Honey Bee Loss, Fruitless Fall, and Catastrophe of Flora and Fauna: Will the Butterfly Effect of Green Crime happen?

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Abstract

In 1962 Rachel Carson predicted a ‘silent spring’ and warned of a ‘fruitless fall’. In recent years, beekeepers watch a great many bees mysteriously die, and they continue to disappear. The remaining pollinators, essential to the cultivation for large part of crops, are now trucked across the country and flown around the world, pushing them closer to collapse. Has a ‘pollinator crisis’ really been occurring during recent decades, or are these concerns just another sign of global biodiversity decline? Several researches have highlighted different factors leading to the pollinators’ decline that have been observed around the world.

One can say that there is no single cause of Colony Collapse Disorder (CCD), and recent population declines are likely caused by a combination of factors acting in concert to weaken bee colonies to the point of collapse, and emerging science points specifically to impaired immunity. Lead suspects in this causal complex include: nutritional stress, pathogens and pesticides. Regulations and phase-outs of acutely toxic pesticides have reduced the number of acute poisonings in most of Europe and North America, but bee exposure to multiple pesticides continues. Sub-lethal effects, less studied and understood than acute effects, have become a key concern as systemic neonicotinoid pesticides —present in small amounts throughout plant tissues from seed to harvest— have become an important and rapidly growing segment of the global insecticide market since their introduction in the 1990s. Other pesticides of concern include those used by beekeepers to control pathogens, and certain fungicides thought to be safe for bees which have recently been found to act synergistically with some neonicotinoids.

Human activities and their environmental impacts may be detrimental to some species, with sometimes subtle and counter-intuitive causal linkages. Pollination is not just a free service but one that requires investment and stewardship to protect and sustain it. This research

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suggests that there should be a renewed focus on the study, conservation and even management of native pollinating species. It also shows how different factors and their complex causal linkage lead to the growing catastrophe.

1 Introduction

United Nations Environmental Programme (UNEP), based on current evidence, demonstrates that a sixth major extinction of biological diversity event is underway. Mainly due to habitat loss, pest invasion, pollution, over-harvesting and disease, between one and ten percent of biodiversity in the earth is being lost per decade. It is obvious that certain natural ecosystem services are vital for human societies. Many fruit, nut, vegetable, legume, and seed crops depend on pollination. Pollination services are provided both by wild, free-living organisms (mainly bees, but also many butterflies, moths, flies and so on), and by commercially managed bee species. Bees are the predominant and most economically important group of pollinators in most regions (UNEP: 1; De La Rúa *et al.* 2009; Klein *et al.* 2007).

In 1962 Carson predicted a 'silent spring', and she also warned us of a 'fruitless fall', a time with no pollination and no fruit (Carson 1962). Only after 46 years, in 2008, Jacobsen wrote the book titled 'Fruitless Fall: The collapse of the honey bee and the coming agricultural crisis.' He insist that the fruitless fall nearly become a reality when, in 2007, beekeepers watched thirty billion bees mysteriously die. Although bees are essential to the cultivation of a third of American crops, while a lot of them continue to disappear, the remaining pollinators are now trucked across the country and flown around the world, pushing them ever closer to collapse. He highlights the growing agricultural catastrophe, emphasizes the miracle of flowering plants and their pollination partners, and warns us not to take the abundance of our Earth for granted (Jacobsen 2008: 100–153; Neumann *et al.* 2010; Gallai *et al.* 2009; Porrini *et al.* 2003).

The starting question presented in this article is the following: has a 'pollinator crisis' really been occurring during recent decades, or are these concerns just another sign of global biodiversity decline? Several researches have highlighted different factors leading to the pollinators' decline that have been observed around the world (UNEP: 1; PSSA 2013; Potts *et al.* 2010a; Potts *et al.* 2010b; Aizen *et al.* 2009).

This article considers the latest scientific findings and analyses possible answers to this question. As the bee group is the most important pollinator worldwide, this article also focuses on the instability of wild and managed bee populations, the driving forces, potential mitigating measures and recommendations.

2 Pesticide and Honey Bees: State of the Science

2.1 Public and scientific controversy

Pesticide Action Network North America (PANNA) explains the state of science which analyzes the relation between pesticide and honey bees.

It mentions that honey bees and other pollinators are dying off at unprecedented rates around the world. First in France, then in the U.S. and elsewhere, colonies have been mysteriously collapsing with adult bees abandoning their hives. Two years after this phenomenon hit the U.S., in 2006, it was named 'Colony Collapse Disorder,' or CCD. U.S. beekeepers have reported annual hive losses of 29%–36% each year since that time. Commercial beekeepers tell that their industry, which is the care and cultivation of an indicator species, is on the verge of collapse. Honey bees pollinate 71 of the 100 most common crops that account for 90% of the world' food supply, making managed honey bees the most economically important pollinator (PANNA 2012: 1; Johnson 2007; Ellis *et al.* 2010; Pettis *et al.* 2010; Cane *et al.* 2001).

It is said that, while few contest that the recent, dramatic decline of honey bee populations present serious challenges to an already-stressed food system, the public debate over what lies behind CCD is at this point so polarized and confusing that concerned citizens find it difficult to know how or where to intervene. Indeed, the debate over the causes of CCD has become a case study in public, scientific controversy. This issue has become characterized by policymaker inaction in the face of irreducibly complex science. In this controversy, two increasingly intractable sides have emerged: beekeepers and environmental health advocates vs. pesticide companies and the scientists supported by them. The weight of evidence demonstrates that pesticides are indeed key in explaining honey bee decline, both directly and in tandem with the other two leading factors, pathogens and poor nutrition (PANNA 2012: 1; Mullin *et al.* 2010).

2.2 Colony Collapse Disorder: Understanding pesticides as a causal factor in context

It may be said that there is no single cause of CCD, and recent population declines are likely caused by a combination of factors acting in concert to weaken bee colonies to the point of collapse; and emerging science points specifically to impaired immunity. Lead suspects in this causal complex include: nutritional stress, pathogens and pesticides (PANNA 2012: 2; Maini *et al.* 2010; Dinat *et al.* 2012; Genersch *et al.* 2010; Meeus *et al.* 2011; Le Conte *et al.* 2010; Goulson 2003).

First, we can find a pesticide prevalence in many places on our earth. Multiple surveys in U.S. and Europe have shown that a mixture of pesticide formulations and types are present in bees, wax, stored food and pollen and nectar on which bees forage. Field studies have found neonicotinoid pesticides in particular in soil, dust, planter exhaust, water (guttation) droplets exuded by treated plants and on nearby, untreated plants and fields (PANNA 2012: 2).

Second, the neonicotinoid has acute, sub-lethal and chronic effects. Neonicotinoids are a relatively new, and very widely used class of insecticides that work on the central nervous system of sucking insects such as fleas and aphids. They were introduced in the 1990s and have since become the fastest-growing class of insecticides in the history of synthetic pesticides. Most U.S. regulatory decision-making addressing risks posed to honey bees by neonicotinoids has hinged, by default, on the establishment of acute toxicity exposure scenarios without requiring tests for sub-lethal effects. Despite repeated calls for a reevaluation of pesticide testing protocols, regulatory processes in the U.S. and Europe have not been adapted to consider sub-lethal, chronic or synergistic effects of pesticides on pollinators. Many independent studies in the U.S. and Europe have shown that small amounts of neonicotinoids — both alone and in combination with other pesticides — can cause impaired communication, disorientation, decreased longevity, suppressed immunity and disruption of brood cycles in honey bees (PANNA 2012: 6–8; Decourtye *et al.* 2010).

Third, multiple factors have synergistic + combined effects. Synergism is a phenomenon in which two or more factors produce a combined effect that is greater than the sum of their separate effects. As investigations into the causes of CCD have continued to point toward multiple factors working in concert to increase bees' susceptibility to disease, synergism and combined effects have emerged as a critical area of research. In 2004, a lab study showed that the acute toxicity of two neonicotinoid pesticides on honey bees dramatically increases when combined with either of two common fungicides. Four years after this finding was published, researchers established that these types of combinations are prevalent in bee hives (PANNA 2012: 11).

Fourth, honey bees are like living in the 'chemical cocktail' (fungicides, pyrethroid insecticide, miticides). Neonicotinoids are but one class of pesticides, honey bees are exposed to dozens of different pesticides on a daily basis. Included among these are a mix, or 'chemical cocktail,' of insecticides, herbicides and fungicides as well as the miticides used by beekeepers to control pathogens in the hive (PANNA 2012: 11; Lawrence *et al.* 2013).

Fifth, there are pathogen interactions: nosema + pesticides. Nosema, a family of fungal gut parasites, and the Varroa destructor mite are two relatively recent honey bee pathogens. Both pathogens have been shown to interact with pesticides to weaken colony health more than either does alone. The overall pattern for bees exposed both to systemic pesticides (neonicotinoids and fipronil) and Nosema infection is that bees get sick more easily and die sooner as a result of both stressors in combination than either in isolation (PANNA 2012: 13; Forsgren 2010; Klee *et al.* 2007; Genersch 2010; Bromenshenk *et al.* 2010; Runckel *et al.* 2011; Pettis *et al.* 2012).

Sixth, there is a problem of microbiota out of balance: gut culture, immunity + nutrition. Unintentional disruption of natural, symbiotic bee microbial cultures is one way in which hive health may be critically undermined by pesticides as well as other stressors in the contemporary, commercial beekeeping environment. Honey bee microbiota (including fungi, bacteria, viruses, *etc.*) exists at two levels: within the individual bee 'gut' culture and throughout the hive considered as an extended organism. While very little is understood about the honey bee's complex and diverse microbial community, scientists do know enough to describe a co-evolved, minimally functioning, or 'core', honey bee microbial community as well as hypothesize about key functions susceptible to disruption — specifically nutrition and immunity. The road to sustainable honey bee pollination may eventually require detoxification of agricultural systems and in the short term, integrated management of honey bee microbial systems (PANNA 2012: 15; Evans *et al.* 2011; Forsgren 2010; Cox-Foster *et al.* 2007).

2.3 Research Challenges

In the context of multiple, interacting factors, methodological challenges are expected. Some are endemic to the task of epidemiological research and therefore unavoidable. Others are the result of equipment limitations, poor research design or regulatory framework failures (PANNA 2012: 17).

On the one hand, concerning equipment limitations (equipment + detection sensitivity), until 2003, analytical techniques were not sensitive enough to detect systemic pesticide residues in plant tissue below a level of 20–50 ppb — much higher than the levels now known to be typical. Pollen had also never been analyzed. Detection of pesticides at very low levels is key for our understanding of the actual pesticide load in bee hives, bees and foraging habitat, including soil (PANNA 2012: 17).

On the other hand, designing researches that accurately assess pollinators' exposure to pesticides under field (*i.e.* outdoor) conditions is especially difficult because of the wide variety of factors in the natural environment. Multiple exposure pathways, synergistic and combined effects from multiple chemicals (*i.e.* the 'chemical cocktail' effect), timing, relative levels of existing pathogens, variability of weather and genetic predispositions all run the risk of confounding any experiment designed to measure pesticide exposure and toxicity in the honey bee environment (PANNA 2012: 18; Krupke *et al.* 2012).

First research design is 'laboratory vs. field research'. Researches seeking to determine the effects of pesticides on honey bees typically begin in the lab with a single pesticide and a sample of adult honey bees. Once several studies achieve similar results, the relationship between the tested substance and the organism is informed with an initial understanding of potential effect. Conditions in the lab are highly controlled to eliminate the possibility that observed effects might actually be caused by some other factor than the tested substance (PANNA 2012: 18).

Second research design is regarding to 'multiple exposure pathways: touch contact and oral ingestion'. There are multiple exposure pathways, mainly two kinds of toxicity: one is contact by touch toxicity (dust, soil and planter exhaust/talc), and the other is oral (ingestion) toxicity (pollen, nectar + guttation droplets). Scientists began to exploring the possibility that bees were being poisoned by the dust emitted from pneumatic drilling neonicotinoid-coated seeds around 2003. More recent studies have confirmed that this rout of exposure is indeed lethal, and exacerbated by humidity. The leading hypothesis is that bees flying through contaminated dust are 'powdered' with acutely toxic levels of neonicotinoids as their abdomens collect airborne fragments of treated seed coating (PANNA 2012: 19).

Established oral toxicity levels neonicotinoids for bees are significantly higher than are contact toxicity level. Potential oral exposure routes that have been recently studied include pollen, nectar and guttation droplets. Guttation droplets are a kind of dew exuded by plants during the night and in the early morning; they have been shown to contain lethal levels of neonicotinoid pesticides. Field studies have shown that bees collect and bring back to the hive pollen and nectar contaminated with neonicotinoid pesticides both from directly treated crops, and from nearby untreated plants known to serve as nutrition sources for bees (PANNA 2012: 21).

Third research design is regarding 'time + timing'. Understanding the effects of pesticides and other stressors on hive health is complicated by issues of time: duration, sequencing and developmental stages of a bee can all play a role. Studying the effects of pesticide exposure over too short a time scale is perhaps the most critical blind-spot of most research to date. Recent research into synergistic effects of pesticides and Nosema has surfaced a potential sequencing issue whereby bees exposed first to infection, then to pesticides show signs of poisoning at sub-lethal levels, when pesticide exposure alone at the same levels do not appear to have a toxic effect (PANNA 2012: 22).

2.4 Structural bias of research

Structural bias is also an important problem for research on relations between pesticide and honey bees. Bias appears to be playing a role in our collective understanding of pesticide effects on honey bees. The prominent role of pesticide manufacturers in conducting and funding studies has generated controversy and concern among independent researchers, beekeepers and citizen groups. Conflicts of interest in honey bee research impact research findings, yield citation bias where contradictory studies are excluded from introductory literature reviews, and exert undue influence on pesticide policymaking decisions (PANNA 2012: 23). Researches on honey bee losses must be carried out carefully like 'decoding the complicated puzzle'.

Science funded by agrochemical companies (including Bayer CropScience, the maker of several neonicotinoids including imidacloprid) have; 1) focused CCD research more on parasites and pathogens than on pesticides; 2) published the most favorable among all results on studies of pesticide effects on honey bees (no significant effects or effects at dose levels that do not correlate to environmental levels); and thus 3) potentially influenced policy decisions made to protect bees from pesticides toward less rigorous risk assessments and less cautious regulations (PANNA 2012: 23).

As for the impact of neonicotinoid insecticides on honey bees *etc.*, among studies showing that imidacloprid has negligible sub-lethal or chronic toxicity to honey bees, or that the effects seen are not relevant to amounts found in the bee environment, most were funded or carried out by the manufacturer. Conversely, a longer list of industry-independent research tends toward opposite results: imidacloprid being sub-lethal and chronically toxic at lower amounts, which are indeed relevant to environmental levels (PANNA 2012: 23).

Results were influenced by factors related to the agendas of those who funded and conducted the studies as well as the regulatory reviewers. The regulatory process is found to be deficient in its assessment for a variety of reasons: lack of standard methodology for investigating sub-lethal effects, failure to investigate long-term, seasonal, conditional, or synergistic effects in the face of compelling evidence for doing so, negligence in requiring studies on larvae, lack of validation criteria for reviewing study methodologies and failure to investigate all possible routes of bee exposure (PANNA 2012: 23).

3 Seed-dressing Systemic Insecticides and Honeybees

3.1 Effects of seed-dressing systemic insecticide

European Environment Agency (EEA) mentions that the widespread use of systemic insecticides raises serious concerns about their threat to wild pollinators. Declines in wild pollinators are reported worldwide, which is particularly worrying since they are essential for 35% of global crop output. This has led to growing concern about agriculture's dependence on pollinators and fears of a global pollination crisis (EEA 2013a: 370).

According to EEA research, in 1994 French beekeepers began to report alarming signs. During summer, many honeybees did not return to the hives. Honeybees gathered close together in small groups on the ground or hovered, disoriented, in front of the hive and displayed abnormal foraging behavior. These signs were accompanied by winter losses (EEA 2013b: 26). Many factors influence the state of honeybees and pollinators more generally. Land use practices and agrochemicals are regarded as particularly important. It is said that the risk to honeybees is resulting from the Bayer's seed-dressing systemic insecticide Gaucho, whose active substance is imidacloprid. There were the vehement controversy over the use of Gaucho and the justification that ultimately lead banning its use on sunflower and maize seed-dressing in France (EEA 2013a: 370).

In the face of this situation, scientific findings were used by stakeholders and decision-makers to influence policy during the controversy. Public scientists were in a difficult position in this case. The results of their work were central to a social debate with high economic and political stakes. In certain cases their work was not judged according to its scientific merit but based on whether or not it supported the position of some stakeholders. This situation tested the ability and courage of researchers to withstand pressure and continue working on imidacloprid. Other European countries also suspended neonicotinoid seed-dressing insecticides. Evidence of the toxicity of neonicotinoids present in the dust emitted during sowing of coated seeds supported such decisions. Most important, French case highlighted the major weaknesses of regulatory risk assessment and marketing authorization of pesticides, and particularly neonicotinoids (EEA 2013b: 26; EFSA 2013).

3.2 Lessons on the governance of controversies

From the case study of Gaucho, EEA draws eight lesson about governance of controversies related to chemical risks.

First, governance must focus on identifying potential properties of new chemicals and anticipating surprises that may arise from them. When dealing with new technologies, verify whether the methods already in use for risk assessment are relevant, given the specific new properties and characteristics of new risks. Second, with the adequacy of the present standardized tests regarding the assessment of pesticide risks to honeybees, new tests must be developed to assess sub-lethal effects of pesticides, their chronic effects and their effects on the colony. Third, policymakers need to ensure adequate personnel in number and competence and financial resources to design efficient regulatory procedures for risk governance and thus reinforce their ability to manage risks effectively. Fourth, the independence and competence of the experts on the issue at hand must be assured, as well as complete transparency of the research process. Fifth, the social quality of the scientific information which one communicates in the debate determines the public trustworthiness. The case study showed major deficiencies in the communication of scientific information by Bayer and by certain administrative services of the French State. Sixth, structures responsible for assessing the scientific adequacy of applications for marketing authorization should develop clear and standardized scientific quality criteria to enable existing studies to be evaluated and compared. Seventh, with multi-causality, the potential causal factors have to be prioritized and addressed separately before assessing potential correlation or synergies among them. Eighth, the regulatory background is needed to protect early-warning scientists (EEA 2013a: 389–392).

In short, if there is a lack of one of these eight factors, such a controversy is not justified and cannot lead to correct results.

4 Ecology of Pesticides and Pest Management

4.1 Modern industrialized agriculture and pesticide use

Angelo insists that, although concerns over the ecological impacts of pesticides gave rise to the environmental movement of the late 1960s and 1970s, pesticide use and its effects have been largely ignored by the law and by legal scholars. Dealing with a wide range of questions relating to pests and pesticides, she focuses on agricultural pesticide use as the largest contaminator, and also examines the legacy of past pesticide use and analyzes how recent developments in ecological science can inform the law and increase our understanding of ecology.

According to her analysis, modern industrialized agriculture, which has its concomitant reliance on chemical pesticide inputs, contributes to substantial harms to both the environment and human health. Through both ecological concepts and related management approaches harm to the environment is best understood.

A variety of past legal and policy efforts to address the risks associated pesticide use have fallen short both at the national and international level, at least in part due to their failure to incorporate ecological concepts and tools (Angelo 2013: 1).

She continue to explain that only recently new ecological understandings have highlighted the fact that current environmental laws a wholly inadequate to address ecological impacts of pesticide use. Recent studies demonstrate that the actions taken in the 1970s and early 1980s to ban or restrict certain ecologically harmful pesticides, such as DDT and its relatives, only partially protect wildlife, including threatened and endangered species, or ecological systems from the harm of pesticide use. Moreover, in 2006, a study demonstrates that the impacts from pesticides extend to international economy. A recent study conclude that non-pest insects, which are frequently non-target victims of pesticide use, provide ecological services such as pest control, pollination, and grazing land clean up, amounting to more than $57 billion per year in the US alone. In 2006 the National Research Council Report concludes that populations of pollinators and other insects providing ecological services are in serious decline, due at least in part to pesticide use (Angelo 2013: 2–3).

4.2 Complex nature of pest ecology, natural pest controls, and adverse effects of chemical pesticides

She analyzes and finds the irony of pest controls that the interactions of humans with their natural environment have created a seemingly perpetual cycle of the evolution of pests leading to the evolution of pesticides, resulting in ecological harms leading to the need for evolution of environmental laws. Accompanying with the alteration of ecology by humans, they have facilitated the emergence of new pests and the expansion of existing pest problems. These newly created pest problems create a need for new pest controls, which ultimately result in the need for new environmental regulations to address the risks posed by controls. The irony is that the pest controls that have been developed to pest problems result in new or worsened pest problems, creating a need for new or more aggressive pest controls, which frequently carry with them new, or more insidious, environmental harms (Angelo 2013: 3).

Moreover, she continues that it is important to acknowledge that in addition to the ecological risks associated with pesticide use, pesticides pose significant risks to human health. The World Health Organization estimates that approximately three million humans are poisoned by chemical pesticides each year. Of these poisonings, approximately 220,000 result in death and 735,000 result in chronic illness. When considering the limited pest control abilities of chemical pesticides in light of the undeniable substantial human health and environmental consequences of chemical pesticide use, it is not clear why society would choose to continue to rely so heavily on chemical pesticides. The reasons why farmers continue to use chemical pesticides despite the problems associated with them are complicated: they include the fear of losing one's livelihood, risk aversion, encouragement from the chemical industry, government research and extension service, and flawed agricultural subsidy system that encourages high-intensity, high-yield practices (Angelo 2013: 4).

Finally, she concludes that new ecological understanding of the complex nature of pest ecology, natural pest controls, and adverse effects of chemical pesticides suggest that there may be better ways to manage pests and protect human health and the environment at the same time. Concerns about the long term sustainability of industrial agriculture and the environmental harms associated with it are leading to a reevaluation of our agricultural system, including the way we control pests. The new focus on eco-agriculture can provide a roadmap for shifting away from a predominantly industrialized agriculture system toward a more sustainable system. The related concept of ecologically based pest management can provide the tools needed to reduce our dependence on chemical pesticides, thereby reducing the harms associated with them. However, despite the scientific basis for such a shift, our current environmental laws and agricultural policies are geared toward maintaining the status quo. Changes our laws and policies will be necessary to move away from a chemical input-dependent agricultural system to an ecologically based one (Angelo 2013: 4).

5 Causal Complexity of the System

5.1 Causal complexity, multiple effects, and thresholds

One must acknowledge complexity when dealing with multiple effects and thresholds. The causal links between stressors and harm are more complex than was previously thought and this has practical consequences for minimizing harm. Much of the harm is caused by several co-causal factors acting either independently or together. For example, bee colony collapse can be linked to viruses, climate changes and neonicotinoid pesticides (EEA 2013a: 674; NHBH-SCSC 2012; Conte *et al.* 2008; Williams *et al.* 2010; Brown *et al.* 2009; Tscharntke *et al.* 2005; Bacandritsos *et al.* 2010).

In some cases, it is the timing of exposure to a stressor that causes the harm, not necessarily the amount; the harm may also be caused or exacerbated by other stressors acting in a particular timed sequence. In other cases, low exposure can be more harmful than high exposure; and in others, the harmful effects of mixtures can be greater than from each separate stressor. There are also varying susceptibilities to the same stressors in different people, species and ecosystems, depending on pre-existing stress levels, genetics and epigenetics. This variation can lead to differences in thresholds or tipping point exposures, above which harm becomes apparent in some exposed groups or ecosystems but not others. Indeed there are some harmful effects that occur only at the level of the system, such as bee colony, which cannot be predicted from analyzing a single part of the system, such as an individual bee (EEA 2013a: 674).

The increased knowledge of complex biological and ecological systems has also revealed that certain harmful substances can move around the world via a range of biogeochemical and physical processes and then accumulate in organisms and ecosystems many thousands of kilometers away. The practical implications of these observations are threefold. First, it is very difficult to establish very strong evidence that a single substance or stressor 'causes' harm to justify timely actions to avoid harm; in many cases only reasonable evidence of co-causality will be available. Second, a lack of consistency between research results is not a strong reason for dismissing possible causal links; inconsistency is to be expected from complexity. Third, while reducing harmful exposure to one co-causal factor may not necessarily lead to a large reduction in the overall harm caused by many other factors, in some cases the removal of just one link in the chain of multi-causality could reduce much harm (EEA 2013a: 674; Thomson 2004; Vandame *et al.* 2010).

From above mentioned consideration, one can insist that a more holistic and multi-disciplinary systems science is needed to analyze and manage the causal complexity of the systems in which we live and to address long-term implications. For example, there would be substantial benefits from exploring, much earlier and more systematically, the multiple effects on people and ecosystems of chemical and other stressors, their cumulative effects, chemical metabolites, and their mixture effects. Exposures to low doses or contaminants and their effects, particularly in susceptible sub groups in populations, should also be more fully investigated, accompanied by more biological monitoring that would improve the detection of the precursors of disease (EEA 2013a: 674; Khoury *et al.* 2011; Johnson *et al.* 2010; Moritz *et al.* 2010; Williams *et al.* 2009).

5.2 Rethink and enrich environment and health research

EEA mentions that greater awareness of the complexity, interconnectedness, multi-causality and uncertainties inherent in global environmental issues underlines the need for greater humility about what science can and cannot tell us. Framing issues as purely scientific and technical inappropriately places scientific perspectives about equally valid social and ethical contributions that should be part of decision-making. A shift is needed to more explicitly integrative environmental science approaches in support of public policy, in which systemic considerations and early warnings feature strongly. This shift has started to take place in discourses but often not in practices (EEA 2013a: 676).

Therefore, we need environmental science to become more attuned to the inherent complexities of socio-ecological systems by, for example, balancing a traditional disciplinary focus with more holistic cross-disciplinary scientific research, thereby complementing precision with relevance and comprehensiveness. Such science would often embrace longer timescales, more end-points, and multi-causality (EEA 2013a: 676).

In addition, we must improve the quality and value of risk assessments. EEA mentions that it is often inappropriate to use a narrow conception of ‘risk’ to manage the complex issues with their inevitable features of ignorance, indeterminacy and contingency. The increasing awareness of the complexity of biological, ecological and technological systems, calls into question the relevance and prevalence of some of the simplistic methods, models and assumptions used in risk assessments. For example, assuming uni-causality is too simplistic when multi-causality is the reality, as in many ecosystems; testing for single substances is inadequate when mixtures are present as in all cases of chemical exposures (EEA 2013a: 676–677; Blacquière *et al.* 2012).

EEA instruct us how the risk assessment should be as follows. Risk assessments could be, in practice, improved by including a wider range of stakeholders when framing the scientific risk agenda, through ensuring all available evidence is readily accessible, by broadening the scope and membership of risk evaluation committees, by increasing transparency and consistency of committee approaches and methods, and by ensuring their independence of vested interests. The case studies on bees, lead and nuclear accident risks have shown that the scope and membership of some risk assessment committees have been too narrow, and they have sometimes been dominated by one discipline or paradigm with shared assumptions which are not therefore questioned. Risk assessments can be made more reliable if they embrace all relevant scientific knowledge and approaches (EEA 2013a: 677).

In short, EEA concludes that the value of being transparent about what is known and not known and about uncertainties and disagreements is equally pertinent. Scientific conclusions should not be portrayed as if there is consensus when there is not. Science by its nature progresses by building on critical appraisal. Several cases show that disagreement can be helpful to decision-makers with a broader picture of the alternative directions and options available before making a decision (EEA 2013a: 677–678).

6 Concluding Remarks

Based on these deliberations, one can remark that currently available global data and knowledge on the decline of pollinators are not sufficiently conclusive to demonstrate that there is a worldwide pollinator and related crop production crisis (Cameron *et al.* 2011; Ghazoul 2005). However, one may say that human activities and their environmental impacts may be detrimental to some species but beneficial to others, with sometimes subtle and counter-intuitive causal linkages (Winfree *et al.* 2009). Pollination is not just a free service but one that requires investment and stewardship to protect and sustain it. There should be a renewed focus on the study, conservation and even management of native pollinating species in order to complement the managed colony tradition (UNEP 2010: 12; Decourtye *et al.* 2010b; Kremen *et al.* 2002; Chauzat *et al.* 2009).

This article focuses on the social consequences of diversity of eco-toxicological effects. A diverse eco-toxicological portfolio allows each stakeholder to identify their own 'scientific arguments' and use them for defending opposite positions in the debate. Declining honeybee colonies have been reported in several countries and have sometimes been related to seed-dressing insecticides. The European Parliament, which has officially acknowledged the issue since December 2001, states that extremely serious damage has been caused to bee populations in several member states by systemic insecticides with extremely long residual activity periods used in arable seed coatings, which have led to the mass poisoning of colonies (EEA 2013a: 392).

The role of honeybee as a bio-indicator for the state of the environment was highlighted during the debate in France. A study found that honeybees tend to respond faster than other insects to environmental pollution. The size of the major detoxifying gene families is smaller in the honeybee, which makes it unusually sensitive to certain pesticides. It must be underlined that honeybee losses can be interpreted as an 'alarm bell' of harm to other entomo-fauna and indirectly to plants, birds and other species. In this context, social concerns are essential to establishing a relevant research agenda. As pollinators, honeybees have an ecologic impact on the survival of plants in the wild. But they have important impacts on people, most notably the economic value of free pollination of many fruits and vegetables (EEA 2013a: 393).

As a final result, one can conclude that human activities and their environmental impacts may be detrimental to some species, with sometimes subtle and counter-intuitive causal linkages. Pollination is not just a free service but one that requires investment and stewardship to protect and sustain it. Different factors and their complex causal linkage may lead to the growing catastrophe. There should be a renewed focus on the research, conservation and even management of pollinating species.

[Notes]

1. This article is based on the paper titled "Butterfly Effects' triggered by Green Crimes? Honey Bee Loss, Fruitless Fall, and Catastrophe of Living Things," and presented at the 14th Annual Conference of the European Socity of Criminology, Prague, Czech Republic, 10–13 September, 2014.

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