SYMPOSIUM ON IMPACTS OF AND ALTERNATIVES TO SYSTEMIC PESTICIDES: A SCIENCE-POLICY FORUM

APRIL 19, 2016

CONFERENCE PACKAGE

Canadian Association of Physicians for the Environment

David Suzuki Foundation

YORK UNIVERSITÉ UNIVERSITY

WELCOME

April 19th 2016

It is an honour to welcome you to today's symposium on the Impacts of and Alternatives to Systemic Pesticides, organized by the David Suzuki Foundation, York University and the Task Force on Systemic Pesticides.

Large-scale prophylactic use of systemic insecticides such as neonicotinoids is having significant, unintended ecological consequences on biodiversity, particularly on pollinators. Adverse effects have also been documented on a wide range of other non-target organisms in terrestrial, aquatic, wetland, marine and benthic habitats.

The Government of Ontario has brought in strict restrictions on neonicotinoid insecticide use as part of a wider strategy to promote pollinator conservation in the province. New regulations prohibit the use and sale of corn and soybean seeds treated with three commercially available neonic pesticides, except under certain conditions. That means farmers will no longer be allowed to routinely plant neonic-treated seeds. Instead, neonic-treated seeds will be allowed only in situations where crops are highly vulnerable to targeted pests.

Ontario's new regulations are extremely important. Corn and soy are Ontario's two largest field crops, with about two million hectares (five million acres) planted annually.

But neonics and other systemic pesticides are used elsewhere in agriculture — as foliar sprays, soil drenches and seed treatments — in horticulture, turf grass production, golf courses and other applications and even in flea and tick treatments for pets. Five neonics are currently registered for use in Canada and they are found in more than 100 end-use pesticide products. Further knowledge is needed on their effects (especially on soil and aquatic biodiversity) and on the development of alternatives, such as biological control, in Integrated Pest Management.

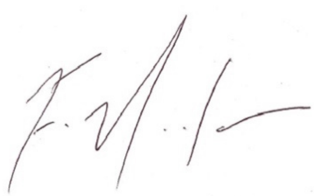
Today's symposium brings together scientists from across Canada, Europe and Asia, as well as senior provincial and federal policy-makers, members of the agriculture and horticultural communities, and non-governmental organizations. Scientists speaking today include visiting members of the International Task Force on Systemic Pesticides (TFSP), whose groundbreaking research on neonicotinoid insecticides is helping educate policy-makers on the impacts of systemic pesticides and the need for alternatives.

The David Suzuki Foundation, one of Canada's largest environmental organizations, supports evidence-based policy-making as critical to the sound management of our environment and our economy. We believe everyone needs access to clean air, safe water, fertile soil and nutritious food in order to survive and thrive.

I would like to thank the following individuals and organizations who have helped with today's symposium: Ole Hendrickson, Jim Chaput (OMAFRA), Dr. Madeleine Chagnon (UQAM), Dr. Maarten Bijleveld van Lexmond (TFSP), Sarah Rang (MOECC), Dr. Amro Zayed (York University), Kim Perrotta (CAPE), Dr. Laurence Packer (York University) and the staff at the David Suzuki Foundation and York University. Funding and in-kind support for the symposium have been provided by the RBQ Foundation, York University, the Canadian Association of Physicians for the Environment (CAPE) and the David Suzuki Foundation.

Thank you for participating in today's symposium.

Warmest wishes,



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AGENDA

Message from Symposium Chair:

- Faisal Moola, Director General, Ontario and Northern Canada, David Suzuki Foundation. Adjunct Professor, University of Toronto and York University. (8:55 – 9:00 AM)

Welcome Address:

- Hon. Glen Murray, Minister of Environment and Climate Change, Government of Ontario. (9:00 – 9:20 AM)

- Laurence Packer, Faculty of Science. York University. An introduction to bees (9:20 – 9:40 AM)

SESSION A: Current state of scientific knowledge on systemic pesticides.

Moderator: John Howard.

- Maarten Bijleveld van Lexmond, Chairman, Task Force on Systemic Pesticides (TFSP), Neuchâtel, Switzerland. Systemic pesticides and the TFSP: a historical perspective. (9:40 – 10:00 AM)

- Jean-Marc Bonmatin, Deputy Chairman TFSP. CNRS-Center for Molecular Biophysics (CBM), Orléans, France. Agricultural use of neonicotinoid insecticides and their impacts on biodiversity. (10:00 – 10:20 AM)

- Amro Zayed, Faculty of Science. York University. The magnitude and consequences of systemic pesticide exposure on honey bee health in Canada's corn growing regions. (10:20 – 10:40 AM)

- Break 10:40 – 11:00 AM

- Nigel Raine, Rebanks Family Chair in Pollinator Conservation. School of Environmental Sciences. University of Guelph. Impacts of systemic pesticides on bees: from individual behaviour to pollination services (11:00 – 11:20 AM)

- Elizabeth Lumawig-Heitzmann. Secretary of TFSP Public Health Working Group. Marinduque Biological Field Station, Philippines. Use of systemic pesticides in the developing world. A case study from the Philippines. (11:20 – 11:40 AM)

- Kumiko Taira. Chair of TFSP Public Health Working Group. Tokyo Women's Medical University, Japan. Human health impacts of exposure to neonicotinoid insecticides: recent memory loss and human neonicotinoid exposure. (11:40 – 12:00 noon)

Lunch: 12:00 – 1:00 pm

SESSION A: Continued:

- David Kreutzweiser. Research Scientist, Canadian Forest Service, Natural Resources Canada. Risks of neonicotinoid insecticides to soil invertebrates (1:00 – 1:20)

SESSION B: Integrated pest management and alternatives to neonicotinoid insecticides.

Moderator: Ole Hendrickson

- Jean-Marc Bonmatin, Deputy Chairman TFSP. CNRS-Center for Molecular Biophysics (CBM), Orléans, France. (1:20 – 1:40 PM)

- Lorenzo Furlan. Chairman of TFSP Working Group on Alternatives. Veneto Agricultura, Centre for Agricultural Research in co-operations with the University of Padua, Italy. IPM and protection of growers by a mutual insurance against pitfalls: powerful alternatives to neonicotinoids in arable crops (1:40 – 2:00 PM)

- Graeme Murphy. IPM and Biological Control Consultant. IPM and alternatives to systemic pesticide application in Ontario horticulture. (2:00 – 2:20 PM)

- Break: 2:20 – 2:40

- Charles Vincent, Saint-Jean-sur-Richelieu Research and Development Centre. Agriculture and Agri-Food Canada. Alternatives to insecticides: a reality check. (2:40 – 3:00 PM)

- Roundtable Panel Discussion on challenges and opportunities to reduce systemic pesticide use with IPM. (3:00 – 3:45 PM)

Closing Remarks:

- Maarten Bijleveld van Lexmond, Chairman, Task Force on Systemic Pesticides (TFSP), Neuchâtel, Switzerland. (3:45 – 4:00 PM)

Thank You:

- Faisal Moola, Director General, Ontario and Northern Canada, David Suzuki Foundation. Adjunct Professor, University of Toronto and York University. (4:00 – 4:02 PM)

AN INTRODUCTION TO THE TASK FORCE ON SYSTEMIC PESTICIDES (TFSP)

www.tfsp.info

The Task Force on Systemic Pesticides is an independent group of scientists from all over the globe, who came together to work on the Worldwide Integrated Assessment of the Impact of Systemic Pesticides on Biodiversity and Ecosystems.

The mandate of the Task Force on Systemic Pesticides (TFSP) has been "*to carry out a comprehensive, objective, scientific review and assessment of the impact of systemic pesticides on biodiversity, and on the basis of the results of this review to make any recommendations that might be needed with regard to risk management procedures, governmental approval of new pesticides, and any other relevant issues that should be brought to the attention of decision makers, policy developers and society in general*."

The Task Force has adopted a science-based approach and aims to promote better informed, evidence-based, decision-making. The method followed is Integrated Assessment (IA) which aims to provide policy-relevant but not policy-prescriptive information on key aspects of the issue at hand. To this end a highly multidisciplinary team of 30 scientists from all over the globe jointly made a synthesis of 1,121 published peer-reviewed studies spanning the last five years, including industry-sponsored ones. All publications of the TFSP have been subject to the standard scientific peer review procedures of the journal (http://www.springer.com/environment/journal/11356).

Key findings of the Task Force have been presented in a special issue of the peer reviewed Springer journal "Environmental Science and Pollution Research" entitled "Worldwide Integrated Assessment of the Impacts of Systemic Pesticides on Biodiversity and Ecosystems" and consists of eight scientific papers, reproduced here with permission of Springer.

In summary the TFSP's scientific assessment indicates that the current large-scale prophylactic use of systemic insecticides is having significant unintended negative ecological consequences. The evidence indicates that levels of systemic pesticides that have been documented in the environment are sufficient to cause adverse impacts on a wide range of non-target organisms in terrestrial, aquatic, wetland, marine and benthic habitats. There is also a growing body of evidence that these effects pose risks to ecosystem functioning, resilience and services such as for example pollination and nutrient cycling.

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EDITORIAL

Worldwide integrated assessment on systemic pesticides

Global collapse of the entomofauna: exploring the role of systemic insecticides

Maarten Bijleveld van Lexmond · Jean-Marc Bonmatin · Dave Goulson · Dominique A. Noome

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Keywords Neonicotinoids · Fipronil · Insecticides · Ecosystem services · Biodiversity · Non-target organisms

The appeal of Notre Dame de Londres

In July 2009, a group of entomologists and ornithologists met at Notre Dame de Londres, a small village in the French department of Hérault, as a result of an international enquiry amongst entomologists on the catastrophic decline of insects (and arthropods in general) all over Europe.

They noted that a perceptible and gradual decline of insects, as part of the general impoverishment of the natural environment, had set in from the 1950s onwards. Amongst many others, they recognized as root causes of this decline the intensification of agriculture with its accompanying loss of natural habitats and massive use of pesticides and herbicides, the manifold increase in roads and motorized traffic as well as a continent-wide nocturnal light pollution and nitrogen deposition.

They equally agreed that a further degradation of the situation, a steeper decline in insect populations, had started in the decade 1990–2000. This first began in western Europe, followed by eastern and southern Europe, is nowadays apparent in the scarcity of insects splattered on windscreens of motorcars and squashed against their radiators and is best documented in the decline of butterflies and the global disorders amongst honey bees. They concluded that these phenomena reflected the now general collapse of Europe's entomofauna.

They also noted that the massive collapse of different species, genera and families of arthropods coincided with the severe decline of populations of different insectivorous bird species up to now considered as "common" such as swallows and starlings.

On the basis of existing studies and numerous observations in the field as well as overwhelming circumstantial evidence, they came to the hypothesis that the new generation of pesticides, the persistent, systemic and neurotoxic neonicotinoids and fipronil, introduced in the early 1990s, are likely to be responsible at least in part for these declines.

They, therefore, issued the Appeal of Notre Dame de Londres under the heading "No Silent Spring again" referring to Rachel Carson's book "Silent Spring" then published almost half a century ago:

> The disappearance of honey bees is only the most visible part of a phenomenon now generalized in all of Western Europe. The brutal and recent collapse of insect populations is the prelude of a massive loss in biodiversity with foreseeable dramatic consequences for natural ecosytems, the human environment and public health. The systematic use of persistent neurotoxic insecticides in intensive agriculture and horticulture (neonicotinoids such as imidacloprid and thiamethoxam, and fipronil as

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a phenylpyrazole), which now form an invisible, widespread, toxic haze on land, in water and in the air, is regarded as a principal cause of this collapse observed by entomologists beginning in the middle of the 1990's and followed by the decline of insectivorous and other bird species by the ornithologists.

For this reason the undersigned raise an alarm and demand a much stricter adherence to the « Precautionary Principle » as enshrined in the E.U. Commission's Directive 91/414, and defined by UNESCO in 2005 as « When human activities may lead to morally unacceptable harm that is scientifically plausible but uncertain, actions shall be taken to avoid or diminish that harm ».

The international scientific Task Force on Systemic Pesticides (TFSP)

In response, an international scientific Task Force on Systemic Pesticides of independent scientists was set up shortly afterwards by a Steering Committee of which Maarten Bijleveld van Lexmond (Switzerland), Pierre Goeldlin de Tiefenau (Switzerland), François Ramade (France) and Jeroen van der Sluijs (The Nederlands) were the first members. Over the years, membership grew and today counts 15 nationalities in four continents. The Task Force on Systemic Pesticides (TFSP) advises as a specialist group two IUCN Commissions, the *Commission on Ecosystem Management* and the *Species Survival Commission*. Its work has been noted by the *Subsidiary Body on Scientific, Technical and Technological Advice* under the Convention on Biodiversity (CBD) and was brought to the attention of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) in the context of the fast-track thematic assessment of pollinators, pollination and food production.

In undertaking the Worldwide Integrated Assessment (WIA), over the course of the last 4 years, the TFSP has examined over 800 scientific peer-reviewed papers published over the past two decades. The TFSP areas of expertise span diverse disciplines, including chemistry, physics, biology, entomology, agronomy, zoology, risk assessment and (eco) toxicology, and this has enabled a truly interdisciplinary evaluation of the evidence, necessary to understand the diverse ramifications of the global use of systemic pesticides on individual organisms, on ecosystems and on ecosystem processes and services.

The findings of the TFSP-WIA

Neonicotinoids were introduced in the early 1990s and are now the most widely used insecticides in the world. They are neurotoxins, binding to nicotinic acetylcholine receptors (nAChRs) in the central nervous system and causing nervous stimulation at low concentrations but receptor blockage, paralysis and death at higher concentrations. Fipronil is another widely used systemic insecticide that shares many of the properties of neonicotinoids and was introduced around the same time; hence, this compound is also included here. Both neonicotinoids and fipronil exhibit extremely high toxicity to most arthropods and a lower toxicity to vertebrates (although fipronil exhibits high acute toxicity to fish and some bird species). They are relatively water soluble and are readily taken up by plant roots or leaves, so they can be applied in a variety of ways (e.g. foliar spray, soil drench and seed dressing). The predominant use of these chemicals, in terms of the area of land over which they are used, is as a seed dressing, whereby the active ingredient is applied prophylactically to seeds before sowing and is then absorbed by the growing plant and spreads throughout the plant tissues, hence protecting all parts of the crop (Simon-Delso et al. 2014).

A range of concerns have emerged as to the impacts of neonicotinoids and fipronil on the environment (Bonmatin et al. 2014; Pisa et al. 2014; Gibbons et al. 2014; Chagnon et al. 2014; Furlan and Kreutzweiser 2014):

- It has become apparent that neonicotinoids can persist for years in soils and so cause environmental concentrations to build up if regularly used. This is likely to be impacting substantially on soil invertebrates, which as a group perform a vital service in maintaining soil structure and in cycling nutrients. Being water soluble, neonicotinoids leach into ponds, ditches and streams and contaminate groundwater. Contamination of marine environments has been observed but as yet has not been monitored systematically. Concentrations exceeding the LC_{50} for aquatic insects frequently occur in waterways, and much higher concentrations have been found in surface water in arable fields and in adjacent ditches. Waterways with higher neonicotinoid concentrations have been found to have depleted insect abundance and diversity.
- Dust created during drilling of treated seeds is lethal to flying insects and has caused large-scale acute losses of honeybee colonies. When applied as foliar sprays, drift is likely to be highly toxic to non-target insects. Non-crop plants, such as those growing in field margins, hedgerows and near contaminated waterways can become contaminated with neonicotinoids either via dust created during drilling, spray drift or contaminated water. This provides the potential for major impacts on a broad range of non-target herbivorous invertebrates living in farmland.
- Neonicotinoids and fipronil are found in nectar and pollen of treated crops such as maize, oilseed rape and sunflower and also in flowers of wild plants growing in farmland. They have also been detected at much higher concentrations in

guttation drops exuded by many crops. In bees, consumption of such contaminated food leads to impaired learning and navigation, raised mortality, increased susceptibility to disease via impaired immune system function and reduced fecundity, and in bumblebees, there is clear evidence for colony-level effects. Studies of other pollinators are lacking. Bees in farmland are simultaneously exposed to some dozens of different agrochemicals, and some act synergistically. The impact of chronic exposure of non-target insects to these chemical cocktails is not addressed by regulatory tests and is very poorly understood.

- Although vertebrates are less susceptible than arthropods, consumption of small numbers of dressed seeds offers a potential route for direct mortality in granivorous birds and mammals, for such birds need to eat only a few spilt seeds to receive a lethal dose. Lower doses lead to a range of symptoms including lethargy, reduced fecundity and impaired immune function. In addition, depletion of invertebrate food supplies is likely to indirectly impact on a broad range of predatory organisms, from arthropods to vertebrates.
- The prophylactic use of broad-spectrum pesticides (as seed dressings) goes against the long-established principles of Integrated Pest Management (IPM) and against new EU directives which make adoption of IPM compulsory. Continual exposure of pests to low concentrations of neonicotinoids is very likely to lead to the evolution of resistance, as has already occurred in several important pest species. Although systemic pesticides can be highly effective at killing pests, there is clear evidence from some farming systems that current neonicotinoid use is unnecessary, providing little or no yield benefit. Agrochemical companies are at present the main source of agronomic advice available for farmers, a situation likely to lead to overuse and inappropriate use of pesticides.

Overall, a compelling body of evidence has accumulated that clearly demonstrates that the wide-scale use of these persistent, water-soluble chemicals is having widespread, chronic impacts upon global biodiversity and is likely to be having major negative effects on ecosystem services such as pollination that are vital to food security and sustainable development. There is an urgent need to reduce the use of these chemicals and to switch to sustainable methods of food production and pest control that do not further reduce global biodiversity and that do not undermine the ecosystem services upon which we all depend (van der Sluijs et al. 2014).

The systemic insecticides, neonicotinoids and fipronil, represent a new chapter in the apparent shortcomings of the regulatory pesticide review and approval process that do not fully consider the risks posed by large-scale applications of broad-spectrum insecticides to ecosystem functioning and services. Our inability to learn from past mistakes is remarkable.

Acknowledgments This manuscript benefited from the discussions in the International Task Force on Systemic Pesticides during its plenary meetings in Paris (2010), Bath (2011), Cambridge (2012), Montegrotto-Padova (2012), Louvain-la-Neuve (2013) and Legnaro-Padova (2013). The work has been funded by the Triodos Foundation's Support Fund for Independent Research on Bee Decline and Systemic Pesticides. This Support Fund has been created from donations by Adessium Foundation (The Netherlands), Act Beyond Trust (Japan), Utrecht University (Netherlands), Stichting Triodos Foundation (The Netherlands), Gesellschaft fuer Schmetterlingsschutz (Germany), M.A.O.C. Gravin van Bylandt Stichting (The Netherlands), Zukunft Stiftung Landwirtschaft (Germany), Study Association Storm (Student Association Environmental Sciences Utrecht University) and citizens. The funders had no role in study design, data collection and analysis, decision to publish or preparation of the manuscript.

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The authors are listed in alphabetic order.

References

Bonmatin JM, Giorio C, Girolami V, Goulson D, Kreutzweiser D, Krupke C, Liess M, Long E, Marzaro M, Mitchell EAD, Noome DA, Simon-Delso N, Tapparo A (2014) Environmental fate and exposure; neonicotinoids and fipronil. Environ Sci Pollut Res. doi:10.1007/s11356-014-3332-7

Chagnon M, Kreutzweiser DP, Mitchell EAD, Morrissey CA, Noome DA, van der Sluijs JP (2014) Risks of large scale use of systemic insecticides to ecosystem functioning and services. Environ Sci Pollut Res. doi:10.1007/s11356-014-3277-x

Furlan L, Kreutzweiser DP (2014) Alternatives to Neonicotinoid insecticides for pest control: case studies in agriculture and forestry. Environ Sci Pollut Res (this issue)

Gibbons D, Morrissey C, Mineau P (2014) A review of the direct and indirect effects of neonicotinoids and fipronil on vertebrate wildlife. Environ Sci Pollut Res. doi:10.1007/s11356-014-3180-5

Pisa L, Amaral-Rogers V, Belzunces LP, Bonmatin JM, Downs C, Goulson D, Kreutzweiser D, Krupke C, Liess M, McField M, Morrissey C, Noome DA, Settele J, Simon-Delso N, Stark J, van der Sluijs JP, van Dyck H, Wiemers M (2014) Effects of neonicotinoids and fipronil on non-target invertebrates. Environ Sci Pollut Res (this issue). doi:10.1007/s11356-014-3471-x

Simon-Delso N, Amaral-Rogers V, Belzunces LP, Bonmatin JM, Chagnon M, Downs C, 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, Stark JD, Tapparo A, van Dyck H, van Praagh J, van der Sluijs JP, Whitehorn PR and Wiemers M (2014) Systemic insecticides (neonicotinoids and fipronil): trends, uses, mode of action and metabolites. Environ SciPollut Res (this issue). doi:10.1007/s11356-014-3470-y

Van der Sluijs JP, Amaral-Rogers V, Belzunces LP, Bonmatin JM, Chagnon M, Downs C, 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 and Wiemers M (2014) Conclusions of the Worldwide Integrated Assessment on the risks of neonicotinoids and fipronil to biodiversity and ecosystem functioning. Environ Sci Pollut Res. doi:10.1007/s11356-014-3229-5

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 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-eighties 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 into the worldwide impact of these chemicals on biodiversity and ecosystems, and in particular on pollinators such as honey bees, bumble bees, butterflies, but also at suspected consequences for public health.

Dr Jean-Marc Bonmatin is researcher for the Centre National de la Recherche Scientifique (CNRS, France). He completed his thesis in 1987 at the University of Bordeaux (Chemistry and Physics) by studying interaction mechanisms between biological membranes and peptides by various spectroscopic techniques. This was his first scientific contact with the fascinating world of bees because these peptides have included bee venom. Just after, he worked for the National Research Council of Canada (Ottawa, Canada) until 1989. Here he was interested in dynamics of cholesterol in membranes by solid state NMR. He joined the Centre de Biophysique Moléculaire late 1989 (CBM, CNRS, Orléans, France) where he started his researches on structure-activity relationships of various biomolecules by high resolution NMR. These biomolecules have in common to be toxic to their target (antibacterial, antifungal, neurotoxins from arthropods, etc.). He shares the idea that 'knowing how it kills, gives clues on biological mechanisms and may allow saving'. From 2008 he was involved during twelve years in European programs on what is called the Colony Collapse Disorder (CCD), especially concerning analytics of pesticides in soil, water, pollen and honey, as well as concerning the finding of a virus of bee mites (Varroa destructor). He joined the Task Force on Systemic Pesticides very early and he is a member of its Steering Committee. He is also involved in risk assessments for pollinators for several public organisms, at national and international levels, such as ITSAP (French Institute of Bee and Pollination), ANSES (French Agency of Environmental and Food Safety) and the Organisation for Economic Co-operation and Development (OECD).

Dave Goulson is Professor of Biology at the University of Sussex. He received his bachelor's degree in biology from Oxford University, followed by a doctorate on butterfly ecology at Oxford Brookes University. Subsequently, he lectured in biology for 11 years at the University of Southampton, before moving to Stirling in 2006, and then to Sussex in 2013. Goulson works mainly on the ecology and conservation of bumble bees. He has published more than 200 scientific articles on the ecology and conservation of insects, with a particular focus on bumblebees. He is the author of Bumblebees; Their Behaviour, Ecology and Conservation, published in 2010 by Oxford University Press, and of A Sting in the Tale, a popular science book about bumble bees, published in 2013 by Jonathan Cape. Goulson founded the Bumblebee Conservation Trust in 2006, a UK-based charity which has grown to 8,000 members. For his work on bumblebee conservation he was made BBSRC Social Innovator of the year in 2010, and received the Zoological Society of London's Marsh Award for Conservation Biology in 2013. He was also elected a Fellow of the Royal Society of Edinburgh in 2013.

Dominique Noome MSc is currently project coordinator for the Task Force on Systemic Pesticides and conservation manager in Kasungu National Park, Malawi. Originally a veterinary epidemiologist, she studied the hematology of Kenyan cattle and economic impacts of emerging infectious diseases on livestock in the Netherlands during her MSc. After graduating as an animal health specialist at Wageningen University, she continued as an independent conservation scientist, being involved with the IUCN Commission on Ecosystem Management, and Foundation Chimbo. During this period she first got acquainted with the Task Force on Systemic Pesticides, starting with field work in 2011 which evolved into project coordinator over the years. In Malawi, where she has just concluded writing the general management plan for Kasungu National Park, she is now focused on coordination of research projects identified in the management plan. Her main areas of interest are protected areas management, more specifically wildlife health, law enforcement and strategies for ecosystem restoration. This also extends to systemic pesticide use in African countries, such as Malawi, where many knowledge gaps about the scale of use and associated impact of these substances still exist.

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EDITORIAL

Conclusions of the Worldwide Integrated Assessment on the risks of neonicotinoids and fipronil to biodiversity and ecosystem functioning

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Introduction

The side effects of the current global use of pesticides on wildlife, particularly at higher levels of biological organization: populations, communities and ecosystems, are poorly understood (Köhler and Triebskorn 2013). Here, we focus on one of the problematic groups of agrochemicals, the systemic insecticides fipronil and those of the neonicotinoid family. The increasing global reliance on the partly prophylactic use of these persistent and potent neurotoxic systemic insecticides has raised concerns about their impacts on biodiversity, ecosystem functioning and ecosystem services provided by a wide range of affected species and environments. The present scale of use, combined with the properties of these compounds, has resulted in widespread contamination of agricultural soils, freshwater resources, wetlands, non-target

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vegetation and estuarine and coastal marine systems, which means that many organisms inhabiting these habitats are being repeatedly and chronically exposed to effective concentrations of these insecticides.

Neonicotinoids and fipronil currently account for approximately one third (in monetary terms in 2010) of the world insecticide market (Simon-Delso et al. 2014). They are applied in many ways, including seed coating, bathing, foliar spray applications, soil drench applications and trunk injection. These compounds are used for insect pest management across hundreds of crops in agriculture, horticulture and forestry. They are also widely used to control insect pests and disease vectors of companion animals, livestock and aquaculture and for urban and household insect pest control and timber conservation (Simon-Delso et al. 2014).

Although the market authorization of these systemic insecticides did undergo routine ecological risk assessments, the regulatory framework has failed to assess the individual and joint ecological risks resulting from the widespread and simultaneous use of multiple products with multiple formulations and multiple modes of action. These applications co-occur across hundreds of cropping systems including all of our major agricultural commodities worldwide and on numerous cattle species, companion animals, etc. Also, the ecological risk assessment did not consider the various interactions with other environmental stressors. Once a market authorization is granted, the authorization poses limits to the dose and frequency per allowed application, but no limits are set to the total scale of use of the active ingredients leading to a reduced potential for the recovery of impacted ecosystems from effects. In addition, there has been no assessment of successive neonicotinoid exposure typical in watersheds and resulting in culmination of exposure and effects over time (Liess et al. 2013). The potential interactions between neonicotinoids and fipronil and other pesticide active substances have not been considered either, although additivity and synergisms of toxic mechanisms of action have been documented (Satchivi and Schmitzer 2011; Gewehr 2012; Iwasa et al. 2004).

The Worldwide Integrated Assessment (WIA) presented in the papers in this special issue is the first attempt to synthesize the state of knowledge on the risks to biodiversity and ecosystem functioning posed by the widespread global use of neonicotinoids and fipronil. The WIA is based on the results of over 800 peer-reviewed journal articles published over the past two decades. We assessed respectively the trends, uses, mode of action and metabolites (Simon-Delso et al. 2014); the environmental fate and exposure (Bonmatin et al. 2014); effects on non-target invertebrates (Pisa et al. 2014); direct and indirect effects on vertebrate wildlife (Gibbons et al. 2014); and risks to ecosystem functioning and services (Chagnon et al. 2014) and finally explored sustainable pest management practices that can serve as alternatives to the use of neonicotinoids and fipronil (Furlan and Kreutzweiser 2014).

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Mode of action, environmental fate and exposure

Due to their systemic nature, neonicotinoids and, to a lesser extent, fipronil as well as several of their toxic metabolites are taken up by the roots or leaves and translocated to all parts of the plant, which, in turn, makes the treated plant effectively toxic to insects that are known to have the potential to cause crop damage. Neonicotinoids and fipronil operate by disrupting neural transmission in the central nervous system of organisms. Neonicotinoids bind to the nicotinic acetylcholine receptor, whereas fipronil inhibits the GABA receptor. Both pesticides produce lethal and a wide range of sublethal adverse impacts on invertebrates but also some vertebrates (Simon-Delso et al. 2014 and Gibbons et al. 2014). Most notable is the very high affinity with which neonicotinoid insecticides agonistically bind to the nicotinic acetylcholine receptor (nAChR) such that even low-dose exposure over extended periods of time can culminate into substantial effects (see the literature reviewed by Pisa et al. 2014).

As a result of their extensive use, these substances are found in all environmental media including soil, water and air. Environmental contamination occurs via a number of disparate routes including dust generated during drilling of dressed seeds; contamination and build-up of environmental concentrations after repeated application in arable soils and soil water; run-off into surface and ground waters; uptake of pesticides by non-target plants via their roots followed by translocation to pollen, nectar, guttation fluids, etc.; dust and spray drift deposition on leaves; and wind- and animal-mediated dispersal of contaminated pollen and nectar from treated plants. Persistence in soils, waterways and non-target plants is variable but can be long; for example, the half-lives of neonicotinoids in soils can exceed 1,000 days. Similarly, they can persist in woody plants for periods exceeding 1 year. Breakdown results in toxic metabolites, though concentrations of these in the environment are rarely measured (Bonmatin et al. 2014).

This combination of persistence (over months or years) and solubility in water has led to large-scale contamination of, and the potential for build-up in, soils and sediments (ppb-ppm range), waterways (ground and surface waters in the ppt-ppb range) and treated and non-treated vegetation (ppb-ppm range). Screening of these matrices for pesticides and their metabolites has not been done in a systematic and appropriate way in order to identify both the long-term exposure to low concentrations and the short-term erratic exposure to high concentrations.

However, where environmental samples have been screened, they were commonly found to contain mixtures of pesticides, including neonicotinoids or fipronil (with their toxic metabolites). In addition, samples taken in ground and surface waters have been found to exceed limits based on regulatory ecological threshold values set in different countries in North America and Europe. Overall, there is strong evidence that soils, waterways and plants in agricultural and urban environments and draining areas are contaminated with highly variable environmental concentrations of mixtures of neonicotinoids or fipronil and their metabolites (Bonmatin et al. 2014).

This fate profile provides multiple routes for chronic and multiple acute exposure of non-target organisms. For example, pollinators (including bees) are exposed through at least direct contact with dust during drilling; consumption of pollen, nectar, guttation drops, extra-floral nectaries and honeydew from seed-treated crops; water; and consumption of contaminated pollen and nectar from wild flowers and trees growing near treated crops or contaminated water bodies. Studies of food stores in honeybee colonies from a range of environments worldwide demonstrate that colonies are routinely and chronically exposed to neonicotinoids, fipronil and their metabolites (generally in the 1–100 ppb range), often in combination with other pesticides in which some are known to act synergistically with neonicotinoids. Other non-target organisms, particularly those inhabiting soils and aquatic habitats or herbivorous insects feeding on non-crop plants in farmland, will also inevitably be exposed, although exposure data are generally lacking for these groups (Bonmatin et al. 2014).

Impacts on non-target organisms

Impacts of systemic pesticides on pollinators are of particular concern, as reflected by the large number of studies in this area. In bees, field-realistic exposures in controlled settings have been shown to adversely affect individual navigation, learning, food collection, longevity, resistance to disease and fecundity. For bumblebees, colony-level effects have been clearly demonstrated, with exposed colonies growing more slowly and producing significantly fewer queens (Whitehorn

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et al. 2012). Limited field studies with free-living bee colonies have largely been inconsistent and proved difficult to perform, often because control colonies invariably become contaminated with neonicotinoids, or there is a lack of replication in the study design, all of which demonstrates the challenges of conducting such a study in the natural environment (Maxim and Van der Sluijs 2013; Pisa et al. 2014).

Other invertebrate groups have received less attention. For almost all insects, the toxicity of these insecticides is very high including many species that are important in biological control of pests. The sensitivity to the toxic effect is less clear with non-insect species. For annelids such as earthworms, the LC_{50} is in the lower ppm range for many neonicotinoids (LOEC at 10 ppb). Crustaceans are generally less sensitive, although sensitivity is highly dependent on species and developmental stage. For example, blue crab megalopae are an order of magnitude more sensitive than juveniles.

At field-realistic environmental concentrations, neonicotinoids and fipronil can have negative effects on physiology and survival for a wide range of non-target invertebrates in terrestrial, aquatic, wetland, marine and benthic habitats (see the literature reviewed by Pisa et al. 2014). Effects are predominantly reported from laboratory toxicity testing, using a limited number of test species. Such tests typically examine only lethal effects over short time frames (i.e. 48 or 96 h tests), whereas ecologically relevant sublethal effects such as impairment of flight, navigation or foraging ability and growth are less frequently described. It has become clear that many of the tests use insensitive test species (e.g. *Daphnia magna*) and are not sufficiently long to represent chronic exposure and therefore lack environmental relevance. Laboratory testing to establish safe environmental concentration thresholds is hindered by the fact that most pesticide toxicity tests are based on older protocols. Although these systemic pesticide classes possess many novel characteristics, testing methodologies have remained largely unchanged, resulting in flawed conclusions on their ecological safety (Maxim and Van der Sluijs 2013). New and improved methodologies are needed to specifically address the unique toxicology profiles of chemicals, including their possible cumulative and delayed lethal and non-lethal effects for a variety of terrestrial, aquatic and marine organisms. Nevertheless, our review shows a growing body of published evidence that these systemic insecticides pose a serious risk of harm to a broad range of non-target invertebrate taxa often below the expected environmental concentrations. As a result, an impact on the many food chains they support is expected.

We reviewed nearly 150 studies of the direct (toxic) and indirect (e.g. food chain) effects of fipronil and the neonicotinoids imidacloprid and clothianidin on vertebrate wildlife—mammals, birds, fish, amphibians and reptiles. Overall, at concentrations relevant to field exposure scenarios in fields sown with coated seeds, imidacloprid and clothianidin pose risks to small birds, and ingestion of even a few treated seeds could cause mortality or reproductive impairment to sensitive bird species (see the studies reviewed by Gibbons et al. 2014). Some recorded environmental concentrations of fipronil have been sufficiently high to potentially harm fish (Gibbons et al. 2014). All three insecticides exert sublethal effects, ranging from genotoxic and cytotoxic effects to impaired immune function, reduced growth or reduced reproductive success. Conclusive evidence was described recently, that neonicotinoids impair the immune response at the molecular level, thus enabling damages by covert diseases and parasites (Di Prisco et al. 2013). All these effects often occur at concentrations well below those associated with direct mortality (Gibbons et al. 2014). This is a trend in many taxa reported throughout the reviewed literature: short-term survival is not a relevant predictor neither of mortality measured over the long term nor of an impairment of ecosystem functions and services performed by the impacted organisms.

With the exception of the most extreme cases, the concentrations of imidacloprid and clothianidin that fish and amphibians are exposed to appear to be substantially below thresholds to cause mortality, although sublethal effects have not been sufficiently studied. Despite the lack of research and the difficulty in assigning causation, indirect effects may be as important as direct toxic effects on vertebrates and possibly more important. Neonicotinoids and fipronil are substantially more effective at killing the invertebrate prey of vertebrates than the vertebrates themselves. Indirect effects are rarely considered in risk assessment processes, and there is a paucity of data, despite the potential to exert population-level effects. Two field case studies with reported indirect effects were found in the published literature. In one, reductions in invertebrate prey from both imidacloprid and fipronil uses led to impaired growth in a fish species, and in another, reductions in populations of two lizard species were linked to effects of fipronil on termite prey (see the studies reviewed by Gibbons et al. 2014).

Impacts on ecosystem functioning and ecosystem services

The concept of ecosystem services is widely used in decision-making in the context of valuing the service potentials, benefits and use values that well-functioning ecosystems provide to humans and the biosphere (e.g. Spangenberg et al. 2014) and as an end point (value to be protected) in ecological risk assessment of chemicals. Neonicotinoid insecticides and fipronil are frequently detected in environmental media (soil, water, air) at locations where no pest management benefit is provided or expected. Yet, these media provide essential resources to support biodiversity and are known to be threatened by long-term or repeated contamination. The literature synthesized in this integrated assessment demonstrates the large-scale bioavailability of these insecticides in the global environment at levels that are known to cause lethal and sublethal effects on a wide range of terrestrial (including soil) and aquatic microorganisms, invertebrates and vertebrates. Population-level impacts have been demonstrated to be likely at observed environmental concentrations in the field for insect pollinators, soil invertebrates and aquatic invertebrates. There is a growing body of evidence that these effects pose risks to ecosystem functioning, resilience and the services and functions provided by terrestrial and aquatic ecosystems. Such services and functions can be provisioning, regulating, cultural or supporting and include amongst others soil formation, soil quality, nutrient cycling, waste treatment and remediation, pollination, food web support, water purification, pest and disease regulation, seed dispersal, herbivory and weed control, food provision (including fish), aesthetics and recreation.

Knowledge gaps

While this assessment is based on a growing body of published evidence, some knowledge gaps remain. These compounds have been subject to regulatory safety tests in a number of countries. However, several potential risks associated with the present global scale of use are still poorly understood. We highlight key knowledge gaps.

- For most countries, there are few or no publicly available data sources on the quantities of systemic pesticides being applied, nor on the locations where these are being applied. Reliable data on the amounts used are a necessary condition for realistic assessments of ecological impacts and risks.
- Screening of neonicotinoid and fipronil residues in environmental media (soils, water, crop tissues, non-target vegetation, sediments, riparian plants, coastal waters and sediments) is extremely limited. Although their water solubility and propensity for movement are known, also, only very scarce data for marine systems exist.
- An even bigger knowledge gap is the environmental fate of a wide range of ecotoxic and persistent metabolites of neonicotinoids and fipronil. Hence, we cannot evaluate with accuracy the likely joint exposure of the vast majority of organisms.
- There is a poor understanding of the environmental fate of these compounds, and how, for example, soil properties affect persistence and whether they accumulate in (usually flowering) woody plants following repeated treatments with the parent compound. The behaviour of degradation products (which can be highly toxic and persistent) in different media (plants, soils, sediments, water, food chains, etc.) is poorly known.
- Long-term toxicity to most susceptible organisms has not been investigated. For instance, toxicity tests have only been carried out on four of the approximately 25,000 globally known species of bees, and there are very few studies of toxicity to other pollinator groups such as hoverflies or butterflies and moths. Similarly, soil organisms (beyond earthworms) have received little attention. Soil organisms play multiple roles in the formation of soil and in the maintenance of soil fertility. Toxicity to vertebrates (such as granivorous mammals and birds which are likely to consume treated seeds) has only been examined in a handful of species.
- Those toxicological studies that have been performed are predominantly focused on acute toxicity tests, whereas the effects of long-term, acute and chronic exposure is less well known, despite being the most environmentally relevant scenario for all organisms in agricultural and aquatic environments. The long-term consequences of exposure under environmentally realistic conditions have not been studied.
- All neonicotinoids bind to the same nAChRs in the nervous system such that cumulative toxicity is expected. At present, no studies have addressed the additive or synergistic effects of simultaneous exposure to multiple compounds of the neonicotinoid family, i.e. imidacloprid, clothianidin, thiamethoxam, dinotefuran, thiacloprid, acetamiprid, sulfoxaflor, nitenpyram, imidaclothiz, paichongding and cycloxaprid, into an aggregated dose of e.g. "imidacloprid equivalents". Currently, risk assessments are done for each chemical separately, while many non-target species, such as pollinators, are simultaneously being exposed to multiple neonicotinoids as well as other pesticides and stressors. As a consequence, the risks have been systematically underestimated. While quantifying the suite of co-occurring pesticides is largely an intractable problem, a single metric that incorporates all neonicotinoid exposures to representative taxa would be an invaluable starting point.
- Cumulative toxicity of successive and simultaneous exposure has not been studied in the regulatory assessment and governance of chemical risks.
- Sublethal effects that often have lethal consequences in a realistic environmental setting have not been studied in most organisms. However, they are known to be profound in bees, and for those few other species where studies have been performed, sublethal doses of these neurotoxic chemicals have been reported to have adverse impacts on behaviour at doses well below those that cause immediate death.
- Interactions between systemic insecticides and other stressors, such as other pesticides, disease and food stress, have been explored in only a handful of studies (on bees), and these studies have revealed important synergistic

effects. For example, in honeybees, low doses of neonicotinoids greatly increase susceptibility to viral diseases. Interactions between systemic insecticides and other stressors in organisms other than bees are almost entirely unstudied. In field situations, organisms will almost invariably be simultaneously exposed to multiple pesticides as well as other stressors, so our failure to understand the consequences of these interactions (or even to devise suitable means to conduct future studies in this area) is a major knowledge gap.
- Impacts of these systemic insecticides on the delivery of a wide range of ecosystem services are still uncertain. The accumulation in soil and sediments might lead us to predict impacts on soil fauna such as earthworms and springtails (Collembola), which may in turn have consequences for soil health, soil structure and permeability and nutrient cycling. Contamination of field margin vegetation via dust or ground or surface water might lead us to expect impacts on fauna valued for aesthetic reasons (e.g. butterflies) and is likely to impact populations of important beneficial insects that deliver pollination or pest control services (e.g. hoverflies, predatory beetles). The general depletion of farmland and aquatic insect populations is likely to impact insectivorous species such as birds and bats. Contamination of freshwater is hypothesized to reduce invertebrate food for fish and so impact fisheries. The same might apply to coastal marine systems, potentially posing serious threats to coral reefs and salt marsh estuaries. None of these scenarios have been investigated.
- The short- and long-term agronomic benefits provided by neonicotinoids and fipronil are unclear. Given their use rates, the low number of published studies evaluating their benefit for yield or their cost-effectiveness is striking, and some recent studies (see Furlan and Kreutzweiser 2014) suggest that their use provides no net gain or even a net economic loss on some crops. It is not currently known what the impact on farming would be if these systemic pesticides were not applied or applied less (though their recent partial withdrawal in the EU provides an opportunity for this to be examined).

Given these knowledge gaps, it is impossible to properly evaluate the full extent of risks associated with the ongoing use of systemic insecticides, but the evidence reviewed in this special issue suggests that while the risks affect many taxa, the benefits have not been clearly demonstrated in the cropping systems where these compounds are most intensively used.

Conclusions

Overall, the existing literature clearly shows that present-day levels of pollution with neonicotinoids and fipronil caused by authorized uses (i.e. following label rates and applying compounds as intended) frequently exceed the lowest observed adverse effect concentrations for a wide range of non-target species and are thus likely to have a wide range of negative biological and ecological impacts. The combination of prophylactic use, persistence, mobility, systemic properties and chronic toxicity is predicted to result in substantial impacts on biodiversity and ecosystem functioning. The body of evidence reviewed in this Worldwide Integrated Assessment indicates that the present scale of use of neonicotinoids and fipronil is not a sustainable pest management approach and compromises the actions of numerous stakeholders in maintaining and supporting biodiversity and subsequently the ecological functions and services the diverse organisms perform.

In modern agricultural settings, it is increasingly clear that insecticide treatments with neonicotinoids and fipronil—and most prominently its prophylactic applications—are incompatible with the original mindset that led to the development of the principles of integrated pest management (IPM). Although IPM approaches have always included insecticide tools, there are other approaches that can be effectively incorporated with IPM giving chemicals the position of the last resort in the chain of preferred options that need be applied first. Note that the current practice of seed treatment is the opposite: it applies chemicals as the first applied option instead of the last resort. The preferred options include organic farming, diversifying and altering crops and their rotations, inter-row planting, planting timing, tillage and irrigation, using less sensitive crop species in infested areas, using trap crops, applying biological control agents, and selective use of alternative reduced-risk insecticides. Because of the persistent and systemic nature of fipronil and neonicotinoids (and the legacy effects and environmental loading that come with these properties), these compounds are incompatible with IPM. We accept that IPM approaches are imperfect and constantly being refined. However, there is a rich knowledge base and history of success stories to work from in many systems where pest management is required. In fact, in Europe, the IPM approach has become compulsory for all crops as of the 1st of January 2014 in accordance with EU Directive 2009/128/EC, but most member states still need to operationalize and implement this new regulation, and IPM is sometimes poorly defined.

Recommendations

The authors suggest that regulatory agencies consider applying the principles of prevention and precaution to further tighten regulations on neonicotinoids and fipronil and consider formulating plans for a substantial reduction of the global scale of use. Continued research into alternatives is warranted, but equally pressing is the need for education for farmers and other practitioners and the need for policies and regulations to encourage the adoption of alternate agricultural strategies to manage pests (e.g. IPM, organic, etc.). In addition, there is a need for research to obtain a better understanding of the institutional and other barriers that hamper large-scale adoption of proven sustainable agricultural practices that can serve as alternatives to the use of neonicotinoids and fipronil—as of many other pesticides as well.

The adequacy of the regulatory process in multiple countries for pesticide approval must be closely considered and be cognizant of past errors. For example, other organochloride insecticides such as DDT were used all over the world before their persistence, bioaccumulation and disruptive impacts on ecosystem functioning were recognized, and they were subsequently banned in most countries. Organophosphates have been largely withdrawn because of belated realization that they posed great risks to human and wildlife health. The systemic insecticides, neonicotinoids and fipronil, represent a new chapter in the apparent shortcomings of the regulatory pesticide review and approval process that do not fully consider the risks posed by large-scale applications of broad-spectrum insecticides.

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References

Bonmatin J-M, Giorio C, Girolami V, Goulson D, Kreutzweiser D, Krupke C, Liess M, Long E, Marzaro M, Mitchell E, Noome D, Simon-Delso N, Tapparo A (2014) Environmental fate and exposure; neonicotinoids and fipronil. Environ Sci Pollut Res. doi:10.1007/s11356-014-3332-7

Chagnon M, Kreutzweiser DP, Mitchell EAD, Morrissey CA, Noome DA, van der Sluijs JP (2014) Risks of large scale use of systemic insecticides to ecosystem functioning and services. Environ Sci Pollut Res. doi:10.1007/s11356-014-3277-x

Di Prisco G, Cavaliere V, Annoscia D, Varricchio P, Caprio E, Nazzi F, Gargiulo G, Pennacchio F (2013) Neonicotinoid clothianidin adversely affects insect immunity and promotes replication of a viral pathogen in honey bees. Proc Natl Acad Sci USA 110:18466–18471. doi:10.1073/pnas.1314923110

Furlan L and Kreutzweiser DP (2014) Alternatives to neonicotinoid insecticides for pest control: case studies in agriculture and forestry. Environ Sci Pollut Res. doi:10.1007/s11356-014-3628-7

Gewehr M (2012) Pesticidal mixtures. Eur Patent EP 2 481 284 A2

Gibbons D, Morrissey C and Mineau P (2014) A review of the direct and indirect effects of neonicotinoids and fipronil on vertebrate wildlife. Environ Sci Pollut Res. doi:10.1007/s11356-014-3180-5

Iwasa T, Motoyama N, Ambrose JT, Roe RM (2004) Mechanism for the differential toxicity of neonicotinoid insecticides in the honey bee, *Apis mellifera*. Crop Prot 23:371–378. doi:10.1016/j.cropro.2003.08.018

Köhler H-R, Triebskorn R (2013) Wildlife ecotoxicology of pesticides: can we track effects to the population level and beyond? Science 341:759–765. doi:10.1126/science.1237591

Liess M, Foit K, Becker A, Hassold E, Dolciotti I, Kattwinkel M, Duquesne S (2013) Culmination of low-dose pesticide effects. Environ Sci Technol 47:8862–8868

Maxim L, Van der Sluijs JP (2013) Seed-dressing systemic insecticides and honeybees. Chapter 16, pp. 401–438. In: European Environment Agency (ed) Late lessons from early warnings: science, precaution, innovation. European Environment Agency (EEA) report 1/2013, Copenhagen

Pisa L, Amaral-Rogers V, Belzunces LP, Bonmatin J-M, Downs C, Goulson D, Kreutzweiser D, Krupke C, Liess M, McField M, Morrissey C, Noome DA, Settele J, Simon-Delso N, Stark J, van der Sluijs, van Dyck H, Wiemers M (2014) Effects of neonicotinoids and fipronil on non-target invertebrates. Environ Sci Pollut Res. doi:10.1007/s11356-014-3471-x

Satchivi NM, Schmitzer PR (2011) Synergistic herbicide/insecticide composition containing certain pyridine carboxylic acids and certain insecticides. US Patent US 2011/0207606

Simon-Delso N, Amaral-Rogers V, Belzunces LP, Bonmatin JM, Chagnon M, Downs C, 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, Stark JD, Tapparo A, van Dyck H, van Praagh J, van der Sluijs JP, Whitehorn PR and Wiemers M (2014) Systemic insecticides (neonicotinoids and fipronil): trends, uses, mode of action and metabolites. Environ Sci Pollut Res. doi:10.1007/s11356-014-3470-y

Spangenberg JH, Görg C, Thanh Truong D, Tekken V, Bustamante JV, Settele J (2014) Provision of ecosystem services is determined by human agency, not ecosystem functions. Four case studies. Int J Biodivers Sci Ecosyst Serv Manag 10:40–53

Whitehorn PR, O'Connor S, Wackers FL, Goulson D (2012) Neonicotinoid pesticide reduces bumble bee colony growth and queen production. Science 336:351–352

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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 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-eighties 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 into the worldwide impact of these chemicals on biodiversity and ecosystems, and in particular on pollinators such as honey bees, bumble bees, butterflies, but also at suspected consequences for public health.

Abstract: In July 2009, a group of entomologists and ornthologists met at Notre Dame de Londres, a small village in the French Department of Hérault, as a result of an international enquiry amongst entomologists on the catastrophic decline of insects (and arthropods in general) all over Europe. They issued the Appeal of Notre Dame de Londres under the heading "No Silent Spring again"referring to Rachel Carson's book "Silent Spring" then published almost half a century ago. In response, an international Task Force on Systemic Pesticides was set up at the end of 2009. Over the years, membership grew and today counts 17 nationalities in four continents. In undertaking the Worldwide Integrated Assessment (WIA), over the course of the last four years, the TFSP has examined over 1,100 scientific peer-reviewed papers published over the last two decades. The WIA was almost simultaneously launched in June 2014, and published in a special issue of the peer-reviewed Springer journal "Environmental Science and Pollution Research" in January 2015.

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Jean-Marc **BONMATIN** is researcher for the Centre National de la Recherche Scientifique (CNRS, France). He completed his thesis in 1987 (Chemistry and Physics) by studying biological membranes in interactions with various peptides, especially a bee venom. Just after, he worked for the National Research Council of Canada (Ottawa, Canada) until 1989. Here, he was interested in dynamics of cholesterol in membranes. He joined the Centre de Biophysique Moléculaire late 1989 (CBM, CNRS, Orléans, France) where he started his researches on structure-activity relationships of various natural toxicants (antibacterial, antifungal, neurotoxins, etc.). From 2008 he was involved during twelve years in coordination of European research programs on the Colony Collapse Disorder (CCD). This concerned analytics of insecticides in soil, water, pollen and honey, as well as the finding of the first virus of bee mites (Varroa destructor). From 2009 he also joined the Task Force on Systemic Pesticides, being now the vice-chairman. He is also involved in risk assessments for pollinators for several public organisms such as ITSAP (French Institute of Bee and Pollination), ANSES (French Agency of Environmental and Food Safety) and OECD.

Abstract: Bee disorders are accompanied by a general collapse of entomofauna (www.iucn.org/) while biodiversity has probably never faced so many threats at a global scale because of human activities. A Worldwide integrated assessment on systemic pesticides (www.tfsp.info) was carried out to explore the role of neonicotinoids (DOI: 10.1007/s11356-014-3220-1).Our meta-analysis has described the uses and metabolism in soil, plants, water and air (DOI: 10.1007/s11356-014-3470-y). The environmental fate and exposures via these compartments (DOI: 10.1007/s11356-014-3332-7) have been linked to large effects on non target invertebrates (aquatic, terrestrial, including bees, DOI: 10.1007/s11356-014-3471-x), and on vertebrates such as fishes and birds, to a lesser extent (DOI: 10.1007/s11356-014-3180-5).Some uses of three neonicotinoids have been restricted (Italy: 2009, Europe: 2013), but because they also threaten agricultural productivity through impacts on ecosystem functioning and services (DOI: 10.1007/s11356-014-3277-x), our conclusions support further restrictions of their prophylactic uses in favor of integrated pest managements (IPM) practices or organic farming, which minimize pesticide use (DOI: 10.1007/s11356-014-3628-7, DOI: 10.1007/s11356-014-3229-5).Our findings on neonicotinoids have been confirmed by EASAC (http://www.easac.eu/) and incorporated in part by IBBES (www.ipbes.net/).

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Lorenzo **FURLAN** graduated in Agricultural Sciences at the University of Padua, has been working on soil insects (wireworms, blackcutworms, Diabrotica virgìfera virgifera) and on implementation of sustainable agriculture since 1981. He is currently the Manager of the Agricultural Research Department at Veneto Agricoltura (an extension Service for regional agricultural activities) where he is in charge of running the pilot farms and the research activity. Significant part of his research is devoted to IPM strategies against pests of arable crops. He is reviewer and the author or co-author of more than 200 papers in national and international Journals; among them the description of practical IPM strategies suitable for a dramatic reduction of soil insecticide usage in Europe.

Abstract: An extensive survey of fields and numerous trials conducted over the last 30 years in Italy made possible a reliable risk assessment of maize damage by soil pests and the implementation of IPM. Strong risk factors include organic matter content >5%, rotations including meadows and alfalfa, double crops one year or two years before maize is sown and landscape around the maize fields including meadows and/or natural grass, alfalfa and double crops. Weaker risk factors include a poor field drainage, late sowing date, a warm spring and clay or loam clay soils. The statistical models also showed how the simultaneous occurrence of two or more of the aforementioned risk factors can conspicuously increase the risk of wireworm damage to maize crop, while the probability of damage for a field with no risk factors is always low (<1%). IPM includes two steps:

1) "area-wide" risk assessment including click-beetle population monitoring with pheromone traps;
2) "complementary field monitoring" where risk assessment has identified the presence of risk factors.

1) "Area-wide" risk assessment: risk factors evaluation enable each cultivated region to be mapped, and high-risk areas to be pinpointed. The first layer of the risk map includes the main soil characteristics (organic-matter content, texture, pH); the second includes the key agronomic characteristics (rotation, drainage); and the third, the available entomological information, such as click-beetle population levels for the main Agriotes species, or wireworm presence/density assessed with bait traps over the years. A fourth layer reproduces the effects

that occur when existing risk factors interact. This system enables areas with different risk levels to be highlighted. Each wireworm-risk category (e.g. low, medium or high, based on the presence of one or more risk factors) will have its own IPM strategy.

2) Complementary field monitoring: where risk factors are present, the suggestion is assessing actual wireworm populations using bait traps and if average number of wireworms does not exceed the thresholds established, maize may be sown without any treatment; if the average number of wireworms exceeds at least one of the thresholds, farmers have the option of moving maize to a no-risk field, as well as of applying organic treatments or chemical treatments. In this way, control strategies will be implemented only when and where economic thresholds for maize are exceeded.

Assessing the risk of wireworm damage affords a solid basis for estimating the amount of farmland that can be left untreated each season without any risk of yield reduction. Precise targets for IPM of soil pests in maize could be set everywhere. For instance, in no-risk areas, soil insecticides or insecticide-coated seeds may need to be used on no more than 1% of maize-cultivated land, and in areas where organic-matter content is over 5%, soil insecticides could be used on about 15% of maize-cultivated land. For large areas with scattered-risk situations, IPM thresholds will be a balanced mean of the damage risk caused by various risk factors and the surface area of cultivated land where each risk factor occurs. In order to facilitate IPM, risk insurance coverage may be extremely useful. Insurance may be taken out privately by associated farmers, or with the support of public regulations. With risks below 1%, a few dollars per hectare (ten times less than soil-insecticide costs) would be enough to pay for damaged fields. As a result, the described IPM strategy may lead to a considerable reduction in the use of soil pesticides and to the immediate containment of the environmental impact of agriculture with no negative repercussions on farmers' income.

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Elizabeth **LUMAWIG-HEINTZMAN** was born in Manila, Philippines, where grew up in a household immersed in entomology. Her parents collected and discovered Philippine butterflies and other insects, some of which have been named after members of her family. In 1986, she received a BS in Secondary Education with a major in Biology and a minor in Earth Science. In 1996, she established the first butterfly house in the Philippines in Quezon City. She has been the owner of Flora Farm (Butterfly House) since 1991, and serves as the director of the Philippine Exotic Butterfly Fund and as Director of the Subic Bay Freeport Zone Butterfly Garden & Breeding Centre since 2004. During her professional career, she routinely conducted seminars on butterfly farming and watershed management, served as an expert for the Department of Environment and Natural Resources (DENR), advised or managed butterfly houses and trails for provincial governments in the Philippines, and served as a consultant on the Livelihood Project on Butterfly Breeding. She previously served as the honorary secretary of IABES External Liaison Committee in 2009, and as a member of the IUCN Task Force on Systemic Pesticides representing the Philippine Protected Ares and Wildlife Bureau in 2011. She is currently the Hon.Sec of TFSP Public Health Working Group. She now heads the Marinduque Biological Field Station.

Abstract: Like in other Asian countries use of neonicotinoid pesticides is wide-spread in the Philippines. Given the virtual absence of marketing regulations these products can be sold under multiple trade names at the lowest retailer levels with the well-entrenched agro-chemical industry strengthening its marketing networks, penetrating into local villages. In addition, the pesticide regulatory process appears to be far too pro-industry to play an effective role. From 2011 statistics it appears that the three principle neonicotinoid pestides, clothianidin, imidacloprid, and thiamethoxam, are being sold under 13 different brand names and imported by four major chemical manufacturers. No information on the quantities imported, however, is available and an early survey of usage of neonicotinoid pesticides around nature reserves was discontinued. The Worldwide Integrated Assessment on the Impact of Systemic Pesticides on Biodiversity (WIA) initiated by the Task Force on Systemic Pesticides (TFSP) was first launched in Manila in June 2014 to be followed in hours by press conferences in Brussels, Ottawa and Tokyo. In response to the WIA the Governor of the Province of Marinduque in order to protect the island's famous butterfly breeding industry, declared to ban all usage, sale and importation of Neonicotinoid pesticides and Fipronil, an initiative that awaits its implementation.

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Ole **HENDRICKSON** has had a 29-year career with the Government of Canada. He has been a leading figure in the biodiversity science-policy interface at the domestic and international levels. Since retiring Ole has continued his involvement in this area by serving as Editor in Chief of Biodiversity: Journal of Life on Earth, published by Taylor & Francis and Biodiversity Conservancy International. He is also active as a volunteer with a number of non-government environmental organizations.

DR. JOHN HOWARD, MD

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John **HOWARD** is the Chair of the Board of the Canadian Association of Physicians for the Environment (CAPE). He is also a Professor Emeritus of Paediatrics and Medicine in the Schulich Faculty of Medicine and Dentistry at Western University. Dr. Howard is a highly recognised teacher, having received over 25 teaching awards in his career. At Schulich, Dr. Howard was the leader and a founder of the Ecosystem Health team which introduced Ecosystem Health into the undergraduate medical curriculum. Dr. Howard is a recognized speaker on health policy, medical education and institutional change – in particular, as these topics relate to the environment.

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David **KREUTZWEISER** is a Research Scientist & Team Leader in the Forest Ecosystems Research and Assessment Team at the Canadian Forest Service in Sault Ste Marie. He is also an Adjunct Professor in Biology at Laurentian University and at the University of New Brunswick in Saint John, and an Associate Graduate Faculty member at the University of Guelph. He leads a research group that investigates the ecological impacts of forest management and forest pest control activities.

Abstract: Neonicotinoid insecticides (neonics) are widely, often prophylactically, used in agriculture, horticulture, turf grass production, golf courses and other applications. These applications can result in neonic residues in soils from coated seeds, aerial deposit, foliar wash-off, soil leachates, and direct soil applications. Neonic concentrations in soils can be persistent for months to years, especially in moist, organic-rich soils, and these concentrations may pose risk of harm to non-target invertebrates. Neonics can also be exposed to soil-dwelling invertebrates through the consumption of residue-bearing plant material that falls or is returned to soils. Almost all data available to assess risks of neonics in soils to non-target invertebrates have been generated through toxicity tests with earthworms. This is relevant because earthworms, in their natural settings, are known to be important environmental engineers that improve soil quality and texture. Toxicity studies indicate that earthworms are at risk of adverse effects from field-realistic concentrations in soils or plant litter, albeit at the upper end of the range of reported concentrations. Sub-lethal, behavioural effects are likely to occur at lower concentrations than what are expected to cause lethal effects. I review these toxicity data and provide a summary showing that soil invertebrates and their ecological functions are at risk of harmful effects from realistic concentrations. Because of the pervasive and persistent nature of some neonics in soils, these risks may be underestimated. The weight of evidence indicates that risks to soil invertebrates are sufficiently high to warrant caution and adjustment in the use of neonicotinoid insecticides. An increasing reliance on alternative pest control products and on integrated pest management (IPM) principles would reduce risks to soil invertebrates and the ecosystem services they support.

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Faisal **MOOLA** is one of Canada's most respected environmental scientists and advocates. His research in conservation science and environmental policy has been published in numerous academic journals and award-winning books and he is a regular contributor to the opinion pages of Canada's leading newspapers. For the past decade Faisal has led an expert team of scientists, policy experts and community organizers at the David Suzuki Foundation, in support of the protection of Canada's cherished wild spaces and endangered species, as well as the greening of our towns and cities. Faisal has been at the forefront of some of Canada's most iconic environmental battles, including successful efforts to protect B.C.'s Great Bear Rainforest and recent regulations that reduce the use of neonic-treated seeds in corn and soy production in Ontario. He is Director General for the Ontario and Canada's North Department at the David Suzuki Foundation and has adjunct faculty appointments at the University of Toronto and York University in forest conservation and environmental planning.

GRAEME MURPHY

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Graeme **MURPHY** completed his undergraduate degree in Biological Sciences and his Masters in Agricultural Science in Melbourne, Australia and worked for 8 years with the Victorian State Government in Australia, initially as an entomologist with the Department of Agriculture, and for 2 years as a Research Scientist with the Department of Natural Resources. In 1988, he moved to Canada and from then until the end of 2014, he worked as the Greenhouse Floriculture IPM Specialist with the Ontario Ministry of Agriculture and Food. During that time, he worked closely with the industry on pest management issues generally, including new and invasive pests, registration of new pesticides, research into new control strategies and development of educational programs and publications for Ontario growers. He also worked with individual growers in developing crop-specific IPM programs with an emphasis on biological control. He has written widely in grower trade publications in Canada and the

USA and has been an invited speaker at many conferences and grower meetings both locally and internationally. Since his retirement at the end of 2014, Graeme has been working as a consultant with greenhouse growers to help refine their pest management programs, focusing on in-house research projects, developing a better understanding of pest management economics and developing staff training sessions geared to the crops and pests of individual greenhouses.

Abstract: The presentation will provide a background on horticulture in Ontario including information on current IPM practices. Some brief examples will be provided of the use of systemic pesticides (primarily neonicotinoids) in Ontario horticulture, and some of the problems that can arise from their use. Finally, questions will be addressed about the role of systemic pesticides in IPM, issues associated with potential alternatives and new information needed to accommodate alternative pest management solutions.

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Glen **MURRAY** has had a lifetime of activism in urban planning, sustainable development and community health, and is a founding member of the Canadian AIDS Society. Murray served as mayor of Winnipeg from 1998 to 2004. He has also served as a Visiting Fellow at the Faculty of Architecture and Landscape Design at the University of Toronto, was appointed Chair of the National Round Table on the Environment and the Economy in 2005, and was named president and CEO of the Canadian Urban Institute in 2007. Murray was first elected to the Ontario legislature in 2010, and currently serves as Ontario's Minister of the Environment and Climate Change.

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Laurence **PACKER** is a Professor of Biology at York University where he has worked since 1988. He teaches Entomology and Biodiversity courses. His research is on bees. He and his students have published over 140 research papers on various topics including sociobiology, conservation, genetics, phylogenetics, biogeography and taxonomy. His book "Keeping the bees" was published by HarperCollins and "Bees: a close-up look at pollinators around the world" with Sam Droege was published by Voyageur Press. He and his team have described almost 100 new species of bees. The collection that he has started at York University now includes several hundred thousand specimens with examples from well over 100 countries and well over 100 new species awaiting description. He has been a member of the Committee on the Status of Endangered Wildlife in Canada and the Natural Science and Engineering Research Council of Canada's Evaluation Group for Ecology and Evolution (twice). His research has been funded by the latter organization as well as National Geographic, Genome Canada, the Weston Foundation and the Canadian Foundation for Innovation.

Abstract: There are over 20,000 described bee species in the world. I will briefly describe the taxonomic, ecological and behavioural diversity of bees.

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Nigel **RAINE** is the Rebanks Family Chair in Pollinator Conservation at the University of Guelph. His research examines the behaviour, ecology and conservation of pollinators, and has focused recently on the impacts of environmental stressors (such as pesticide exposure) on bumblebees. Nigel has been lucky enough to spend almost two decades investigating bees and their intimate relationships with flowers on three continents. Before coming to Guelph in 2014, he studied at the University of Oxford, worked as a postdoctoral researcher at the University of Sheffield and Queen Mary University of London, and held his first faculty position at Royal Holloway University of London. In addition to excellent and high impact research, Nigel is actively engaged with a wide range of stakeholders (including policy makers, farming & grower's association, grocery chains and beekeepers), on issues related to pollinator health and conservation.

Abstract: Bees are essential pollinators of many crops and wild plants. Whilst pesticides are suggested to be one factor that could be driving bee declines, a key question is to what extent exposure to field-realistic levels of pesticides might have significant (sublethal) impacts on individual behaviour, colony success and ecosystem service provision. To date, the majority of studies of potential pesticide impacts have been conducted on honeybees (with much less information available for other social bees, like bumblebees, or solitary bee species), and most of the recent attention in this field has been focused on neonicotinoid insecticides. Field-realistic levels of neonicotinoid exposure can lead to both acute and chronic effects on overall foraging activity, including changes to floral preferences and reductions in individual pollen collection efficiency. Chronic exposure also has negative impacts on the speed with which workers learn to associate floral cues as predictors of reward and their ability to remember these associations. These sublethal impacts on individual bee behaviour can have knock-on effects for forager recruitment, worker losses and overall colony productivity. The pollination services provided by bees can also be adversely affected following field-realistic exposure to neonicotinoids. This could have widespread implications for the sustainable production of many pollinator limited crops and maintenance of wild plant biodiversity.

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Kumiko **TAIRA** received her medical degree from Kobe University in 1982. Since 2001, she has been involved in studying the effects of environmental exposure of organophosphates and neonicotinoids on human health in collaboration with Dr. Yoshiko Aoyama in Gunma. Together, they have published eleven academic articles. She received the Japanese Society of Environmental Ecology President's awards in 2004 and 2006, an incentive award from the Japanese Society of Environmental Ecology in 2007, and an award for excellence from the Japanese Society for Clinical Toxicology in 2009. Dr. Taira is a part-time lecturer at the Department of Anesthesiology at Tokyo Women's Medical University Medical Center East, a

part-time lecturer at the Department of Environmental Education at Tokyo Kasei University, a board member of the Japanese Society of Clinical Ecology, and the chairman of the Public Health working group of IUCN Task Force on Systemic Pesticides.

Abstract: Neonicotinoid (neonic) pollution in the human body is ubiquitous and increasing in Japan. Eight neonics are now registered in Japan. Flupyradifurone is newly registered. Dinotefuran is the most commonly used neonic, followed by clothianidin, imidacloprid, acetamiprid, and thiamethoxam; while thiacloprid and nitenpyram are also used in small amounts. Last year, a small-scale epidemiological study revealed that 7 neonics were detected in the urine of Japanese women (approximately 300) at nM levels. We speculated that neonics are retained in the human body in spite of their water solubility and that continuous use of neonics may pollute human tissues.

Continuous exposure to neonics, especially acetamiprid and thiamethoxam, may cause typical symptoms, e.g. recent memory loss. In the summer of 2006, we met a large-scale pandemic of patients with typical symptoms. All of them were nonsmokers, original healthy, and became ill after consecutive intake of tea beverages and/or conventional domestic fruits. We started chemical analysis of patients' urine from 2007. We detected some neonicotinoid metabolites in their urine. We then conducted a prevalence case control study prospectively, and analyzed urinary neonics and an acetamiprid metabolite, N-desmethyl-acetamiprid (DMAP), by LC-MS/MS. 35 patients were divided into two groups, typical symptomatic group (TSG) and atypical symptomatic group (ASG) by symptoms. Typical symptoms are named neo-nicotinic symptoms including 6 subjective symptoms, i.e. headache, general fatigue, chest pain or palpitation, stomach ache, muscle pain or weakness or spasm and cough, and 3 objective symptoms, e.g. postural tremor, recent memory loss, and fever. 50 sex- and age-matched volunteers without any symptoms were recruited as non-symptomatic group (NSG). DMAP and thiamethoxam were more detected from TSG group significantly. Odds ratio of neo-nicotinic symptoms for urinary DMAP detection was 14. The details of the patient's symptoms are as follows: In addition to neo-nicotinic symptoms, ECG abnormality, such as sinus tachycardia, sinus bradycardia, supraventricular or ventricular arrhythmia, was consistently found from TSG patients. They also complained of neuropsychiatric symptoms, such as sleepless, depression, aggressiveness, auditory and sensory hallucination, and hypersensitivity. Dermal symptoms, Kaposi varicelliform eruption, or diffused ringworm disease were observed sometimes. Edema with oliguria was also found. (Marfo et al. 2015).

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Charles **VINCENT** completed a B.Sc. in Agriculture at Université Laval (Quebec City, Canada), a M.Sc. and a Ph.D. (1983) in Entomology at McGill University (Montreal, Canada). Since 1983, he worked as an entomologist for the Horticultural Research and Development Center (Agriculture and Agri-Food Canada) at Saint-Jean-sur-Richelieu, Quebec, Canada. In 1984, he has been appointed adjunct professor at the Macdonald Campus of McGill University. He has been appointed as adjunct at Université du Québec à Montréal in 1992, and, since 2000, is invited professor at l'Université de Picardie Jules Verne (Amiens, France). He co-supervised the work of 36 graduate students and 100 interns. He works on alternatives to insecticides, notably knowledge-based methods, including biological (e.g. biopesticides) and physical control methods. To date he published 177 scientific papers, 6 reviews (refereed) and more than 200 technical papers. He edited 24 books or technical bulletins. He did >500 presentations before various national and international audiences.

Abstract: To meet the tenets of sustainable agriculture and the growing demand of green products by consumers, growers need to have sound alternatives to insecticides. To achieve success in agricultural plant protection, a management method must meet several criteria, notably technical efficacy, practical efficacy, commercial viability, sustainability, public benefit, and compliance with laws and regulations. Drawing from my professional experience, I will discuss five cases of development of alternatives to insecticides. These cases are netting for bird control; development of a botanical; development of a viral bioinsecticide; classical biological control of the European Apple Sawfly and management of blueberry maggot with extreme cold temperatures. Lessons learned from these cases will conclude the presentation.

DR. AMRO ZAYED, PHD

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Amro **ZAYED** completed his bachelor's degree in Environmental Science (BSc Hons. 2000) and doctorate in Biology (PhD 2006), both at York University. Dr. Zayed was awarded the Governor General's Gold Medalin 2007 for his doctoral research on bee conservation genetics. He held a Natural Sciences and Engineering Research Council of Canada's Postdoctoral Fellowship at the University of Illinois' Department of Entomology (2006-2008). Dr. Zayed then served as a Fellow for the Institute for Genomic Biology's Genomics of Neural & Behavioral Plasticity Theme at the University of Illinois (2008-2009). Dr. Zayed rejoined York University's Department of Biology in 2009, where he leads a research program on the genetics, genomics and behaviour of social insects using the honey bee as a model organism. Dr. Zayed received the Ontario Government of Research and Innovation's Early Researcher Award in 2010, and the Faculty of Science's Early Career Researcher Award in 2014.

Abstract: We report on a 2-year study investigating the presence of agrochemical in corn-growing regions of Ontario, and their effect on honey bees.

Canadian Association of Physicians for the Environment

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