Available online at www.sciencedirect.com

ScienceDirect

Current Opinion in Insect Science

Editorial overview: Halting the pollinator crisis requires entomologists to step up and assume their societal responsibilities

Jeroen P van der Sluijs, Stéphane Foucart and Jérôme Casas

Current Opinion in Insect Science 2021, **46**:vi–xiii

For a complete overview see the Issue

https://doi.org/10.1016/j.cois.2021.08.004

2214-5745/© 2021 Published by Elsevier Inc.

Jeroen P van der Sluijs[1,2]

[1] Centre for the Study of the Sciences and the Humanities, University of Bergen, PB 7805, 5020 Bergen, Norway
[2] Department of Chemistry, University of Bergen, PB 7805, 5020 Bergen, Norway
e-mail: jeroen.sluijs@uib.no

Jeroen P. van der Sluijs is professor at the Centre for the Study of the Sciences and the Humanities at the University of Bergen, Norway. Originally trained as a natural scientist (MSc in chemistry with major in theoretical ecology form Leiden University 1990, and PhD on uncertainty in climate risk assessment form Utrecht University, 1997) he developed a research interest in actionable knowledge for risk governance in a context of scientific uncertainty and controversy. Over the past 15 years he has been studying amongst other the emerging science-policy interface around pollinator decline, insect decline and insect conservation, as well as risk assessment and risk governance of neonicotinoid insecticides. He leads the case-study on bees and pesticides of the European H2020 project "REconciling sCience, Innovation and Precaution through the Engagement of Stakeholders (RECIPES)". He (co-)authored more than 100 peer reviewed publications and is in the top 2% of the most cited scientists in the world (Stanford list). He ranked regularly high in "The Sustainable 100", a list of the most influential Netherlands persons contributing to sustainable development, by daily newspaper Trouw.

Pollinators in crisis

Pollinator decline, and more broadly insect decline has become a pressing societal challenge. Global, regional and local policies to halt the decline and restore pollinator diversity and abundance are urgently needed [1]. A recent analysis of the most comprehensive long term global observational dataset available, the Global Biodiversity Information Facility (GBIF), indicates that worldwide, between 2006 and 2015, 25% fewer species of wild bees were seen than was the case before 1990 [2]. Human food production is at stake with pollinator loss [3]. Nearly 90% of all wild flowering plant species on the planet depend on pollinators for reproduction and evolution [4]. These plants in turn are critical for ecosystem functioning as providers of food, habitat and other resources to many other species. Ultimately, ecosystem resilience is at stake.

The social construction of ignorance

Recently, this journal published a review of the changes over time in scientific research of threats to bee populations [5]. That review found a drastic change over the past 30 years. The initial research focus on bio-aggressors (such as *Varroa sp.*, *Nosema c.* etc) of managed honeybees shifted towards increased research attention for global change related factors in bee decline such as landscape alteration, agricultural intensification, climate change and invasive species. It further found increased recognition of, and research attention for, the essential contribution of wild bees and non-bee insects to crop pollination.

It is increasingly recognized that the status and health of managed honeybees is unrepresentative for the status and health of wild pollinators. Wild pollinators are more vulnerable than honeybees to most environmental stressors, because the extraordinary large colony size of honeybees makes them more resilient to shocks [6] and beekeepers monitor the condition of the managed bee hives and intervene frequently. Beekeepers replace dead queens, treat bee diseases, supply extra food, and move the hives [7]. Wild pollinators don't have the continuous helping hand of a beekeeper. To make pollinator conservation efforts effective, the research community thus urgently needs to change the dominant framing away from a "honeybee health" frame towards a "wild pollinator conservation and restoration" frame.

Scholars that studied the development of science and policy around bee and pollinator decline from the angles of *social studies of science* and *science and technology studies* have highlighted the phenomenon of social construction of ignorance [8]. The privileging of certain taken-for-granted approaches to, and foci of, knowledge production leads to a systematic and often strategic

Stéphane Foucart

Le Monde, 67-69, avenue Pierre-Mendès-France, 75013 Paris Cedex 13, France

A physicist by training (MSc in physics, with major in nuclear physics from University Pierre-et-Marie-Curie, Paris), Stéphane Foucart is the environmental science correspondent for the French daily newspaper *Le Monde*. He is interested in scientific controversies and the corporate influence on science and the public's understanding of science. His work on the climate-skeptic movement was awarded the European Meteorological Society (EMS) journalism prize and his investigations on the Monsanto Papers, together with Stéphane Horel, won a European Press Prize in 2018. His latest book (*Et le monde devint silencieux*, Points, 2021) focuses on the links between insect decline and systemic pesticides, as well as the strategies used by private interests to influence expertise on the matter, blur scientific knowledge, and influence the perception of science by the public and decision makers.

Jérôme Casas

Institut de Recherche sur la Biologie de l'Insecte (IRBI), Université de Tours, 37200 Tours, France

Jérôme Casas is Professor at the University of Tours, Insect Biology Research Institute (IRBI), honorary member of the Institut Universitaire de France (IUF) and was awarded the Humboldt research award for lifetime achievement in 2020. Having trained as a population ecologist, his interests span organismal biology and ecology; behavior and population dynamics of consumer-resource interactions; the sensory ecology of mimetism; flow sensing in biotic interactions; locomotion, physicochemical transport in

production of ignorance around the aspects that remain out of focus [8,9]. These are often aspects that are unwelcome to powerful stakeholders [10].

A key example of the social production of ignorance is that the dramatic transformation of the toxicity of the agrochemical landscape for pollinators by the large scale prophylactic use of neonicotinoid insecticides has for an extended period of time been out of focus. This occurred because pesticide impacts have routinely been discussed by industry, regulators and government institutions on the basis of decreasing applied amounts of chemicals, without accounting for the large but environmentally relevant variations and sharp increases over time in substance-specific toxicity and the increased areal of farmland prophylactically treated with pesticides. By including the toxicity of the substances to pollinators and the areas treated, recent studies have now revealed that due to their unprecedented toxicity to bees, neonicotinoids have transformed the world's farmland into a historically unprecedented toxic threat to pollinators [11,12,13,14]. Considering all the agrochemicals applied to farmland (fungicides, herbicides and insecticides), neonicotinoid insecticides alone are responsible for a 6-fold increase in the toxicity of farmland to bees in the UK in the period 1990 to 2015, see Figure 1 below [11]. In the US, insecticide toxicity of farmland to bees increased 48-fold from 1992 to 2014. The analysis shows that 92% of the increase in insecticide toxicity of farmland is solely attributable to neonicotinoids [13]. Schulz et al [14] assessed changes in the use of 381 pesticides over 25 years by considering 1591 substance-specific acute toxicity threshold values for eight nontarget species groups. They quantified the total applied toxicity (TAT) and find that the TAT for pollinators has more than doubled between 2005 and 2015 with an annual increase of about 8%, almost entirely driven by neonicotinoids.

It is worrisome that the global use of neonicotinoids is still increasing despite the partial EU ban. Even in the EU, the use of neonicotinoids has only been banned for outdoor use as plant protection products. Neonicotinoids are however also used at large scale for other purposes than plant protection. In the EU its use has continued at large scale as biocides (for example to eliminate flies in cattle stables), veterinary medicine (pet flea treatments) and for indoor use in plant protection in greenhouses. These uses continue to pollute surface water and soils with neonicotinoids and subsequently pollute wild floral resources. Also, regrettable substitution for outdoor crop protection has occurred with insecticides with similarly high toxicity to pollinators and the same mode of action [15] and new markets for neonicotinoids have opened such as the use in mariculture, including salmon farming (Sea lice medicine approval ratified in EU law).

Further, there is a growing denial of the decline of pollinators and insects in general, which seems now also rooted in the scientific literature. Recently, two high-profile meta-analyses have downplayed the severity of the situation. The first [16] suggests that no decline in insect abundance and diversity in the United States is observed, in stark contrast to many taxon-specific studies. The second [17] concludes that the decline in terrestrial insect abundance is limited to 9% per decade, and that the amount of aquatic insects would have increased by a surprising 11% per decade. Despite the considerable attention they have received, both meta-analyses have been heavily criticized by other scholars for various biases: over-representation of proliferating species in the datasets and statistical problems [18,19], inclusion of invasive species in the datasets, sampling bias, misinterpretation of satellite imagery, inclusion of species assemblages not exclusively consisting of insects, use of data generated by remediation experiments (designed to olfaction and biologically inspired technology. Physics, mathematics and chemistry are powerful tools but they cannot replace the knowledge and contextualization gained while observing real living beings in natural conditions. A notable feature of his approach is thus the blending of natural history with both state-of-the-art technology and modeling.

observe insect recolonization of certain environments following cessation of a disruption), under-representation of pollinators in the datasets [20,21]. This tendency to downplay the extent of insect decline is part of a growing and worrying denial of biodiversity decline [22].

Recent advances in the study of human and policy dimensions of pollinator decline

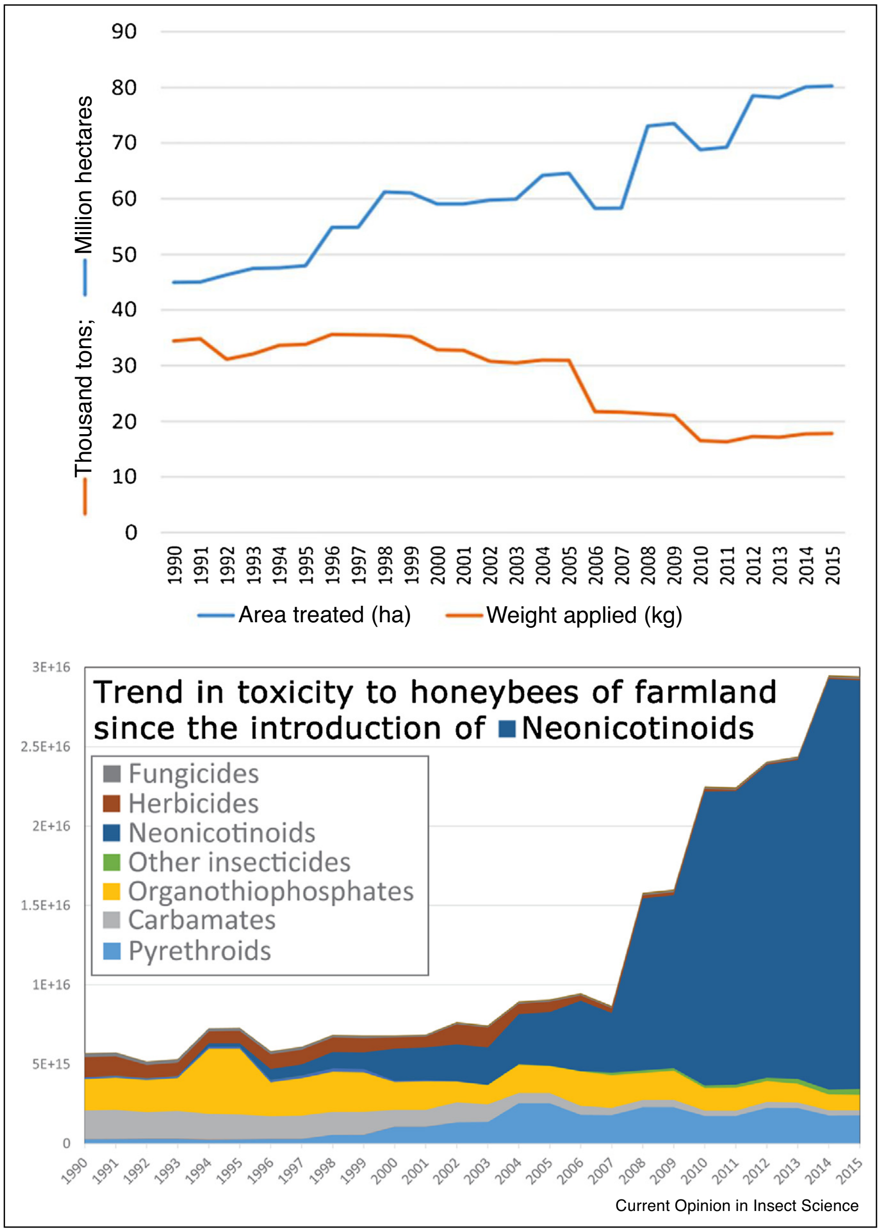
This issue of *Current Opinion in Insect Science* aims to provide an overview of the recent advances in the study of human and policy dimensions of pollinator decline. The papers cover three major somewhat overlapping themes: the status of pollinator decline and its drivers, the study of the interface between science and policy around pollinator decline, and the state of knowledge on policy options for pollinator conservation and restoration.

Drivers of pollinator decline are discussed in two reviews. The first one by LeBuhn and Luna reviews the various causes of pollinator decline. The review is focussed on non-*Apis* bee pollinators in non-agricultural systems. It discusses amongst others land use change, climate change, spillover of bee viruses and other pathogens from managed bees to wild bees, pesticides and pollutants. Habitat loss stands out as the best studied driver. The effects of pollution with pesticides, nitrogen, heavy metals and diseases are also widely recognised in the reviewed literature as significant factors. The review highlights in addition a role for the feedback loop between climate change induced droughts, reduced nectar and pollen production, reduced pollination success, plant inbreeding, reduced nectar quality and pollinator decline. Significant gaps in knowledge remain, in particular regarding the interactions among pesticides, bee diseases and other drivers of pollinator decline.

The second review by Tooker and Pearsons discuss how older classes of insecticides such as DDT lead to insect biodiversity loss and accumulation in food webs with large scale ecological impacts. Introduction of Integrated Pest Management (IPM) promised fewer non-target effects, but the shift to neonicotinoids has posed new and unique threats to insect populations. Because neonics are used prophylactically, insecticides are now applied on more crop acres than any time in history. In addition, not only treated crops are a source of exposure. The high water solubility of neonics implies that significant pollution of non-target habitats is inevitable. Their systemic properties make it possible that wild plants (including flowering trees) translocate neonic residues from polluted soil, surface water and ground water to pollen and nectar. Flower visiting insects and other taxa are thus chronically exposed to these chemicals on a very large scale and during the entire foraging season. Neonics influence the food web by reducing the abundance and diversity of insects so that members of higher tropic levels (e.g. insectivores) may suffer prey scarcity. Such cascading effects of neonicotinoids in food webs have indeed been documented for predatory insects, insectivorous birds and fish. Evidence of bioaccumulation of neonics has also been found in a few studies, including salamanders and earthworms, amongst others. The authors conclude that based on their ubiquity and available evidence, neonicotinoids are likely to be playing a role in insect declines via direct and indirect effects on food webs, mainly through simplification of the impacted food webs.

The interface between the science of pollinator decline and policy making for protecting and restoring pollinator diversity and abundance is discussed

Figure 1



Upper panel: Area of crop treated (blue line, million hectares) and mass of pesticide applied (red line, thousand tons) from 1990 to 2015; Lower panel: Number of honeybee median lethal doses (LD50) in pesticides applied to UK farmland 1990-2015. Reproduced from [11], copyright by Goulson et al. (CC BY). Note that the legend on the vertical axis in the upper panel has been improved and the legend in the lower panel has been placed inside the figure.

in three contributions. The first one is a critical review by Arnold on the making of the thematic assessment on pollinators [4] by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). IPBES is tasked with assessing the state of biodiversity and ecosystem services in response to requests from decision makers. Scientific assessment by IPBES are written by large groups of authors where 80% of authors are nominated by governments, and 20 % by stakeholders. Governments adopt assessment texts. Arnold was one of the external experts who formally reviewed the first draft of the IPBES pollinator assessment. In his contribution in this thematic issue he critically reflects on the biased evaluation in the draft pollinator assessment of the scientific literature on the role of pesticides, identified by the external review process. The review of IPBES' first draft revealed an incomplete and biased literature review, strongly biased towards selfcitation of one of its authors and high reliance on studies by neonicotinoid producer Syngenta. Large amounts of academic key-studies on the role of pesticides were not included, and the seminal and exhaustive systematic reviews of the '*Worldwide Integrated Assessment on the risks of neonicotinoids and fipronil to biodiversity and ecosystem functioning*' (WIA) were not even cited. The result of this shortcoming was that the risks of neonicotinoids to pollinators was systematically downplayed by IPBES. While a large body of peer reviewed literature demonstrates that at field-realistic exposures, neonicotinoids adversely affect individual navigation, learning, food collection, longevity, resistance to disease and fecundity, this was not acknowledged in IPBES' first draft. The review process yielded 10 300 comments from 280 expert reviewers and helped to bring the IPBES report to be more in line with the reality of scientific knowledge regarding the state of knowledge on sublethal effects of pesticides on pollinators and their impact on pollination. The analysis further shows how IPBES, substantially but only partly, repaired the major shortcomings flagged in the review process in the published final version while other key-points and flaws raised by the review process remained unchanged. The remaining flaws include that the weaknesses of industry-led field studies (lack of statistical power and an experimental set up that is flawed by design) that are well-documented in the peer reviewed literature remain unaddressed, and the resulting huge uncertainty ranges regarding what constitutes a field realistic exposure at normal authorised use are not made explicit. Further, IPBES presents an unsubstantiated high estimate of 15% for the so called honeybee back-ground mortality, with no references to any source. Insiders know that this is a key-quantity in the regulatory risk assessment of pesticides, because the "bee guidance" [23] of the European Food Safety Authority (EFSA) compares pesticide induced mortality to background mortality. In the war on EFSA's bee guidance between the pesticide lobby and scientists (EU's battle over bees heads for another brick wall) that is ongoing since 2013, this quantity plays a key role. The higher the background mortality of honeybees, the more pesticides can be authorised, the less pollinators are protected. Overall the analysis calls for better guarantees of impartiality and improved practices of participation and inclusion in science for policy. Indeed, while redressing wrongdoings is feasible to some extent, Arnold clearly shows the over-proportional impact of the first decisions in drafting scientific assessment reports.

The next review on the use of science for informing policy making is the contribution by Demortain on the science behind the EU ban on neonicotinoids. In the 30 years since their introduction in the early 1990s they became the most widely used insecticides but also increasingly a target of public regulation. Under its pesticide regulation, the EU restricted the use of a group of 3 neonics at once. The French biodiversity law of 2016 banned the use of 5 neonicotinoids, effective per 2018. The banning of a group of active substances from the same chemical family is highly exceptional in pesticide regulation. Previous pesticides of which the unacceptable impacts were only discovered after the market introduction have been phased out one by one. The review seeks to advance our understanding of how research knowledge, as opposed to regulatory science, is included or excluded from the regulatory space. The review focuses on the question how knowledge claims that classified the whole family of neonics as hazardous to bees (rather than the individual active substances in that family), emerged and were acted upon by regulators and under what conditions this could occur. Sublethal effects of pesticides were the key to understanding how neonics impact pollinators. Knowledge about sublethal effects is not routinely produced in the pesticide regulatory space where knowledge production is bound to protocols that follow a reductionist approach. The so called invisible cognitive architecture of the regulatory space has three key elements: acute risks, risk/benefit balancing, and substance-centric thinking. First, it focuses predominantly on acute toxicity measured in standardised lab experiments. Second, safety knowledge is combined with economic or use knowledge such as the efficacy and practical value as a plant protection tool, which is balanced against the knowledge on the hazards to non-target organisms. Third, the regulatory knowledge is substance centred. This implies that knowledge covering a family of chemicals with similar mode of action and their joint overall impact on the environment and non-target species has little chance of being produced in a normally configured regulatory space. The review shows how in the neonic case, alternative regulatory knowledge emerged because public researchers, beekeepers, NGOs, and politicians advocating environmental action formed a coalition that managed to intervene in the regulatory space. This reconfigured the regulatory space to include new actors and a higher plurality of sources and forms of knowledge. This pluralisation of the knowledge that is considered in regulatory risk appraisal remedied the blind spots of routine regulatory science for low dose chronic and sublethal effects which in turn enabled the ban. Key factors why this could occur are that public researchers did not shy away from contributing their knowledge to the bureaucracies involved, despite the uphill struggle this constitutes. They brought key-knowledge from public research on neonics directly to expert agencies across Europe such as EFSA and EEA and to national and European policy makers. Second, researchers teamed up with beekeepers that were in turn associated with public interest groups. Journalists stepped up their coverage and specialised NGOs teamed up with public scientists to make their actions evidence-informed. All this together created the momentum that ultimately led to a reconfiguration of the regulatory space to include the wider range of scientific evidence that was necessary to see and understand the unacceptable harm to pollinators of normal authorised use of neonics. This externally-forced inclusion of a wider range of scientific evidence in the regulatory science, enabled the exceptional phenomenon that a group of chemicals was banned together. This constitutes an inversion of the routine, closed functioning of the regulatory space, and of the production of a standard regulatory science that structurally disregards low-dose and chronic, sublethal effects of pesticides. Unfortunately this inversion has been incidental and is far from a structural inversion of the regulatory space. This implies a high probability that routine regulatory science will continue to have serious blind spots in detecting risks to pollinators of existing and new pesticides. It also implies a continued need for public scientists to assume their societal responsibility and engage in coalitions with other societal actors to help bring excluded relevant knowledge and early warning signals to the attention of the regulatory space and policy makers.

The third review on the science-policy interface by Drivdal and van der Sluijs focusses on the role of the precautionary principle (PP) in decision making for pollinator conservation. The PP asks for an anticipatory approach to protect humans and the environment against the uncertain risks of human action. It can justify policy interventions to reduce potential risks in cases where scientific evidence of risk is insufficient, inconclusive or uncertain and preliminary objective scientific evaluation has indicated that there are reasonable grounds for concern that the potentially dangerous effects on the environment, human, animal or plant health may be unacceptable. It has been incorporated into national and international biodiversity-related law and environmental policies. The review shows that the research front on precautionary pollinator conservation is fragmented. In studies on pollinator biodiversity conservation the PP seem to be perceived as a general approach, mentioned in the context of our limited knowledge (scientific uncertainty) on insect species and biodiversity. In addition, two separate strands of literature discuss the role the PP has played in the regulation of pesticides and of international pollinator trade. The analysis revealed inconsistencies in how, where and when the PP has been applied. The procedure to apply the PP is often prolonged, resulting in delayed, fragmented, narrow and flawed regulations. The review further highlights the challenges of invoking precaution in a context of scientific uncertainty and controversy and corporate capture of regulatory science. The neonic case is illustrative of this. Scientific uncertainty gives room to diverging interpretations of the science, often fuelled by merchants of doubt strategies. When stakes are high and economic interests are involved, proposed PP regulations meet with resistance from powerful stakeholders. To move forward in such a situation, the authors call for a transdisciplinary approach in which entomologists join with social scientists, legal scholars, legislators and policymakers to form an extended peer community that jointly addresses the human dimensions of pollinator decline and co-produce adequate policy options.

Lastly, three reviews address political and societal response options to mitigate pollinator decline. The contribution by Gemmil-Herren et al. explores what evidence informed policies can be built to conserve pollinators. Diverse and abundant native pollinator communities can provide effective pollinator services and are often as or more effective than managed pollinators per-visit in providing these services. Both pollinator abundance and pollinator diversity are key. Managing for pollinator richness is a critical goal because higher flower-visitor richness often improves crop pollination. Different pollinator species handle flowers differently, visit flowers at different times of the day, change the behaviour of other pollinator species, increase the chance that an effective pollinator is present in the community, or respond differentially to weather or other environmental conditions. Increased crop diversity and richness of overall vegetation is a further factor that increases pollinator diversity and abundance. Landscapes with high edge densities of vegetation support the highest levels of pollinators and natural enemies of plague insects. Provisioning of nesting habitats in the landscape is crucial to sustaining native pollinators in agroecosystems. At the landscape scale, the loss of semi-natural habitat patches in the surrounding landscape has consistently reduced pollinator abundance and richness and has led to reduced pollination services and yields. Pollinator stewardship in pesticide practices is a further key ingredient for pollinator conservation. The review highlights the key importance of respecting the perspectives of farmers and local communities. The emerging concept of ecological intensification resonates with both indigenous knowledge, local communities and scientific understanding. It seeks to maintain or increase agricultural productivity through promoting ecosystem services to replace synthetic agricultural inputs. Through diversification, ecological intensification often enhances ecosystem services such as biodiversity, pollination, pest control, nutrient cycling, soil fertility and water regulation while maintaining crop yields. The regulating functions of nature require both agroecosystem design at the landscape-level and recognition of the complexity of agricultural systems. The literature synthesis provides a basis for systemic solutions that respond to the identified needs for co-creation of knowledge, participatory approaches to decision making and innovative management across agroecosystem landscapes. Holistic policy approaches are needed, engaging a wide range of actors in the transition to sustainable pollinator friendly food systems.

Next, Iwasaki and Hogendoorn critically review the adequacy of conservation actions for pollinators starting from an analysis of the relative importance of managed honeybees compared to wild bees and non-bee insect pollinators. Non-bee flower visiting insects are increasingly recognized as important crop pollinators. The public perception wrongly equates pollinator decline with honeybee decline. However, despite increased honeybee disorders and increased colony losses, managed honeybees have shown consistent increases for several decades, simply because beekeepers breed extra colonies to compensate for the lost ones and to match increasing demand for pollination. It are the native wild bee species and non-bee insect pollinators that are in decline and at risk of extinction. The public misunderstanding has in many cases misguided conservation action by implementing pollinator protection policies that mainly help honeybees, even to the detriment of declining wild pollinator communities. For example by planting flowers in field margins that are selected for their importance for honeybees. Competition of honeybees with other pollinators can be highly variable but ample evidence indicates that native pollinators and ecosystems are often negatively affected if honeybees are added in nature areas. The increased popularity of urban beekeeping can also have negative impacts on wild pollinators in urban areas. To remedy the misguiding effect of the honeybee flagship, it is important to promote new flagship species such as native bumblebees and culturally significant bees. Successful examples are the stingless bees (*Meliponines*) in south and central Americas, and the blue banded and teddy bear bees in Australia (genus *Amegilla*). Such local native flagship species can help educate the public about wild pollinators and can direct pollinator conservation in directions that are more adequate. Further, politicians should look beyond crop pollination and aim at the protection of endangered pollinators for the sake of the health and functioning of endangered ecosystems.

The last review by Fontaine et al. addresses the increasing involvement of amateurs and citizens in the advancement of scientific research and in the development of effective pollinator conservation practices. Non-professional experts make important contributions ranging from building insect taxonomical knowledge to the collection of large range and long scale monitoring data. The development of online taxonomical and bibliographical databases, digital photography, and social media for photo sharing and collaborative identification of the insect species on the photos, has given a new momentum to the input of amateurs to the knowledge of insect biodiversity. The synergy between amateurs and professionals in insect systematics has been qualified as ‘a backbone of the primary research on biodiversity’. The Krefeld Entomological Society in Germany, with ca. 50 members, provided the data for the iconic Hallmann et al. study [24], showing a 75% decline in flying insect biomass in 27 years. Nowadays, numerous participatory monitoring schemes are flourishing, targeting bees, flower-visiting insects, butterflies and moths, or documenting flower-insect interactions. Insect citizen science helps insects’ conservation. The relationship between science and society also largely benefits. Insect citizen-science projects make insects more real and relevant for the society and provides opportunities for volunteers to be in close contact with insects in their habitats, to experience nature, and to learn different ways to do science. Amateurs enter a community of participants in which they engage with scientists. These extended knowledge networks increase knowledge on insects and how to better conserve them. Citizen science projects help to entrench science and insect conservation issues in society. It provides incentives to care about insects. The embodied, emotional and close relationships with natural living elements is also key to the motivation and creativity of academics.

The unique social responsibility of entomologists

The decline of bees and other pollinators continues at a high pace, and time for action is running out. Entomologists are holders of expertise that could be the key to halt and reverse the crisis of pollinator decline. This gives entomologists a unique societal responsibility, on par only with the one expected from them in the Western world a century ago on combatting vector diseases and plant pests. Then they invented strong chemicals and biological control. Today, they need to work with and for insects, in a much more complex settings but in a more positive and nurturing attitude [25]. They need to step up to increase the policy relevance of their research, to help adequately diagnose the problem, and to help develop timely structural solutions and policy options. Attention for these dimensions is growing, slowly, too slowly [26], partly because the mass media still fails to give this issue the place it deserves in the news coverage [27]. Entomologists need to be aware of the production of ignorance mechanisms and to team up with social researchers to improve the impact of socio-cultural and policy relevant research on pollinator conservation. Breakthroughs such as the ban of an entire class of proven harmful pesticides implied in pollinator decline became only possible following deep engagement of scientists with all stakeholders and entomologists assuming their societal responsibilities. This needs to become the norm, not the exception.

Funding

For author JvdS, this work benefited from the RECIPES project. This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 824665.

References

1. Van der Sluijs JP: **Insect decline, an emerging global environmental risk**. *Curr Opin Environ Sustain* 2020, **46**:39-42 http://dx.doi.org/10.1016/j.cosust.2020.08.012.
2. Zattara EE, Aizen MA: **Worldwide occurrence records reflect a global decline in bee species richness**. *One Earth* 2020, **4 (1)**:114-123 http://dx.doi.org/10.1016/j.oneear.2020.12.005.
3. Van der Sluijs JP, Vaage NS: **Pollinators and global food security: the need for holistic global stewardship**. *Food Ethics* 2016, **1**:75-91 http://dx.doi.org/10.1007/s41055-016-0003-z.
4. IPBES: **The Assessment Report on Pollinators, Pollination and Food Production**. *Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. 2016 http://dx.doi.org/10.5281/zenodo.3402856. Bonn.
5. Decourtye A, Alaux C, Le Conte Y, Henry M: **Toward the protection of bees and pollination under global change: present and future perspectives in a challenging applied science**. *Curr Opin Insect Sci* 2019, **35**:123-131 http://dx.doi.org/10.1016/j.cois.2019.07.008.
6. Straub L, Williams GR, Pettis J, Fries I, Neumann P: **Superorganism resilience: eusociality and susceptibility of ecosystem service providing insects to stressors**. *Curr Opin Insect Sci* 2015, **12**:109-112 http://dx.doi.org/10.1016/j.cois.2015.10.010.
7. Ferrier PM, Rucker RR, Thurman WN, Burgett M: **Economic effects and responses to changes in honey bee health ERR-246 USDA, Economic Research Service**. *Economic Research Report Number 246*. 2018 https://ageconsearch.umn.edu/record/276245/files/ERR-246.pdf.
8. Kleinman DL, Suryanarayanan S: **Dying bees and the social production of ignorance**. *Sci Technol Hum Values* 2013, **38**:492-517 http://dx.doi.org/10.1177/0162243912442575.
9. Saltelli A, Benini L, Funtowicz S, Giampietro M, Kaiser M, Reinert E, van der Sluijs JP: **The technique is never neutral. How methodological choices condition the generation of narratives for sustainability**. *Environmental Science & Policy* 2020, **106**:87-98 http://dx.doi.org/10.1016/j.envsci.2020.01.008.
10. Foucart S: **Et le monde devint silencieux**. *SEUIL*. 2019. 336 pp..
11. Goulson D, Thompson J, Croombs A: **Rapid rise in toxic load for bees revealed by analysis of pesticide use in Great Britain**. *PeerJ* 2018, **6**:e5255 http://dx.doi.org/10.7717/peerj.5255.
12. DiBartolomeis M, Kegley S, Mineau P, Radford R, Klein K: **An assessment of acute insecticide toxicity loading (AITL) of chemical pesticides used on agricultural land in the United States**. *PLoS One* 2019, **14(8)**:e0220029 http://dx.doi.org/10.1371/journal.pone.0220029.
13. Douglas MR, Sponsler DB, Lonsdorf EV, Grozinger CM: **County-level analysis reveals a rapidly shifting landscape of insecticide hazard to honey bees (Apis mellifera) on US farmland**. *Scientific reports* 2020, **10(1)**:1-11 http://dx.doi.org/10.1038/s41598-019-57225-w.
14. Schulz R, Bub S, Petschick LL, Stehle S, Wolfram J: **Applied pesticide toxicity shifts toward plants and invertebrates, even in GM crops**. *Science* 2021, **372**:81-84 http://dx.doi.org/10.1126/science.abe1148.
15. Siviter H, Muth F: **Do novel insecticides pose a threat to beneficial insects?** *Proceedings of the Royal Society B* 2020, **287(1935)**:20201265 http://dx.doi.org/10.1098/rspb.2020.1265.
16. Crossley MS, Meier AR, Baldwin EM, Berry LL, Crenshaw LC, Hartman GL, Lagos-Kutz D, Nichols DH, Patel K, Varriano S, Snyder WE, Moran MD: **No net insect abundance and diversity declines across US Long Term Ecological Research sites**. *Nature Ecology and Evolution* 2020, **4(10)**:1368-1376 http://dx.doi.org/10.1038/s41559-020-1269-4.
17. van Klink R, Bowler DE, Gongalsky KB, Swengel AB, Gentile A, Chase JM: **Meta-analysis reveals declines in terrestrial but increases in freshwater insect abundances**. *Science* 2020, **368(6489)**:417-420 http://dx.doi.org/10.1126/science.aax9931.
18. Welti EAR, Joern A, Ellison AM *et al.*: **Studies of insect temporal trends must account for the complex sampling histories inherent to many long-term monitoring efforts**. *Nature Ecology and Evolution* 2020, **5**:589-591 http://dx.doi.org/10.1038/s41559-021-01424-0.
19. Desquilbet M, Cornillon P, Gaume L, Bonmatin J: **Adequate statistical modelling and data selection are essential when analysing abundance and diversity trends**. *Nature Ecology and Evolution* 2021, **5(5)**:592-594 http://dx.doi.org/10.1038/s41559-021-01427-x.
20. Desquilbet M, Gaume L, Grippa M, Céréghino R, Humbert J-, Bonmatin J-, Cornillon P-, Maes D, Dyck HV, Goulson D: **Comment on "meta-analysis reveals declines in terrestrial but increases in freshwater insect abundances"**. *Science* 2021, **370(6523)**:1-5 http://dx.doi.org/10.1126/science.abd8947.
21. Jähnig SC, Baranov V, Altermatt F, Cranston P, Friedrichs-Manthey M, Geist J *et al.*: **Revisiting global trends in freshwater insect biodiversity**. *Wiley Interdisciplinary Reviews: Water* 2021, **8 (2)**:e1506 http://dx.doi.org/10.1002/wat2.1506.
22. Lees AC, Attwood S, Barlow J, Phalan B: **Biodiversity scientists must fight the creeping rise of extinction denial**. *Nature Ecology and Evolution* 2020, **4(11)**:1440-1443 http://dx.doi.org/10.1038/s41559-020-01285-z.
23. EFSA: **EFSA Guidance Document on the risk assessment of plant protection products on bees (Apis mellifera, Bombus spp. and solitary bees)**. *EFSA Journal* 2013, **11(7)**:3295 http://dx.doi.org/10.2903/j.efsa.2013.3295.
24. Hallmann CA, Sorg M, Jongejans E, Siepel H, Hofland N, Schwan H, Stenmans W, Mu ller A, Sumser H, Ho rren T, Goulson D, de Kroon H: **More than 75 percent decline over 27 years in total flying insect biomass in protected areas**. *PLoS One* 2017, **12**:e0185809 http://dx.doi.org/10.1371/journal.pone.0185809.
25. Dangles O, Casas J: **Ecosystem services provided by insects for achieving sustainable development goals**. *Ecosystem services* 2019, **35**:109-115 http://dx.doi.org/10.1016/j.ecoser.2018.12.002.
26. Hall DM, Martins DJ: **Human dimensions of insect pollinator conservation**. *Curr Opin Insect Sci* 2020, **38**:107-114 http://dx.doi.org/10.1016/j.cois.2020.04.001.
27. Althaus SL, Berenbaum MR, Jordan J, Shalmon DA: **No buzz for bees: Media coverage of pollinator decline**. *Proceedings of the National Academy of Sciences of the United States of America* 2021, **118(2)** http://dx.doi.org/10.1073/pnas.2002552117.