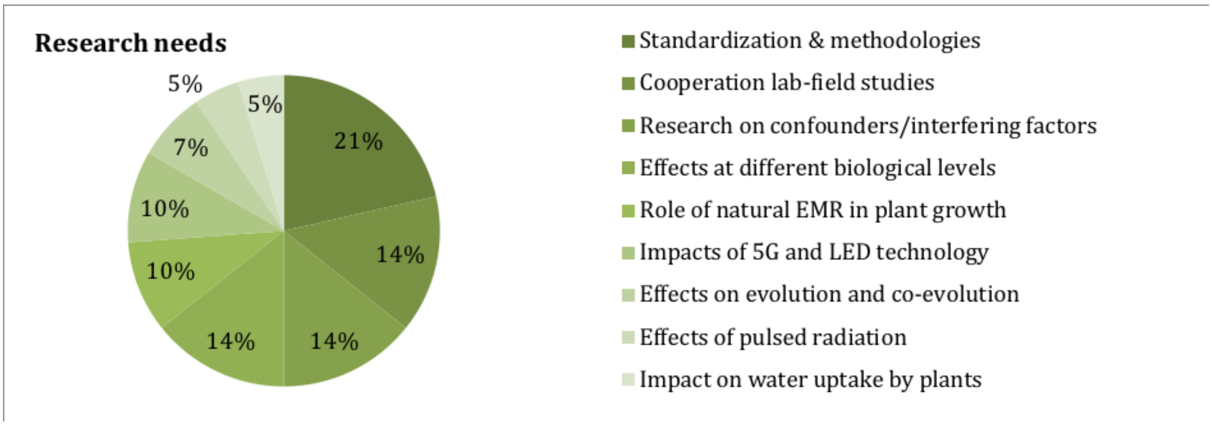


Figure 5 Results of the voting on research needs

Finally, the participants were asked to discuss and answer the following question:

"Based on the knowledge available, what policy recommendations would you propose?"

The results were compiled into main recommendations. After being presented to them, participants were able to vote on the most important ones (up to 2 recommendations per participant). The recommendations are presented below in rank order with percentages indicated.

- Foster cross-institutional/inter-disciplinary collaboration (including leading experts on exposure/dosimetry and biology/ecology) in the studies of EMR effects (46%)
- Define legal limits of EMR (based on scientific results), that will not be harmful to humans and wildlife (25%)
- Ensure knowledge sharing and faster learning through the establishment and use of open databases (14%)
- Use the precautionary principle in relation to EMR and their environmental impacts (14%)
- Develop alternative technology (regarding mobile phones, Wi-Fi) (0%)

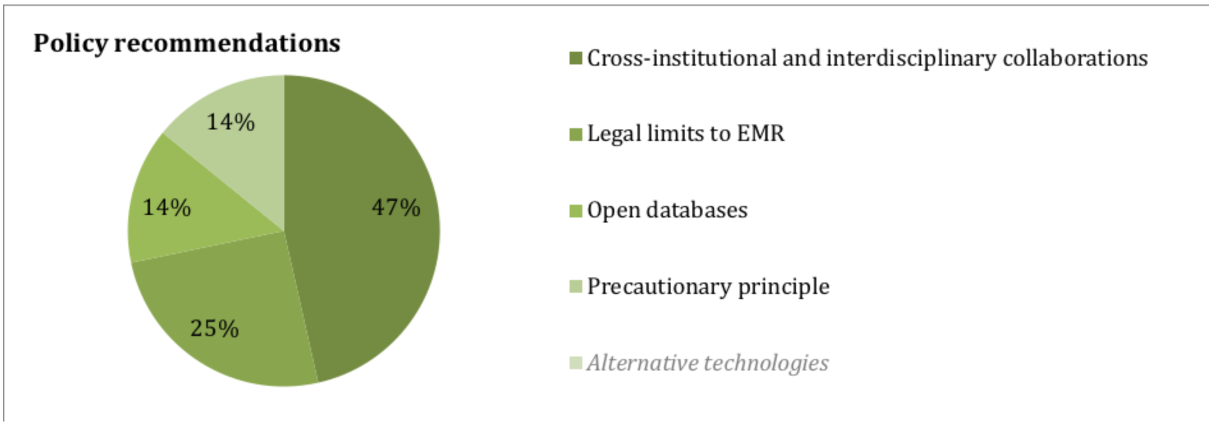


Figure 6 Results of the voting on policy recommendations

4.3 Session on a specific taxonomic group: Vertebrates

The participants were asked to discuss and answer the following question:

"In reviewing the key knowledge gaps in the background document, what stands out for you? Is anything missing?"

The results were compiled into main themes:

Gaps in the background document:

- Studies on lab animals (rodents,...)
- Search with keywords "radio-frequency" and "microwave"
- Older studies (before 2000)

General knowledge gaps:

- Research at the cellular level
- Knowledge about how real-world levels compare to the levels considered in lab experiments
- Studies pertaining to EMR mechanisms & dosimetry of EMR
- Observations from local people

- Rigorous research on animal populations near EMR sources (e.g. cell towers)
- Evidence for population declines of birds that are attributable to EMR

The participants were asked to discuss and answer the following question:

“Based on the identified knowledge gaps, what do you consider as the most important research needs/priorities?”

The results were compiled into main research priorities/needs. After being presented to them, participants were able to vote on the most important ones (up to 4 research needs per participant). The research priorities/needs are presented below in rank order with percentages indicated.

- Better replicated studies and high-quality papers (16%)
- Better understand better the patterns of real world exposure, including dosimetry (14%)
- Organisational coordination to develop standard data models and experimental methodologies, including standard reporting protocol, e.g. around powerful radars (14%)
- Multidisciplinary teams, especially including GIS experts (14%)
- Research of effects of EMR on different levels of biological organisation: at protein level, at genomic level, at assemblage level, etc. (11%)
- Improve understanding of the possible effects of EMR on movement, location and migration of vertebrates in real world situations (9%)
- Inclusion of citizens and consider citizen science approaches to improve knowledge base (7%)
- Research on how different frequencies interact in relation to affecting organisms (5%)
- Standardization of exposure levels and measurements (5%)
- Further explore the research on the Radical-Pair mechanism (4%)
- Establish how the (electro)magnetic sense in birds works (2%)

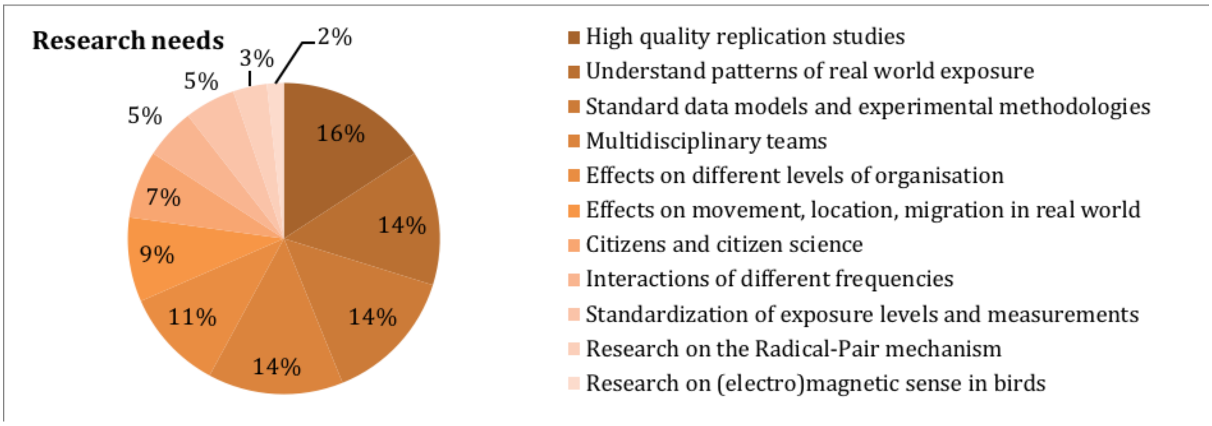


Figure 7 Results of the voting on research needs

Finally, the participants were asked to discuss and answer the following question:

“Based on the knowledge available, what policy recommendations would you propose?”

The results were compiled into main recommendations. After being presented to them, participants were able to vote on the most important ones (up to 4 recommendations per participant). The recommendations are presented below in rank order with percentages indicated.

- More funding available on EMR research (19%)
- Establish a cross-disciplinary platform in order to enhance understanding and foster collaborations between institutions, countries, and disciplines (19%)
- Conduct cross-institutional studies that include cooperation of dosimetry/technical experts and biology experts (13%)
- Find ways to ensure unbiased, independent research preceding deployment (8%)
- Set up advisory groups for governments on research needs and priorities (7%)
- Avoid putting EMR sources (e.g. cell towers) in wildlife areas (7%)
- Apply safe levels and/or exposure limits for EMR exposure (6%)
- Collaborations between nations and encourage young scientists (6%)
- Proper education about the potential risks of EMR, especially in poorer nations (5%)
- Apply the precautionary principle in relation to EMR and their environmental impacts (5%)
- Developers (companies) should fund research, study, and report on the technologies they develop, together with their testing (5%)

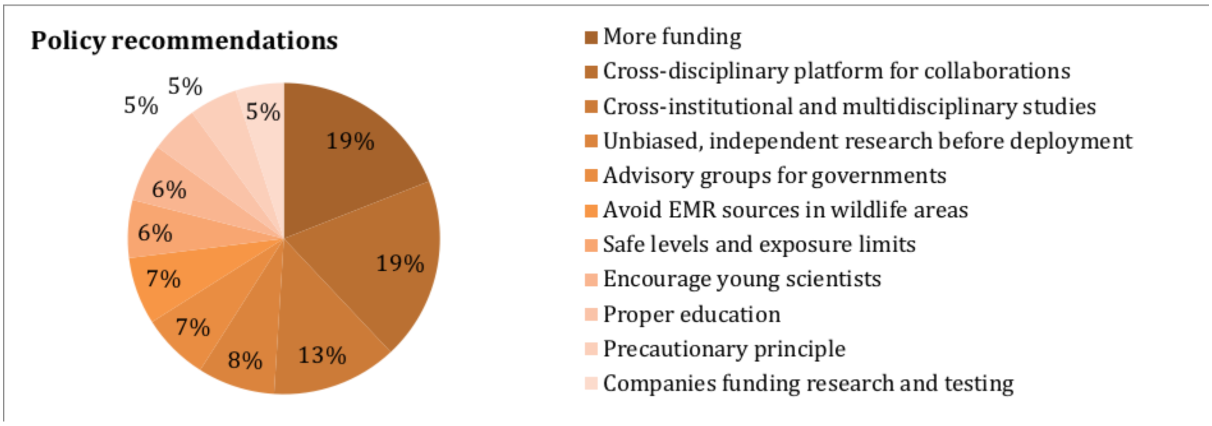


Figure 8 Results of the voting on policy recommendations

4.4 Session on a specific taxonomic group: Invertebrates

The participants were asked to discuss and answer the following question:

"In reviewing the key knowledge gaps in the background document, what stands out for you? Is anything missing?"

The results were compiled into main themes:

Gaps in the background document:

- Literature before the year 2000 had not been included

General knowledge gaps:

- Studies on the effects of EMR on aquatic invertebrates, i.e. molluscs, crustaceans, but also studies on other organisms, e.g. bacteria
- Research on the effects of photovoltaics and solar plants on invertebrates
- Research on the effects of EMR on migratory insects (e.g. dragonflies in Portugal, monarchs in North America, etc.)
- Studies into indirect effects on invertebrates via impacts on the plants that are hosting and/or serve as food supply for them
- More field studies

Then, the participants were asked to discuss and answer the following question:

"Based on the identified knowledge gaps, what do you consider as the most important research needs/priorities?"

The results were compiled into main research needs/priorities. After being presented to them, participants were able to vote on the most important ones (up to 3 needs per participant). The research priorities/needs are presented below in rank order with percentages indicated.

- More funding to study EMR impacts on invertebrates (29%)
- Standardised and agreed research methodologies/protocols to facilitate more comparable data (22%)
- Undertake both - laboratory and field work - iteratively, they are complementary (14%)
- Consider the observations of people who are not scientists, but who collectively observe changes. Anecdotal observations can drive experimental science (14%)
- Better understand the risks from EMR to reproduction, behaviour and populations in the field (11%)
- Identify a clear correlation between new types of EMR sources (e.g. (cell towers, smart meters) and insect population abundance (6%)
- Use radar stations to investigate the impacts of high levels of EMR in the field (2%)
- Discern light pollution effects from other EMR effects (2%)

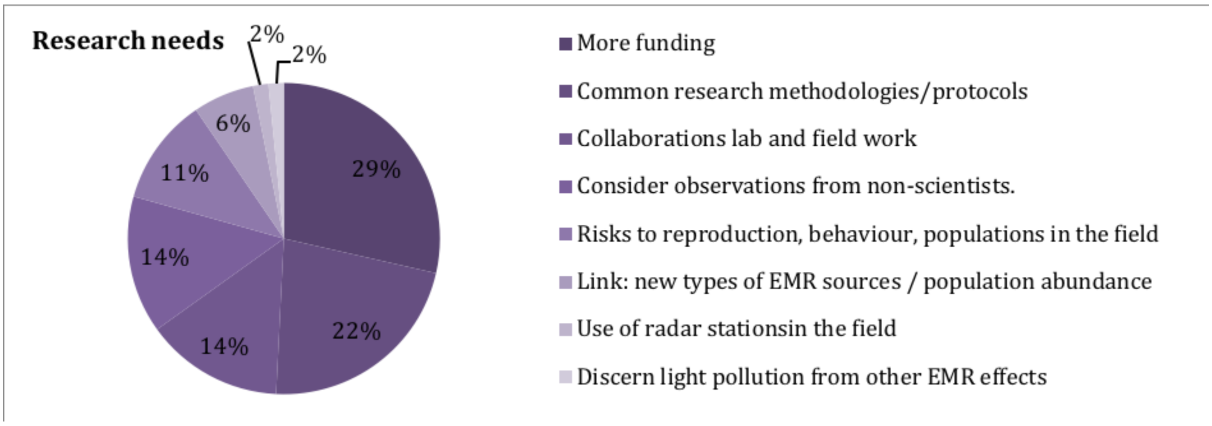


Figure 9 Results of the voting on research needs

Finally, the participants were asked to discuss and answer the following question:

"Based on the knowledge available, what policy recommendations would you propose?"

The results were compiled into main recommendations. After being presented to them, participants were able to vote on the most important ones (up to 3 recommendations per participant). The recommendations are presented below in rank order with percentages indicated.

- Allocate more funding for research on the topic (20%)
- Set up a stakeholders' group, bringing together scientists, industry, etc. to have open discussions on the effects of EMR (17%)
- Use "proof of safety" standards prior to the widespread proliferation/use of new technologies/EMR emissions (13%)
- Prohibit EMR sources such as phone masts in nature reserves (11%)
- Apply the precautionary principle (11%)
- Include EMR when evaluating effects of anthropogenic disturbances (chemicals, pollutants, climate change, etc.) to account for potential negative synergistic effects on invertebrates (11%)
- Identify "No Effect" EMR levels on a range of invertebrates in laboratory conditions and use these to develop Environmental Quality Standards that should not be exceeded (9%)
- Consider ecosystem services provided by invertebrates when developing regulations for EMR (7%)

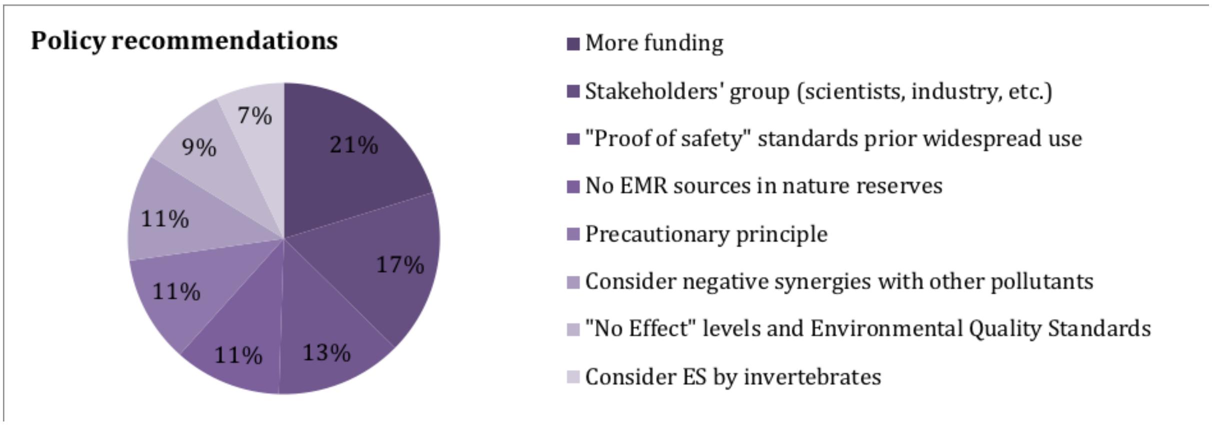


Figure 10 Results of the voting on policy recommendations

4.5 Session on cross-cutting themes

Based on the results of the discussions from the specific sessions, EKLIPSE compiled a list of research priorities and policy recommendations that were highlighted in the different sessions.

Transversal research needs:

- Develop standardization/methodologies/protocols to better design future studies & compare research results, which could include:
  - Standardisation of EMR types, exposure levels and measurements
  - Common data models, experimental methodologies, protocols
  - Specific methodologies for different taxonomic groups/organisms
  - High-quality research and well-replicated studies to ascertain what are the consistent results
- Set up more field studies, more ecological studies & better integration amongst laboratory studies
- Initiate research on the impacts of new technologies, such as:
  - 5G technology, LED lamps, pulsed radiation, cell towers, smart meters, etc.
- Study the impacts of EMR at different biological organisations/levels, including:
  - On whole ecosystems, at populations' levels, etc.
  - At protein level, at genomic level, at the level of assemblages, etc.
- Account for confounding/interfering factors in analysing the effects of EMR & on how different frequencies interact
- Develop more and better cooperation/collaborations, especially interdisciplinary teams, in particular:
  - Cooperation between different countries, teams, etc.
  - Including GIS experts in studies
- Include observations and knowledge from local people & consider citizen science approaches

The participants were then asked to rate them on a scale from 1 to 5 for the three following criteria:

- The general importance or urgency to address the need

- The feasibility or ease to implement such a study (including the financial feasibility)
- The contribution of the expected results to the knowledge base and to support evidence-based decision-making

The results of the polling were presented with the average score for each research priority, per criteria, (see Figure 11) and depicted in a graphic representation (see Figure 12).

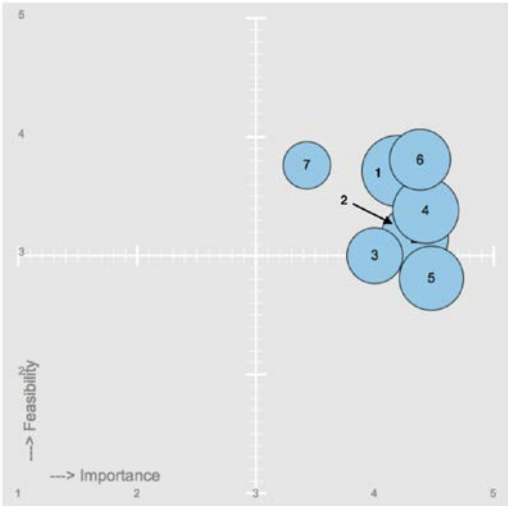
Research needs related to the content of the studies (confounding/interfering factors; impacts at different levels; effects of new technologies) and on how studies should be carried on (standard methodologies; more field studies; collaborations and interdisciplinarity) were considered particularly important and urgent (+ 4.0).

The polling reveals that the feasibility of such studies may appear more complicated to implement (3.0-3.8), especially regarding confounding/interfering factors (2.8).

As for the contribution to knowledge, standardization methods and field studies ranked quite high (+4.00), the other proposed research priorities being viewed as average to good (3.3-3.9), with the exception of local knowledge/citizen science which listed particularly low in the ranking (2.8).

		Importance	Feasibility	Contribution
1	*Develop standardization/methodologies/protocols to better design future studies & compare research results*	4,20	3,70	4,20
2	*Set up more field studies, more ecological studies & better cooperation with lab studies*	4,30	3,10	4,00
3	*Initiate research on the impacts of new technologies*	4,00	3,00	3,30
4	*Study the impacts of EMR at different biological organisations/levels*	4,40	3,40	3,90
5	*Collect data on confounding/interfering factors & on how different frequencies interact*	4,50	2,80	3,80
6	*Develop more and better cooperation/collaborations, especially interdisciplinary teams*	4,40	3,80	3,60
7	*Include observations and knowledge from local people & consider citizen science approaches*	3,40	3,80	2,80

Figure 11 Average weighting of the assessment of research needs per criteria



X axis = importance ; Y axis = feasibility ; size = contribution

Figure 12 Graphic representation of the assessment of research needs per criteria

Transversal policy recommendations:

- Provide/release more funds for research on the effects of EMR
- Foster research collaborations at different levels, including:
    - Cross-institutional
    - Interdisciplinary (esp. biology/ecology vs technology/dosimetry experts)
    - Facilitate access for younger scientists
    - Between countries
- Enable data sharing and open discussions, in the form of:
    - Open databases
    - Platform for exchanges
    - Advisory group to governments
    - Stakeholders’ group composed of companies, researchers, citizens, etc.
    - Adopt common standards

- Apply the precautionary principle for current and new technologies, for example:
    - Define safe levels and exposure limits
    - Avoid EMR sources in wildlife areas
    - Independent research in impacts before deployment
    - “Proof of safety” before widespread use

A word cloud was produced representing the recurring themes and ideas for recommendations to policymakers, whether in the environmental or other sectors (see Figure 13).

Figure 13 Word cloud of recurring themes for policy recommendations

5. Conclusions

The web conference was a success in terms of organisation, as the innovative, interactive tools used enabled an active participation of a very diverse audience from all over the world.

In terms of content, the participants further discussed the current state of knowledge related to the EMR impacts on wildlife, generally, in line with what the experts’ group had identified. They contributed by discussing and providing a significant list of knowledge gaps, research needs or priorities and policy recommendations for each taxonomic group.

The most recurring problem in the current scientific studies (in all taxonomic groups) appeared to be the **lack of standardised and controlled technical set-ups** for the experiments and the monitoring of exposure levels and frequencies. The participants suggested several ways to overcome this shortcoming (standard methodologies, protocols, exposure levels and measures, common data models, etc.) to ensure the comparison and replication of the studies. In addition, it would require the s**haring and accessibility of open data** to the research community at large.

Among the other knowledge gaps, there is a need to address **some species or families that are currently being understudied**, but also to better understand the **interactions at different levels**. The participants also suggested potential improvements in the management of the scientific research itself, citing elements such as the importance of including **observations from local people** and the use of **citizen science**; the need for **collaborations** between areas of expertise, or institutions.

A key policy recommendation refers to the urgent need to allocate **more funding to research** on the topic. Participants also emphasized the importance of **bringing together different stakeholders** (not only scientists, but also policymakers, businesses, citizens, decision makers, etc.) and to set up advisory groups. Finally, some participants recommended to apply the **precautionary principle**, to define and set **safe limits** to EMR exposure, and to **avoid placing EMR sources in nature reserves/wildlife areas**.

In terms of **science-policy interface**, a next step would be to determine more precisely which EMR frequencies and sources appear to have the most significant effects, to characterise the range of impacts, and to scope the scale of their potential effects on wildlife, so that policy and research priorities can be better framed. The current research needs to be grounded in studies with solid data and background to make sure a message, based on correct and verified knowledge, can be conveyed to decision-makers and the society in general.

6. Lessons learnt

In accordance with the "learning by doing" philosophy behind EKLIPSE, the method used for answering the request was adapted during the process. Instead of only being a support for discussions during the web conference, the analyses of the experts' group provided much more input and answers to the requesters' question than was initially expected. The web conference participants provided valuable feedback on the work already done and complemented the experts' findings with new reflections and policy recommendations.

The community related to research on EMR is very limited, and the topic appeared to be very specific and sensitive. Many non-scientists showed an interest in the web conference and some contributed actively to the discussions. However, this specificity might have been better taken into account in the organisation of and the dissemination on the web conference, as it might explain – at least partly – the relatively low numbers of participants. The timing (January) and length (5 sessions of 2 hours) of the event might also not have been ideal and might also explain why fewer people were available than we had hoped.

The technical online tools were very useful but might not be the best option for a small conference aiming to answer specific questions of a very technical and scientific nature. Rather, with its potential to host hundreds of participants and make them work together in breakout groups, these tools would be a perfect fit for large consultation events where the objectives are to bring together a variety of stakeholders (scientists, policy-makers, citizens, businesses,…) around scientific topics and issues.

7. Glossary

Term	Definition
EKLIPSE	EKLIPSE (Establishing a European Knowledge and Learning Mechanism to Improve the Policy-Science-Society Interface on Biodiversity and Ecosystem Services) is a H2020 funded project that aims to develop an innovative and self-sustainable EU support mechanism for evidence-based and evidence-informed policy on biodiversity and ecosystem services.
Electromagnetic radiation	Electromagnetic fields (EMF) are a combination of invisible electric and magnetic fields of force. They occur both naturally and due to human activity. Naturally occurring EMF are for example, the earth static magnetic field to which we are constantly exposed, electric fields caused by electrical charges in the clouds or by the static electricity produced when two objects are rubbed together as well as sudden electric and magnetic fields caused by lightning, etc. Man-made electromagnetic fields (EMF) are for example generated by extremely low frequency (ELF) sources, such as power-lines, wiring and appliances as well as by higher frequency sources such as radio and television waves and, more recently, cellular telephones and their antennas.[3]
IPBES	The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) is the intergovernmental body which assesses the state of biodiversity and of the ecosystem services it provides to society, in response to requests from decision makers.

[3] Source: Greenfacts, 2018.

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Appendix I: Members of the Experts Steering Group

Matt Shardlow (requester)

Buglife is the only organisation in Europe devoted to the conservation of all invertebrates, and we are actively working to save Britain's rarest little animals, everything from bees to beetles, worms to woodlice and jumping spiders to jellyfish. There are more than 40,000 invertebrate species in the UK, and many of these are under threat as never before. Invertebrates are vitally important to a healthy planet – humans and other life forms could not survive without them. The food we eat, the fish we catch, the birds we see, the flowers we smell and the hum of life we hear, simply would not exist without bugs. Invertebrates underpin life on earth and without them the world's ecosystems would collapse.

Prof Mario Babilon (expert)

Prof Babilon got his final degree in physics ("Diplom Physiker") in July, 2001 from the Technical University of Darmstadt. Thereafter he graduated in Nuclear Physics. During that time, he spent one year at Wright Nuclear Structure Lab at YALE University in the United States as a visiting assistant in research. He received his PhD in December 2004 and spent about one more year as a post-doc in Darmstadt, before switching to industry. He started a career in the corporate research department of BOSCH. Meanwhile he was giving lectures at the Cooperative State University in Stuttgart. He completely switched to the University in 2011 and since then he is a Professor in Computer Science.

Dr Erich Pascal Malkemper (expert)

Dr Malkemper is a biologist who received his PhD at the University of Duisburg-Essen in Germany. His thesis "The sensory biology of the red fox – hearing, vision, magnetoreception" was awarded the Fritz-Frank-Award of the German Society for Mammalian Biology in 2015. His research focusses on sensory systems, which he studies with behavioural experiments, histology and physiology, to understand ecological adaptations of a given species. He is currently based at the Research Institute of Molecular Pathology (IMP) in Vienna, Austria, where he conducts research on magnetoreception in homing pigeons.

Dr Benoît Stockbroeckx (expert)

Dr Stockbroeckx received the degree of Electrical Engineer from the Université Catholique de Louvain (UCL), Louvain-la-Neuve, Belgium, in 1993. He received his PhD degree in Applied Sciences in 1998 with a thesis on Space waves and surface waves in the Vivaldi antenna. He is involved in EMF exposure assessments since 1998. He is now the head of laboratory division at ANPI in charge of alarm systems, active fire prevention, theft prevention, CE marking (EMC, LVD, CPR), electromagnetic compatibility. He is also expert at the Belgian Health Council for non-ionising radiations.

Dr Thomas Tscheulin (expert)

Dr Tscheulin, holding a PhD in Population Ecology from Imperial College London, is currently an Assistant Professor at the University of the Aegean, Greece. He has a strong track record of collaborative research, both within and between host institutions in three different European countries. His main research interest is to relate assessments of the abundance, diversity, functional structure and trophic interactions of invertebrates, to the impacts of ecosystem disturbances such as agricultural practices, alien species invasion, climate change, wildfires, habitat loss and degradation. He is an associate editor for Animal Conservation and has so far published 36 scientific papers.

Dr Adam J. Vanbergen (expert)

Dr Adam Vanbergen is an invertebrate ecologist who received his PhD on 'Landscape to host-plant scales: bottom-up heterogeneity affects invertebrate diversity & interactions' from Cardiff University. He has been working for the Centre for Ecology & Hydrology since 1998. His research focusses on species interactions, community structure, and the relationship between biodiversity and ecosystem functions and services. He is particularly interested in understanding how anthropogenic disturbance across spatial scales governs diversity and interactions, above and belowground and at trophic levels directly (herbivores, pollinators) and indirectly (predators, parasites) connected to plants.

Prof Alain Vian (expert)

Prof Vian obtained his PhD in plant physiology at the University Blaise Pascal (1995) under the supervision of Dr Marie-Odile Desbiez, working on plant responses to wounding. He then performed a 2-years postdoctoral period in the laboratory of Prof. Eric Davies (North Carolina State University), working on the rapid molecular events following plant flaming. He obtained an assistant professor position at the university Blaise Pascal (Clermont-Ferrand) and rapidly specialized in plant responses to high frequency electromagnetic field, in collaboration with physicists (Profs Françoise Paladian and Pierre Bonnet). In 2008, he obtained a prize from the French Academy of Sciences for this work. He became full professor in 2009 at the University of Angers and since 2012 has worked in the Institut de Recherche en Horticulture et Semences (UMR 1345), studying the effect of environmental factors (mainly nitrogen nutrition) on the regulation of axillary bud outgrowth, a major event in the establishment of plant architecture. He is also continuing his work on the biological effects of high frequency electromagnetic field on plant development.

Appendix II: Agenda of the web conference

Monday, 22 Jan 2018 // 16:00-18:00 CET // Introduction session

Time	Activity
16:00	Welcome Agenda and concept of the web conference Introduction to EKLIPSE and Buglife Introduction to Covision and the online tools
16:25	Small group discussion: "*What expectations do you have for this conference on EMR effects on wildlife?*"
16:40	Sharing of the expressed expectations with the audience.
16:50	Presentation of the background document by Lise Goudeseune
17:10	Small group discussion: "*What do you think of the results presented in the background document? What stands out for you? Is there anything missing?*"
17:30	Sharing of the main ideas with the audience.
17:45	Wrap up and end of the session

Tuesday, 23 Jan 2018 // 13:30-15:30 CET // Session on Plants

Time	Activity
13:30	Introduction
13:35	Presentation of the results of analyses for Plants by Prof Alain Vian
13:55	Small group discussion: *"In reviewing the key knowledge gaps in the background document on EMR impacts, what stands out for you? Anything missing?"*
14:10	Sharing of the identified knowledge gaps
14:15	Small group discussion: *"Based on the identified knowledge gaps, what are the most important research needs/priorities?"*
14:40	Small group discussion: *"Based on available knowledge, what policy recommendations (environmental or other sectors) would you propose?"*
14:55	Sharing of research needs/priorities and voting
15:05	Sharing of policy recommendations and voting
15:15	Summary and closing of the session

Tuesday, 23 Jan 2018 // 16:00-18:00 CET // Session on Vertebrates

Time	Activity
16:00	Introduction
16:05	Presentation of the results of analyses for Vertebrates by Dr Pascal Malkemper
16:25	Small group discussion: *"In reviewing the key knowledge gaps in the background document on EMR impacts, what stands out for you? Anything missing?"*
16:40	Sharing of the identified knowledge gaps
16:45	Small group discussion: *"Based on the identified knowledge gaps, what are the most important research needs/priorities?"*
17:10	Small group discussion: *"Based on available knowledge, what policy recommendations (environmental or other sectors) would you propose?"*
17:25	Sharing of research needs/priorities and voting
17:35	Sharing of policy recommendations and voting
17:45	Summary and closing of the session

Wednesday, 24 Jan 2018 // 16:00-18:00 CET // Session on Invertebrates

Time	Activity
16:00	Introduction
16:05	Presentation of the results of analyses for Invertebrates by Dr Thomas Tscheulin & Dr Adam Vanbergen
16:25	Small group discussion: *"In reviewing the key knowledge gaps in the background document on EMR impacts, what stands out for you? Anything missing?"*
16:40	Sharing of the identified knowledge gaps
16:45	Small group discussion: *"Based on the identified knowledge gaps, what are the most important research needs/priorities?"*
17:10	Small group discussion: *"Based on available knowledge, what policy recommendations (environmental or other sectors) would you propose?"*
17:25	Sharing of research needs/priorities and voting
17:35	Sharing of policy recommendations and voting
17:45	Summary and closing of the session

Thursday, 25 Jan 2018 // 16:00-18:00 CET // Closing session

Time	Activity
16:00	Introduction & summary
16:10	Presentation of the results from the last three sessions
16:25	Presentation of transversal research needs by Lise Goudeseune
16:35	Voting on transversal research needs
16:45	Presentation of transversal policy recommendations by Jorge Ventocilla
16:55	Voting on transversal policy recommendations
17:05	Small group discussion: *“What are your final thoughts about the results that have been presented? What should be done next?”*
17:20	Sharing of the final thoughts
17:30	Wrap up and closing of the session

Appendix III: List of participants (who agreed to share their information)

Title	First name	Last name	Email	Country	Organisation	Position
Dr	Olga	AMEIXA	olga.ameixa@ua.pt	Portugal	University of Aveiro/CESAM	
Dr	Niels	BOEHLING	nboehling@flora-x.de	Germany	ecologist, free	
Mr	James	BUTLER	emfguy@gmail.com	Canada	HomeSafe	President
Dr	Chris	CONNOLLY	c.n.connolly@dundee.ac.uk	United Kingdom	University of Dundee	Reader in Neurobiology
Dr	Suleyman	DASDAG	sdasdag@gmail.com	Turkey	Medical School of Istanbul Medeniyet University	Full Professor
Mr	Fórika	ENDRE	e@eaposztrof.com	Hungary		
Mr	David	GAZDAG	david.gazdag@wildpower.org	United Kingdom	Wild Power	Development Director
Ms	Alison	GIACOMELLI	alison.giacomelli@naturalengland.org.uk	United Kingdom	Natural England	Ornithologist
Ms	Arlene	HOPKINS	arlene.hopkins@gmail.com	United States of America	Arlene Hopkins & associates	Resilience Strategist
Ms	Alise	KARCEVSKA	AKarcevska@clientearth.org	United Kingdom	ClientEarth	Wildlife Intern
Dr	Elizabeth	KELLEY	lkelley_45@msn.com	United States of America	Electromagnetic Safety Alliance	Director
Dr	Francine	KERSHAW	fkershaw@nrdc.org	United States of America	Natural Resources Defense Council	Project Scientist
Dr	Kavindra	KESARI	kavindra.kesari@aalto.fi	Finland	Aalto University	Postdoc
Pr	Afifullah	KHAN	afifkhan@rediffmail.com	India	Department of Wildlife sciences,	Professor

					Aligarh Muslim University	
Dr	Tarmo	KOPPEL	tarmo@koppel.ee	Estonia	Tallinn University of Technology	researcher
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Ms	Marie-Anne	LE MOIGNE	marieanne.lemoigne@univ-angers.fr	France	IRHS	PhD student
Dr	Esteban	MANRIQUE REOL	e.manrique@csic.es	Spain	Spanis Research Council - National Museum of Natural Sciences	Research Professor
Mr	Siraj Uddin	MAZUMDER	sirajwls@gmail.com	India	Aligarh Muslim University	PhD Student
Mr	Lance	MCKEE	lmckee76@gmail.com	United States of America	No organizational affiliation.	Independent writer and researcher
Dr	Michael	PAINTER	painter@fld.czu.cz; mipainte@vt.edu	Czech Republic	Czech University of Life Sciences	Post-Doc
Mr	Alexander	PAKHOMOV	sasha_p.bio@mail.ru	Russia	Biologocal Station Rybachy, Zoological Institute of RAS	scientific researcher
Ms	Barbara	PAYNE	barbara.payne@iexistworld.org	Canada	Electromagnetic Pollution Illnesses Canada Foundation (EPIC) [not for profit organization]	President

Dr	Petr	PETRIK	petrik@ibot.cas.cz	Czech Republic	Institute of Botany, The Czech Academy of Sciences	Senior Researcher
Dr	Blanka	POPHOF	bpophof@bfs.de	Germany	Federal Office for Radiation Protection	scientist
Dr	Mary	REDMAYNE	redmaynereports@gmail.com	New Zealand	Mary Redmayne (Working independently as researcher, educator and consultant)	Director
Pr	Thorsten	RITZ	tritz@uci.edu	United States of America	University of California Irvine	Professor of Physics
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Dr	Cornelia	WALDMANN-SELSAM	dr.waldmannselsam@googlemail.com	Germany	Competence Initiative for the Protection of Humanity, Environment	MD

					and Democracy e.V.	
Dr	Lee	WALKER	leew@ceh.ac.uk	United Kingdom	NERC Centre for Ecology & Hydrology	Vertebrate Ecotoxicologist

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