Electromagnetic pollution risks to bees

With grateful acknowledgements

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In a moving editorial that paid tribute to the late Adrian Waring NDB, an expert in practical beekeeping, and also to the late Mary Hopkinson, the editor explores several topics and concludes, on impending 5G networks: “Naturally the question of security is of great importance, but little concern is being shown for 5G and all the other networks as regards the profound effect radiation from masts and devices can have on our own health and on all forms of living organisms. Lynne Wycherley brings us up to date on the impact of this new form of technology”

ENVIRONMENTAL POLLUTION

A Fresh Perspective

Lynne Wycherley

AS nations race to adopt 5G, driving up environmental electromagnetic pollution, Lynne Wycherley asks whether such trends pose veiled risks to our bees and other pollinators. Conscious of bees' exquisite electromagnetic sensitivity, she invites us to explore many recent peer-reviewed findings and to take a new look at electromagnetic hygiene.

Each year wild bees take refuge in our home. There is little to disturb them here. No garden pesticides; few dioxides from traffic. Nor much electromagnetic radiation: we prefer clean cable to wireless transmitters. On warm days, we watch the bees weave, soothed by their grace. Bumblebees, rotund, tour the blackcurrant bushes with a low, melodic thrum.

I think of neighbouring Somerset, where Bristol University researchers made an astonishing discovery: bumblebees can detect changes in the exquisitely weak electrostatic fields emitted by flowers. Like a conversation between one form of beauty and another, the surface positive electrical charge of a bee interacts with the negative charge of receiving petals(1). This poetic synergy may be as old as land-based life itself.

Bees' long-studied electromagnetic sensitivity continues to attract research. It plays a role in their waggle dance: tipped with vibration-sensitive flagella, audience bees' antennae "read" the dancer's shifting electric fields (2). Dancers freeze if another bee emits a weak electrical and acoustic "stop" signal (3); they can also be affected by artificial magnetic changes (3a). More generally, in the hive's sociable darkness, tiny charged hairs (trichoid sensilla) between bees' eyes detect other bees' static electricity and weak sound waves, complementing scent (4).

Beyond the hive, worker bees can sense minute fluctuations in the Earth's magnetic field (5). Detecting its compass direction (polarization) (6), they have evolved a navigational aid for cloudy days, particularly when distant from the hive or nest. Magnetite crystals in bees' abdomens expand or contract in response to their alignment with the Earth's magnetic field (7). The role of smaller magnetite particles, diffused through bees' head and thorax, is less well understood. Even honeycomb-building can be guided by the Earth's magnetic field(7a).

A pulsing cacophony: breakneck wireless trends.

So far, so good, but what are the implications to bees and other insects from the ever-rising artificial electromagnetic fields penetrating so many environments? Diverse habitats are being filled, in effect, with cacophonous radiofrequency "noise" – set to rise sharply with 5G. From high-bandwidth 4G to "smart" mesh networks and rural WiMax, the pulsed-microwave output from our wireless boom is growing in complexity and flux-density. If reproducible in any bee strains, the recent controlled findings showing poor return-rates to hives near a telecoms mast (Taye et al 2017) (8) have troubling implications.

A finding by Russian physicists piqued my curiosity: electric fields from honeybees' waggle dance were found to be pulsed in low Hertz cycles (9). Tired bees have since been seen to react to weak electric fields pulsed at 230Hz (matching the waggle dance) and 400Hz (the "stop" signal)[2] Today's wireless boom uses piercing microwave carrier waves pulsed with a wide range of low Hertz frequencies – poised to multiply with 5G. At what point might they possibly interfere with bee-to-bee communication or other processes?

Today's mobile and wireless output is artificially pulsed, polarised, and variable, three characteristics that can drive up biological effects (10,11). I am reminded of the words of Dr Robert Becker, a pioneer in this field: "Since the present relationship between living things and the electromagnetic environment is the result of several billions of years of development, the question of... abnormal electromagnetic parameters introduced into the environment by man's activities becomes of... importance" (Electromagnetism and Life 1982).

Waymarks to a wider view

Discussion of possible risks to bees from artificial EMFs has tended to focus on small cautioning studies of colonies closely exposed to mobile or cordless phones. Though the samples were small and the studies attracted fair criticism where methodology was sparse (see Carreck 2014, Odemer 2018) (12 ,12a), their pattern of dwindling bees suggests a need for alertness (13, 14, 14a and 15).

In a better-regarded, peer-reviewed study, Swiss apiarist Dr Daniel Favre recorded worker bees' responses to cell-phones in 83 auditory field trials. Dormant phones elicited no response. When the phones were remotely activated, however, worker bees gradually emitted intense, shrill "piping"–a known cue for colonies to swarm (16). Lebanese researchers presented similar findings from a small sample. Though these exceed field exposures, heavy wireless use is growing. Might there be clues for human health in the bees' restless song?

In a 2014 pilot study, Dr Tjeerd Blacquière compared bee colonies shielded from a combined 2G and 3G telecoms mast (cell tower) at a distance of 200m to colonies in near-identical but unshielded housing (17). Though they were equally successful by early measurements, fewer of the unprotected colonies went on to survive the winter, something that invites more research. Exposure to 4G , or to multiple cumulative RF sources, are meanwhile in pressing need of study.

In work showing that altered magnetic fields can impair bees' homing ability, Dr Thomas Ferrari highlighted risks to colonies from geomagnetic storms (18). He stressed that genetic variability may place some bee strains at greater risk of EMF disturbance than others – and may explain any future null findings. Similarly, it's best not to assume from a study that found no altered feeding, aggression or flight navigation in cell-phone exposed bees (19), that genetic variants would be equally unaffected.

Discussions about bees tend to overlook research on higher fauna revealing risks from alien EMFs at a cellular level. Given that insect and human cellular immune response is strikingly similar (Kavanagh & Reeves 2017) (19a), it's worth noticing, for example, that damage to peripheral

immune cells was recently found to be higher in people living 80m from cell towers than those based at greater distances (Zothansiama 2017, peer-reviewed).

Drosophila flies are a pupating "cousin" of honeybees often used to gauge toxins. In pioneering, peer-reviewed work led by biophysicist Dr Dimitris J Panagopoulos, brief exposures to 2G and 3G cell-phones led to DNA fragmentation followed by cell-death, precisely mapped, in the flies' ova, stunting their fertility, for example (20, 20a). A degree of harm was found even from weak microwave levels (1 microwatt per cm2)21 : I notice in my field measurements these levels are quite often exceeded in outdoor micro-environments. Mains-electricity magnetic fields were later found to be similarly harmful (21a). Dr Panagopoulos, Dr Favre, and others recently defended their methodologies in useful detail (22).

A gift for bees? A master mechanism of electromagnetic harm

Landmark work by award-winning biochemistry professor Martin L Pall can offer an exciting new perspective on potential wireless-pollution risks to life. In detailed work that won a Global Medical Discovery listing and a high volume of citations (ongoing), he highlights the role of hypersensitive voltage-gated calcium channels or VGCCs in the walls of living cells – insects' included (23).

Drawing on peer-reviewed studies of counter-effects by calcium-blocking drugs, Professor Pall demonstrates that weak wireless output (and also low frequency EMFs) can readily over-stimulate these VGCCs, triggering calcium imbalance and a toxic chemical cascade. The main downstream effect? Oxidative stress (free-radical damage) risking creeping, systemic, biological damage including to DNA, fertility, immunity, and nerve function, as glimpsed in growing, peer-reviewed literature and perceptive reviews, Pall's included. (24, 25). Oxidative damage to life is the most common precautionary finding from weak RF exposure, as seen in 216 recent peer-reviewed published studies (Bandara & Weller 2017). Further oxidative mechanisms may add to the harm, including from magnetic fields (26).

Overall, I perceive that insects' antioxidant nutrition may be key to their ability to withstand rising anthropogenic EMFs, not least from heavy 5G. (Notice, too, the peer-reviewed papers showing antioxidant nutrients can curb WiFi damage to animals' organs e.g. 27, 27a, and 27b). This may be timely, given that bees' nutrition is depleted by intensive farming, climate-change-stressed habitats, flower losses, and sometimes over-harvesting of honey or propolis.

Pall calculates that VGCCs' voltage-sensors, sensitive right across the non-ionizing spectrum, can detect EMFs 7.2million times lower than our current exposure standards – standards under growing fire from precautionary EMF scientists worldwide: please see the International EMF Scientist Appeal to the UN and the EMF Call (emfscientist.org/ emfcall.org).

These appeals contrast to old-paradigm thinking that is raising bees' intimate exposure to EMFs: for example, by gluing RFID transponders to their bodies and fitting wireless sensors in hives – monitoring methods in which low-power RF radiation may potentially introduce subtle unwanted effects, such as radical-pair changes, VGCC activation, or altered pathogen ecology (Notice at higher exposures that WiFi can boost antibiotic resistance) (28). A study on RFID's frequency looked only at emerged bees' death rates (Darney 2016).

A troubled trio: fertility, immunity, and neuro-behaviour

Some of the most striking implications of Pall's mechanism of wireless harm, whether for starved rural bees or 5G-imperilled bees (see below) or other insect populations, are the possible creeping oxidative risks to their fertility, immunity, and neural health.

Though Martina Vijver and team found no reduced egg-laying by insects after a short exposure to outdoor 2G, they pleaded for "more attention to [EMR's] potential impacts on biodiversity". Aware of Panagopoulos' (above), and mounting non-insect findings on fertility (29), I would echo this plea. In one haunting peer-reviewed paper, mice raised in a telecoms-mast park were irreversibly sterile in five generations (Magras & Xenos 1997).

Turning to immunity, might recent findings on RF exposure be helpful? For example: 1, risks to bees' haemolymph [30] or 2) potentially mitochondria, 3) changes in gene expression; (31) bees depend, for example, on rapid RNA expression to make immune peptides that were found lacking in CCD colonies; other immune transcriptions are linked to their winter survival 4) impairment of polymers such as chitin:31c might this pose a fringe risk to mid-gut chitin, so vital to hatched bees' resistance to infection? And (5), reduced melatonin, (32) the antioxidant body-clock hormone (tailored to bees' different roles33) that is fundamental to immunity.

Turning to insects' neural health, Pall stresses that VGCCs are most numerous in nerve cells.(33a) If we picture honeybees' covering of tiny hairs, each with a nerve at its base, then this theme begins to take life. In larger fauna, humans included, a wealth of peer-reviewed neurotoxic/ neuro-developmental effects have been recorded from weak pulsed RF-microwave radiation, albeit from slightly stronger exposures than in the field e.g, (34 35).

Any creeping neural effects from EMR could potentially disturb bees' behaviour, such as their brood or hive care, waggle dance, foraging, aggression levels, or social cohesion. I notice, for example, that finely balanced levels of the neurochemical 5HT are critical to bees' feeding and social behaviour (Vleugels 2015)(36) and that imbalances can impair their memory (Mercer 1982).(36a) Although excreted slightly differently in small mammals, striking serotonin/5HT imbalances were found in mice from RF-induced brain changes (Ezz 2014).

Research has indicated that pesticides, in themselves, can be neurotoxic to insects.(37) Rising exposure to EMFs, potentially triggering insects' VCGGs, may aggravate these effects. Crucially, pyrethoid pesticides have some explicit effects on insects' VGCCs, as explored by Annabelle Quintavelle (2012).(38) At its worst, wireless exposure may therefore become co-morbid.

Tests on any of these risk factors would be wise. In the meantime, wherever bees are struggling, perhaps we could revive the Precautionary Principle and explore easy, clean, fibre technologies for our bulk data traffic – while placing hives away from powerline corridors.

Nourished garden bees v. starved arable bees

When researchers at Royal Holloway University relocated queen bumblebees, those that were moved to village or city settings went on to found larger colonies, with more stored nectar, than those on intensively farmed land.(39) Richer forage and lower pesticides aided their success. To my mind, these factors may help to explain why some urban bee populations are buoyant, for the present, despite poor air quality and RF pollution. In forage-rich outer London, for example, where beekeeping is fashionable, hive numbers have risen. Garden birds, however, being larger, risk more electrical-coupling than insects from current frequencies (notice

pilot studies on RF-microwaves and sparrow losses (40) – until, that is, 5G takes hold. It would be interesting to test whether any strains of migrant queens tend to select low-radiation pockets.

The Holloway findings suggest to me a need to test for EMF effects on pesticide-stressed, malnourished, or infected bees rather than only on healthy samples. (Notice RF radiation's toxic synergies). We may also want to monitor creeping EMF risks to forage. Pall identifies voltage-sensors throughout plants (41) while others have identified some EMF oxidant harm to them. There is also pilot evidence of harm to, for example, cell-tower-irradiated trees (even at 2 miles), various seedlings, tomato plants, and from ambient RF, trembling aspens. (42,43,44) This does not bode well for climate-change stressed biodiversity as we accelerate into 5G (see below).

Flecks in the wind: the fate of hoverflies and moths

What of EMF pollution risks to pollinators other than bees, some of which may be more vulnerable? Amparo Lázaro and team (2016) found that numbers of above-ground-nesting wild species such as hoverflies plummeted spatially with cell-tower radiation levels: the spectrum included 4G. Though this favoured underground-nesting bees and bee flies, who filled the vacated niches, the authors pointed out that such dramatic changes could have unpredictable costs to "wild plant diversity, crop production" and more.

Not all underground nests will be protective: telecoms firms are snapping up underground rights, such as use of manholes for powerful wireless cells, so that future environments can be radiation-saturated. This is only one facet of the fast expansion in stark conflict with the international precautionary research on EMFs.

A survey in 2013 revealed that most common large moth species were in spiralling decline across much of Britain. Richard Fox, CEO of Butterly Conservation warned "If this is happening to this enormous group of moths, there's no reason to think it's not happening in all those other insect groups [flies, beetles, etc.] Without insects we are in big trouble because a lot of the ecosystem services that humankind relies on, such as pollination, are going to start falling apart." (The Guardian 1.2.2013) While urbanisation, pesticides, and hedgerow loss were deservedly thought to be contributing, it's worth noticing that many moths' larval stages lack material shelter. They may be less buffered against wireless pollution than bees – including from urban spread.

When insects or birds lose their compass-rose

Key stressors on bees such as chemicals, pathogens, and floral losses, among others, have been eloquently explored to help explain Colony Collapse Disorder from around 2007. A mystifying lack of dead bees near hives, however – the "disappearance" syndrome – raises questions about whether bees' navigation played a part. While some almond valleys with early CCD were free of pulsed telecoms output, for example (notes Carreck 2014), let's consider whether any EMF risks to navigation may impinge on stressed pollinators today.

An ability to use magnetoreception for spatial orientation has been shown in many vertebrates. Woodmice, to illustrate, can be disoriented by weak RF magnetic fields. (46) Though broadcast RF in the AM band (a band also used by RFID) can disorientate robins (also cockroaches),(47) any effects from the expanding higher spectra used by wireless rollouts need testing – especially given the global race for EMF saturation rather than electromagnetic hygiene.

Though bees can draw on solar, landmark, scent, and magnetic cues for spatial orientation, Ferrari 2014 (see above) found that added static or oscillating magnetic fields led to fewer bees returning home. Might the magnetic-field component of wireless rollouts' low-Hertz pulse become a problem? Bees' magnetite is very sensitive up to 10 Hz,(48) a common frequency in WiFi-type beacon signals.

To enrich thinking, let's also ask: are there EMF risks to pollinators' other navigational cues, sight included, from direct effects on their thinking? Shepherd and team found that foraging bees' learning and flying-ability suffers near high-voltage powerlines.(49) Ants irradiated by wireless devices can suffer a "wipe out", losing visual/scent cues and coordination(50) while WiFi- irradiated rodents struggle with maze-tests and object-recognition.(51) As more and more mobile-addicts carry multi-antennas fed by dense wireless cells, will our flying fauna struggle to adapt? Simultaneously, might big rural transmitters confuse some butterflies or bats, for example, more than urban RF "white noise?" There are many pressing questions.

The planetary race for 5G: an insecticidal tipping point?

In last year's "Horizon Scan" global conservation report, Professor Bill Sutherland and team added blanket 5G pollution to their list of emerging conservation challenges. Foreseeing "saturating coverage of WiFi and 5G", Mark Shardlow, CEO of the UK charity Buglife, warned "Just because humans cannot see [such] electromagnetic radiation this does not mean that animals cannot... be significantly impacted at a neural or cellular level".

In a global race for high bandwidth and "immersive entertain- ment", commercial powers are pushing 5G into untested spectrum over 6GHz, including mm-waves (30GHz+). These short wavelengths will concentrate the energy and pulse in surface tissue – at cumulative risk, various scientists foresee, to insects,leaves,andeyes/exposedskin,ourownincluded.(52,52a Close to insects' body sizes, these wavelengths risk resonance effects (Jamieson 2012)(52, b) and higher coupling (energy transfer) – Peer-reviewed computer modelling by Arno Thielens and team (2018) reveals far greater radiation- absorption by insects than from earlier frequencies.(53) They warn "insects show a maximum in absorbed radio-frequency power at wavelengths that are comparable to their body size".

At the same time, poor penetration of obstacles over 6GHz is driving plans for high-density 5G transmitters, large and small. The ongoing doctors' and scientists' appeal for an EU moratorium warns humanity of a net "massive increase in mandatory exposure" to pulsed RF radiation (notice the high downlink exposures(54) at the very time when peer-reviewed cautioning health research is accelerating: 5Gappeal.eu. There are concerns that 5G's phased-array technology (concentrated beams) will be subtly toxic to life. Though mm-waves will be targeted initially at built up areas, rural zones face a rise in wideband RF pollution. Across nations, piecemeal 5G rollouts are going ahead with no ecological or health monitoring due to the high, unreformed safety limits already mentioned (notice also the AGNIR scandal).

Early peer-reviewed studies of weak mm-waves point towards risks of antibiotic resistance, yeast changes (re: bee pathogens), subtle inflammatory effects, and more e.g.(55) In his 90- page 5G warning report for the EU, [25] Professor Pall warns that the "high pulsation rates" may drive up effects and insects and flora(56)may be at special risk, partly from VGCC activation. Other thinkers question plans to rush 20,000 5G satellites into the Earth's magnetosphere. The radio-electrical

fug that will result, meanwhile, from plans to connect many billions of objects wirelessly (5G IoT), to milk consumers with new products, is being questioned as a senseless biological experiment(57). By contrast, optical frequencies that do not pierce living tissue (used by LiFi, for example) suggest a more bio-sensitive way forward – something that, alongside clean fibre broadband, may inspire beekeepers, doctors, and conservationists alike.

Conclusion:
working for a bio-friendly world

In 2016 the inter-governmental panel on biodiversity and ecosystem services (IPSBE) flagged a 40% decline in wild pollinator species in many areas. In 2017, German nature parks in busy lowland zones, including densely populated Nordrhein Westfalen, revealed a staggering loss of total flying insects(58). Such findings confirm insects need to be spared from any added artificial pressures on them.

Last year's EU Eklipse seminar rightly concluded that more field research is needed on EMF impacts on wildlife. Whatever the perceived gaps, wildlife findings to date are only part of a far larger, eloquent, precautionary picture. New peer-reviewed cautioning findings, revealing EMF interactions with life (human biology included), reach me week after week. It is as if a great landscape is edging into view at the very time we need it most – a time in which e-pollution is visibly spiralling beyond wise control.

Commercial and military pressures held back acceptance of ionizing (nuclear) radiation risks for decades. Growing published evidence of non-ionizing risks, a reflection of life's exquisite, humbling, electro-chemical nature – pollinators' included – faces similar blocks. To be open to its cautioning message is ecologically urgent; to seek safer ways forward is an act of life- protective vision.

A study of global insect resilience concluded "pollinator populations may collapse suddenly once drivers of pollinator decline reach a critical point."(59) While pesticide, pathogen and climate- change risks to bees have received deserving attention, other stressors are growing. If abandoned to 5G and other rocketing EMFs, many insects will face pollution levels that far exceed emerging biological wisdom – a wisdom with dazzling possibilities for our sensitive husbandry of the living world. From garden to bee-farm, suburb to skyline, let us work for EMF hygiene where we can.

Unfortunately, there was insufficient room in this magazine to list the many references. In order to refer to them they will be available on: tinyurl.com/bee-refs-LW

Lynne Wycherley is a contributor to flagship environmental journals Resurgence and The Ecologist. A nature poet, she has a postgraduate diploma in nutrition & physiology. She has been tracking the bio-risks of non-ionizing radiation for seven years, working alongside pioneering doctors. She lives in a farm cottage with a bee-friendly garden.

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Environmental Pollution: a fresh perspective (on bees and EMFs)

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