Food and Agriculture Organization of the United Nations

PESTICIDES AND ENVIRONMENTAL INCIDENTS

ROTTERDAM CONVENTION ON THE PRIOR INFORMED CONSENT PROCEDURE FOR CERTAIN HAZARDOUS CHEMICALS AND PESTICIDES IN INTERNATIONAL TRADE

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ABBREVIATIONS

ANLA (Colombia)
Autoridad Nacional de Licencias Ambientales

CILSS
Permanent Interstate Committee for Drought Control in the Sahel

DDT
Dichlordiphenyltrichlorethan

EBI (fungicide)
Ergosterol biosynthesis-inhibiting

EFSA
European Food Safety Authority

EPA (United States of America)
Environmental Protection Agency

FAO
Food and Agriculture Organization of the United Nations

FERA (United Kingdom of Great Britain and Northern Ireland)
Food and Environment Research Agency

GEF
Global Environment Facility

HSE (United Kingdom of Great Britain and Northern Ireland)
Health and Safety Executive

IAP
InterAcademy Partnership

ICA (Colombia)
Instituto Colombiano Agropecuario

INRAE
L'Institut National de Recherche pour L'Agriculture, L'Alimentation et L'Environment

MTR
Maximum Tolerable Risk

NRA (Australia)
National Registration Authority for Agricultural and Veterinary Chemicals

OECD
Economic Co-operation and Development

ONCFS
Office National de la Chasse et de la Faune Sauvage

RTL
Regulatory Threshold Level

SAGIR (France)
Surveillance Sanitaire National du Gibier

SHPF
Severely Hazardous Pesticide Formulation

TFSP
Task Force on Systemic Pesticides

UNEP
United Nations Environment Program

WHO
World Health Organization

WIIS (United Kingdom of Great Britain and Northern Ireland)
Wildlife Incident Investigation Scheme

FOREWORD

Pesticides are an important but potentially dangerous/harmful group of chemicals that are dispersed in huge quantities into the environment and that therefore need careful management. Such management is the objective of the International Code of Conduct on Pesticide Management (FAO/WHO 2014), a voluntary framework endorsed by the FAO Members and supported by key pesticide industry associations and civil society organizations. The Code of Conduct provides guidance for designing laws, policies, and technical approaches that promote sound management of pesticides, and it identifies the responsibilities of the various stakeholders, most notably FAO Members and the pesticide industry. A framework for sound management of pesticides is therefore in place.

Nevertheless, incidents involving pesticide use with negative repercussions on human health and the environment regularly occur. While poisoning incidents involving humans are more frequently reported, data related to environmental incidents are comparatively scarce.

This report provides a brief overview of the situation and it highlights, based on wide-ranging examples, some of the main challenges related to the detection, monitoring, and reporting of environmental incidents and the determination of their causes.

The report also identifies actions that can be taken to address these challenges and types of technical support that can be provided by the Rotterdam Convention and others.

Parties to the Rotterdam Convention are encouraged to use this document as an entry point to exchange information with other parties and to engage with the Convention Secretariat for discussion of their specific needs for prevention of environmental incidents with pesticides.

Dr. Christine Fuell
Senior Technical Officer
Coordinator FAO part of the
Rotterdam Convention Secretariat

1 INTRODUCTION

This document presents the insights derived from a desk review carried out by the Secretariat of the Rotterdam Convention, which investigated the worldwide occurrence of "environmental incidents" resulting from the use of pesticides. The review focused on incidents involving the poisoning of birds, fish and honey bees, as described in approximately 80 published studies in English as well as a small number of reports from other sources. This document:

- describes the nature and extent of environmental incidents and the limitations to our knowledge of them;
- lists the pesticides frequently identified in poisoning incidents described in the studies reviewed;
- discusses key factors that explain the extent of such incidents and other issues highlighted by the study authors;
- identifies guidance that has been developed to assist governments in monitoring and reporting environmental incidents and describes examples of systems used in different countries;
- identifies ways the Rotterdam Convention Secretariat can support governments to better address environment incidents.

Information about the Rotterdam Convention and how it addresses environmental incidents is contained in Annex A.

1.1 Purpose

The purpose of this document is to raise awareness among Parties to the Rotterdam Convention of the frequency of pesticide-related environmental incidents and to support their efforts to monitor and report them.

Although the studies included in the desk review described a vast number of environmental incidents, this document describes only a few of the incidents, as examples. The examples were chosen from publications based on long-running incident schemes, but also from scientific publications and newspaper articles reporting single incidents, and from personal communication with experts, to illustrate the type of incidents that can occur, and measures taken by governments to reduce the risks of pesticides to the living environment. Readers who wish to learn more about the studies reviewed, and notably about how pesticides act in the bodies of different organisms, are referred to the references listed in the Bibliography.

It is hoped that this document will encourage the Rotterdam Convention Parties to establish national pesticide incident monitoring and reporting systems, to share information with one another and with the Convention Secretariat about environmental incidents, and to strengthen their regulatory and farmer advisory systems to potentially prevent the occurrence of such incidents in the future.

2 ENVIRONMENTAL INCIDENTS

Definition of an environmental incident

As defined under the Rotterdam Convention and other FAO guidelines, an environmental incident is:

- the contamination of land, water and/or air which has caused the temporary or permanent impairment or mortality of non-target organisms or biological processes (UNEP/FAO/RC, 2020)
- an incident in which pesticide use has caused adverse field effects to fish, wildlife, aquatic invertebrates, bees, or non-target plants (FAO/WHO, 2009)

2.1 Pesticide poisoning of birds

Birds are important sentinels of ecological health in every environment.
Mineau and Tucker 2002

Bird poisonings were among the first incidents recorded in the course of our earliest attempts to control pests on a broad scale with chemicals. The earliest incident identified in this desk review occurred in the mid-1920s, when the application of calcium arsenate dust to German forests resulted in extensive mortality of woodlarks (Lullula arborea) and whitethroats (Sylvia communis) (Brown, 1978). The use of chemical insecticides greatly increased following the introduction of the organochlorine insecticides in the mid-1940s and 1950s. The broadscale use of these chemicals without consideration of their impacts on non-target organisms resulted long-term environmental contamination. Most visible was the impact on birds, whose populations were decimated.

In the early 1960s, Rachel Carson's internationally best-selling book Silent Spring (Carson, 1962), evoking a future without

Flying songbirds (Starlings, *Sturnus vulgaris*)

birds, denounced the indiscriminate use of pesticides that killed not only the target pests but also birds, fish and beneficial insects, and that sickened humans. Carson was not the first scientist to express alarm about pesticides' environmental impact, but Silent Spring was the warning that was widely heard: it spoke to and galvanized the general public, igniting a global environmental movement that transformed countries' pesticide policies.

In 1969, a comprehensive review of pesticides and their relationship to environmental health also expressed concern about the worldwide effects of insecticides, as seen by their impacts on birds. The review was undertaken at the request of the U.S. Secretary of Health, Education and Welfare, by a commission that involved approximately 100 experts and a review of some 5000 scientific studies. The commission's report (Mrak, 1969) referred to the eggshell thinning caused by DDT and the extensive contamination and kills of seed-eating birds and their predators by the highly toxic cyclodiene insecticides, such as aldrin and dieldrin. The report warned of the need to "abate widespread contamination of the environment" by such pesticides and to "take anticipatory regulatory action to prevent future problems caused by other pesticides."

Governments in many countries responded during the 1970s to the 1990s by restricting or prohibiting agricultural uses of organochlorine insecticides.
These actions contributed to the survival of raptor and other bird populations, but the next generation of insecticides, the highly acutely toxic cholinesterase-inhibiting organophosphorus and carbamate insecticides, also proved problematic. The lethal impacts on birds were immediately apparent. Numerous monitoring reports and studies describe the poisoning of birds caused by use of these insecticides (Elliott *et al.*, 1996; Elliott *et al.*, 1997; Goldstein *et al.*,1999; Pain *et al.*, 2004; Fleischli *et al.*, 2004, 2004; Mineau, Odino and Ogado, 2008; Lyon and Mcmillin, 2012). Examples from North America are illustrative.

In the United States of America, where the organophosphates and carbamates were extensively used on farmland, they were estimated to cause on the order of 70 million bird deaths per year during the 1980s-1990s (American Bird Conservancy, 2020 and Pimentel, 2001, cited in Mineau and Tucker, 2002). A review of the U.S. Geological Survey National Wildlife Health Center mortality database from 1980 to 2000, to identify cases of poisoning caused by organophosphorus and carbamate pesticides, found that of 24 pesticides identified in the carcasses, the most frequent were carbofuran, diazinon, famphur, and fenthion (Fleischli *et al.*, 2004). Cancellation of registration of more than a dozen organophosphates and carbamates in the United States of America, including carbofuran, chlorfenapyr, ethyl parathion, and fenthion, and restrictions on the use of others, reduced bird deaths from pesticide poisoning dramatically, to perhaps fewer than 15 million per year by 2012, according to the advocacy group American Bird Conservancy (2020).
Another example is provided from the Lower Fraser Valley region of southwest British Columbia, where the deaths of thousands of waterfowl and other birds from carbofuran and other anticholinesterase inhibitors were documented during the 1970s and 1980s. Impacts on raptors began to be monitored in the 1990s, when bald eagles were found dead or debilitated on agricultural lands, with symptoms of poisoning by anti-cholinesterase insecticides.

As outlined in articles by experts from the Canadian wildlife service (Elliott *et al.*, 1996; Elliott *et al.*, 1997; Elliott *et al.*, 2008; Elliott, Wilson and Vernon, 2011), carbofuran was withdrawn from the local market in 1979 after killing large numbers of waterfowl. It was reintroduced in 1986 (without consultation with the wildlife service),

was again implicated in the poisoning of raptors, and was again withdrawn from the market. Other organophosphate insecticides tried as replacements – phorate, fonofos, and granular formulations of fensulfothian and diazinon – were subsequently withdrawn from the market for the same reason. The wildlife service carried out an experiment to investigate the persistence of a select group of granular organophosphorus and carbamate insecticides, by placing granules in small permeable bags that were planted along with the crop (seed potatoes). Later retrieval of the bags showed that phorate, fonofos and carbofuran planted in the spring persisted in soils well into the autumn, and that the granules remained sufficiently active through the winter to poison ducks ingesting relatively small amounts.

Unlike the organochlorine insecticides, the organophosphate and carbamate insecticides have not largely disappeared from agriculture. Although some countries have restricted or cancelled their use because of the impact on human health, birds and other organisms, many other countries worldwide continue to allow the use of both classes of insecticides. (UNEP/CMS/COP11/Inf.34, 2014).

Cape spurfowl (*Pternistis capensis*) in South Africa

Beginning in the 1990s, the insecticide market has shifted to the neonicotinoids, now the most widely used insecticides in the world. The impact on bees has been a principal concern, but the neonicotinoids have also been identified in bird kills.

Imidacloprid, the first neonicotinoid commercialized, was identified as potentially risky when used as seed treatment. It was found that consumption of just a few dressed seeds could be lethal to seed-eating birds. The risk was confirmed by incidents in France and South Africa. In France, a review of 103 mortality incidents reported by the French SAGIR Network from 1995 to 2014 concluded that bird kills due to the consumption of imidacloprid treated seeds occur regularly in the field (Millot *et al*., 2017). Imidacloprid was also confirmed to be the cause of poisoning incidents involving Cape spurfowl (Pternistis capensis) in South Africa, prompting suggestions that regulatory authorities re-evaluate the risk posed by imidacloprid treated seeds to granivorous birds, as the risk mitigation measures of covering seeds with a soil layer and avoiding spilling were not always effective (Botha *et al*., 2018).

Anti-coagulants used to control rodents have also been identified in bird kills. Investigators found that bird poisoning by anti-coagulants greatly increased in the late 1990s and early 2000s, coinciding with the increased use of a new generation of single dose products (including difenacoum, brodifacoum, bromadiolone, flocoumafen, and difethialone) that are much more toxic than earlier anti-coagulants and much more likely to lead to secondary poisoning in non-target species (Berny *et al*., 1997; Berny *et al*., 1998). In France, the imposition of regulations and changed practices of rodent control to restrict the quantity of poisoned bait used by farmers significantly reduced the number of wildlife poisoning cases reported by the French surveillance network SAGIR.

In Spain, granivorous birds have shown the highest prevalence of anticoagulant rodenticide exposure, especially to chlorophacinone, as revealed by poisonings in a region treated against a vole population peak in 2007. Nocturnal raptors and carnivorous mammals have been found to be the main "secondary consumers," especially of the second-generation anticoagulants. The history of wildlife kills led researchers to recommend that the use of accumulative second-generation anticoagulant rodenticides (SGARs) and the application of baits on surfaces (i.e. treated grain applied by spreader machines) be discontinued in future European regulations (Sanchez-Barbudo, Camarero and Mateo, 2012).

A common buzzard next to an agricultural field searching for prey

Most bird poisoning reports involve insecticides or rodenticides, but the herbicide paraquat has also been identified in poisonings of various wild and domestic animals and of wild geese and farmland birds. A comprehensive review by the Institute of Environmental Sciences of Leiden University (commissioned by Syngenta) revealed around 185 paraquat-related incidents between 1985 and 2002 involving mainly hares but also birds, based on information from the incident monitoring schemes of France, Germany, The Netherlands, the United Kingdom of Great Britain and Northern Ireland, and the United States of America (Van Oers *et al.*, 2005).

The urgent need to stop the poisoning of migratory birds is underscored in a recent Resolution adopted by the Conference of the Parties to the Convention on Migratory Species (CMS). The Resolution, adopted at the 13th meeting of the Convention Parties in 2020, notes that "very large numbers of migratory birds are killed annually as a result of poisoning," that this "can

severely affect the conservation status of vulnerable species, including many listed under CMS and its associated instruments," and that "for some species poisoning is the primary cause of their unfavourable conservation status." The Resolution identifies agricultural pesticides as a cause, along with poison bait, veterinary pharmaceutical treatments, lead used for hunting and fishing, and "the synergistic effects of different poisons through ingestion from various food sources such as prey species." The Resolution explicitly notes the objectives of the Rotterdam Convention, "which promotes the environmentally sound use of hazardous chemicals and shared responsibility to protect the environment from harm" (UNEP/CMS/Resolution11.15).

Excerpts from the CMS Resolution on Preventing poisoning of migratory birds

The Resolution:

- Encourages CMS Parties to monitor and evaluate the impact of poisoning on migratory species regularly at national level, as well as the effectiveness of measures put in place to prevent, minimize, reduce, or control poisoning impacts, …

- Calls on Parties and non-Parties … to elaborate strategies to address poisoning, …

- Invites the Rotterdam Convention … to cooperate actively with CMS on matters related to poisoning of migratory birds, …

- Encourages all those concerned with preventing poisoning of migratory birds to engage with [other] groups and create active partnerships….

Annex C. Table C.1 lists pesticides most frequently identified in bird poisoning incidents in the studies included in the current review. The table also gives the location of the poisoning incidents, the organisms affected, and references to the sources that describe them.

2.1.1 Key factors in bird poisoning

The following key factors in pesticide-related bird poisoning incidents were highlighted in the studies reviewed:

- The most common route of exposure is by ingestion of poisoned insects, treated seeds or granules, or carcasses of poisoned prey.
- The principal measures that are intended to achieve acceptable or negligible risks to birds – such as burying and avoiding spillage of treated seeds – have often in practice proved ineffective. Although treated cereal seeds may be partially avoided in the wild, the risk to granivorous birds is still high (Stanley and Bunyan, 1979; Greig-Smith, 1987; Fletcher *et al.*, 1995, cited in McKay *et al.*, 2001).
- Experience has revealed species variation in sensitivity to the organophosphorus and carbamate pesticides: Stanley and Bunyan (1979) cite the example of Anser geese, which are particularly susceptible to carbophenothion poisoning. This presents difficulties for registration authorities, as pre-registration testing cannot predict such variation, and argues for critical surveillance of wildlife impacts during the early years of commercial use of a new chemical (Stanley and Bunyan, 1979).
- Diagnosis of poisoning by cholinesterase-inhibiting insecticides (e.g. organophosphates and carbamates) can be difficult, as the quantity of pesticide found in poisoned birds is often poorly correlated with measured levels of cholinesterase depression. Carbamate poisonings in particular are often hard to diagnose (Mineau and Tucker, 2002).
- The cholinesterase inhibition caused by organophosphate and carbamate insecticides can cause not only lethal but also sub-lethal effects, such as blurred vision, motor impairment, poor condition resulting from a reduced ability to feed, disruption in normal circadian patterns and thermoregulation. The sub-lethal effects can lead to injury or death, for example, through collision with motor vehicles or inability to migrate successfully (Mineau and Tucker, 2002).
- Sub-lethal secondary poisoning by anti-coagulants used for rodent control has also been shown to make birds more susceptible to predation or to collision with objects. The latter is often the case with injured raptors brought to rehabilitation centers (Mineau and Tucker, 2002).

2.2 Pesticide poisoning of fish

Great attention gets paid to rainforests because of the diversity of life there. Diversity in the oceans is even greater.

Sylvia Earle
Oceanographer

The extent of pesticide impacts on aquatic life worldwide is poorly understood even today. This is not only because fish kills are known to be exceptionally under-reported, but also because pesticide concentrations in water bodies – which are compared to regulatory thresholds or aquatic organisms' toxic endpoints as a way to estimate pesticide exposures and effects – are largely unmonitored.

In the largest global review of insecticide surface water concentrations to date, Stehle and Schulz (2015) found that there is lack of monitoring data for approximately 90% of high-intensity agricultural areas in the world (**Figure 1**). Moreover, the authors point out that even regular monitoring can fail to detect residues that were present in the (recent) past, as pesticides are generally applied only once or a few times per growing season and often dissipate rapidly from the water column because of water flow, metabolism, degradation, and adsorption to sediment and organic matter in the water. Unless monitoring is done soon after the pesticide treatment, no residues might be found in the water, but the pesticide might still be in the system, either bound to organic matter floating in the water or to the sediment which fish might feed on. An earlier study (Stehle, Knabel and Schulz, 2013) cites an estimate that water monitoring based on fixed intervals, even though technically well conducted, would still miss nearly 100% of insecticide exposure events. Pesticides can be highly toxic to aquatic life, so even short-term exposure peaks can lead to important adverse effects.

Consistent with this analysis, the global review (Stehle and Schultz, 2015) found few cases where insecticide residues were detected: (i.e., no measurable residues were found in 97.4 percent of the water samples analyzed). However, more than 50 percent of the cases with measured residues (n = 11,300) exceeded regu-

latory threshold levels (Figure 1). This led the authors to conclude that surface water pollution by agricultural pesticides is threatening aquatic biodiversity at the global scale, and that a revision of current regulatory procedures and pesticide application practices in high-intensity agriculture is needed.

Confirming the need for action, an FAO project funded by the Global Environment Facility in the Senegal and Niger River basins found that levels of pesticides far above the respective Dutch maximum tolerable risk (MTR) levels enter villages in Northern Senegal through irrigation channels and drains and are very likely to cause ecological damage in the waters near the villages (GEF, 2016). The study was extended across six western African countries (Mali, Mauretania, Guinea, Niger, Benin and Senegal), resulting in 63 sampling sites where pesticide residues continued to be detected, most frequently 4,4-DDT and the pyrethroid permethrin used for mosquito and household pest control. Chlorpyriphos and the metabolites of lindane were also found at many sites, and the fungicide chlorothalonil was found at some sites (Anderson *et al.*, 2014).

Other recent global reviews, focusing on the neonicotinoids (Morrissey *et al.*, 2015; Sánchez-Bayo, Goka and Hayasaka, 2016) and pyrethroids (Tang *et al.*, 2018), revealed that insecticides from these groups were widely found in surface waters across all global regions. Average concentrations of neonicotinoids exceeded ecological thresholds in 74% of cases. Sánchez-Bayo, Goka and Hayasaka (2016) found that neonicotinoid concentrations in surface waters have increased over the last 15 years.

Reports of fish kills in areas where pesticides are used confirm the presence of residues in water sources and the impact on aquatic life.

In one example, a study focusing on the frequent fish kills occurring along the southeastern coast of Costa Rica, where pesticide application is intense for export plantains, bananas and pineapple, detected various pesticides but was unable to single out any individual chemical as the principal cause of the poisoning (a common difficulty

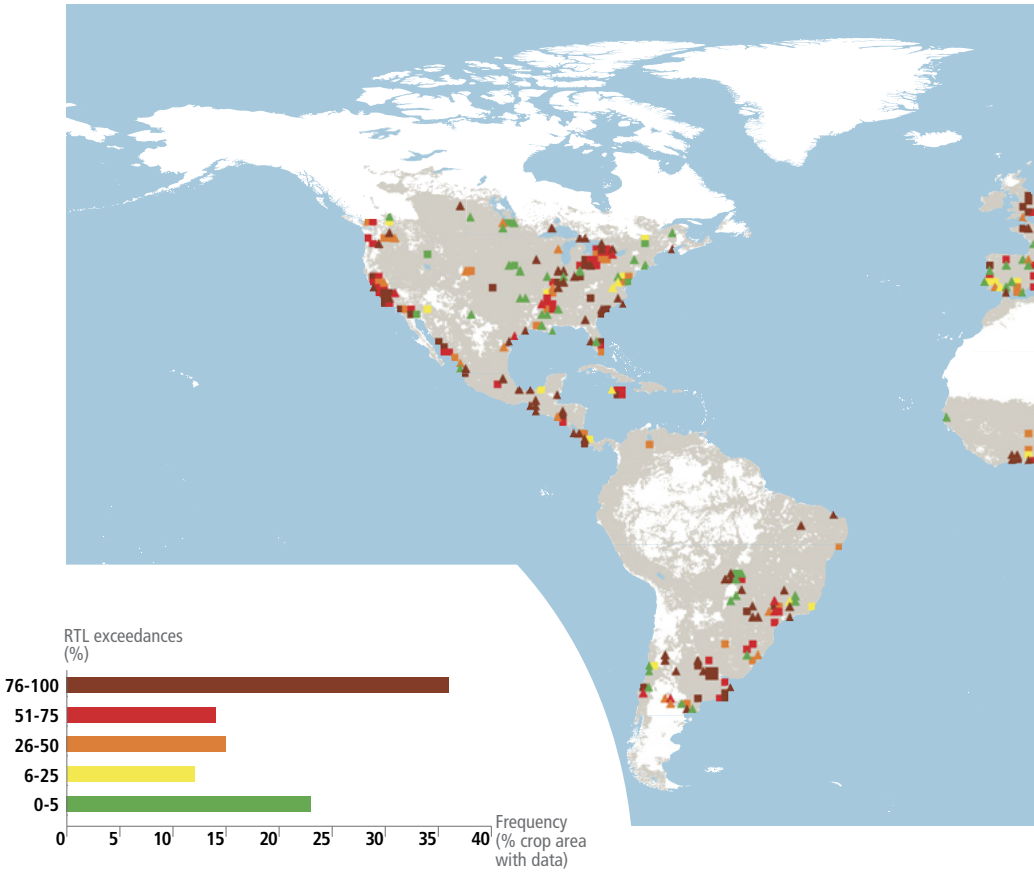
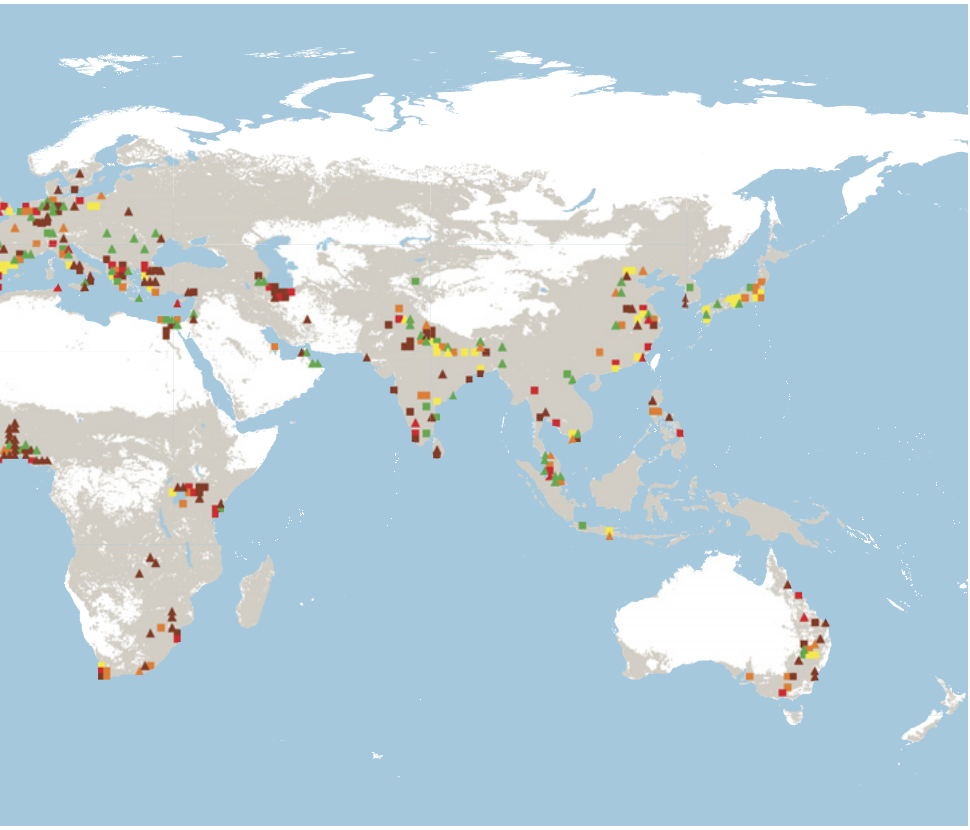


Figure 1

Global crop area and the distribution of regulatory threshold level (RTL) exceedance rates for reported measured insecticide concentrations (MICs) (Stehle and Schulz, 2015)

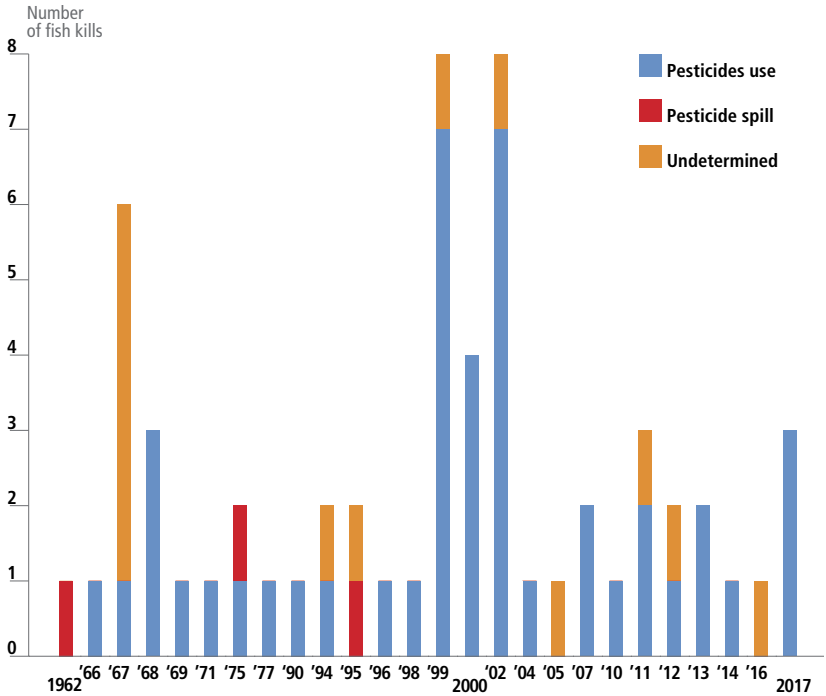


in the analysis of fish poisoning incidents, which contributes to their being far less reported than bird and bee incidents). None of the residues of the three most prevalent pesticides detected – chlorpyriphos, terbufos and difenoconazole – exceeded the lowest published acute or chronic toxicity value of any species examined, so it was concluded that the kills were due to both the pesticide mixture and the stressful environmental conditions, including high temperatures (which can make fish more sensitive to toxins), low dissolved oxygen concentrations, and low stream flow velocity (Polidoro and Morra, 2016). Another fish kill in Costa Rica, reported in an online newspaper, was determined to have been caused by ethoprophos used in pineapple production (Villabos, 2015).

On Prince Edward Island in Canada, where fish kills often occur, 44 of the

60 fish poisoning events recorded between 1962 and 2017 were attributed to pesticides being washed into the streams (see Figure 2). Azinphos-methyl (listed under Annex III of the Rotterdam Convention) was identified as the cause of poisoning in two agricultural runoff events that killed thousands of fish on the Wilmot River (in west-central Prince Edward Island) in 2002. Pesticide runoff was also suspected as the cause of a shift in the fish population from native brook trout to rainbow trout, an exotic species in the region, and a decrease in the population of young-of-the-year trout of both species. The researchers noted that the possibility of pesticide runoff events selecting for exotic species, to the detriment of local species, should be considered in the management of agriculturally impacted rivers (Gormley 2003, Gormley, Teather and Guignion, 2005). In later years, from 2002 onwards, the fungicide chlorothalonil was considered the main cause of the fish kills linked to pesticide use (P.E.I. 2021).

Figure 2 **Fish kills by year at Prince Edward Island in Canada, based on data from P.E.I. 2021**



School of fish swimming next to a see turtle in Cape Verde

Major fish kills have also been recorded in U.S. and European lakes following aerial spraying of pyrethroids for mosquito control. In one incident in 2005, for example, 100,000 to 300,000 black crappie fish were found dead in Clear Lake in Waseca County, Minnesota, two days after permethrin spraying (Beyond Pesticides, 2012b). Similar waves of fish deaths following mosquito-control campaigns with deltamethrin have occurred in recent decades in Lake Balaton, in Hungary (Csillik *et al*., 2000).

Annex D, Table D.1 lists some of the pesticides positively identified in fish poisoning incidents (a more complete table would be difficult to create because of the scarcity of information on fish kills). The table also gives the location of the poisoning incidents, the organisms affected, and references to the sources that describe them.

2.2.1 Key factors in fish poisoning and pesticide contamination of aquatic systems

The following key factors in fish poisoning and water contamination were

highlighted in the studies considered in this review:

- Pesticides can enter aquatic systems though spray drift, run-off and drainage from treated croplands and orchards, rinsing of pesticide containers, or accidental spillage (Rios del Planeta, 2017). Flash run-off from treated areas after heavy rains can cause massive fish kills from pesticide poisoning (Mutch *et al.* 2002, Gormley 2003). Drainage, spillage (Bille *et al.*, 2017) or intentional release of pesticides from industrial areas or factories can also be a significant source of water pollution, as can insecticide spraying campaigns for mosquito control (Csillik *et al.*, 2000; Beyond Pesticides, 2012).

- Peak levels of insecticides are common in agricultural surface waters but are difficult to capture through monitoring. Even at contaminated sites, they often occur for only a few hours a day, on perhaps 4 to 6 days a year during application seasons (Stehle, Knabel and Schulz, 2013).

- Drainage of repeated low doses of pesticides from continuous pesticide applications can cause significant harm to nearby water sources, disrupting natural ecosystems and repeatedly exposing fish (and other aquatic life) to the chemicals. This can result in reduced fish egg production and hatching, nest and brood abandonment, lower resistance to disease, decreased body weight, hormonal changes, loss of attention, and reduced avoidance of predators. While not immediately killing the fish, the sublethal doses of pesticides can in this way reduce adult survival and population abundance (Helfrich *et al.* 2009).

- Studies suggest that the persistence in aquatic environments of important classes of insecticides has been underestimated. For example, although the organophosphorus pesticides are assumed to degrade very rapidly in aquatic systems, research (notably with chlorpyrifos and parathion) has shown that they may persist for relatively long periods of time in soils and sediments. This is a matter of much concern, according to Caravalho (2017). Another example is the pyrethroids, which are extremely toxic to fish and other aquatic organisms (Richterova and Svodobova, 2012) and are among the most commonly used insecticides worldwide. Studies have shown that while the pyrethroids are rapidly degraded in water and

plants, they are persistent in soils and sediments, causing water contamination via run-off from treated areas (Luo and Zhang, 2011).

- The pesticide mixtures that are often present in aquatic systems can be more toxic to aquatic organisms than the individual chemicals. Research has shown that many insecticide combinations (e.g. diazinon, malathion and chlorpyriphos, carbaryl and carbofuran) produce additive toxicity at the low concentrations that are detected in surface waters. Certain combinations, such as diazinon and chlorpyrifos, show a clear pattern of synergism even at relatively low concentrations (Laetz *et al.*, 2009). The increased toxicity of mixtures may explain an important finding of studies of fish kills, that the pesticides identified are often below lethal concentrations (Mutch *et al.* 2002; Polidoro & Morra, 2016).

- Herbicide runoff into water sources can result in fish kills both by acute poisoning and by the impact on the aquatic environment. Herbicides are generally less toxic to fish and aquatic life than insecticides, and many are short-lived, but some are highly toxic to aquatic animals and their impact can be significant (Helfrich *et al.*, 2009). In the United States of America, for example, the National Marine Fisheries Service informed the Environmental Protection Agency in 2012 that the approved uses of the herbicides oryzalin, pendimethalin, and trifluralin – widely applied on farms, lawns, home gardens and rights-of-way – were likely to jeopardize half of the 26 aquatic salmon populations on the West Coast due to their toxicological properties (National Marine Fisheries Service, 2012; Beyond Pesticides, 2012a). The indirect impacts of herbicides can also be important, even when the herbicides themselves are not directly toxic to fish. In addition to modifying the aquatic system and reducing food sources, herbicides can cause fish to die from suffocation as masses of rotting water weeds killed by the chemicals decompose, reducing oxygen levels (Helfrich *et al.*, 2009).

- Mitigation measures required to limit the risks of certain pesticides, such as leaving buffer zones between treated areas and waterways, are not always observed. There may be many reasons for this, including that proposed mitigation measures are unrealistic under local conditions of use (personal communication with H. van der Valk).

Spawning Kokanee salmon, United States of America

- Even when fish kills are associated with specific pesticide applications, the principal agent is often difficult to determine in laboratory analysis, due, in part, to the frequent presence of multiple chemicals in the dead fish and the fact that water residues of pesticides did not exceed the lowest published acute or chronic toxicity value of any species (Mutch *et al.* 2002; Polidoro and Morra, 2016).

2.3 Pesticide poisoning of honey bees

Bees may serve as a bioindicator for environmental pollution
(Celli & Maccagani, 2003)

While bird kills first alerted the world to the environmental impacts of pesticide use, today the worldwide decline in populations of honey bees and of arthropods in general is causing alarm (Van Lexmond *et al.*, 2015). Several factors are known to contribute to the decline, but there is no doubt that exposure to pesticides is an important cause.

Insecticides are usually (highly) toxic to bees, and even insecticides considered to be harmless to bees may be harmful if higher than prescribed application rates are used. Registration risk assessments must therefore consider such factors as: the formulation (e.g., whether it increases toxicity or increases or reduces exposure); the application rate, method and timing; the growth stage of the treated crop and its attractiveness to bees as a food resource; the presence of flowering weeds that are also a food resource for bees; and the effectiveness and real-life feasibility of risk mitigation measures.

Bee poisoning incidents may involve the death of foragers, hive and nurse bees, and/or bee brood, and can lead to severe damage of the colony up to a total loss. The impact of insecticides may not be immediate but can involve the colony's overwintering ability, honey production and pollination activity, and it can interfere with the normal growth and development of the honey bee larvae that replenish the adult population. Estimates of insecticide damage based solely on counts of dead bees may therefore be much too low (Davis, 1989).

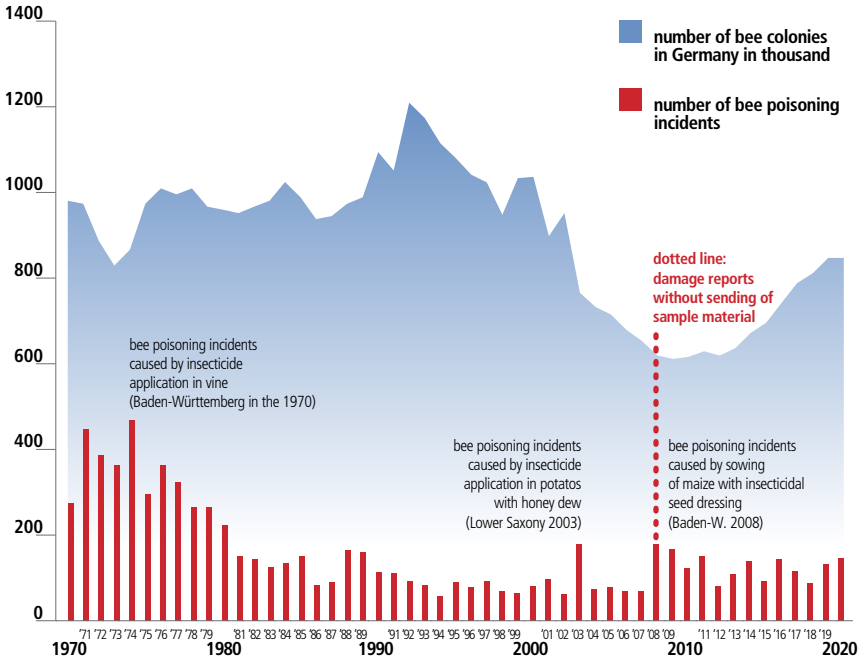
Long-running national incident reporting schemes, such as those in Germany, the Netherlands and the United Kingdom of Great Britain and Northern Ireland, have been used to obtain feedback on the real-life impacts of specific insecticides on bees, on the accuracy of pre-registration risk assessments, and on the sufficiency of risk management and mitigation measures. In recent decades, several issues that needed to be investigated were detected by incident investigation (Brasse, 2007). Among these were: the impact of carbaryl used in vineyards, as it was found that grapevine pollen is collected by foragers; the impact of fenoxycarb, which was found to cause malformed and dying pupae (Oomen 2001); and the synergistic toxicity of tank mixtures that increase the hazardous properties of the individual chemicals, as such mixtures were found to cause brood damage. The issue with organophosphates used for aphid control and applications on honey dew and the abrasion of insecticidal dust from treated seeds have also been detected through incident monitoring schemes.

Data from these national incident schemes show that the organophosphates and carbamates had a great impact on honey bee colonies before governments began to restrict or ban their use. After incidents were reported and bans and restrictions imposed,

starting in the 1980s, the schemes show a decline in bee poisoning incidents (Seefeld 2006; Brasse 2007; Kovács-Hostyánszki *et al.*, 2016).

One of the earliest bee poisoning cases identified in the current review concerned the carbamate carbaryl, which was banned in Germany in 1982 after it was found to cause frequent and serious honey bee incidents in vineyards (Thompson & Thorbahn, 2009) (**Figure 3**). In another early study, the organophosphates dimethoate, parathion and methyl parathion were reported to be one of the main causes of honey bee losses during the 1990s in the Netherlands. There, the main incidents occurred in potato fields infested by aphids, where bees were exposed either through aphid excretion of honeydew or through contaminated pollen in the flowering weeds. The incidents resulted in the imposition of new risk mitigation measures on these pesticide products (Oomen, 2001).

Figure 3 **Occurrence of bee poisoning incidents from 1970 to 2020 in Germany (JKI, 2021) translated from the German.**



Similar incidents resulting from bees foraging on aphid honeydew and flowering weeds in potato crops, in this case treated mainly with the organophosphate methamidophos, occurred in Germany (Thompson and Thorbahn, 2009; JKI, 2021; Figure 3). In that country, the government reacted by lowering the threshold for aphid control in potatoes (to avoid secretion of contaminated honeydew) and by undertaking a farmer education campaign (JKI, 2021).
In the United Kingdom of Great Britain and Northern Ireland, approval for use of dimethoate in oilseed rape was withdrawn after it caused many bee poisoning incidents (Barnett *et al.*, 2007). In 2019, all authorizations of dimethoate were withdrawn in the European Union (European Commission, 2020).

While there is no longer any doubt about the impacts of the organophosphate and carbamate insecticides on honey bees and other pollinating insects, researchers and bee keepers have also sounded alarms about the neonicotinoids and fipronil, the latter often grouped with the neonicotinoids because of its similar action and high toxicity. The neonicotinoids and fipronil are both persistent and systemic (fipronil is often co-formulated with polymers to increase its systemic action); they are transported within the plant, for example from treated soil into all parts of the plant including the flowers, nectar and pollen, and they are still present in the plant long after the insecticide was applied.

A literature review by Kiljanek, Niewiadowska and Posyniak (2016) that compiled data from different countries identified several neonicotinoids (clothianidin, imidacloprid, thiamethoxam, thiacloprid and acetamiprid) as the cause of many bee poisoning incidents, with clothianidin causing the highest number (270 incidents). Sowing of clothianidin-coated maize seeds by drilling, which raises a cloud of dust containing the insecticide, was cited by various countries as the source of severe poisoning incidents. This was the case, for example, in a massive poisoning of bees in Germany in 2008 (Pistorius *et al.*, 2009; Figure 3) which resulted in a national ban on seed treatments containing clothianidin in maize as well as a ban on the use of clothianidin in cereal dressings as a precautionary measure (as sowing of cereals can raise similar dust levels) (Heimbach *et al.*, 2014). France and Italy also reported honey bee losses after sowing of clothianidin-coated maize seeds with a pneumatic drilling machine (Bortolotti *et al.*, 2009; Chauzat *et al.*, 2010; Marzaro *et al.*, 2011), and similar incidents were cited in the United States of America

and Canada (Cutler, Scott-Dupree and Drexler, 2014; Krupke *et al.*, 2012; U.S. Environmental Protection Agency, 2020).

Regulatory authorities in a number of countries and regions (e.g. Canada, Europe, Fiji, the United States of America, and Marinduque Island, the "Butterfly Capital of the Philippines"), have banned or severely restricted specific uses of neonicotinoid products that they consider most harmful to bees (primarily those containing imidacloprid, clothianidin and thiamethoxam). The restrictions include such measures as banning all outdoor use, banning use on crops like orchards that attract bees, prohibiting spraying of budding or flowering plants, and minimizing exposure to dust from treated seeds. Evaluations of the situation have also been initiated (Cutler, Scott-Dupree and Drexler, 2014; European Commission, 2020; Fijian Government, 2019; US EPA, 2019). In Africa, for example, the **InterAcademy Partnership** (IAP, 2020) project "Neonicotinoids and their impact on ecosystem services in agriculture and biodiversity in Africa" was launched, and in Brazil, a reevaluation of neonicotinoids was undertaken by regulatory authorities (personal communication with B. Cavalheiro Breitenbach).

Honey bees collecting pollen from apple blossoms

Bees in the Pacific Islands

The insecticide fipronil has also been cited in many honey bee poisonings. Fipronil was determined to be the cause of 54 bee poisoning incidents recorded between 2007 and 2015 in Europe (Fazekas *et al*. 2012, cited in EFSA 2013; Kiljanek, Niewiadowska and Posyniak, 2016), where the determination of high risk to honey bees resulted in a partial ban in 2013. The ban was overruled by the European court in 2018, but in the meantime, the product registration had expired (in 2017). The result is that fipronil can no longer be used in the European Union for agricultural production, although it is still allowed for the frequent uses identified as "biocidal" (such as veterinary treatments). Data from Germany indicate that poisonings by fipronil often originate from such "biocidal" routes of exposure, as plant protection uses were de-registered in that country in 2012. In Germany, in an evaluation of incidents from 2016, to 2020 fipronil was still the most frequently detected insecticide in dead bee samples sent for investigation (Pistorius, personal communication).

Fipronil was also implicated in bee kills in South Africa, Russia and Colombia. In Cape Town, South Africa, a conversation on Cape Radio in 2018 reported that beekeepers were finding tens of thousands of dead bees. Fipronil mixed with molasses (which seems to attract bees) to control ants was assumed to have caused the poisoning (New Food Magazine, 2018). In 2019, a major bee incident in Russia reported in an online newspaper was determined through an-

alytical analysis to have been caused by fipronil applied on flowering rapeseed. Fipronil is still registered in Russia but restricted to use on potatoes, cereals and pastures, with application only at night in non-windy weather, and with bees kept away for several days (NST, 2019).

In Colombia, fipronil was identified as the cause of five honey bee kills between 2012 and 2018. As a result of these cases and the continuing complaints of beekeepers, the National Agency of Environmental Licenses (ANLA, abbreviation in Spanish) withdrew permission to use fipronil in open environments on citrus, passionflower, avocado and coffee crops (personal communication, Instituto Colombiano Agropecuario, ICA and ANLA).

The short-term acute impact of the neonicotinoids and fipronil on honey bees, and subsequent mortality, is not the only subject of concern. Fipronil is also known to have an accumulative toxicity, and some researchers describe more "insidious" sub-lethal impacts.

An evaluation of six published reviews of the impacts of these insecticides by the Intergovernmental-Science Policy Platform on Biodiversity and Ecosystem Services (IPBS, 2016) found that field studies appear to provide conflicting evidence of sub-lethal effects – at least on managed honey bees, which appear to be less sensitive to the pesticides than wild bees – depending on the species of bee and pesticide use.

A different view was expressed by the international, inter-disciplinary Task Force on Systemic Pesticides, established by the International Union for Conservation of Nature in March 2011. Based on an examination of more than a thousand published, peer-reviewed studies, the Task Force concluded that bees' chronic exposure to sub-lethal doses of the chemicals resulted in impaired learning and navigation, raised mortality, increased susceptibility to disease, reduced fecundity, and colony-level effects (Van Lexmond *et al.*, 2015). The ongoing chronic exposure is explained by research confirming that the neonicotinoids and fipronil can persist for years in soils, frequently contaminate waterways and the surface water in arable fields and adjacent ditches and are found months after treatment in nectar and pollen of treated crops, in flowers of wild plants growing on farmland, and at high concentrations in guttation drops exuded by many crops (Bonmantin *et al.*, 2015; Van Lexmond *et al.*, 2015).

Kiljanek, Niewiadowska and Posyniak (2016), Van Lexmond *et al*. (2015), and Pisa *et al*. (2015) also cite the systemic effects in bees caused by exposure to systemic pesticides that persist in plant matter, causing both secondary poisoning of

bees through ingestion of contaminated pollen, nectar and guttation water from treated crops and nearby vegetation, and sub-poisoning of winter bees that gradually eat stocks of pesticide-contaminated food over winter, leading to nervous system dysfunction, failure to fulfil their social role, and disintegration of the hive.

ANNEX E, Table E.1 lists the pesticides most frequently identified in honey bee poisoning incidents in the studies retrieved in the review. (This desk review focused on incidents involving managed honey bees rather than wild bees or other pollinators, as it is mainly honey bees that are addressed in pesticide registration (hazard/exposure assessment) and post-registration monitoring. However, more resources are becoming available that also address risks to wild pollinators.)

2.3.1 Key factors in honey bee poisoning

The following key factors in pesticide-related honey bee poisoning incidents were highlighted in the studies considered in this review:

- Bees have been shown to have an extreme sensitivity to pesticides due to a deficiency in the number of genes encoding detoxification enzymes (Kiljanjek, Niewiadowska and Posyniak, 2016).
- Insecticides are usually (highly) toxic to bees: even those considered harmless to bees can be harmful at higher than prescribed application rates.
- Highly acutely toxic insecticides can have a quick "knock down effect" that may kill bees before they can return to the hive where they might be detected or reported: this is most often found with the pyrethroids but also with organophosphates and others (Kiljanek, Niewiadowska and Posyniak, 2016).
- Pesticide product combinations, such as mixes of insecticides and fungicides, can have synergistic effects which improve the efficacy of pest control but also increase toxicity to bees (Krohn, Becker and Hungenberg, 2008). The synergism between EBI fungicides and a pyrethroid insecticide in the honey bee, earlier recognized by Pilling and Jepson (1993), is the reason why mixing of pyrethroids and EBI fungicides is generally prohibited during flowering in Germany (Brasse, 2001).
- Synthetic chemical "inert" ingredients and adjuvants can increase product toxicity but have no mandated tolerances and are largely unmonitored, although they are consistently found in beehive sam-

ples (Mullin, 2015; Mullin *et al.*, 2015; Zhao *et al.*, 2011 cited in Mullin *et al.*, 2015).

- Certain systemic pesticides have been shown to affect insect immunity and to promote replication of a viral pathogen in honey bees: Di Prisco *et al*. (2013) noted this effect with clothianidin.
- Exposure can occur from nectar and pollen of flowering plants, from water, and from aphid honeydew on non-flowering or non-bee-attractive plants.
- Timing of insecticide application is important: products should never be applied during daylight hours when honey bees are foraging. Precision and calibration of application machinery is also important, to avoid exceeding prescribed doses.
- Pesticide formulations and application methods can result in high levels of exposure. Examples include spraying of microencapsulated pesticides that bees can mistake for pollen and bring back to the hive (Johansen, 1977; Niell *et al.*, 2016); and drilling of treated seeds (described above), which may lead to abrasion and dispersal of insecticidal dusts into the environment and deposition on flowers, nectar and pollen. (Treated cereal and maize seeds are especially prone to abrasion.) Such dusts can be lethal to flying insects and have caused large-scale acute poisonings (Pistorius *et al.*, 2009; Chauzat *et al.*, 2010; Marzaro *et al.*, 2011; Cutler, Scott-Dupree and Drexler, 2014; Krupke *et al.*, 2012; Van Lexmond *et al.*, 2015).
- Persistent systemic insecticides applied to a crop some time before flowering may remain at high and adverse levels in the plants long after the application and can contaminate flowers, nectar and pollen.
- Governments may accept proposed risk mitigation measures – such as avoiding pesticide application during flowering of crops and weeds or limiting application to late evening or night, so as to avoid daylight hours when honey bees are foraging – that may not be feasible or realistic under local conditions and that are not always sufficient, as they fail to account for the persistence of systemic insecticides or the presence of other pollinators like bumblebees which forage late in the evening.
- As shown in a survey conducted by the Rotterdam Convention Secretariat in the Caribbean, farmers may not be aware of, or pay attention to, the need to protect bees (see Figure E.1 in Annex E).

3 LIMITATIONS TO THE DETECTION AND REPORTING OF ENVIRONMENTAL INCIDENTS

Although the desk review found a considerable number of studies documenting environmental incidents, it was frequently noted that the full impact of pesticide exposure on wildlife cannot be "quantified," as most incidents go unreported. There are several reasons why.

3.1 Detecting environmental incidents

The most important reason is that wildlife poisoning incidents are often not detected. This is the case for all of the animals addressed in this document. Birds suffering from lethal or sub-lethal pesticide exposure often escape the notice of humans. Observed poisonings comprise often the larger birds of prey and waterfowl that graze on treated crops. Songbirds can also be killed when ingesting treated seed, granular insecticides, or contaminated seeds or insects, but their small body size means that these incidents may easily be overlooked, and the carcasses are likely to be quickly removed by scavengers (Mineau and Tucker, 2002). Unless a system of post-treatment monitoring is in place, most small bird kills will not be recorded unless they are observed shortly after the treatment, while the dying birds are still moving, and are immediately reported. Acutely poisoned honey bees are similarly unlikely to be noticed if they die before reaching the hive or exhibit abnormal behavior that dissociates them from the colony, such as disorientation, aggressiveness, or incapacity to enter the hive (Kiljanek, Niewiadowska and Posyniak, 2016).

Pesticide-related fish kills are the least often reported, as scavengers quickly remove carcasses from a kill site, and stressed and dying fish may hide or leave the area. The remoteness of some aquatic bodies further diminishes chances of a fish kill being detected. In addition, aquatic incidents may go unreported due to their being considered

unimportant, fear of liability, or a failure to associate the kill with a pesticide application. Even in documented cases, the number of fish killed is likely to be underestimated, as the small size and camouflage coloring of many fish, especially young fish, make accurate counts difficult (Helfrich *et al.*, 2009). Even more difficult than finding incidents resulting from acute poisoning is detection of incidents involving chronic toxicity, which are rarely identified. Even in managed honey bees, which are frequently observed, only well-informed and trained beekeepers will recognize symptoms of chronic pesticide intoxication (Oomen, 2001). In wildlife, symptoms such as reduced reproduction are nearly impossible to detect without rigorous environmental monitoring (Vyas, 1999).

Herbicides and fungicides, used in agriculture in larger quantities than insecticides (FAO, 2019), have indirect effects on pollinators, insects, and herbivorous birds and mammals, by removing their food source and nesting sites. These indirect effects are even more difficult to detect in the field, and to attribute to a specific cause, than acute poisonings by insecticides. In addition, as previously mentioned, herbicides can result in fish kills due to suffocation, as water weeds killed by the herbicide decompose and reduce oxygen levels (Helfrich *et al.*, 2009).

3.2 Monitoring environmental incidents

Worldwide, relatively few countries appear to require monitoring of pesticide impacts on wildlife with an established system that would increase the chance of detection. According to FAO/WHO survey Global situation of pesticide management in agriculture and public health (2017-2018), only 30% of the 44 responding countries collect data on aquatic ecosystems, 23% on terrestrial ecosystems, 16% on endangered species, 14% on wildlife, and 25% on specific incidents that have harmed the environment (e.g., fish poisonings) (**Table 1**, FAO/WHO 2019).

This is an important limitation, because voluntary reporting of incidents cannot be counted on, notably by farmers who may fear the consequences (e.g., receiving a punishment or penalty), for example, in the case of a bee killing, if the farm is close to beehives. The lack of an official monitoring system can make it difficult to obtain reliable information about how incidents occurred, what pesticides were used, and how they were applied.

3.3 Reporting environmental incidents

The frequent lack of standardization and consolidation of incident reports,

Item	World	African	Americas	E.Mediter'n	S-E.Asia	W.Pacific
Aquatic ecosystems	30%	6%	43%	17%	67%	40%
Terrestrial ecosystems	23%	6%	29%	17%	50%	20%
Endangered species	16%	6%	29%	0%	33%	20%
Wildlife	14%	6%	29%	0%	33%	0%
Specific incidents	25%	12%	43%	0%	67%	20%
(n)	44	17	7	6	6	5

Table 1 Data on pesticide effects on ecosystems collected in the past 3 years (FAO/WHO 2019)

even in countries with established surveillance and monitoring systems, also makes it difficult to obtain a comprehensive overview. Among countries which have systems in place, it was found that schemes for collecting honey bee and wildlife incidents were often operated by different authorities, that incident reports were often filed separately rather than being organized in a single database, and that the reports were frequently unpublished and not easily accessible. In addition, the number of recorded incidents was found to vary greatly among countries, depending on how the surveillance system was set up and who is responsible for sending dead animals to the authorities.

3.4 Determining the cause of environmental incidents

Still another important limitation to quantifying the full impact of pesticides on wildlife is that even when incidents are linked to pesticide use, the main agent responsible for the poisoning is not always easy to determine. After an incident is detected, and the dead birds, fish or bees are sent to the authorities, the carcasses must be analyzed in laboratories. This is obviously a constraint for the many developing countries that have limited or no laboratory facilities, but the analysis can also be complicated in developed countries. The laboratories must be able to distinguish between poisoning and other causes of death, and, using chemical analysis, to detect and identify pesticides in the carcasses. Identifying the main causative agent can be difficult due to the frequent presence of multiple pollutants in the carcasses, or to residues that are below the levels considered to be lethal.

4 CREATING A NATIONAL SYSTEM FOR MONITORING AND REPORTING ENVIRONMENTAL INCIDENTS: RESOURCES AND COUNTRY EXAMPLES

4.1 Resources

Guidelines and forms to assist governments in building a national system for monitoring and reporting environmental incidents have been developed by the FAO as well as by other international organizations, individual governments, and independent experts. Guidance for assessing and managing pesticide risks to bees and other pollinators, and for inspecting alleged cases of honey bee poisoning, is also available. These resources are listed with their respective web links in Annex B.

In addition to these resources, the examples that follow of existing pesticide incident monitoring and reporting systems can serve as models for the creation of a national system.

4.2 Country examples

In **Canada**, incident reports involving registered pesticides that are reported to Health Canada's Pest Management Regulatory Agency (PMRA) are recorded in the **Canadian Pesticide Incident Reporting database**. The database contains information about suspected adverse effects of marketed pesticides that have occurred in Canada and, in some cases, the United States of America. The information is available to the public (Health Canada, 2020). The PMRA began gathering incident reports in 2007. Since then, manufacturers have been legally required to report incidents. Health professionals and laypersons can report pesticide related incidents either to the manufacturer or directly to Health Canada. Beekeepers who believe their bees have been affected by pesticides are expected to report the poisoning event to the PMRA, which will do an on-site investigation and include the results in its database. The Health Canada website explains that incident reports are used to help identify risks from the "real-life" use of pesticides. This is done by searching for serious effects or trends, such as repeated effects or multiple incidents for a particular pesticide. If a trend is identified, Health Canada will further investigate to confirm the link to the pesticide. If

a "safety issue" is identified, action ranging from a minor label change to discontinuation of the product may be taken.

In **Colombia**, the environmental impacts of pesticides to be registered are evaluated and environmental management plans may be presented as a basis for monitoring to be carried out by the national licensing agency (Autoridad Nacional de Licencias Ambientales, or ANLA). In addition, Colombia is implementing an early warning system, starting with pollinator poisonings (ANLA, 2020).

France's national monitoring system, the wildlife network SAGIR, founded in 1968, was created by the French Office National de la Chasse et de la Faune Sauvage (ONCFS), responsible for hunting and wildlife. The main aim is to record and report wildlife mortality incidents and to alert authorities in case of unusual mortality. Hunters and ONCFS agents are responsible for collecting dead wild animals and transporting them to the local veterinary diagnostic laboratory, where they are necropsied by trained veterinarians with bacteriologic, histologic, or parasitological tests as deemed necessary. If acute poisoning is suspected, biological samples and necropsy findings are submitted to the toxicology laboratory at the veterinary college. Information for each case is entered into a database for future reference. As of 2010, the database included some 58,000 records. For each reported case, SAGIR tries to identify if it was a misuse, abuse or approved use of pesticides, based on information from observers and from the **e-phy database**, which catalogues "unintentional" effects of pesticides (E-Phy, 2020). Due to its experience, SAGIR was involved in post-registration studies of thiamethoxam, tefluthrin, methiocarb and mercaptodimethur in 2009, and in the development of protocols to survey wildlife mortality at the time of corn and rape seeding (Berny *et al.*, 2010).

Germany has a wildlife incident monitoring scheme hosted by the Federal Office of Consumer Protection and Food Safety (Bundesamt für Verbraucherschutz und Lebensmittelsicherheit). However, it is possible that not all incidents are reported to the national scheme because the regional governments (Länder) are responsible for investigations and national-level reporting is voluntary (Van Oers *et al.*, 2005). A study by De Snoo, Scheidegger and De Jong (1999) found that the majority of incidents in the national scheme were reported by the Plant Protection Service or nature conserva-

tion organizations. The Berlin University of Zoology and Wildlife also investigates the cause of mortality of dead animals (K. Rauert, personal communication). The main rivers in Germany are monitored, and every federal state also collects data on small water bodies. However, these data have so far not been included in a comprehensive national database, as is the case for data on terrestrial wildlife incidents (K. Rauert, personal communication). At the time of writing, the German central environmental authority (Umweltbundesamt, or UBA) was carrying out a project to monitor small water bodies and analyze samples (Wick *et al.*, 2019).

Managed honey bee incidents are collected by the Julius Kuehn Institute called "**Untersuchungsstelle für Bienenvergiftungen**" and are made publicly available (JKI 2020).

In the **United Kingdom of Great Britain and Northern Ireland**, most animal poisoning incidents are reported by private citizens to the **Wildlife Incident Investigation Scheme** (WIIS), which is run by the Health and Safety Executive (HSE) (De Snoo, Scheidegger and De Jong, 1999). The WIIS scheme analyzes carcasses from wildlife kills and bee colony incidents where pesticides are thought to be the cause of death, in order to identify the pesticides responsible and the field conditions that led to the poisoning (HSE, 2020a). The post-mortems and ecotoxicology are carried out by the Food and Environment Research Agency (FERA, 2020), which also runs annual pesticide usage surveys that are used not only to track the frequency and quantity of pesticide treatments but also to relate poisoning incidents to product misuse, abuse or approved use.

The WIIS publishes **quarterly reports** which are publicly available (HSE, 2020b). Brown *et al.* (1996) note several limitations to the WIIS investigations (which most likely apply to all reporting programs), including that: rare bird deaths are probably much more reported than deaths of the common pigeon or sparrow; small mammals may die unnoticed, hidden by undergrowth; and death from disease may be assumed when the cause of an animal's death cannot be determined from a routine post-mortem examination. The Department for Environment, Food and Rural Affairs (DEFRA) has been working with partners such as Natural England to improve its understanding of pesticide impacts on the terrestrial environment and to consider how to improve its current monitoring schemes. The WIIS system counts on beekeepers and other interested organizations or individuals to report and

submit dead bee samples for analysis. The samples are chemically analyzed to rule out such factors as mite infestations and to detect any pesticide residues that may have caused the incident. Pollen (from pollen baskets on the dead bees) is also analyzed to identify the crops the bees have been visiting (Barnett, Charlton and Fletcher, 2007).

In **West Africa**, the **CILSS** sub-regional intergovernmental organization (with responsibility for pesticide registration) produced guidelines in 2019 for monitoring the health and environmental effects of authorized pesticides. Under these guidelines, CILSS member countries will be required to record environmental incidents resulting from pesticide use on an online system where the information will be centralized regionally. The CILSS pesticide committee is currently training member states to use the system, and data are expected to be submitted in the coming years (S. Ouedraogo, personal communication).

Prince Edward Island in Canada (Mutch *et al.* 2002; Gormley 2003) and the **United States of America** EPA both collect and hold data on fish poisoning events related to pesticide use. The state of **California** has an advanced scheme for monitoring aquatic contamination by pesticide residues, called the **California Surface Water Protection Program**. The aim is to identify the pesticides and the sources of the contamination (the factors that resulted in the pesticides moving off-site) and to develop site-specific mitigation strategies. Several different agencies are engaged in the monitoring, and farmers contribute to the chemical analysis of pesticides found in the water bodies (CDPR, 2020).

The **OECD** runs a **Pollinator Incidents Information System** (created in 2014) for collecting and sharing reports about pollinator poisoning incidents potentially linked to pesticide applications (OECD, 2014). The system is primarily used as a rapid alert system rather than for reporting on a regular basis (J. Pistorius personal communication).

5 TAKING ACTION

The examples of environmental incidents and the key factors summarized in this document suggest that pesticides are having a significant impact on wildlife and honey bees and underscore the importance of **post-registration monitoring** of the real-life environmental impacts of pesticides. Such monitoring is an essential mechanism to measure the validity of any registration decision, in particular with respect to a pesticide's biological efficacy, human health effects, and environmental concentrations and impact.

The great number of environmental incidents identified in the document and the continued discovery of key factors not addressed in risk assessments further underscore the need to adopt better pest and pesticide management strategies to minimize the impacts of chemical pest control.

As a first step, Designated National Authorities to the Rotterdam Convention are encouraged to reach out to the Convention Secretariat for technical assistance and support to raise awareness of this issue among all stakeholders, and to strengthen national capacities to monitor, report and reduce pesticide-related environmental incidents.

In addition to the cooperation between the Rotterdam Convention Secretariat and Governments, partnerships with FAO and other UN agencies, with non-governmental organizations, development aid agencies, and independent farmer advisers could be sought. Bilateral partnerships with countries that are experienced in addressing environmental incidents are also encouraged.

Examples of assistance include:

- field projects to monitor, detect, evaluate and report environmental incidents caused by pesticide use;
- projects to establish a national system to monitor and analyze the environmental impacts of pesticide use, and to collect, organize and publish (or otherwise make accessible) the resulting data;
- projects to support farmers in keeping records of their pesticide appli-

cations, both to help identify the products causing environmental incidents and as proof that the farmers have used the pesticides correctly according to the label;

- projects to support farmers in the application of integrated pest management, non-chemical pest control, and other farming strategies that reduce the use and adverse impacts of pesticides;
- projects to increase farmer awareness of the potential hazards of pesticide use both to themselves and to the environment, the need to use and store products correctly and to take measures to protect wildlife;
- projects to assist government authorities in improving the quality and efficiency of their pesticide risk evaluation process, by using existing pesticide hazard and risk assessments (available in the pesticide toolkit as well as by contacting other governments directly) that can be adapted to national conditions of use;
- assistance in sharing experiences related to environmental incidents with other Rotterdam Convention Parties, during events organized by the Secretariat (such as webinars, or side events and fairs at Convention meetings) or on a dedicated web page for country case studies;
- assistance in using the FAO environmental surveillance guidelines, the **Toolkit for SHPFs**, and other resources listed in Annex B to monitor and report environmental incidents to the Rotterdam Convention Secretariat.

It is hoped that this document will bring change, that it will inspire the Convention Parties to improve their capacity to address the environmental impacts of pesticide use, and that they will take action to do so.

BIBLIOGRAPHY

Adjlane, N., Doumandji, S. E. & Haddad, N. 2012. Beekeeping in Algeria: The factors threatening the survival of the honey bee *Apis mellifera* intermissa. *Cahiers Agricultures,* 21(4): 235–241. 10.1684/agr.2012.0566.

Akratankul, P. 1990. Beekeeping in Asia. *FAO Agricultural Services Bulletin,* 68.

American Bird Conservancy. 2020. *EPA Cancels Registrations of Two Bird-Killing Pesticides*. [Cited 24 June 2020]. https://abcbirds.org/article/epa-cancels-registrations-of-two-bird-killing-pesticides

American Expatriate Costa Rica. 2018. *Banned agrochemical was found in drinking water from the North Zone.* [Cited 24 June 2020]. https://www.usexpatcostarica.com/banned-agrochemical-was-found-in-drinking-water-from-the-north-zone

ANLA. 2020. *Agroquímicos y Proyectos Especiales*. [Cited 24 June 2020]. http://www.anla.gov.co/entidad/tematicas/evaluacion-y-seguimiento/agroquimicos-y-proyectos-especiales

Al Naggar, Y., Codling, G., Vogt, A., Naiem, E., Mona, M., Seif, A. & Giesy, J. P. 2015. Organophosphorus insecticides in honey, pollen and bees (*Apis mellifera L.*) and their potential hazard to bee colonies in Egypt. *Ecotoxicology and Environmental Safety,* 114: 1–8. 10.1016/j.ecoenv.2014.12.039.

Altieri M.A. 2018. *Agroecology: The Science of Sustainable Agriculture*, 2nd ed. CRC, Boca Raton, FL, United States of America.

Anderson, K. A., Seck, D., Hobbie, K. A., Traore, A. N., Mccartney, M. A., Ndaye, A., Forsberg, N. D., Haigh, T. A. & Sower, G. J. 2014. Passive sampling devices enable capacity building and characterization of bioavailable pesticide along the Niger, Senegal and Bani Rivers of Africa. *Philosophical Transactions of the Royal Society B-Biological Sciences,* 369(1639). 10.1098/rstb.2013.0110.

Aupinel, P., Fortini, D., Michaud, B., Marolleau, F., Tasei, J. N. & Odoux, J. F. 2007. Toxicity of dimethoate and fenoxycarb to honey bee brood (*Apis mellifera*), using a new in vitro standardized feeding method. *Pest Management Science,* 63(11): 1090–1094. 10.1002/ps.1446.

Barnett, E. A., Charlton, A. J. & Fletcher, M. R. 2007. Incidents of bee poisoning with pesticides in the United Kingdom of Great Britain and Northern Ireland, 1994-2003. *Pest Management Science,* 63(11): 1051–1057. 10.1002/ps.1444.

Berny, P. 2007. Pesticides and the intoxication of wild animals. *Journal of Veterinary Pharmacology and Therapeutics,* 30(2): 93–100. 10.1111/j.1365-2885.2007.00836.x.

Berny, P. & Gaillet, J. R. 2008. Acute poisoning of Red Kites (*Milvus milvus*) in France: Data from the SAGIR network. *Journal of Wildlife Diseases,* 44(2): 417–426. 10.7589/0090-3558-44.2.417.

Berny, P., Lamarque, F., Buronfosse, F. & Lorgue, G. 1998. Pesticide poisoning in raptors in France: Results from the SAGIR network. *Gibier Faune Sauvage – Game and Wildlife, Vol 15 (Special Number Pts 2 and 3) 1998*: 343–350.

Berny, P., Mastain, O., Decors, A., Poulsen, V., Moinet, M. & Dunoyer, C. 2010. The SAGIR network in France: A 40-year active and passive toxicovigilance scheme for pesticide poisoning in wildlife. *Toxicology Letters,* 196: S322–S322. 10.1016/j.toxlet.2010.03.1017.

Berny, P. J., Buronfosse, R., Videmann, B. & Buronfosse, T. 1999. Evaluation of the toxicity of imidacloprid in wild birds. A new high performance thin layer chromatography (HPTLC) method for the analysis of liver and crop samples in suspected poisoning cases. *Journal of Liquid Chromatography & Related Technologies,* 22(10): 1547–1559. 10.1081/jlc-100101750.

Berny, P. J., Buronfosse, T., Buronfosse, F., Lamarque, F. & Lorgue, G. 1997. Field evidence of secondary poisoning of foxes (*Vulpes vulpes*) and buzzards (*Buteo buteo*) by bromadiolone, a 4-year survey. *Chemosphere,* 35(8): 1817–1829. 10.1016/s0045-6535(97)00242-7.

Beyond Pesticides. 2012a. Fisheries service tells EPA to better protect endangered species from pesticides. In: *Beyond Pesticides Daily News Blog* [online]. https://beyondpesticides.org/dailynewsblog/2012/04/fisheries-service-tells-epa-to-better-protect-endangered-species-from-pesticides

Beyond Pesticides. 2012b. Pesticides Blamed for Fish Kill on Canadian Coast. In: *Beyond Pesticides Daily News Blog* [online]. **https://beyondpesticides.org/dailynewsblog/2012/07/pesticides-blamed-for-fish-kill-on-canadian-coast**

Bille, L., Binato, G., Gabrieli, C., Manfrin, A., Pascoli, F., Pretto, T., Toffan, A., Pozza, M. D., Angeletti, R. & Arcangeli, G. 2017. First report of a fish kill episode caused by pyrethroids in Italian freshwater. *Forensic Science International,* 281: 176–182. 10.1016/j.forsciint.2017.10.040.

BirdLife Botswana. 2015. *Create Report on dead vultures and other animals* [online]. [Cited 24 June 2020]. **http://www.birdlifebotswana.org.bw/node/add/vulture-and-animal-sightings**

Blacquiere, T., Smagghe, G., Van Gestel, C. A. M. & Mommaerts, V. 2012. Neonicotinoids in bees: a review on concentrations, side-effects and risk assessment. *Ecotoxicology,* 21(4): 973–992. 10.1007/s10646-012-0863-x.

Bonmatin, J.M., Giorio, C., Girolami, V.; Goulson, D., Kreutzweiser, D.P., Krupke, C., M. Liess, M., Long, E., Marzaro, M., Mitchell, E.A.D., Noome, D.A., Simon-Delso, N., &Tapparo, A. 2015 Environmental fate and exposure; neonicotinoids and fipronil. *Environmental Science and Pollution Research*, 22: 35–67 (2015). **https://doi.org/10.1007/s11356-014-3332-7**

Bortolotti, L., Sabatini, A.G., Mutinelli, F., Astuti, M., Lavazza, A., Piro, R., Tesoriero, D., Medrzycki, P., Sgolastra, F., &Porrini, C. 2009. Spring honey bee losses in Italy. *Julius-Kühn Archiv*, 423: 148–152.

Botha, C. J., Du Plessis, E. C., Coetser, H. & Rosemann, M. 2018. Analytical confirmation of imidacloprid poisoning in granivorous Cape spurfowl (*Pternistis capensis*). *Journal of the South African Veterinary Association* 89: 1–5.

Brasse, D. 2001. Overview about the poisoning incidents in honey bee populations and their clarification in Germany from 1996–1998, in L. P. Belzunces *et al*, Eds., Hazards of Bees to Pesticides, INRAE, Avignon, France. pp. 141–147

Brasse, D. 2007. Der Arbeitsbereich Bienenschutz in der Geschichte der BBA. *Mitt. Biol. Bundesanst. Land- Forstwirtsch.* 410: 14–24.

Brown, A. W. A. 1978. *Ecology of pesticides.* New York, United States of America, John Wiley and Sons1978.

Brown, P., Charlton, A., Cuthbert, M., Barnett, L., Ross, L., Green, M., Gillies, L., Shaw, K. & Fletcher, M. 1996. Identification of pesticide poisoning in wildlife. *Journal of Chromatography A,* 754(1–2): 463–478. 10.1016/s0021-9673(96)00311-1.

Bunyan, P. J. & Stanley, P.I. 1983. The Environmental cost of pesticide usage in the United Kingdom of Great Britain and Northern Ireland. *Agriculture, Ecosystems & Environment*, 9(2): 187–209. **10.1016/0167-8809(83)90041-5**.

Calatayud-Vernich, P., Calatayud, F., Simo, E., Aguilar, J. A. P. & Pico, Y. 2019. A two-year monitoring of pesticide hazard in-hive: High honey bee mortality rates during insecticide poisoning episodes in apiaries located near agricultural settings. *Chemosphere,* 232: 471–480. 10.1016/j.chemosphere.2019.05.170.

Carson, R. 1962. *Silent Spring.* New York, Penguin Books.

Carvalho, F. P. 2017. Pesticides, environment, and food safety. *Food and Energy Security,* 6(2): 48 – 60. 10.1002/fes3.108.

Carvalho, F. P., Gonzalez-Farias, F., Villenueve, J. P., Cantani, C., Hernandez-Garza, M., Mee, L. & Fowler, S. W. 2002. Distribution, fate and effects of pesticide residues in tropical coastal lagoons of northwestern Mexico. *Environmental Technology,* 23(11): 1257 – 1270. 10.1080/09593332308618321.

Casado, J., Brigden, K., Santillo, D. & Johnston, P. 2019. Screening of pesticides and veterinary drugs in small streams in the European Union by liquid chromatography high resolution mass spectrometry. *Science of the Total Environment,* 670: 1204–1225. 10.1016/j.scitotenv.2019.03.207.

Castilhos, D., Dombroski, J. L. D., Bergamo, G. C., Gramacho, K. P. & Goncalves, L. S. 2019. Neonicotinoids and fipronil concentrations in honey bees associated with pesticide use in Brazilian agricultural areas. *Apidologie,* 50(5): 657–668. 10.1007/s13592-019-00676-x.

CBC. 2017. *Pesticides probable cause of most P.E.I. fish kills, provincial data shows.* CBC News [online]. [Cited 24 June 2020]. **https://www.cbc.ca/news/canada/prince-edward-island/pei-fish-kills-numbers-1.4353843**

CDPR (California Department of Pesticide Regulation). 2020. *Overview of the Surface Water Protection Program* [online]. [Cited 24 June 2020]. **https://www.cdpr.ca.gov/docs/emon/surfwtr/overvw.htm**

Celli G., Maccagnani B. 2003. Bees as bioindicators of environmental pollution. *Bulletin of Insectology* **56, 137–139.**

Chauzat, M. P., Martel, A. C., Blanchard, P., Clement, M. C., Schurr, F., Lair, C., Ribiere, M., Wallner, K., Rosenkranz, P. & Faucon, J. P. 2010. A case report of a honey bee colony poisoning. *Journal of Apicultural Research,* 49(1): 113–115. 10.3896/ibra.1.49.1.22.

Cheke, R. A. & Sidatt, M. E. 2019. A review of alternatives to fenthion for quelea bird control. *Crop Protection,* 116: 15 – 23. 10.1016/j.cropro.2018.10.005.

Christensen, K., Harper, B., Luukinen, B., Buhl, K. & Stone, D. 2009. *Chlorpyrifos Technical Fact Sheet*. Oregon State University. http://npic.orst.edu/factsheets/chlorpgen.html

Coeurdassier, M., Riols, R., Decors, A., Mionnet, A., David, F., Quintaine, T., Truchetet, D., Scheifler, R. & Giraudoux, P. 2014. Unintentional wildlife poisoning and proposals for sustainable management of rodents. *Conservation Biology,* 28(2): 315–321. 10.1111/cobi.12230.

Cramp, S. 1973. The effects of pesticides on British wildlife. *British Veterinary Journal,* 129.

Csillik, B., Fazakas, J., Nemcsók, J. & Knyihár-Csillik, E. 2000. Effect of the pesticide Deltamethrin on the Mauthner cells of Lake Balaton fish. *Neurotoxicology,* 21: 343–352.

Cutler, G. C., Scott-Dupree, C. D. & Drexler, D. M. 2014. Honey bees, neonicotinoids and bee incident reports: the Canadian situation. *Pest Management Science,* 70(5): 779–783. 10.1002/ps.3613.

Davis, A.R. 1989. The study of insecticide poisoning of honey bee brood. *Bee World* 70:163–174

De Snoo, G. R., Scheidegger, N. M. I. & De Jong, F. M. W. 1999. Vertebrate wildlife incidents with pesticides: a European survey. *Pesticide Science,* 55(1): 47 – 54. 10.1002/ps.2780550109.

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. *Proceedings of the National Academy of Sciences*, 110 (46) 18466-18471 https://www.pnas.org/content/110/46/18466

Dinham, B. 1996. The success of a voluntary code in reducing pesticide hazards in developing countries. In Bergesen, H. & Parmann, G., eds. *Green Globe Yearbook of International Co-operation on Environment and Development 1996: An Independent Publication on Environment and Development from the Fridtjof Nansen Institute, Norway,* pp. 29 – 36. United Kingdom of Great Britain and Northern Ireland, Oxford University Press.

Elliott, J. E., Birmingham, A. L., Wilson, L. K., Mcadie, M., Trudeau, S. & Mineau, P. 2008. Fonofos poisons raptors and waterfowl several months after granular application. *Environmental Toxicology and Chemistry,* 27(2): 452–460. 10.1897/07-178r.1.

Elliott, J. E., Langelier, K. M., Mineau, P. & Wilson, L. K. 1996. Poisoning of bald eagles and red-tailed hawks by carbofuran and fensulfothion in the Fraser Delta of British Columbia, Canada. *Journal of Wildlife Diseases* 32:486–491.

Elliott, J. E., Wilson, L. K., Langelier, K. M., Mineau, P. & Sinclair, P. H. 1997. Secondary poisoning of birds of prey by the organophosphorus insecticide, phorate. *Ecotoxicology 6*:219–231.

Elliott, J. E., Wilson, L. K. & Vernon, R. 2011. Controlling Wireworms Without Killing Wildlife in the Fraser River Delta. In Elliott, J. E., Bishop, C. A. & Morrissey, C. A., eds. *Wildlife Ecotoxicology: Forensic Approaches,* pp. 213 – 237. New York, Springer. Available: <Go to ISI>://WOS:000300582100008.

E-Phy. 2020. *Le catalogue des effets non intentionnels des produits phytosanitaires* [online]. [Cited 24 June 2020]. http://e-phy.agriculture.gouv.fr

European Commission. 2020. *EU Pesticides database* [online]. [Cited 24 June 2020]. **https://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=activesubstance.detail&language=EN&selectedID=1154**

European Food Safety Authority (EFSA). 2009. Guidance Document on Risk Assessment for Birds & Mammals on request from EFSA. *EFSA Journal,* 7(12):1438: 358 pp. doi:10.2903/j.efsa.2009.1438.

European Food Safety Authority (EFSA). 2013a. EFSA Guidance Document on the risk assessment of plant protection products on bees (*Apis mellifera, Bombus* spp. and solitary bees). *EFSA Journal,* 11(12): 3295: 268 pp. doi:10.2903/j.efsa.2013.3295.

European Food Safety Authority (EFSA). 2013b. Conclusion on the peer review of the pesticide risk assessment for bees for the active substance fipronil. *EFSA Journal,* 11(5): 3158: 51 pp. 10.2903/j.efsa.2013.3158.

FAO/WHO. 2009. *Guidelines on Developing a Reporting System for Health and Environmental Incidents Resulting from Exposure to Pesticide.* Rome, FAO.

FAO/WHO 2014. *The Code of Conduct on Pesticide Management*. Rome, FAO.

FAO/WHO. 2016. *Guidelines on Highly Hazardous Pesticides*. Rome, FAO.

FAO/WHO. 2019. *Global situation of pesticide management in agriculture and public health.* Rome, FAO. **http://www.fao.org/3/ca7032en/ca7032en.pdf**

FAO. 2010. Regular monitoring report 2008. International code of conduct on the distribution and use of pesticides. Rome, FAO.

FAO. 2015. Pesticide Procurement Report. Unpublished.

FAO. 2019. *FAOSTAT* [online]. [Cited 24 June 2020]. **http://www.fao.org/faostat/en/#data/RP/visualize**.

FAO Pesticide Registration Toolkit. undated [online]. [Cited 24 June 2020]. **http://www.fao.org/pesticide-registration-toolkit/en**

FAO Pesticide Registration Toolkit. undated. *Risk mitigation* [online]. [Cited 24 June 2020]. **http://www.fao.org/pesticide-registration-toolkit/registration-tools/risk-mitigation/en**

Fazekas, B., Woynarovichne, L. M., Deakne, P. P., Csaba, G. & Orosz, E. 2012. Pesticide poisoning of honey bees between 2007 and 2011. *Magyar Allatorvosok Lapja,* 134(4): 213–220.

FERA. 2020. The Wildlife Incidents Investigation Scheme (WIIS). [online]. [Cited 24 June 2020]. **https://www.fera.co.uk/chemical-regulation/post-market-stewardship/wildlife-incident-unit)**

Fleischli, M. A., Franson, J. C., Thomas, N. J., Finley, D. L. & Riley, W. 2004. Avian mortality events in the United States of America caused by anticholinesterase pesticides: A retrospective summary of National Wildlife Health Center records from 1980 to 2000. *Archives of Environmental Contamination and Toxicology,* 46(4): 542–550. 10.1007/s00244-003-3065-y.

Fletcher, M. & Barnett, L. 2003. Bee pesticide poisoning incidents in the United Kingdom of Great Britain and Northern Ireland. *Bulletin of Insectology,* 56: 141 – 145.

Fijian Government. 2019. [online]. [Cited 24 June 2020] **https://www.fiji.gov.fj/Home**

Global Environment Facility. 2016. *Reducing Dependence on POPs and other Agro-Chemicals in the Senegal and Niger River Basins through Integrated Production, Pest and Pollution Management* [online]. [Cited 24 June 2020]. **https://www.thegef.org/project/reducing-dependence-pops-and-other-agro-chemicals-senegal-and-niger-river-basins-through**

Giger, W., Berg, M., Pham, H. V., Duong, H. A., Tran, H. C., Cao, T. H. & Schertenleib, R. 2003. Environmental analytical research in Northern Vietnam – A Swiss–Vietnamese cooperation focusing on arsenic and organic contaminants in aquatic environments and drinking water. *Chimia,* 57(9): 529 – 536. 10.2533/000942903777678993.

Goldstein, M. I., Lacher, T. E., Woodbridge, B., Bechard, M. J., Canavelli, S. B., Zaccagnini, M. E., Cobb, G. P., Scollon, E. J., Tribolet, R. & Hopper, M. J. 1999. Monocrotophos-induced mass mortality of Swainson's hawks in Argentina, 1995-96. *Ecotoxicology,* 8(3): 201-214. 10.1023/a:1026496331396.

Gormley, K.L. 2003. Assessing the impacts of stream habitat and land use variables on population and community structure of salmonoids of Prince Edward Island. Master Thesis, Charloteetown, P.E.I.

Gormley, K. L., Teather, K. L. & Guignion, D. L. 2005. Changes in salmonid communities associated with pesticide runoff events. *Ecotoxicology,* 14(7): 671–678. 10.1007/s10646-005-0017-5.

Greig-Smith, P. 1987. Aversions of starlings and sparrows to unfamiliar, unexpected or unusual flavours and colours in Food. *Crop Protection* 6(6): 402–409

Guitart, R., Sachana, M., Caloni, F., Croubels, S., Vandenbroucke, V. & Berny, P. 2010. Animal poisoning in Europe. Part 3: Wildlife. *Veterinary Journal,* 183(3): 260–265. 10.1016/j.tvjl.2009.03.033.

Health Canada. 2020. *Pesticide Public Registry – Pest Management Regulatory Agency* [online]. [Cited 24 June 2020]. **https://pr-rp.hc-sc.gc.ca/pi-ip/disclaimer-avertissement-eng.php**

Heimbach U., Stähler M., Schwabe K., Schenke D., Pistorius J., Georgiadis P.-TH. 2014. Emission of pesticides during drilling and deposition in adjacent areas. *Julius-Kühn-Archiv* 444, 68–75.

Helfrich, L. A., Weigmann, D. L., Hipkins, P. and Stinson, E. R. 2009. Pesticides and Aquatic Animals: A Guide to Reducing Impacts on Aquatic Systems. Virginia, United States of America: Virginia Polytechnic Institute and State University.

HSE. 2020a. *Wildlife Incident Investigation Scheme* [online]. [Cited 24 June 2020]. **https://www.hse.gov.uk/pesticides/reducing-environmental-impact/wildlife/index.htm**

HSE. 2020b. *WIIS Quarterly Reports* [online]. [Cited 24 June 2020]. **https://www.hse.gov.uk/pesticides/reducing-environmental-impact/wildlife/wiis-quarterly-reports.htm**

IAP. 2020 Assessing the Impact of Neonicotionids in Africa [online]. [Cited 24 June 2020]. **https://www.interacademies.org/node/50850**

Julius Kuehn Institute (JKI). 2020. *Untersuchungsstelle für Bienenvergiftungen* [online]. [Cited 24 June 2020]. **https://bienenuntersuchung.julius-kuehn.de**

JKI. 2021. https://bienenuntersuchung.julius-kuehn.de/index.php?menuid=74&downloadid=9&reporeid=0 [online]. [Cited April 2021]

Johansen, C. 1977. Pesticides and Pollinators. *Annual Review of Entomology,* 22: 177–192.

Kendall, R.J. 2016. Wildlife toxicology: where we have been and where we are going. *Journal of Environmental and Analytical Toxicology*, 6(348): 2161–0525.

Kibria, G. 2014. Global fish Kills: Causes and Consequences. 10.13140/RG.2.1.1422.8965.

Kiljanek, T., Niewiadowska, M., Semeniuk, S., Gaweł, M., Borz cka, M. & Posyniak, A. 2016. Multi-residue method for the determination of pesticides and pesticide metabolites in honey bees by liquid and gas chromatography coupled with tandem mass spectrometry—Honey bee poisoning incidents. *Journal of Chromatography A*, 1435: 100–114. DOI: 10.1016/j.chroma.2016.01.045.

Kiljanek, T., Niewiadowska, M. & Posyniak, A. 2016. Pesticide poisoning of honey bees: A review of symptoms, incident classification and causes of poisoning. *Journal of Apicultural Science,* 60(2): 5–24.

Kiljanek, T., Niewiadowska, S., Gaweł, M., M., Semeniuk, Semeniuk, S., Borz cka, M. Posyniak, A. & Pohorecka, K. 2017. Multiple pesticide residues in live and poisoned honey bees–Preliminary exposure assessment. *Chemosphere*, 175: 36–44.

Klein, A. M., Vaissiere, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C. & Tscharntke, T. 2007. Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B-Biological Sciences,* 274(1608): 303–313. 10.1098/rspb.2006.3721.

Kohler, H. R. & Triebskorn, R. 2013. Wildlife ecotoxicology of pesticides: Can we track effects to the population level and beyond? *Science* 341(6147): 759–765. 10.1126/science.1237591.

Kovács-Hostyánszki, A., Li, J., Pettis, J., Settele, J., Aneni, T., Espíndola, A., Kahono, S., Szentgyörgyi, H., Thompson, H., Vanbergen, A.J. & Vandame. R. 2016. Drivers of change of pollinators, pollination networks and pollination. Chapter 2 (pp. 27-149) In: The assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production. SG Potts VL Imperatriz-Fonseca & HT Ngo (eds). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), Bonn, Germany.

Krohn, P.W., Becker, R.C., & Hungenberg, H. 2008. United States of America Patent Application 20080261811. Synergistic mixtures exhibiting insecticidal and fungicidal action. https://www.freepatentsonline.com/20080261811.pdf. [online]. [Cited 28 April 2021]

Krupke, C. H., Hunt, G. J., Eitzer, B. D., Andino, G. & Given, K. 2012. Multiple routes of pesticide exposure for honey-bees living near agricultural fields. *Plos One,* 7(1). 10.1371/journal.pone.0029268.

Kwon, Y. K., Wee, S. H. & Kim, J. H. 2004. Pesticide poisoning events in wild birds in Korea from 1998 to 2002. *Journal of Wildlife Diseases,* 40(4): 737–740. 10.7589/0090-3558-40.4.737.

Laetz, C. A., Baldwin, D. H., Collier, T. K., Hebert, V., Stark, J. D. & Scholz, N. L. 2009. The synergistic toxicity of pesticide mixtures: Implications for risk assessment and the conservation of endangered pacific salmon. *Environmental Health Perspectives,* 117(3): 348–353. 10.1289/ehp.0800096.

Lelièvre, F., Berny, P., Buronfosse, F., Pineau, X., Fréjat, A. & Lamarque, F. 2001. La toxicovigilance animale en France. exemple du suivi de la mortalité de pigeons par intoxication au furathiocarbe. *Revue de Médecine Vétérinaire,* 152: 835–842.

Luo, Y. Z. & Zhang, M. H. 2011. Environmental modeling and exposure assessment of sediment-associated pyrethroids in an agricultural watershed. *Plos One,* 6(1). 10.1371/journal.pone.0015794.

Maini, S., Medrzycki, P. & Porrini, C. 2010. The puzzle of honey bee losses: a brief review. *Bulletin of Insectology,* 63(1): 153–160.

Martinez-Haro, M., Mateo, R., Guitart, R., Soler-Rodriguez, F., Perez-Lopez, M., Maria-Mojica, P. & Garcia-Fernandez, A. J. 2008. Relationship of the toxicity of pesticide formulations and their commercial restrictions with the frequency of animal poisonings. *Ecotoxicology and Environmental Safety,* 69(3): 396–402. 10.1016/j.ecoenv.2007.05.006.

Marzaro, M., Vivan, L., Targa, A., Mazzon, L., Mori, N., Greatti, M., Toffolo, E. P., Di Bernardo, A., Giorio, C., Marton, D., Tapparo, A. & Girolami, V. 2011. Lethal aerial powdering of honey-bees with neonicotinoids from fragments of maize seed coat. *Bulletin of Insectology,* 64(1): 119–126.

McKay, H. V., Prosser, P. J., Hart, A. D. M., Langton, S. D., Jones, A., McCoy, C., Chandler-Morris, S. A., and Pascual, J. A. 2001. Do wood-pigeons avoid pesticide-treated cereal seed? *Journal of Applied Ecology*, Vol 36, Issue 2, pages 283-296. https://besjournals.onlinelibrary.wiley.com/doi/full/10.1046/j.1365–2664.1999.00398.x

Mendoza Gobierno. 2019. *Estrategia Nactional Contra Cebos Tóxicos (ENCT)* [online]. [Cited 25 June 2020]. **https://www.argentina.gob.ar/sites/default/files/taller_de_const_participativa.pdf**

Millot, F., Decors, A., Mastain, O., Quintaine, T., Berny, P., Vey, D., Lasseur, R. & Bro, E. 2017. Field evidence of bird poisonings by imidacloprid-treated seeds: a review of incidents reported by the French SAGIR network from 1995 to 2014. *Environmental Science and Pollution Research,* 24(6): 5469–5485. 10.1007/s11356-016-8272-y.

Mineau, P., 2002. Estimating the probability of bird mortality from pesticide sprays on the basis of the field study record. Environmental Toxicology and Chemistry 2003 Jan; 22(1):232.

Mineau, P., Lyon, L. & Mcmillin, S. 2012. Impacts of carbofuran on birds in Canada and the United States of America. *Carbofuran and Wildlife Poisoning: Global Perspectives and Forensic Approaches*: 208–250.

Mineau, P. & Tucker, K. R. 2002. Improving detection of pesticide poisoning in birds, part II. *Journal of Wildlife Rehabilitation,* 25(3): 4–12.

Ministerio de la protección social ministerio de ambiente vivienda y desarrollo territorial 2010. [online]. [Cited 25 June 2020]. **https://www.minsalud.gov.co/sites/rid/Lists/BibliotecaDigital/RIDE/DE/DIJ/Resoluci%C3%B3n%204716%20de%202010.pdf**

Morrissey, C. A., Mineau, P., Devries, J. H., Sanchez-Bayo, F., Liess, M., Cavallaro, M. C. & Liber, K. 2015. Neonicotinoid contamination of global surface waters and associated risk to aquatic invertebrates: A review. *Environment International* 74: 291–303. 10.1016/j.envint.2014.10.024.

Mrak, E. M. 1969. Report of the Secretary's Commission on pesticides and their relationship to environmental health. Washington DC, US Department of Health, Education and Welfare.

Mullie, W. C., Diallo, A. O., Gadji, B. & Ndiaye, M. D. 1999. Environmental hazards of mobile ground spraying with cyanophos and fenthion for Quelea control in Senegal. *Ecotoxicology and Environmental Safety,* 43(1): 1–10. 10.1006/eesa.1998.1744.

Mullie, W. C. & Keith, J. O. 1993. The effects of aerially applied fenitrothion and chlorpyrifos on birds in Northern Senegal. *Journal of Applied Ecology,* 30: 536–550.

Mullin, C. A. 2015. Effects of 'inactive' ingredients on bees. *Current Opinion in Insect Science,* 10: 194–200. 10.1016/j.cois.2015.05.006.

Mullin, C. A., Chen, J., Fine, J. D., Frazier, M. T. & Frazier, J. L. 2015. The formulation makes the honey bee poison. *Pesticide Biochemistry and Physiology,* 120: 27–35. 10.1016/j.pestbp.2014.12.026.

Murray, M. 2011. Anticoagulant rodenticide exposure and toxicosis in four species of birds of prey presented to a wildlife clinic in Massachusetts, 2006-2010. *Journal of Zoo and Wildlife Medicine*, 42: 88–97.

Mutch, J. P., Savard, M. A., Julien, G. R. J., Maclean, B., Raymond, B. G. & Doull, J. 2002. *Pesticide monitoring and fish kill investigations on Prince Edward Island, 1994-1999.* Canada, Canadian Technical Report of Fisheries and Aquatic Sciences.

National Marine Fisheries Service (NMFS) 2012. Final biological opinion. Environmental Protection Agency registration of pesticides Oryzalin, Pendimethalin, Trifluralin. Silver Spring, United States of America: National Marine Fisheries Service.

National Marine Fisheries Service (NMFS) 2008. Biological Opinion. Environmental Protection Agency Registration of Pesticides Containing Chlorpyrifos, Diazinon, and Malathion. Silver Spring, United States of America: National Marine Fisheries Service. **https://repository.library.noaa.gov/view/noaa/16997**

National Registration Authority for Agricultural and Veterinary Chemicals (NRA) 2003. The NRA review of chlorpyrifos – environmental assessment. Australia: NRA.

New Food Magazine. 2018. Death of one million bees in South Africa linked to fipronil. In: *New Food Magazine* [online]. [Cited 24 June 2020]. **https://www.newfoodmagazine.com/news/76270/million-bees-death-fipronil**

Niell, S., Gerez, N., Jesus, F., Cesio, V. & Heinzen, H. 2016. Case study: Beehive devastation by microencapsulated parathion-methyl. *Chromatographia,* 79(17–18): 1085-1090. 10.1007/s10337-016-3027-y.

NST. 2019. Buzz kill: Mass bee deaths sting Russian beekeepers. In: *NST Online* [online]. [Cited 24 June 2020]. **https://www.nst.com.my/world/2019/08/509119/buzz-kill-mass-bee-deaths-sting-russian-beekeepers**

Odino, M. & Ogada, D. L. 2008. Furadan use in Kenya and its impacts on birds and other wildlife: A survey of the regulatory agency, distributors, and end-users of this highly toxic pesticide. Kenya: Zoology Department Ornithology Section National Museums of Kenya.

Ogada, D. L. 2014. The power of poison: pesticide poisoning of Africa's wildlife. In Ostfeld, R. S. & Power, A. G., eds. *Year in Ecology and Conservation Biology,* pp. 1–20. Oxford, Blackwell Science Publ.

Oomen, P. A. 2001. Honey-bee poisoning incidents over the last ten years, as reported by bee keepers in the Netherlands. *Hazards of Pesticides to Bees,* (98): 129–135.

Organisation for Economic Co-operation and Development (OECD). 2010. OECD survey of pollinators testing, research, mitigation and information management: Survey results. Paris, France: OECD.

Organisation for Economic Co-operation and Development (OECD). 2014. *OECD Work Related to Bees/Pollinators* [online]. [Cited 24 June 2020]. **https://www.oecd.org/chemicalsafety/testing/work-related-beespollinators.htm**

Organización Panamericana de la Salud. 2003. *Efectos de los plaguicidas en la salud y el ambiente en Costa Rica.* San José, Costa Rica: Organización Panamericana de la Salud Ministerio de la Salud.

Pain, D. J., Gargi, R., Cunningham, A. A., Jones, A. & Prakash, V. 2004. Mortality of globally threatened Sarus cranes *Grus antigon* from monocrotophos poisoning in India. *Science of the Total Environment,* 326(1-3): 55–61. 10.1016/j.scitotenv.2003.12.004.

Pashte, V. V. & Patil, C. S. 2017. Monitoring on impact of insecticides on mortality of honey bees (*Apis mellifera* L.) in front of beehives. *Journal of Applied and Natural Science,* 9 (2): 905–911.

Pashte, V. V. & Patil, C. S. 2018. Toxicity and poisoning symptoms of selected insecticides to honey bees (*Apis mellifera mellifera* L.). *Archives of Biological Sciences,* 70(1): 5–12. 10.2298/abs170131020p. http://www.serbiosoc.org.rs/arch/index.php/abs/article/view/1441

Pesticide Action Network North America. 2006. Chlorpyrifos factsheet. [online]. **http://www.panna.org/sites/default/files/ChlorpyrifosFactsheet2006.pdf**

Pesticide Action Network North America. 2010. Paraquat factsheet. [online]. **https://panap.net/resource/paraquat-monograph**

Pilling, E.D. & Jepson, P.C. 1993. Synergism between EBI fungicides and a pyrethroid insecticide in the honey bee (*Apis mellifera*). *Pest Management Journal,* 39: 293–297.

Pistorius, J., Bischoff, G., Heimbach, U. & Stähler, M. 2009. Bee poisoning incidents in Germany in spring 2008 caused by abrasion of active substance from treated seeds during sowing of maize *Julius-Kühn-Archiv,* 423: 118–126.

Pisa, L. W., Amaral-Rogers, V., Belzunces, L. P., Bonmatin, J. M., Downs, C. A., Goulson, D., Kreutzweiser, D. P., Krupke, C., Liess, M., McField, M., Morrissey, C. A., Noome, D. A., Settele, J., Simon-Delso, N., Stark, J. D., Van der Sluijs, J. P., Van Dyck, H. & Wiemers, M. 2015. Effects of neonicotinoids and fipronil on non-target invertebrates. *Environmental Science Pollution Research,* 22: 68–102.10.1007/s11356-014-3471-x

Polidoro, B. A. & Morra, M. J. 2016. An ecological risk assessment of pesticides and fish kills in the Sixaola watershed, Costa Rica. *Environmental Science and Pollution Research,* 23(6): 5983–5991. 10.1007/s11356-016-6144-0.

Porrini, C., Mutinelli, F., Bortolotti, L., Granato, A., Laurenson, L., Roberts, K., Gallina, A., Silvester, N., Medrzycki, P., Renzi, T., Sgolastra, F. & Lodesani, M. 2016. The status of honey bee health in Italy: Results from the nationwide bee monitoring network. *Plos One,* 11(5): 22. 10.1371/journal.pone.0155411.

P.S.I. 2021.Island fish kills from 1962–2019. [online]. [Cited 24 May2021]. https://www.princeedwardisland.ca/sites/default/files/publications/pei_fish_kills_summary_1962-2017.pdf

Ramirez, D. H., Zuluaga, A. M., Gomez, E. J. 2007. Evaluación del riesgo de contaminación por metamidofos en la microcuenca el salto del municipio de el santuario, Antioquia. *Escuela de Ingeniería de Antioquia;* 8: 165–180. http://www.scielo.org.co/pdf/eia/n8/n8a13.pdf

Ramo, R. A., Van Den Brink, P. J., Ruepert, C., Castillo, L. E. & Gunnarsson, J. S. 2018. Environmental risk assessment of pesticides in the River Madre de Dios, Costa Rica using PERPEST, SSD, and msPAF models. *Environmental Science and Pollution Research,* 25(14): 13254–13269. 10.1007/s11356-016-7375-9.

Rattner, B. A. 2009. History of wildlife toxicology. *Ecotoxicology,* 18(7): 773–783. 10.1007/s10646-009-0354-x.

Richterova, Z. & Svobodova, Z. 2012. Pyrethroids influence on fish. *Slovenian Veterinary Research,* 49(2): 63–72.

Rios del Planeta. 2017. Río La Pasión: contaminación, y todo lo que necesita saber de él. In: *Conozcamos Todos Los Rios De Nuestro Planeta* [online]. [Cited 24 June 2020]. https://riosdelplaneta.com/rio-la-pasion

Rotterdam Convention Text. 2019. Rotterdam Convention on the prior informed consent procedure for certain hazardous chemicals and pesticides in international trade. Rome, Italy: FAO, Geneva, Switzerland: UNEP. http://www.pic.int/TheConvention/Overview/TextoftheConvention/tabid/1048/language/en-US/Default.aspx

Rotterdam Convention. 2017. The SHPF toolkit – A toolkit to help you to monitor and report incidents of pesticide poisoning caused by Severely Hazardous Pesticide Formulations in your Country under Article 6 of the Rotterdam Convention. Rome, Italy: FAO.100 pp. http://www.pic.int/Implementation/SeverelyHazardousPesticideFormulations/SHPFKit/tabid/3114/language/en-US/Default.aspx

Rotterdam Convention Secretariat. 2018. Field Survey: Collection and Analysis of Data on Agro-ecological/IPM practices and chemical /non-chemical alternatives to Annex III and candidate Pesticides in six Caribbean Island States. CARDI Report.59 pp. Unpublished.

Rotterdam Convention. 2020. *Rotterdam Convention Home Page* [online]. [Cited 24 June 2020]. http://www.pic.int

Salcedo, A., Díaz, S., González, J., Rodríguez, A. & Varona, M. 2012. Exposición a plaguicidas en los habitantes de la ribera del río Bogotá (Suesca) y en el pez Capitán. *Rev. Cienc. Salud,* 10 (Especial): 29-41. https://revistas.urosario.edu.co/index.php/revsalud/article/viewFile/2026/1782

Sanchez-Barbudo, I. S., Camarero, P. R. & Mateo, R. 2012. Primary and secondary poisoning by anticoagulant rodenticides of non-target animals in Spain. *Science of the Total Environment,* 420: 280–288. 10.1016/j.scitotenv.2012.01.028.

Sánchez-Bayo, F., Goka, K. & Hayasaka, D. 2016. Contamination of the Aquatic Environment with Neonicotinoids and its Implication for Ecosystems. *Frontiers in Environmental Science* 4. 10.3389/fenvs.2016.00071.

Servir. 2014. *Contaminación por Atrazina, Rio La Villa, Azuero - Panamá*. [online]. [Cited 24 June 2020]. **http://www.servir.net/servir-en-accion/analisis-ambientales/553-contamina cion-por-atrazina-rio-la-villa-azuero-panama.html**

Seefeld F. 2006. Chemical detection of damage to honey bees caused by pesticides *Nachrichtenbl. Deut. Pflanzenschutzd.* 58:59–66.

Soares Pires, C. & Ribeiro De Sá Torezani, K. 2018. Selecao de especies de abhelas nativas para avaliacao de risco de agrotoxicos. Brazil: IBAMA.

Stanley, P. I. and Bunyan, P. J. 1979. Hazards to Wintering Geese and other Wildlife from the Use of Dieldrin, Chlorfenvinphos and Carbophenothion as Wheat Seed Treatments. *Proceedings of the Royal Society of London*. Series B, Biological Sciences Vol. 205, No. 1158, Long-Term Hazards to Man from Man-Made Chemicals in the Environment (Jul. 18, 1979), pp. 31–45. **https://www.jstor.org/stable/77454?seq=1**

Stehle, S., Knabel, A. & Schulz, R. 2013. Probabilistic risk assessment of insecticide concentrations in agricultural surface waters: a critical appraisal. *Environmental Monitoring and Assessment,* 185(8): 6295–6310. 10.1007/s10661-012-3026-x.

Stehle, S. & Schulz, R. 2015. Agricultural insecticides threaten surface waters at the global scale. *Proceedings of the National Academy of Sciences of the United States of America,* 112(18): 5750–5755. 10.1073/pnas.1500232112.

Stehle, S., Bub, S. & Schulz, R. 2018**.** Compilation and analysis of global surface water concentrations for individual insecticide compounds. *Science of the Total Environment* 639: 516–525. 10.1016/j.scitotenv.2018.05.158.

Tang, W., Wang, D., Wang, J., Wu, Z., Li, L., Huang, M., Xu, S. & Yan, D. 2018. Pyrethroid pesticide residues in the global environment: An overview. *Chemosphere* 191 (308): 990–1007. 10.1016/j.chemosphere.2017.10.115.

Thompson, H. M. 1996. Interactions between pesticides. A review of reported effects and their implications for wildlife risk assessment. *Ecotoxicology,* 5(2): 59–81. 10.1007/bf00119047.

Thompson, H. M. 2001. Assessing the exposure and toxicity of pesticides to bumble bees. *Hazards of Pesticides to Bees,* (98): 197–205.

Thompson, H. M. & Thorbahn, D. 2009. Review of honey bee pesticide poisoning incidents in Europe – evaluation of the hazard quotient approach for risk assessment. *Julius-Kühn-Archiv 423:* 103–108.

TFSP **http://www.tfsp.info/en/about-us**

TFSP. 2015. Worldwide integrated assessment of the impacts of systemic pesticides on biodiversity and ecosystems. Notre Dame de Londres, France. http://www.tfsp.info/assets/WIA_2015.pdf

Unearthed/Greenpeace. Loophole keeps bee-killing pesticides in widespread use, two years after EU ban [online]. [Cited 2 April 2021] https://unearthed.greenpeace.org/2020/07/08/bees-neonicotinoids-bayer-syngenta-eu-ban-loophole

US Environmental Protection Agency (EPA). 1998. Memorandum. https://www3.epa.gov/pesticides/chem_search/cleared_reviews/csr_PC-058001_17-Nov-98_118.pdf

US Environmental Protection Agency (EPA). 1999. Reregistration: Eligibility science chapter for chlorpyrifos fate and environmental risk, assessment chapter. Washington DC, United States of America: United States of America Environmental Protection Agency.

US Environmental Protection Agency (EPA). 2009. Chlorpyrifos summary document registration review: Initial document March 2009. Washington D.C., United States of America: United States of America Environmental Protection Agency.

US Environmental Protection Agency (EPA). 2016. Guidance for inspecting alleged cases of pesticide-related bee incidents Washington DC, United States of America: United States of America Environmental Protection Agency.

US Environmental Protection Agency (EPA). 2019. *Federal Register*. [online]. [Cited 24 June 2020]. https://www.govinfo.gov/content/pkg/FR-2019-05-20/pdf/2019-10447.pdf

US Environmental Protection Agency (EPA). 2020. Clothianidin and Thiamethoxam Proposed Interim Registration Decision Review Decision Case Numbers 7620 and 7614 January 2020. Docket Numbers EPA-HQ-OPP-2011-0865 and EPA-HQ-OPP-2011-0581 www.regulations.gov [online] https://www.epa.gov/sites/production/files/2020-01/documents/clothianidin_and_thiamethoxam_pid_final_1.pdf

UNECE. 2019c. *GHS (Rev.8) (2019) – Transport – UNECE* [online]. [Cited 24 June 2020]. https://www.unece.org/trans/danger/publi/ghs/ghs_rev08/08files_e.html

UNEP/CMS/COP11/Inf. 2014. Review of the ecological effects of poisoning on migratory birds. https://www.cms.int/sites/default/files/document/COP11_Inf_34_Review_effects_of_Poisoning_on_Migratory_Birds_Eonly.pdf

UNEP/CMS/Resolution 11.15 2020. Preventing of poisoning of migratory birds. https://www.cms.int/sites/default/files/document/cms_cop13_res.11.15_rev.cop13_e.pdf

UNEP/FAO/RC/CRC 2018 Handbook of working procedures and policy guidance for the Chemical Review Committee. Rome, Italy: FAO. http://www.pic.int/TheConvention/ChemicalReviewCommittee/Guidance/tabid/1060/language/en-US/Default.aspx

UNEP/FAO/RC 2020. *How to report an incident*. [online]. [Cited 24 June 2020]. http://www.pic.int/tabid/1192/language/en-US/Default.aspx

USGS. 2020d. *Environmental Health – Data and Tools Topics* [online]. [Cited 24 June 2020]. https://www.usgs.gov/products/data-and-tools/data-and-tools-topics/environmental-health

Van Der Valk, H. & Koomen, I. 2013. *Aspects Determining the Risk of Pesticides to wild bees - Risk Profiles for focal crops on three continents.* Rome, Italy: FAO.

Van Lexmond, M. B., Bonmatin, J. M., Goulson, D. & Noome, D. A. 2014. Worldwide integrated assessment on systemic pesticides. *Environmental Science and Pollution Research,* 22(1): 1–4. 10.1007/s11356-014-3220-1.
http://www.tfsp.info/assets/WIA_2015.pdf

Van Oers, L., Tamis, W., De Koning, A. & De Snoo, G. 2005. Review of incidents with wildlife related to paraquat. Leiden, The Netherlands.90 pp. 2005].

Vandame, R. 2017. Abejas y insecticidas. In Bejarano, F., ed. *Los plaguicidas altamente peligrosos en México,* pp. 167–186. Mexico, Red de Acción sobre Plaguicidas y Alternativas en México A.C.

Villabos, N. 2015. Muerte de peces en Pococí podría deberse a plaguicidas de piña [online]. [Cited 24 June 2020]
https://www.elpais.cr/2015/10/06/muerte-de-peces-en-pococi-podria-deberse-a-plaguicidas-de-pina

Villar, D., Balvin, D., Giraldo, C., Motas, M. & Olivera, M. 2010. Plasma and brain cholinesterase in methomyl-intoxicated free-ranging pigeons (*Columba livia f. domestica*). *Journal of Veterinary Diagnostic Investigation,* 22(2): 313–315. 10.1177/104063871002200229.

Vyas, N. B. 1999. Factors influencing estimation of pesticide-related wildlife mortality. *Toxicology and Industrial Health,* 15(1-2): 186–191. 10.1191/074823399678846628.

Watts, M. 2013. Chlorpyrifos. Pacific: PANAP.
http://dev.panap.net/sites/default/files/monograph-chlorpyrifos.pdf.

Walker, L.A., Llewellyn, N.R., Pereira M.G., Potter, E.D., Sainsbury, A.W. & Shore, R.F. 2012. Anticoagulant rodenticides in predatory birds 2010: a Predatory Bird Monitoring Scheme (PBMS) report. Centre for Ecology & Hydrology, Lancaster, United Kingdom of Great Britain and Northern Ireland. 17pp.

Wick, A., Bänsch-Baltruschat, B., Keller, M., Scharmüller, A., Schäfer, R., Foit, K., Liess, M., Maaßen, S. & Lischeid, G. 2019. Umsetzung des Nationalen Aktionsplans zur nachhaltigen Anwendung von Pestiziden Teil 2. Dessau-Roßlau, Germany: Umweltbundesamt.
https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2019-02-04_texte_08-2019_monitoring-kleingewaesser-agrar.pdf

Worm, B. 2015. Silent spring in the ocean. *Proceedings of the National Academy of Sciences*, *112*(38): 11752-11753.

Zhao, S., Yuan, S., Cai, B., Jiang, H., Wang, X., Lin, R., Qu, W. & Zhang, Z. 2011. The acute oral toxicity of 300 formulated pesticides to A*pis mellifera Agrochemical,* 50: 278–280.

ANNEX A

Addressing environmental incidents under the Rotterdam Convention

The Rotterdam Convention is a multilateral environmental agreement intended to promote shared responsibility and cooperation among the participating countries (the Convention Parties) in the international trade of certain hazardous chemicals including pesticides. The Convention facilitates information exchange about the characteristics of the chemicals and provides for an informed national decision-making process on their import and export.

Under Annex III of the Convention, three categories of chemicals can be "listed" and thereby made subject to the Convention's requirements: industrial chemicals, pesticides, and severely hazardous pesticide formulations (SHPFs).

For industrial chemical and pesticide ***active ingredients*** to be considered for listing, two notifications of final regulatory action (banning or imposition of severe restrictions) are needed. The notifications may come from any Convention Party (i.e. from developed, developing, or transitional countries) but must come from two different PIC regions. The Parties must provide health and environment risk evaluations to show the basis of their regulatory action.
To be identified and considered for listing as a ***severely hazardous pesticide formulation***, a proposal based on one or more severe poisoning cases or environmental incidents from a single developing country or country with an economy in transition is sufficient.

Definition of SHPF

A severely hazardous pesticide formulation (SHPF) is defined by the Rotterdam Convention as *a chemical formulated for pesticidal use that produces severe health or environmental effects observable within a short period of time after single or multiple exposure, under conditions of use* (Art. 2, Rotterdam Convention Text, 2019).

ARTICLE 6

Procedures for severely hazardous pesticide formulations

1 Any Party that is a developing country or a country with an economy in transition and that is experiencing problems caused by a severely hazardous pesticide formulation under conditions of use in its territory may propose to the Secretariat the listing of the severely hazardous pesticide formulation in Annex III. In developing a proposal, the Party may draw upon technical expertise from any relevant source. The proposal shall contain the information required by part 1 of Annex IV.

ANNEX B

Guidance for monitoring, investigating and reporting pesticide poisoning incidents

SHPF Kit 2017. Guidance on how to monitor and report incidents of pesticide poisoning caused by Severely Hazardous Pesticide Formulations
http://www.pic.int/Implementation/SeverelyHazardousPesticideFormulations/SHPFKit/tabid/3114/language/en-US/Default.aspx

Rotterdam Convention forms and instructions for reporting environmental incidents
http://www.pic.int/Procedures/SeverelyHazardousPesticideFormulations/FormsandInstructions/tabid/1192/language/en-US/Default.aspx

FAO/WHO. 2009. Guidelines on developing a reporting system for health and environmental incidents resulting from exposure to pesticides. Food and Agriculture Organization of the United Nations and World Health Organization
http://www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/Code/Incidentreporting09.pdf

EU Monitoring scheme 2017
https://ec.europa.eu/food/sites/food/files/plant/docs/pesticides_sup_monitoring-guidance_en.pdf

Grant IF and Tingle CCD (eds.) (2002) Ecological monitoring methods for the assessment of pesticide impacts in the tropics and method sheets. Natural Resources Institute, Chatham, United Kingdom of Great Britain and Northern Ireland
https://gala.gre.ac.uk/id/eprint/11699

Helfrich, L. A., Weigmann, D. L., Hipkins, P. and Stinson, E. R. 2009. Pesticides and Aquatic Animals: A Guide to Reducing Impacts on Aquatic Systems. Virginia, United States of America: Virginia Polytechnic Institute and State University.
https://vtechworks.lib.vt.edu/bitstream/handle/10919/48060/420-013_pdf.pdf?sequence=1

Akratankul, P. 1990. Beekeeping in Asia. FAO Agricultural Services Bulletin, 68.
http://www.fao.org/3/x0083E/X0083E00.htm#Contents

Brasse, D. 2001. First draft of "Field inquiry into suspected poisoning incidents involving honey bees." *Hazards of Pesticides to Bees*, (98): 137–139.

U.S. Environmental Protection Agency. 2013. Guidance for inspecting alleged cases of pesticide-related bee incidents - a comprehensive guide for inspecting alleged cases of pesticide-related honey bee death incidents.
https://www.epa.gov/sites/production/files/2013-09/documents/bee-inspection-guide.pdf

ANNEX C

Bird poisoning incidents

Table C 1 Pesticides identified in bird poisoning incidents

Pesticide Class	Active ingredient	Organisms	Region/Countries
Organophosphate	Chlorpyrifos	American robin, nestling ibis	United States of America Australia
Organophosphate	Diazinon	waterfowl waterfowl	United States of America Canada
Organophosphate	Fensulfothion	waterfowl birds	Canada United States of America
Organophosphate	Fenthion	owls, blue naped mousebirds raptors, songbirds	Senegal, United States of America
Organophosphate	Fonofos	raptors	Canada
Organophosphate	Parathion-Methyl Parathion	birds	Costa Rica United States of America
Organophosphate	Monocrotophos	Swainson's hawks Sarus cranes	Argentina India
Organophosphate	Phorate	waterfowl, raptors	Canada
Organophosphate	Famphur	raptors, songbirds	United States of America
Carbamate	Carbofuran	waterfowls, songbirds, raptors waterfowls, songbirds, raptors vultures	Canada United States of America Kenya
Carbamate	Furathiocarb	pigeons, geese	France
Neonicotinoid	Imidacloprid	cape spurfowl, Greywing francolin patridges, pigeons	South Africa France
Anticoagulant rodenticide	Brodifacoum Bromadiolone Chlorophacinone Difenacoum Flocoumafen	 red kites, buzzards birds and raptors red kites, barn owls raptors	France Spain United Kingdom of Great Britain and Northern Ireland United States of America
Bipyridylium	Paraquat	wild geese, geese, raptors, pheasant birds	United States of America Cuba United Kingdom of Great Britain and Northern Ireland France

* U.S. Geological Survey National Wildlife Health Center (NWHC) mortality database from 1980 to 2000 reviewed, no exact years of the incidents were reported in the published article.

103 wildlife mortality incidents reported by the French SAGIR Network from 1995 to 2014, for which toxicological analyses detected imidacloprid residues.

Year	Reference
1980-2000* 1995	EPA 1999 (cited in Christensen *et al*. 2009) Fleischli *et al*. 2004 NRA 2000
1980-2000* ~1992	Fleischli *et al*. 2004 Wilson *et al*. 1995 cited in Elliot *et al*. 2011
1990 1980-2000*	Elliot *et al*. 1996 Fleischli *et al*. 2004
1995/1996 1980-2000*	Mullie *et al*. 1999 Fleischli *et al*. 2004
1992-1994	Elliot *et al*. 1997
1988 1980-2000*	Organización Panamericana de la Salud 2003 Fleischli *et al*. 2004
1995/1996 2000	Goldstein *et al*. 1999 Pain *et al*. 2004
1994-1998	Elliot *et al*. 2008
1980-2000*	Fleischli *et al*. 2004
1973-1975/1986/1990 1980-2000* 2004	Mineaut *et al*. 2012 Elliot *et al*. 1996 Fleischli *et al*. 2004 Odino and Ogada 2009
1993-1995	Lelièvre *et al*. 2001
2017 1995-2014#	Botha *et al*. 2017 Millot *et al*. 2017
1992-2002 2005-2010 2010 2006-2010	Berny *et al*. 1997; 2008 Sanchez-Barbudo *et al*. 2012 Walker *et al*. 2012 Murrey 2011
1992-1994 na 1987-2002 1986-2003	van Oers *et al*. 2005 Rivera 1973 cited in van Oers *et al*. 2005 MAFF, 1986-2002 cited in van Oers *et al*. 2005 Gaillet 2004 cited in van Oers *et al*. 2005

ANNEX D

Fish poisoning incidents

Table D 1 Insecticides identified in fish kills

Pesticide Class	Active ingredient	Organisms	Region/Countries
Organophosphate	Azinphos-Methyl	fish	United States of America, Canada
Organophosphate	Chlorpyrifos	fish	United States of America, Australia, United Kingdom of Great Britain and Northern Ireland
Organophosphate	Parathion-Methyl	fish	United States of America
Organophosphate	Terbufos, Dichlorvos	shrimps, fish	Costa Rica
Organophosphate	Ethoprofos	fish	Costa Rica
Pyrethroid	Permethrin, Deltamethrin	black crappie fish, fish	United States of America Europe
Chloronitrile	Chlorothalonil	fish	Canada

* Between 1974 and 2005, chlorpyrifos was reported as the probable causative agent of 108 fish kills.

Year	Reference
1991 2002	Beyond Pesticides 2012 (online article) Gormley *et al*. 2005
1974-2003* 1989/1995/1996 2001	EPA 2009 cited in Watts 2013 NRA 2000 PAN United Kingdom of Great Britain and Northern Ireland 2001
1995	Beyond Pesticides 2012 (online article)
1993	Organización Panamericana de la Salud 2003
2015	Villabos 2015 (online article)
2005	Beyond Pesticides 2012 (online article) Csíllik *et al*. 2000
2002-2017	P.E.I. 2021

ANNEX E

Honey bee poisoning incidents

Classification of bee poisoning incidents

Honey bee deaths are classified to distinguish between normal death rates and above normal rates due to poisoning or other causes. The classification of bee poisoning incidents varies between countries and regions, although the common indicator used to identify pesticide poisoning is generally the high number of dead bees. The following are a few examples:

- **Canada** (Cutler, Scott-Dupree and Drexler, 2014)
  - bee poisonings classified as minor, moderate and major, based both on number of dead bees and also on abnormal behavior observed.
- **European Food Safety Authority** (EFSA, 2013)
  - 5.3% dead foragers a day considered to be the natural background mortality (as a conservative acceptance level for risk assessment)
- **FAO** (Akratankul, 1990)
  - 100 dead bees a day: normal death rate
  - 200-400 dead bees a day: low level of pesticide poisoning
  - 500-1000 dead bees: medium level of pesticide poisoning
  - Over 1000 dead bees: high level of pesticide poisoning

- **Germany and Poland** (Kiljanek, Niewiadowska and Posyniak, 2016)
  - honey bee poisoning investigation starts with the collection of 1000 dead bees

- **Italy** (Porrini *et al.*, 2016)
  - 250 dead bees per station per week used to identify potential bee poisoning

- **United Kingdom of Great Britain and Northern Ireland** (Fletcher and Barnett, 2003)
  - an incident is considered for pesticide poisoning if the residue concentration is near or above the median lethal dose.

Table E 1 Pesticides identified in honey bee poisoning incidents

Pesticide Class	Active ingredient	Countries
Organophosphate	Chlorpyrifos	Poland Spain United States of America Canada
Organophosphate	Diazinon	Canada
Organophosphate	Dimethoate/ Omethoate	Spain United Kingdom of Great Britain and Northern Ireland Netherlands Canada
Organophosphate	Parathion-Methyl	Uruquay Netherland United States of America
Carbamate	Carbaryl	Germany United States of America
Neonicotinoid	Clothianidin	Germany France Italy Poland Canada United States of America
Neonicotinoid	Thiamethoxam	Brazil Italy Canada United States of America
Neonicotinoid	Imidacloprid	Brazil Spain Italy
Phenylpyrazole	Fipronil	Brazil South Africa Poland Hungary Russia Colombia
Pyrethroid	Zeta-Cypermethrin Lambda-Cyhalothrin	Poland

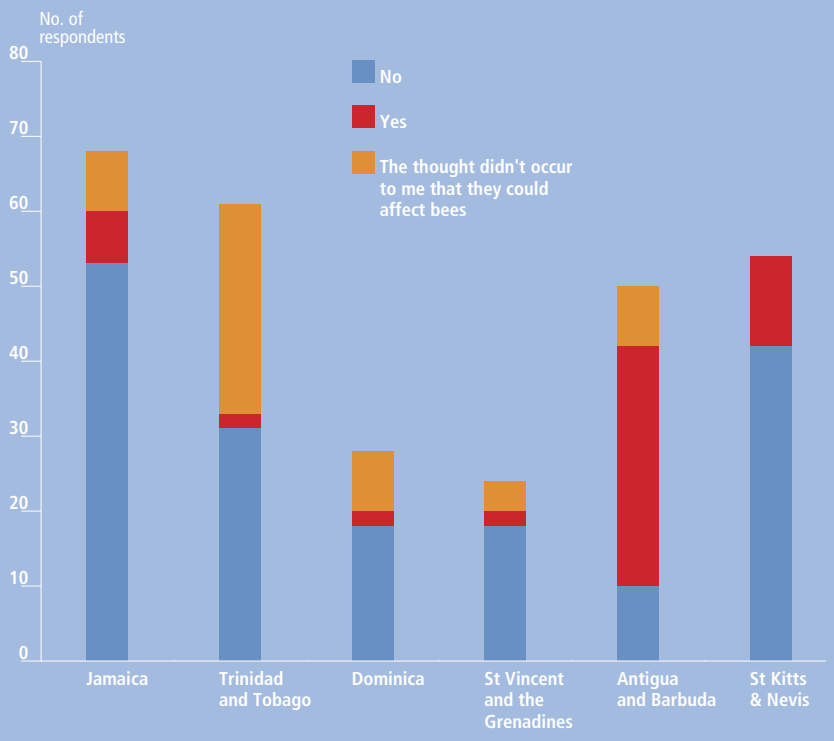
* In the United States of America, chlorpyrifos was reported as the main cause of 79 terrestrial incidents between 1997 and 2005, involving mainly bird and bee kills.

[#] The WIIS database from 1994-2003 was reviewed, no exact years of the incidents were reported in the published article.

[§] The database from the Netherland incidents monitoring scheme was reviewed between 1989-1998, no exact years of the incidents were reported in the published article.

Year	Reference
2014-2015 2016-2018 1997-2005* 2012	Kiljanek *et al.* 2017 Calatayud-Vernich *et al.* 2019 US EPA 2009 (cited in Watts 2013) Cutler, Scott-Dupree and Drexler, 2014
2010	Cutler *et al.* 2014
2016-2018 1994-2003[#] 1989-1998[§] 2012	Calatayud-Vernich *et al.* 2019 Barnett *et al.* 2007 Oomen 2001 Cutler, Scott-Dupree and Drexler, 2014
2012 1989-1998[§] 1976	Niell *et al.* 2016 Oemen 2001 Johansen 1977
1970-1982 1959/1967	Thompson and Thorbahn 2009 Johansen 1977
2008 2008 2008 2014-2015 2009-2012 2010-2018	Pistorius 2009 Chauzat *et al.* 2010 Bortolotti *et al.* 2009 Kiljanek *et al.* 2017 Cutler, Scott-Dupree and Drexler 2014 US EPA 2020
2013-2017 2008 2010-2012 2010-2018	Castilhos *et al.* 2019 Bortolotti *et al.* 2009 Cutler, Scott-Dupree and Drexler 2014 US EPA 2020
2013-2017 2016-2018 2008	Castilhos *et al.* 2019 Calatayud-Vernich *et al.* 2019 Bortolotti *et al.* 2009
2013-2017 2018 2014-2015 2007-2011 2019 2012-2018	Castilhos *et al.* 2019 New Food Magazine, 2018 (online article) Kiljanek *et al.* 2017 Fazekas *et al.* 2012, cited in EFSA 2013 NST 2019 (online article) ICA personal communication
na	Kiljanek *et al.* 2016

Figure E 1 Results of a survey in six Caribbean islands: Farmer consideration of risks to bees when selecting insecticides (Rotterdam Convention Secretariat, 2018)



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pic@fao.org

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Rome, Italy

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