Environmental Science and Pollution Research (2021) 28:11709–11715
https://doi.org/10.1007/s11356-021-12853-6

EDITORIAL

An update of the Worldwide Integrated Assessment (WIA) on systemic insecticides

Jean-Marc Bonmatin[1] · Chiara Giorio[2,3] · Francisco Sánchez-Bayo[4] · Maarten Bijleveld van Lexmond[5]

Published online: 23 February 2021

The Task Force on Systemic Pesticides and the WIA

A steep decline in insect populations started in the decade 1990–2000 (Bijleveld van Lexmond et al. 2015; Vogel 2017; Sánchez-Bayo and Wyckhuys 2019). In the early 1990s, neonicotinoids were introduced into the pesticide market to provide systemic protection for crops from a wide range of insect pests, and they have been blamed to be responsible at least in part for these declines (Woodcock et al. 2016).

The Task Force on Systemic Pesticides (TFSP), an independent group of scientists from all over the globe, came together to carry out a comprehensive, objective, scientific review and assessment of the impact of systemic pesticides on biodiversity. Findings and pieces of evidence around the role of neonicotinoids and fipronil in the collapse of global fauna have been presented and discussed in the TFSP working meetings. From the foundation of the TFSP (Bijleveld van Lexmond et al. 2015), members came together in working meetings, which took place in Paris (France, 2010), Bath (UK, 2011), Cambridge (UK, 2012), Tokyo (Japan, 2012), Montegrotto (Italy, 2012), Louvain-la-Neuve (Belgium, 2013), Tokyo (Japan, 2013), Legnaro (Italy, 2013), Ostheim (France, 2014), Padova (Italy, 2016), Padova (Italy, 2017), Paris (France, 2018), and Orléans (France, 2019).

In 2015, the "Worldwide Integrated Assessment on the risks of Systemic Pesticides to Biodiversity and Ecosystems" (WIA) has been published as a synthesis of more than 1200 published peer-reviewed studies until June 2014, including industry-sponsored ones. It has been the first comprehensive synthesis of the state of knowledge on the risks to biodiversity and ecosystem functioning posed by the widespread global use of neonicotinoids and fipronil (Bijleveld van Lexmond et al. 2015).

The WIA of 2015 assessed respectively the trends, uses, mode of action, and metabolites of these insecticides (Simon-Delso et al. 2015); their environmental fate and exposure (Bonmatin et al. 2015); effects on non-target invertebrates (Pisa et al. 2015); direct and indirect effects on vertebrate wildlife (Gibbons et al. 2015); risks to ecosystem functioning and services (Chagnon et al. 2015); and explored case studies of sustainable pest management practices that can serve as alternatives to the use of neonicotinoids and fipronil (Furlan and Kreutzweiser 2015). The WIA of 2015 concluded that the existing literature clearly showed that levels of contamination of all environmental compartments with neonicotinoids and fipronil, caused by authorized uses, frequently exceed the lowest observed adverse effect concentrations (LOAEC) for a wide range of non-target species, and are thus inevitably to have a wide range of negative biological and ecological impacts (van der Sluijs et al. 2015).

The EASAC, the European Academies Science Advisory Council, in their report, references the WIA of 2015 and comes to similar conclusions especially in terms of agricultural ecosystem services and for restoring biodiversity (EASAC 2015). The IPBES, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination, and food production, also references the WIA of 2015 in its report (IPBES 2016a). Particularly, it was found that pesticides, including neonicotinoid

Responsible editor: Philippe Garrigues

✉ Jean-Marc Bonmatin
bonmatin@cnrs-orleans.fr

1 Centre de Biophysique Moléculaire, Centre National de la Recherche Scientifique (CNRS), Rue Charles Sadron, 45071 Orléans, France

2 Dipartimento di Scienze Chimiche, Università degli Studi di Padova, Via Marzolo 1, 35131 Padova, Italy

3 Present address: Department of Chemistry, University of Cambridge, Lensfield Road, Cambridge CB2 1EW, UK

4 School of Life and Environmental Sciences, The University of Sydney, 1 Central Avenue, Eveleigh, NSW 2015, Australia

5 Task Force on Systemic Pesticides, Charles-Knapp 29, 2000 Neuchâtel, Switzerland

insecticides, threaten pollinators worldwide, although the long-term effects are still unknown (IPBES 2016b).

In the conclusive paper of the WIA of 2015 (van der Sluijs et al. 2015), a series of key knowledge gaps were highlighted:

- For most countries, there were few or no publicly available data sources on the quantities of systemic pesticides being applied;
- Screening of neonicotinoid and fipronil residues in environmental media was limited, especially in marine systems;
- Knowledge on environmental fate of neonicotinoids and fipronil and their metabolites was extremely limited, especially concerning their possible accumulation in soil and plants after repeated treatments;
- Long-term toxicity and effects of long-term/chronic exposure for susceptible organisms were unknown;
- Additive or synergistic effects due to simultaneous exposure to multiple compounds (neonicotinoids bind to the same nAChRs in the nervous system) were not studied;
- Interactions between systemic insecticides and other stressors, including other pesticides, were not studied;
- Impacts of these systemic insecticides on the delivery of a wide range of ecosystem services were uncertain;
- The short- and long-term agronomic benefits provided by neonicotinoids and fipronil were unclear.

After publication of the WIA of 2015, the TFSP was asked to contribute the expertise of its members to explore alternatives to systemic insecticide use. This was done by co-organising scientific and outreach symposia focussing on impacts and alternatives to these insecticides. These events were held in Paris (France, 2015), Berlin (Germany, 2015), Toronto (Canada, 2016), Ottawa (Canada, 2016), Montréal (Canada, 2016), Manila (Philippines, 2016), Tokyo (Japan, 2016), Hangzhou (China, 2017), Nay Pyi Taw (Myanmar, 2017), Belmopan (Belize, 2017), Toronto (Canada, 2017), Davao (Philippines, 2018), Taipei (Taiwan 2018), Pretoria (South Africa, 2018), and Orléans (France, 2019). At the same time, the TFSP continued its integrative works based on newly published studies showing pieces of evidence on mechanisms and impacts of neonicotinoids and fipronil on biodiversity and ecosystems. This constitutes the present updated WIA on these systemic pesticides.

Main conclusions and knowledge gaps issuing from this updated WIA

Numerous research studies were undertaken in response to large gaps of knowledge, as attested by an exponential increase of publications on neonicotinoids and bees in the past five years. At the same time, manufactures have been expanding the neonicotinoid family, marketing new products under different sub-groups of neonicotinoids. In this update of the WIA, we have reviewed the peer-reviewed literature published after June 2014. Further discussions will address whether the newly published scientific literature fills the knowledge gaps highlighted above and highlight new emerging issues.

New molecules, metabolism, fate, and transport (Giorio et al., 2017)

New evidence around the mode of action of neonicotinoids has revealed additional targets, together with neurological and genotoxic effects previously unknown. Research has also discovered new degradation products and metabolisation pathways of neonicotinoids, in particular for the new and fourth generation of neonicotinoids.

Organisms are exposed to a cocktail of pesticides and affected by other stressors in the environment. Recent research started to investigate these aspects. Interestingly, some mixtures of neonicotinoids seem to have antagonistic effects, whereas exposure to several neonicotinoids is generally known to lead to synergistic toxicity. Other combinations of stressors, including *Varroa* mite, microsporidian *Nosema* spp. or some honeybee virus with exposure of honeybees to neonicotinoids also trigger synergistic effects.

Concerning environmental dispersion, new research confirms and supports previous findings on the contamination of air, soil, and food. Beyond the archetypical neonicotinoid imidacloprid, the persistence of other neonicotinoids has been shown in the environment. Recent water surveys in more than a dozen countries highlighted a widespread contamination of surface waters around the world. Worryingly, the current wastewater treatments seem to be inadequate to degrade and remove neonicotinoids, fipronil, and their toxic metabolites.

Knowledge gaps remaining are:

- Synergistic effects of pesticide cocktails and other environmental stressors
- Identification and toxicity of metabolites and degradation products of new molecules
- Persistence of new compounds and their metabolites in soils and contamination of subsequent crops
- Screening of the environment for toxic metabolites and degradation products
- Dispersion of dusts and spray drifts in the environment, their atmospheric lifetime and fate, including contamination of the urban environment through atmospheric depositions
- Biological and photochemical degradation in soils and sediments

- Efficiency of translocation of active ingredients from treated seeds to plant tissues
- Residues in fruits, vegetables, foodstuffs, and animals, all over the world
- Effective remediation strategies, especially given the widespread water contamination

Impacts on organisms and ecosystems (Pisa et al. 2017)

An enormous research effort carried on bees has revealed new aspects of sublethal effects, including the reduced fecundity of queen bees, impairment of sperm in drones, negative interactions with parasites (e.g. *Varroa* mites) and on the immune system. Research on wild bees has shown that they are more sensitive to neonicotinoids than honeybees. A few studies showed a correlation between the use of neonicotinoids and the declines in wild bees and butterflies in Europe and America, since the mid-1990s.

The toxicological effects of neonicotinoids extend far beyond the selected pest targets. Detrimental effects have been evidenced on predators and parasitoids of pests, thus confirming the unsuitability of neonicotinoids for integrated pest control programs.

Concerning the aquatic environment, studies have shown how the current contamination of surface waters is negatively affecting insect communities, which constitute a food source to fish, birds, and other insectivorous vertebrates. There are now sufficient data to set protective limits for aquatic invertebrate communities in the legislation.

Concerning terrestrial vertebrates, fipronil and the neonicotinoids imidacloprid and clothianidin exert sub-lethal neurological effects in rats and bats. Moreover, ingestion of treated seeds by birds can cause not only sublethal effects on immunity but also lethal effects.

The negative impacts of neonicotinoids on terrestrial and aquatic invertebrates can translate into indirect impacts for the entire ecosystem.

Knowledge gaps remaining are:

- Monitoring of population trends of wild pollinators (e.g. bees, butterflies) in regions contaminated with these residual systemic insecticides
- Effects of these insecticides on a large set of typical invertebrate species that are representatives of terrestrial invertebrate biodiversity
- Susceptibility of beneficial non-target invertebrates (e.g. predators, parasitoids) to new neonicotinoids
- Recovery of beneficial arthropods in areas treated with neonicotinoids and fipronil
- Effects on soil biota (e.g. grubs, earthworms) and their impact on soil fertility
- Monitoring of aquatic invertebrate biodiversity in waters contaminated with these systemic insecticides
- While laboratory studies suggest that neonicotinoids and fipronil can kill or harm vertebrates, and inferences can be made from laboratory studies adopting field-realistic conditions, there are only a few studies of their impacts on vertebrate wildlife in their natural environment. Even fewer studies have investigated indirect (e.g. cascades through the food-chain) and population-level impacts.
- More than half of all vertebrate studies were done of five species. Given the large variation in sensitivity to systemic pesticides among species, extrapolating results from such a small number of species to all vertebrates carries great risks, as they may not be representative.
- Lack of data on the characterisation and quantification of the impacts on ecosystem functioning and services

Resistance and alternatives to systemic insecticides (Furlan et al. 2018; Veres et al. 2020)

First, prophylactic use of neonicotinoids does not guarantee an increase in crop yield. Second, when necessary, the use of systemic insecticides should be restricted to the specific areas affected by pest outbreaks. Pest control, on the other hand, can be implemented effectively using integrated pest management tools for most of major crops. In particular, case studies on economic insurance initiatives, as for maize crops in Italy, can provide reimbursements to the farmers for yield losses in case of economic damage.

Increasing resistance to neonicotinoids is now common and is affecting most crops worldwide. Replacement with new chemicals from the same class does not solve the problem, as all neonicotinoids target the same type of receptors and the resistance mechanisms are similar for all these compounds. The solution, therefore, is not to develop new chemicals with the same mode of action, but to favour the natural systems of pest control, such as predators and parasitoids because the latter's prevent the outbreak of pests in the first place. Many alternatives to systemic insecticides are efficient and already available. Interestingly, in 78% of the 152 authorized uses of neonicotinoids in France, there is an efficient and environmentally friendly alternative to neonicotinoids, without any insecticide (Jactel et al. 2019). Alternatives allow to increase the net revenue for farmers. Actually, farmers can (i) save money with less pesticides and (ii) sell their production at a higher price because of a better quality. However, these alternatives need to be adapted, crop by crop, to various landscapes in various countries. Furthermore, farmers should be helped (independent advises and funds) for such a transition towards a more sustainable crop production.

Regulations and conclusions

The WIA of 2015 has been submitted to the European Food Safety Authority (EFSA) in charge of performing, for the European Commission, a risk assessment for bees concerning the use of neonicotinoids and fipronil in seed and granular treatments currently under a EU moratorium (EC 2013a, 2013b). To date, most neonicotinoid uses are (or are planned to be) suspended in Europe, with the exception of acetamiprid. Here, it is interesting to note that acetamiprid appeared one of the less toxic neonicotinoids for pollinators, but it is one of the most worrying neonicotinoids for human health (Ichikawa et al. 2019).

France banned fipronil for all agricultural uses in late 2004. After a series of some use suspensions between 1999 and 2015, France decided in 2016 to totally ban all neonicotinoids for agricultural uses, with a very few numbers of exceptions. This total ban was applied in 2018 (AN 2016). Furthermore, France decided by law to ban all new molecules having the same mode of action (AN 2018). This particularly applies for sulfoxaflor and flupyradifurone. However, special derogations have been granted in 2020 in France and in several European countries, for a limited time, for sugar beet production.

A few other initiatives occurred after the publication of the WIA 2015. For instance, in the Philippines, C. O. Reyes, the Governor of the island province of Marinduque, has taken the decision to ban totally the use of neonicotinoids and fipronil in order to protect the butterfly industry of this province. Another example is given in Canada. Starting from the 1st of July 2015, the Canadian province of Ontario decided to restrict some use of neonicotinoids by 80% in a few years (ERO 2015). However, there is no reliable data to support the results of such restrictions and the process is still in progress for corn and soybean seeds (ERO 2019). At the national level, Canada is now consulting about 5 neonicotinoids for the protection of aquatic life (CCME 2020).

However, despite the evidence of negative effects on ecosystems as far as sediments (Bonmatin et al. 2019), and little productivity gains in food production, worldwide use of these and other insecticides continues to grow unabated with only a few exceptions as exemplified above. A new framework for a truly sustainable agriculture that relies mainly on natural ecosystem services instead of pesticides is required (Goulson and 232 signatories 2018). It should be based on sound scientific knowledge and robust assessment, the precautionary principle (Patterson and McLean 2019) and use the diverse range of alternative tools available through integrated pest management for pest control or organic farming (Brühl and Zaller 2019; Wyckhuys et al. 2020).

Finally, there is an increasing set of data showing that the deleterious effects of these systemic insecticides are not only restricted to invertebrates (e.g. Hallmann et al. 2017; Krupke and Tooker 2020; Pelosi et al. 2020; Ewere et al. 2021) but affects also vertebrates, directly or indirectly (Paquet-Walsh et al. 2019; Eng et al. 2019). In addition, there is also growing pieces of evidence that mammals (including humans) can be directly affected by these insecticides (Taira 2014; Cimino et al. 2016; Caron-Beaudoin et al. 2017; Wang et al. 2017; Berheim et al. 2019; Ospina et al. 2019; Ichikawa et al. 2019; Wang et al. 2020; Thompson et al. 2020; Oya et al. 2020; Bonmatin et al. 2020); this in sharp opposition to what was expected at the time of their registration.

Acknowledgements The authors would like to thank the Stichting Triodos Foundation (The Netherlands) for funding the Task Force on Systemic Pesticides (TFSP) as a totally independent research group. The Stichting Triodos Foundation received funds from the Umwelt Stiftung Greenpeace (Germany), Pollinis (France), the M.A.O.C. Gravin van Bylandt Stichting (The Netherlands) and Zukunftsstiftung Landwirtschaft" (GLS Treuhand, Germany).

Declarations

Conflict of interest The authors declare no competing interests.

Disclaimer The funders had no role in the study design, data collection and data analysis, decision to publish and preparation of the manuscript.

References

AN (2016) Assemblée Nationale, Reconquête de la Biodiversité N° 3833, Amendement N°452, 22 juin 2016. http://www.assemblee-nationale.fr/14/amendements/3833/AN/452.asp. Accessed 31 January 2021.

AN (2018) Assemblée Nationale, Equilibre dans le secteur agricole et alimentaire N° 627, Amendement CE2049, 13 avril 2018. http://www.assemblee-nationale.fr/dyn/15/amendements/0627/CION-ECO/CE2049. Accessed 31 January 2021.

Berheim EH, Jenks JA, Lundgren JG, Michel ES, Grove D, Jensen WF (2019) Effects of Neonicotinoid Insecticides on Physiology and Reproductive Characteristics of Captive Female and Fawn White-tailed Deer. Sci Rep 9:4534. https://doi.org/10.1038/s41598-019-40994-9

Bijleveld van Lexmond M, Bonmatin J-M, Goulson D, Noome DA (2015) Worldwide integrated assessment on systemic pesticides. Global collapse of the entomofauna: exploring the role of systemic insecticides. Environ Sci Pollut Res. 22(1):1–4. https://doi.org/10.1007/s11356-014-3220-1,2015

Bonmatin J-M, Giorio C, Girolami V, Goulson D, Kreutzweiser DP, Krupke C, Liess M, Long E, Marzaro M, Mitchell EAD, Noome DA, Simon-Delso N, Tapparo A (2015) Environmental fate and exposure; neonicotinoids and fipronil. Environ Sci Pollut Res. 22(1):35–67. https://doi.org/10.1007/s11356-014-3332-7

Bonmatin JM, Noome D, Moreno H, Mitchell E, Glauser G, Soumana OS, Bijleveld van Lexmond M, Sanchez-Bayo F (2019) A survey and risk assessment of neonicotinoids in water, soil and sediments of

Belize. Env. Pollut 249:949–958. https://doi.org/10.1016/j.envpol.2019.03.099

Bonmatin J-M, Mitchell EAD, Glauser G, Lumawig-Heitzman E, Claveria F, Bijleveld van Lexmond M, Taira K, Sánchez-Bayo F (2020) Residues of neonicotinoids in soil, water and people's hair: A case study from three agricultural regions of the Philippines. Science of the Total Environment 757:143822. https://doi.org/10.1016/j.scitotenv.2020.143822

Brühl CA, Zaller JG (2019) Biodiversity Decline as a Consequence of an Inappropriate Environmental Risk Assessment of Pesticides. Front. Environ. Sci. 7:177. https://doi.org/10.3389/fenvs.2019.00177

Caron-Beaudoin E, Viau R, Hudon-Thibeault AA, Vaillancourt C, Sanderson JT (2017) The use of a unique co-culture model of fetoplacental steroidogenesis as a screening tool for endocrine disruptors: The effects of neonicotinoids on aromatase activity and hormone production. Toxicol Appl Pharmacol. 332:15–24. https://doi.org/10.1016/j.taap.2017.07.018

CCME (2020) Scientific Criteria Document for the Development of Canadian Water Quality Guidelines for the Protection of Aquatic Life: Neonicotinoid insecticides, March 2020, https://www.ccme.ca/files/DRAFT%20CWQG%20NNIs%20SCD%20EN%20v3.5%20secure.pdf. Accessed 30 March 2020.

Chagnon M, Kreutzweiser D, Mitchell EAD, Morrissey CA, Noome DA, van der Sluijs JP (2015) Risks of large-scale use of systemic insecticides to ecosystem functioning and services. Environ Sci Pollut Res. 22(1):119–134. https://doi.org/10.1007/s11356-014-3277-x

Cimino AM, Boyles AL, Thayer KA, Perry MJ (2016) Effects of Neonicotinoid Pesticide Exposure on Human Health: A Systematic Review. Environ Health Perspect. 2017 Feb 125(2):155–162. https://doi.org/10.1289/EHP515

EASAC (2015) European Academies' Science Advisory Council: Ecosystem services, agriculture and neonicotinoids, German National Academy of Sciences Leopoldina. https://www.easac.eu/fileadmin/Reports/Easac_15_ES_web_complete_01.pdf. Assessed 31 January 2021

EC (2013a) European Commission, Commission implementing regulation (EU) No 485/2013 of 24 May 2013 amending Implementing Regulation (EU) No 540/2011, as regards the conditions of approval of the active substances clothianidin, thiamethoxam and imidacloprid, and prohibiting the use and s, Off. J. Eur. Union, L 139, 12–26, 2013a.

EC (2013b) European Commission, Commission implementing regulation (EU) No 781/2013 of 14 August 2013 amending Implementing Regulation (EU) No 540/2011, as regards the conditions of approval of the active substance fipronil, and prohibiting the use and sale of seeds treated with plant p, Off. J. Eur. Union, L 219, 22–25, 2013b.

Eng ML, Stutchbury BJM, Morrissey CA (2019) A neonicotinoid insecticide reduces fueling and delays migration, in songbirds. Science, 13 SEPTEMBER 2019 • 365(6458):1177–1180

ERO (2015) Environmental Registry of Ontario, Regulatory Amendments to Ontario Regulation 63/09 under the Pesticides Act to Reduce the Use of Neonicotinoid Insecticides, EBR Registry Number: 012-3733, June 09, 2015, http://www.ebr.gov.on.ca/ERS-WEB-External/displaynoticecontent.do?noticeId=MTI0NjI4&statusId=MTg4NDgx&language=en. Accessed 30 March 2020.

ERO (2019) Environmental Registry of Ontario, Amendments to the Pesticide Regulation (63/09 General), ERO number 019-0601, October 28, 2019, https://ero.ontario.ca/notice/019-0601. Accessed 30 March 2020.

Ewere EE, Reichelt-Brushett A, Benkendorff K (2021) Impacts of Neonicotinoids on Molluscs: What We Know and What We Need to Know. Toxics *9*:21. https://doi.org/10.3390/toxics9020021

Furlan L, Kreutzweiser D (2015) Alternatives to neonicotinoid insecticides for pest control: case studies in agriculture and forestry. Environ Sci Pollut Res Int. 22(1):135–147. https://doi.org/10.1007/s11356-014-3628-7

Furlan L, Pozzebon A, Duso C, Simon-Delso N, Sánchez-Bayo F, Bijleveld van Lexmond M, Bonmatin J.-M. (2018). An update of the Worldwide Integrated Assessment (WIA) on systemic insecticides. Part 3: Alternatives to systemic insecticides. Environ Sci Pollut Res. https://doi.org/10.1007/s11356-017-1052-5

Gibbons D, Morrissey C, Mineau P (2015) A review of the direct and indirect effects of neonicotinoids and fipronil on vertebrate wildlife. Environ. Sci. Pollut. Res. 22(1):103–118. https://doi.org/10.1007/s11356-014-3180-5

Goulson D, 232 signatories (2018) Call to restrict neonicotinoids. Science 360(6393):973 http://science.sciencemag.org/content/360/6392/973.1

Hallmann CA, Sorg M, Jongejans E, Siepel H, Hofland N, Schwan H, Stenmans W, Müller A, Sumser H, Hörren T, others (2017) More than 75 percent decline over 27 years in total flying insect biomass in protected areas. PLoS One 12(10):e0185809

Ichikawa G, Kuribayashi R, Ikenaka Y, Ichise T, Nakayama SMM, Ishizuka M, Taira K, Fujioka K, Sairenchi T, Kobashi G, Bonmatin J.-M., Yoshihara S (2019) LC-ESI/MS/MS analysis of neonicotinoids in urine of very low birth weight infants at birth. PLoS ONE, 14(7): e0219208. https://doi.org/10.1371/journal.pone.0219208

IPBES (2016a) The assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production. S.G. Potts, V. L. Imperatriz-Fonseca, and H. T. Ngo, (eds). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. 552 pages. http://www.ipbes.net/sites/default/files/downloads/pdf/individual_chapters_pollination_20170305.pdf. Accessed 30 March 2020.

IPBES 2016b. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production. Pollinators Vital to Our Food Supply Under Threat, https://www.ipbes.net/article/press-release-pollinators-vital-our-food-supply-under-threat. Accessed 30 March 2020.

Jactel H, Verheggen F, Thiéry D, Escobar-Gutiérrezd AJ, Gachete E, Desneux N (2019) the Neonicotinoids Working Group1 (2019) Alternatives to neonicotinoids. Environment International 129:423–429. https://doi.org/10.1016/j.envint.2019.04.045

Krupke CH, Tooker JF (2020) Beyond the Headlines: The Influence of Insurance Pest Management on an Unseen, Silent Entomological Majority. Front. Sustain. Food Syst. 4:595855. https://doi.org/10.3389/fsufs.2020.595855

Ospina M, Wong L-Y, Baker S, Serafim AB, Morales-Agudelo P, Calafat AM (2019) Exposure to neonicotinoid insecticides in the U.S. general population: Data from the 2015–2016 national health and nutrition examination survey. *Environmental Research*. https://doi.org/10.1016/j.envres.2019.108555

Oya N, Ito Y, Ebara T, Kato S, Ueyama J, Aoi A, Nomasa K, Sato H, Matsuki T, Sugiura-Ogasawara M, Saitoh S, Kamijima M (2020) Cumulative exposure assessment of neonicotinoids and an investigation into their intake-related factors in young children in Japan. Science of the Total Environment 750(2021):141630. https://doi.org/10.1016/j.scitotenv.2020.141630

Paquet-Walsh A, Bertolo A, Landry C, Deschamps L (2019) & Boily M (2019) Interactive effects of neonicotinoids and natural ultraviolet radiation on yellow perch (Perca flavescens) larvae. Science of the Total Environment 685:690–701. https://doi.org/10.1016/j.scitotenv.2019.05.113

Patterson A, McLean C (2019) 2018 The precautionary principle at work: The case of neonicotinoids and the health of bees. Science and Public Policy 46(3):441–449. https://doi.org/10.1093/scipol/scy072

Pelosi C, Bertrand C, Daniele G, Coeurdassier M, Benoit P, Nélieu S, Lafay F, Bretagnolle V, Gaba S, Vulliet E, Fritsch C (2020)

Residues of currently used pesticides in soils and earthworms: A silent threat?, Agriculture. Ecosystems and Environment 305(2021):107167. https://doi.org/10.1016/j.agee.2020.107167

Pisa, L. W., Amaral-Rogers, V., Belzunces, L. P., Bonmatin, J.-M., Downs, C. A., Goulson, D., Kreutzweiser, D. P., Krupke, C., Liess, M., McField, M., Morrissey, C. A., Noome, D. A., Settele, J., Simon-Delso, N., Stark, J. D., van der Sluijs, J. P., Van Dyck, H. and Wiemers, M. (2015) Effects of neonicotinoids and fipronil on non-target invertebrates, Environ. Sci. Pollut. Res. Int., 22(1), 68–102, doi:https://doi.org/10.1007/s11356-014-3471-x, 2015.

Pisa L, Goulson D, Yan EC, Gibbons D, Sánchez-Bayo F, Mitchell E, van der Sluijs J, MacQuarrie C, Giorio C, Long EY, McField M, Bijleveld van Lexmond M, Bonmatin JM (2017) An update of the World Integrated Assessment (WIA) on systemic insecticides. In: Part 2: Impacts on organisms and ecosystems. Res, Environ. Sci. Pollut. https://doi.org/10.1007/s11356-017-0341-3

Sánchez-Bayo F, Wyckhuys KAG (2019) (2019) Worldwide decline of the entomofauna: A review of its drivers. Biological Conservation 232:8–27. https://doi.org/10.1016/j.biocon.2019.01.020

Simon-Delso N, Amaral-Rogers V, Belzunces LP, Bonmatin J-M, Chagnon M, Downs C, Furlan L, Gibbons DW, Giorio C, Girolami V, Goulson D, Kreutzweiser DP, Krupke CH, Liess M, Long E, McField M, Mineau P, Mitchell EAD, Morrissey CA, Noome DA, Pisa L, Settele J, Stark JD, Tapparo A, Van Dyck H, van Praagh J, van der Sluijs JP, Whitehorn PR, Wiemers M (2015) Systemic insecticides (neonicotinoids and fipronil): trends, uses, mode of action and metabolites. Environ. Sci. Pollut. Res. 22(5–34):2015–2034. https://doi.org/10.1007/s11356-014-3470-y

Taira, K. (2014) Human neonicotinoids exposure in Japan, Jpn J Clin Ecol, Vol.23 No.1, https://i.kawasaki-m.ac.jp/jsce/jjce23_1_14.pdf. Assessed 31 January 2021.

Thompson DA, Lehmler H-J, Kolpin DW, Hladik ML, Vargo JD, Schilling KE, LeFevre GH, Peeples TL, Poch MC, LaDuca LE, Cwiertny DM, Field RW (2020) A critical review on the potential impacts of neonicotinoid insecticide use: current knowledge of environmental fate, toxicity, and implications for human health. Environmental Science Processes & Impacts 22:1315–1346. https://doi.org/10.1039/c9em00586b

van der Sluijs JP, Amaral-Rogers V, Belzunces LP, Bijleveld van Lexmond MFIJ, Bonmatin J-M, Chagnon M, Downs CA, Furlan L, Gibbons DW, Giorio C, Girolami V, Goulson D, Kreutzweiser DP, Krupke C, Liess M, Long E, McField M, Mineau P, Mitchell EAD, Morrissey CA, Noome DA, Pisa L, Settele J, Simon-Delso N, Stark JD, Tapparo A, Van Dyck H, van Praagh J, Whitehorn PR, Wiemers M (2015) Conclusions of the Worldwide Integrated Assessment on the risks of neonicotinoids and fipronil to biodiversity and ecosystem functioning. Environ. Sci. Pollut. Res. 22(1): 148–154. https://doi.org/10.1007/s11356-014-3229-5

Veres A, Wyckhuys KAG, Kiss J, Tóth F, Burgio G, Pons X, Avilla C, Vidal S, Razinger J, Bazok R, Matyjaszczyk E, Milosavljević I, Le XV, Zhou W, Zhu Z-R, Tarno H, Hadi B, Lundgren J, Bonmatin J-M, Bijleveld van Lexmond M, Aebi A, Rauf A, Furlan L (2020) An update of the Worldwide Integrated Assessment (WIA) on systemic pesticides. Part 4: Alternatives in major cropping systems. Environ. Sci. Pollut. Res. 27(24):29867–29899

Vogel G (2017) Where have all the insects gone? Science. Science 356(6338):576–579. https://doi.org/10.1126/science.356.6338.576

Wang X, Anadón A, Wu Q, Qiao F, Ares I, Martínez-Larrañaga MR, Yuan Z, Martínez MA (2017) Mechanism of Neonicotinoid Toxicity: Impact on Oxidative Stress and Metabolism. Annual Review of Pharmacology and Toxicology, Vol. 58:471–507. https://doi.org/10.1146/annurev-pharmtox-010617-052429

Wang A, Mahai G, Wan Y, Yang Z, He Z, Xu S, Xia W (2020) Assessment of imidacloprid related exposure using imidacloprid-olefin and desnitro-imidacloprid: Neonicotinoid insecticides in human urine in Wuhan, China. Environment International 141(2020): 105785. https://doi.org/10.1016/j.envint.2020.105785

Woodcock BA, Isaac NJ, Bullock JM, Roy DB, Garthwaite DG, Crowe A et al (2016) Impacts of neonicotinoid use on long-term population changes in wild bees in England. Nature Communications 7:12459. https://doi.org/10.1038/ncomms12459

Wyckhuys KAG, Aebi A, Bijleveld van Lexmond MFIJ, Bojaca CR, Bonmatin JM, Furlan L, Guerrero JA, Mai TV, Pham HV, Sanchez-Bayo F, Ikenaka Y (2020) Resolving the twin human and environmental health hazards of a plant based diet. Environment International 144(2020):106081. https://doi.org/10.1016/j.envint.2020.106081

Dr Jean-Marc Bonmatin is a researcher for the Centre National de la Recherche Scientifique (CNRS, France). He completed his thesis in 1987 in Chemistry and Physics (Bordeaux, France). Then, he worked for the National Research Council of Canada (Ottawa). He joined the Centre de Biophysique Moléculaire (CNRS) in late 1989 in Orléans where he started his researches on structure-activity relationships of toxic molecules to their target (antibacterial, antifungal, and neurotoxins, from bacteria and arthropods). From 1988, J.-M. Bonmatin was involved during 12 years in European programs on the so-called Colony Collapse Disorder (CCD) of honeybees, especially concerning analytics of pesticides in the environment and toxicology of pesticides on insects. He joined the Task Force on Systemic Pesticides (TFSP) from its very beginning in 2010, and he is now vice-President of the TFSP (www.tfsp.info). At the national level, he is currently an expert for the scientific committees of ITSAP (French Institute of Bee and Pollination) and of ANSES (French Agency of Environmental and Food Safety). He is the author of more than 80 publications. His book, co-edited with Sánchez-Bayo F. and Janairo, J.I.B, entitled *Systemic Pesticides*, has been awarded the first prize from the National Academy of Sciences of Philippines in 2018. Nowadays, he becomes more and more involved in risk assessment for public health.

Dr Chiara Giorio is a lecturer at the University of Cambridge (UK). She received her Master's degree in Chemistry in 2008 from the University of Padua (Italy), where she then completed her PhD in Molecular Sciences in 2012. She was a postdoctoral researcher at the University of Cambridge (UK) until the end of 2016, a researcher at the Centre National de la Recherche Scientifique (CNRS, France) until the end of July 2017, and tenure-track Assistant Professor at the University of Padua (Italy) until the end of February 2020. She has also been an Honorary Research Associate at the University of Birmingham (UK) since 2009. Her research interests concern formation pathways, processes, and impacts of atmospheric aerosols and trace analysis of contaminants in remote, rural, and urban environments. She came into contact with the world of bees in 2008, participating in a project to study the translocation of neonicotinoids from treated seeds to seedling guttation drops as a possible route of exposure of honeybees to neonicotinoids. Later on, she investigated the environmental dispersion of neonicotinoids from dusts emitted by seeders during sowing of corn seeds treated with neonicotinoids, and the consequent in-flight contamination of, and toxicity for, honeybees. She also worked on testing abatement devices to reduce emissions of neonicotinoids-bearing dusts during sowing operations.

Dr Francisco Sánchez-Bayo is an Honorary Associate at the School of Life & Environmental Sciences of the University of Sydney, Australia. He obtained a Master's degree in Environmental Sciences and a doctorate in Ecology at the Autonomous University of Madrid. After some post-doctoral years in Australia, he became Assistant Professor at Chiba University (Japan), where he taught ecotoxicology and risk assessment of pesticides and became concerned about the ecological impacts of neonicotinoids in paddy fields. Upon his return to Australia, he was a Research Associate at the University of Technology Sydney, worked in the Ecotoxicology laboratories at the Office of the Environment & Heritage NSW, and at the School of Life & Environmental Sciences, University of Sydney. Dr Sánchez-Bayo is author and co-author of over ninety scientific articles and book chapters on the environmental impact and risk of pesticides, ecology, and related subjects and is editor and author of the well-known online book "Ecological Impacts of Toxic Chemicals." He serves as an Associate Editor of the journal *Entomologia Generalis*, as a reviewer of over 60 international journals and as an expert assessor for the evaluation of scientific projects in eight countries.

Dr Maarten Bijleveld van Lexmond is a biologist and conservationist by training. He studied at Leiden and Amsterdam Universities obtaining his PhD. in 1974 with the publication of his first book: *Birds of Prey in Europe*. As one of the founders and Hon. Secretary for 10 years of the World Wildlife Fund in the Netherlands, he joined the WWF international secretariat in Switzerland and later led the Commission on Ecology of the International Union for the Conservation of Nature (IUCN). In the mid-1980s, he founded the Swiss Tropical Gardens in Neuchâtel, now in Kerzers (Switzerland), in parallel with the Shipstern Nature Reserve in Belize, Central America. For many years, he also served as President of the Foundation for the Conservation of the Bearded Vulture which succeeded in reintroducing the species into the Alps and other parts of Europe. At present, dividing his time between Switzerland and the south of France most of it since 2009 is taken up by his function as Chairman of the International Task Force on Systemic Pesticides (TFSP) which now looks not only into the worldwide impact of these chemicals on biodiversity and ecosystems, and in particular on pollinators such as honey bees, bumblebees, butterflies, but also at suspected consequences for public health.